Exotic meson search at J-PARC

Tsutomu Mibe
Department of Physics,
Ohio University

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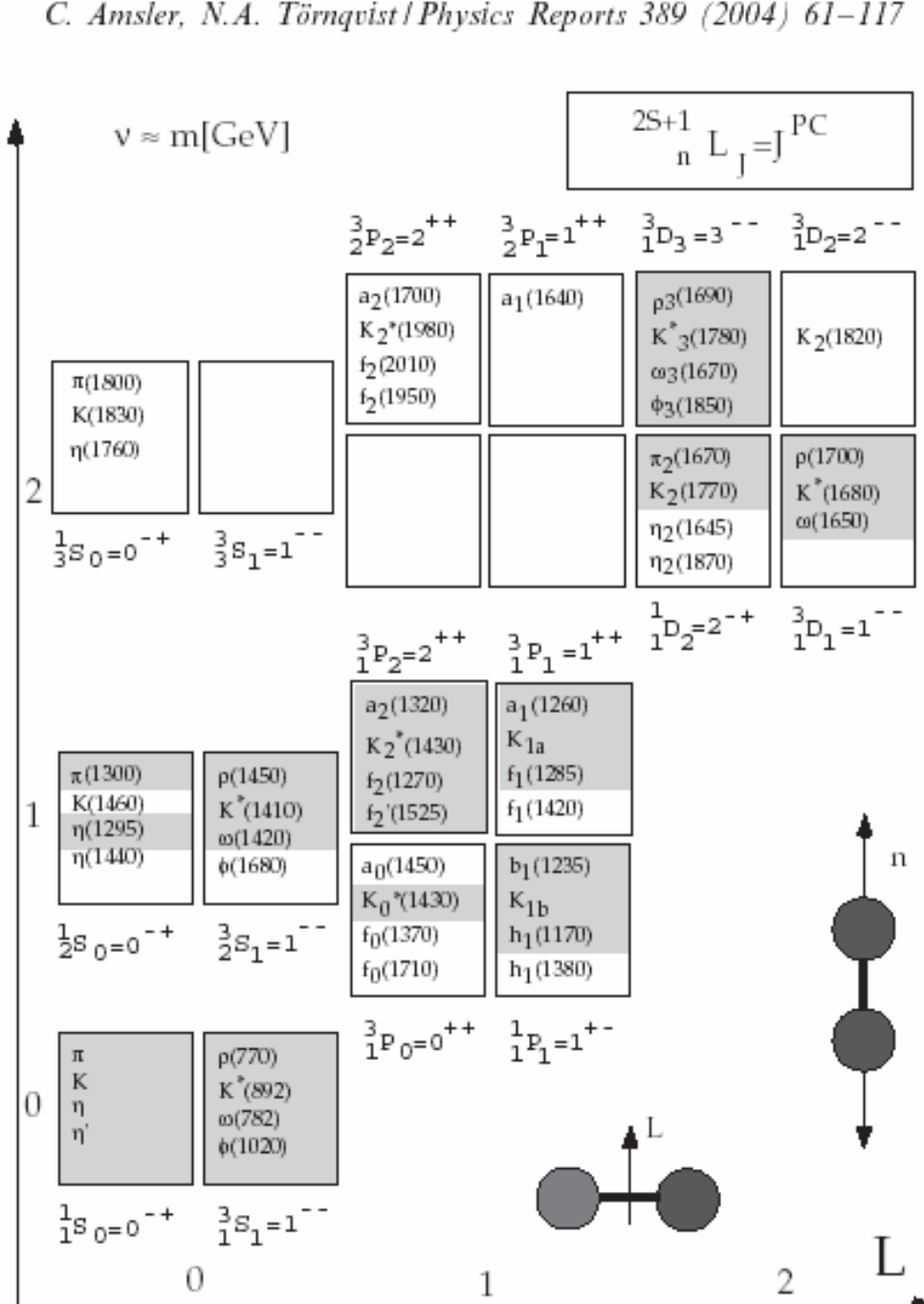
q q-bar mesons

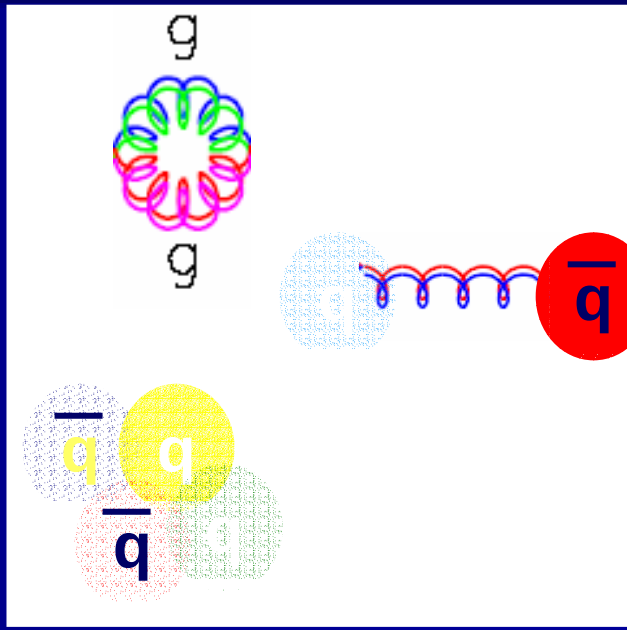
- Idea of quark comes from lowest lying scalar and vector mesons (Gell-mann).
- Existence of analogous symmetry in excited states is a great success of Quark model.

- Is there any meson which doesn't fit this scheme…?



Non q q-bar mesons

- Glueballs
  - which have no valence quarks
- Hybrid mesons
  - which contain a valence quark-antiquark pair and one or more gluons.
- Tetra-quark states
  - which have two valence quark-antiquark pairs.



- These states are identified experimentally as a state with exotic quantum number and/or anomalous properties beyond q q-bar description.

Tetra-quark meson candidates

- $a_0(980)$ and $f_0(980)$
  - Non-exotic quantum number
  - Large branching to K K-bar
  - Production in ϕ radiative decay favors a compact 4q state
- $\pi(1400)$
  - Exotic spin-parity $J^{PC}=1^{-+}$
  - Found in $\eta\pi$ decay.
  - $\eta\pi$ coupling is suppressed for qqg hybrid, possibly 4q state.
- $f_1(1420)$, $f_1(1510)$
  - Three 1^{++} states around M~1.5 GeV/c^2 ,$f_1(1285)$, $f_1(1420)$, $f_1(1510)$
  - Two are expected to be members of P-wave q q-bar nonet, another state is possibly 4q state.

Tetra-quark meson candidates cont'd

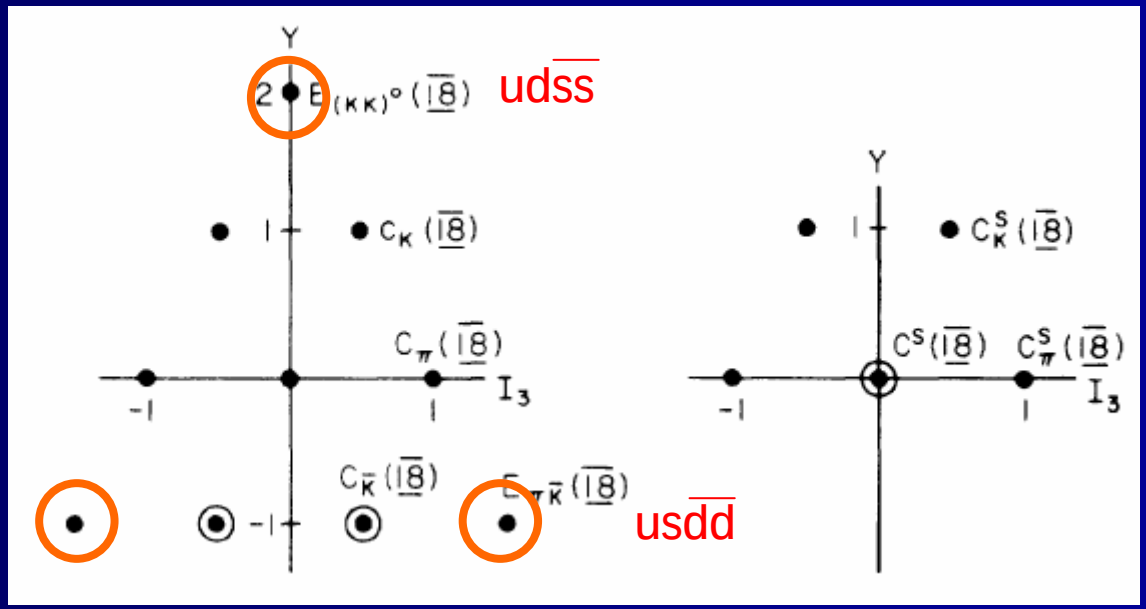
- D_{SJ} (2317) and D_{SJ} (2460)
  - Data consistent with non-exotic quantum number
  - Mass is below the quark model prediction.
  - Tetra-quark?, T. Browder et al, PLB578, 365 (2005)
- X(3872)
  - Doesn't fit quark model prediction
  - Tetra-quark?, Maiani et al, PRD 71, 014028 (2005)
  - or $D^0\overline{D}^{0*}$ bound state?

- There is no definitive evidence of flaver-exotic tetraquark states.

Flavor exotic tetra quark states

- R. Jaffe, Phys. Rev. D15, 267 (1977)
  - spires citation 1000+!
  - Example, $J^P=1^+$ qqqq states in 18 group.

Flavor exotic state



$uds\bar{s}\bar{s}$

$dsu\bar{u}\bar{u}$

$usd\bar{d}\bar{d}$

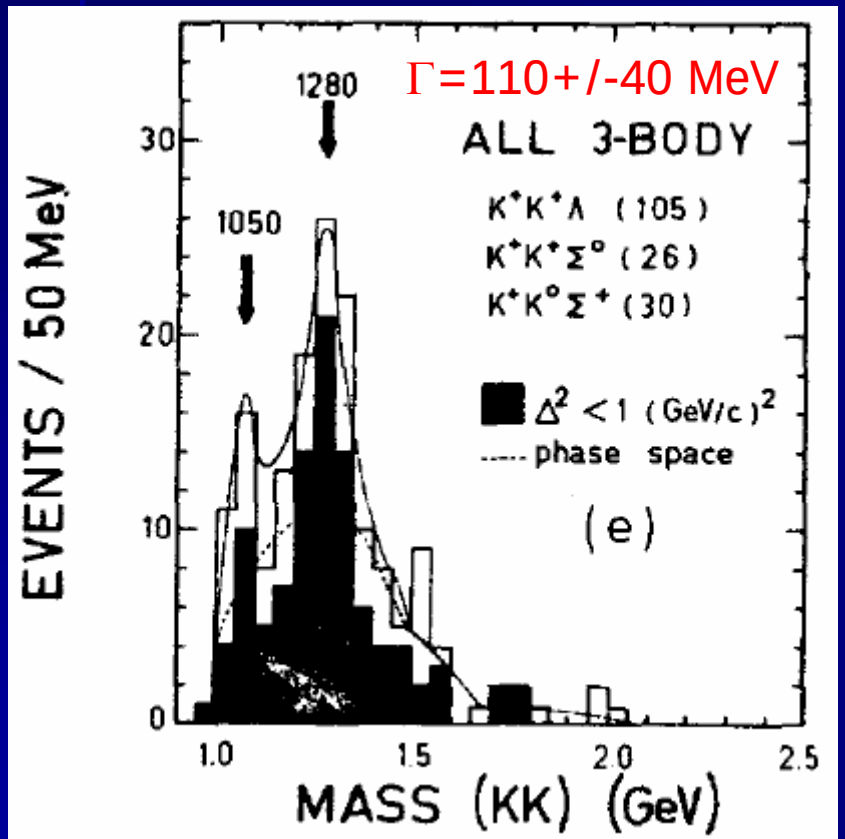
S=+2 meson search

EVIDENCE FOR A MESON RESONANCE WITH STRANGENESS +2

M. FERRO-LUZZI, R. GEORGE, Y. GOLDSCHMIDT-CLERMONT *, V. P. HENRI, B. JONGEJANS
D. W. G. LEITH, G. R. LYNCH **, F. MULLER and J. M. PERREAU
CERN, Geneva, Switzerland

Phys. Lett. 17 155 (1965)

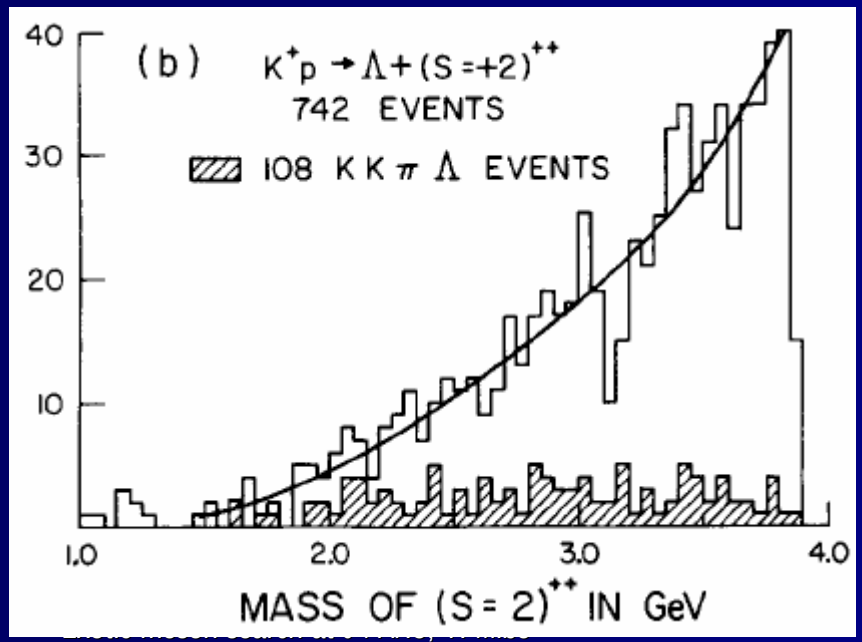
Received 12 May 1965



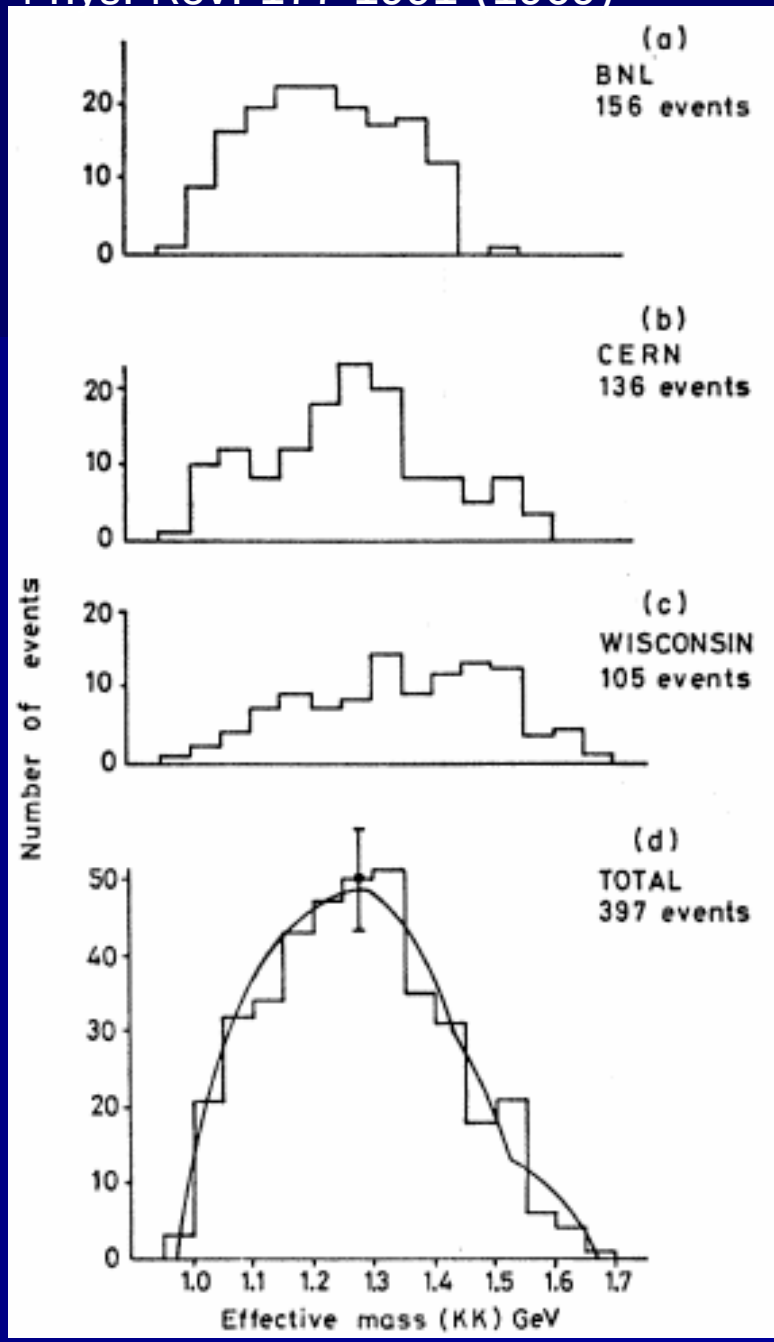
- K^+p scattering at CERN with $p(K^+)$=3-5 GeV/c.
- Structure beyond phase space around M(KK,S=+2)=1280 MeV
- Selection of forward going KK pair enhances the structure. Consistent with peripheral production.

S=+2 meson ?

- Following K^+p experiments didn't confirm the peak at 1280 MeV in M(KK,S=+2) system.



Phys. Rev. 177 1991 (1969)

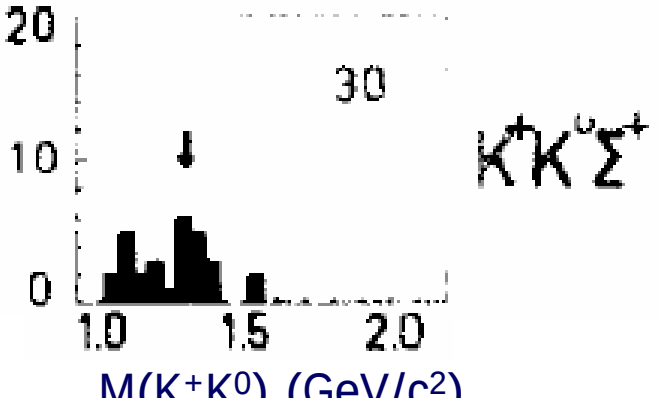


Phys. Lett. 37B 665 (1968)

Is S=+2 meson ruled out?

- No signal for $X^{++} \rightarrow KK, KK\pi$
  - Iso-vector states have not been found.
  - if it exists, cross sections should be too small or width is too wide to see a peak in old low statistics data (~a few 10 events/bin).
- Remaining possibility is I=0 sector.
  - renewed interests in Θ^+ era
  - Tetra-quark state as a cousin of Θ^+ (several theoretical suggestions, next slide)
  - only one published data with
  - very limited statistics.

Phys. Lett. 17 155 (1965)



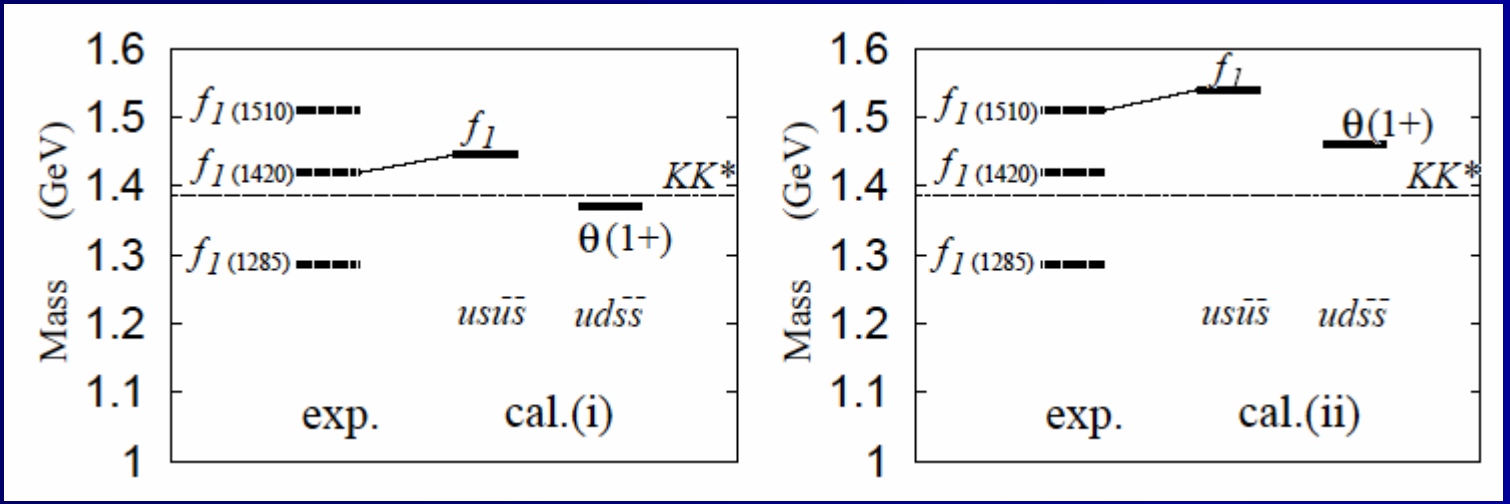
Possible I=0, S=+2 states as a cousin of Θ^+

J^P	Dominant decay mode	Reference
0^-	$KK\pi$	
0^+	$KK\pi\pi$	Karliner and Lipkin, Phys. Lett. B612, 197 (2005)
1^-	KK (P wave)	Burns, Close and Dudek, Phys. Rev. D71, 014017(2005)
1^+	$KK\pi$ or KK^*	Kanada-En'yo, Morimatsu and Nishikawa, Phys. Rev. D72, 014505 (2005) Cui et al.,hep-ph/0511150

all model predicts width of state < 100 MeV

$J^P=1^+$ S=+2 tetra-quark meson and a non-strange partner

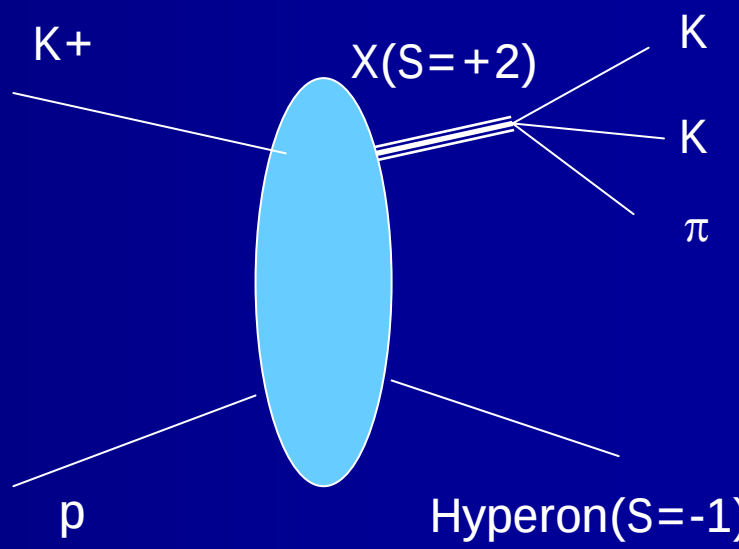
Kanada-En'yo, Morimatsu and Nishikawa, Phys. Rev. D72, 014505 (2005)



- Three f_1 mesons ($J^{PC}=1^{++}$) in M~1.5 GeV/c^2
- Two f_1 mesons are expected to appear in this mass region as P-wave q q-bar nonet.
- The other may be non q q-bar meson, e.x. 4q state.
- Flux-tube quark model supports this idea.

High statistics K^+p experiment at J-PARC

- J-PARC
  - Intense secondary Kaon beam from 50 GeV protons
- Search for Iso-scalar S=+2 meson in K^+p reaction
  - Initial state strangeness =+1
  - Only requires $\Delta S=+1$ to make S=+2 final state
- Final states
  - $\Sigma^+ K^+K^0$
  - $\Sigma^+ K^+K^+\pi^-$
  - $\Sigma^+ K^+K^0\pi^+\pi^-$
- Analogous search for S=-2 meson is possible in K^-p reaction

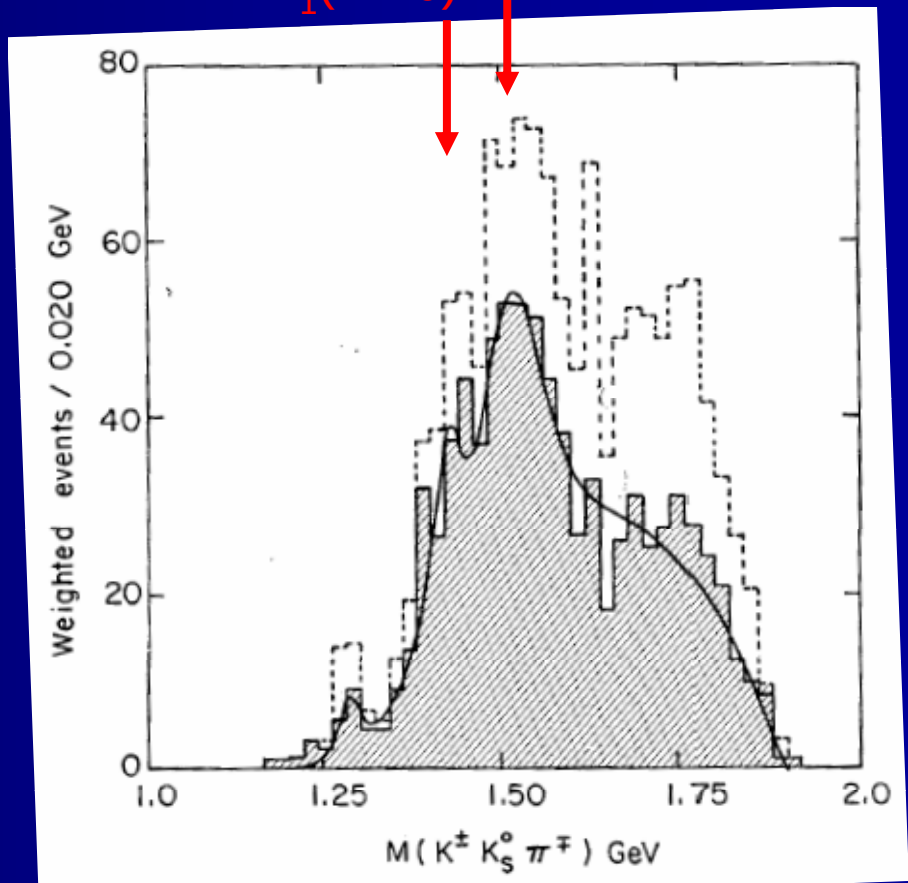


$f_1(1420)$ and $f_1(1510)$ in K^-p scattering

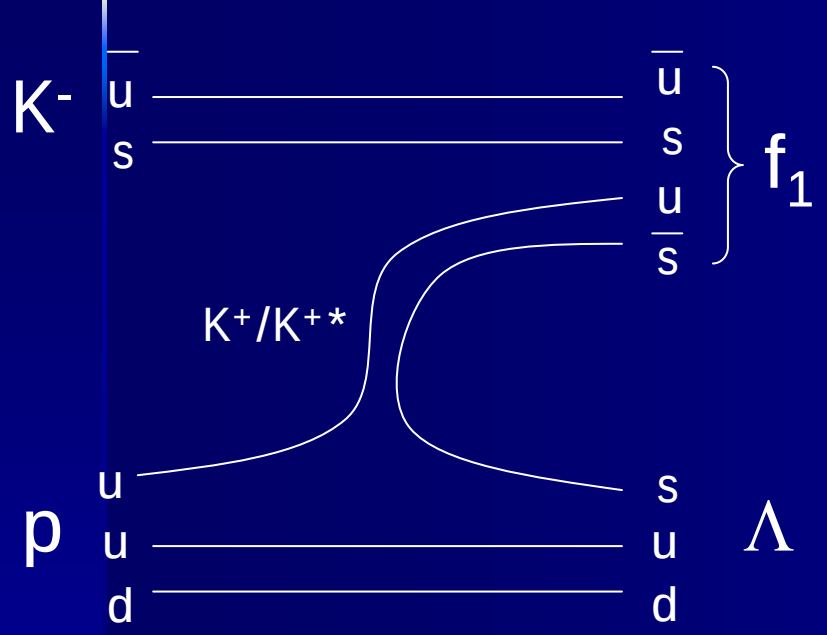
- $K^-p \rightarrow K^{-(+)} K^0_s \pi^{+(-)} \Lambda$
- PWA favors $J^{PC}=1^{++}$
- Peripheral production
- $\sigma(K^-p \rightarrow f_1\Lambda)BR(f_1 \rightarrow KK^0\pi)$
  - $f_1(1420)$: 4.8 +/- 1.5 ub
  - $f_1(1510)$: 18 +/- 2 ub
  - (in forward hemisphere)

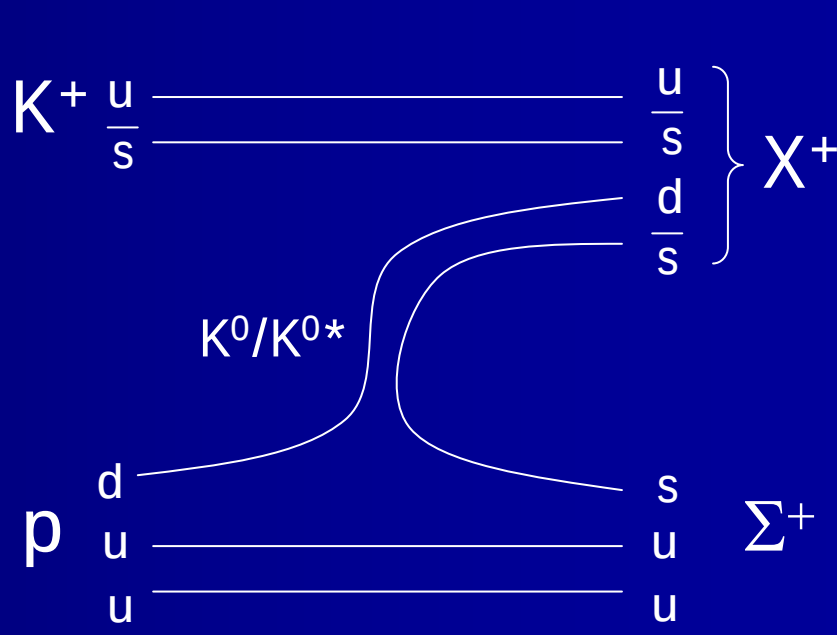
- $f_1(1510)$ was also observed in K^-p scattering at SLAC LASS (D. Aston et al., PLB201 573(1988))

4.2 GeV/c K- beam @CERN
Gavillet et al., Z.Phys.C16,119(1982)



Production mechanism of tetra-quark meson in KN scattering





$\sigma(K^- p \rightarrow f_1(u\bar{u}s\bar{s})^0\Lambda)$
~5-20 μb

$\cong$
?

$\sigma(K^+ p \rightarrow X(ud\bar{s}\bar{s})^+\Sigma^+)$

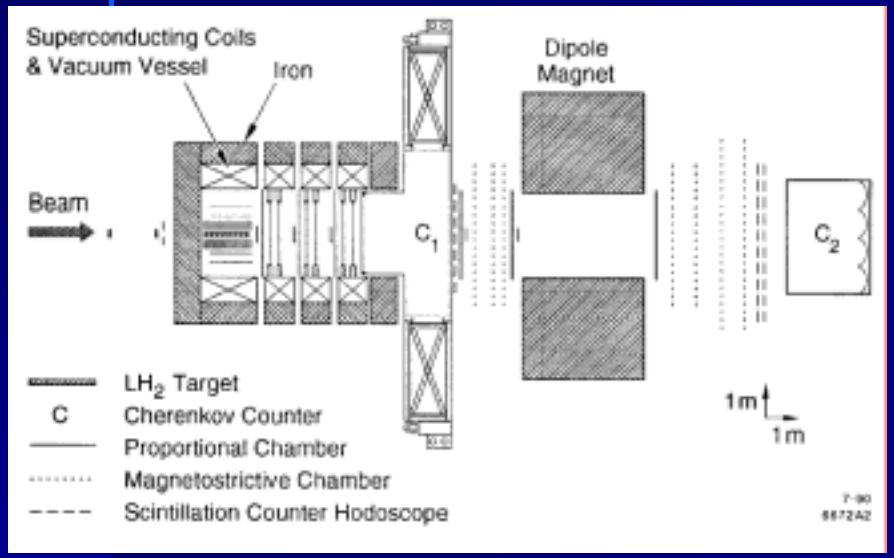
Requirements

- 5 GeV/c K^+ beam for S=2 meson search up to M~2 GeV/c^2 in $K^+p \rightarrow Y\,X$ reaction.
- If cross section for f_1 is taken as a guide, sensitivity ~1 μb
  - 10^5 K^+/sec, 50 cm LH_2, 1 μb cross section
  - 0.2 event/sec, 22k events/day
- Large acceptance at forward angles for peripheral meson productions.
- Capability of multi-particle detection for charged particles (detection of neutrals is optional).

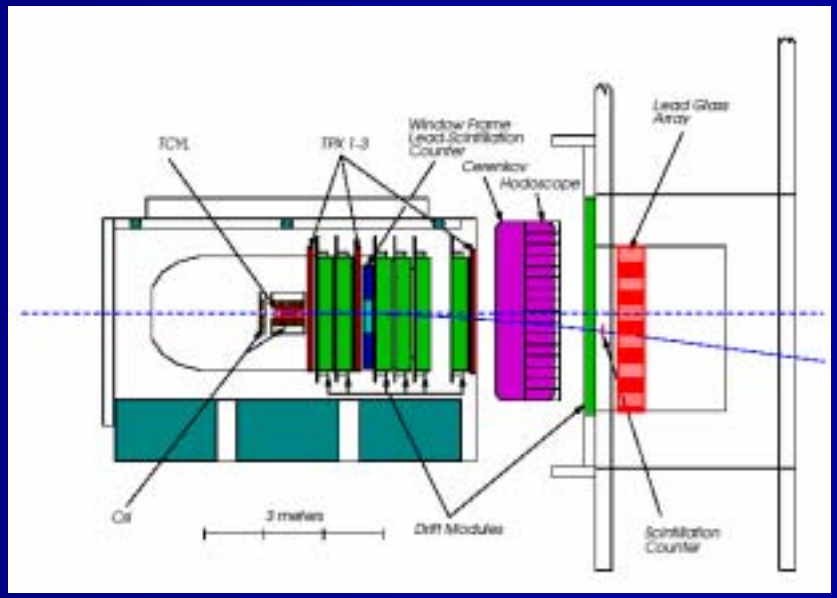
- Good examples in past meson factories with charged particle spectromenter
  - LASS @SLAC
  - E852 @BNL AGS

Historical major players in meson spectroscopy

LASS @ SLAC



E852 @ BNL AGS



Summary

- Renewed interest for flavor exotic S=+2 tetra-quark mesons.
- Existence of such states can be tested in a high statistics experiment in K^+p reaction.
- J-PARC is an ideal place for such an experiment.
- Key requirements for the experiment are
  - High intensity K^+ beam.
  - Large acceptance spectrometer at forward angles
  - Capability of multi-particle detection