Pentaquarks: update and open questions

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[a] hep-ph/0307243, hep-ph/0307343, hep-ph/0401072, hep-ph/0402008, hep-ph/0405002
[b] hep-ph/0401127, [c] hep-ph/0409121, [a] hep-ph/0411136

Renaissance of QCD Spectroscopy

Several new surprising experimental results:

- two new extremely narrow mesons containing c and $\bar{s}$ quarks (BaBar, CLEO, Belle)
- new very narrow resonance precisely at $D^{0*}D^0$ threshold (Belle, CDF, D0)
- enhancements near $\bar{p}p$, $\bar{\Lambda}p$ thresholds (BES, Belle)
- a $\Lambda_c\,\bar{p}$ resonance (Belle)
- narrow $D_{sJ}^+(2632)$: $\Gamma(D_s^+\eta)/\Gamma(D^0K^+) = 6$ (SELEX)
- exotic 5-quark resonances: Θ^+ (KN), Ξ^{*--}, Θ_c

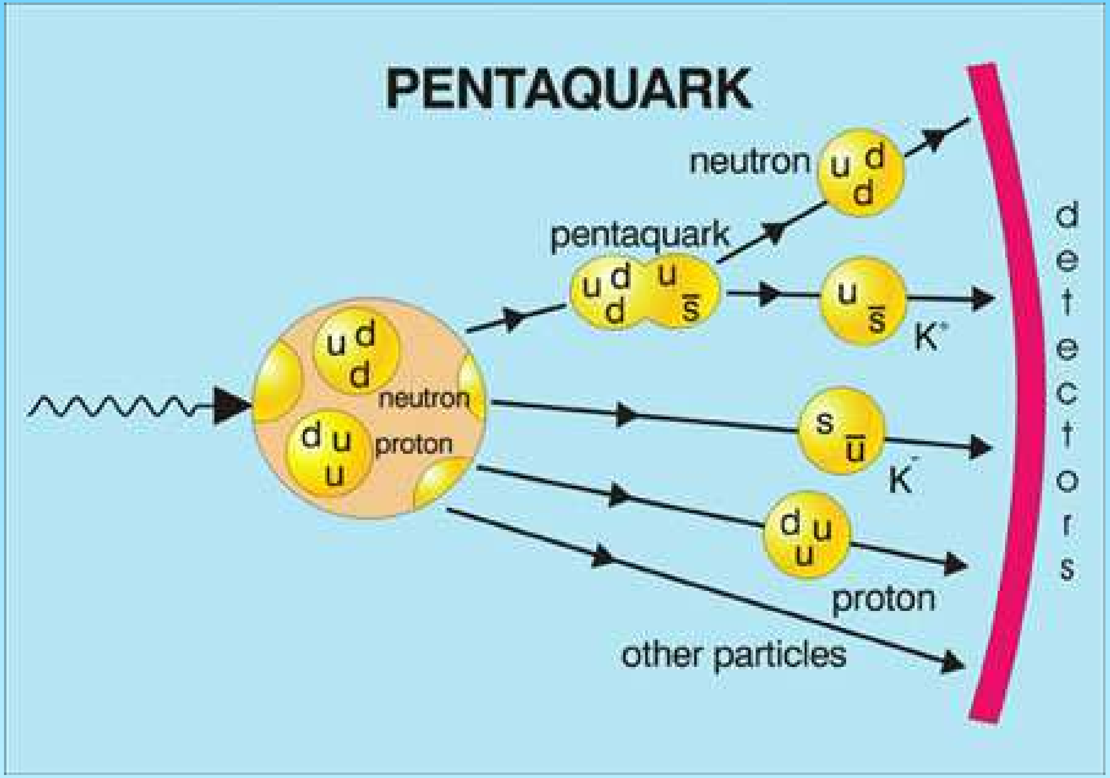
QCD bound-state dynamics

again an exciting challenge for EXP and TH

more surprises likely to come

The discovery of Θ^+

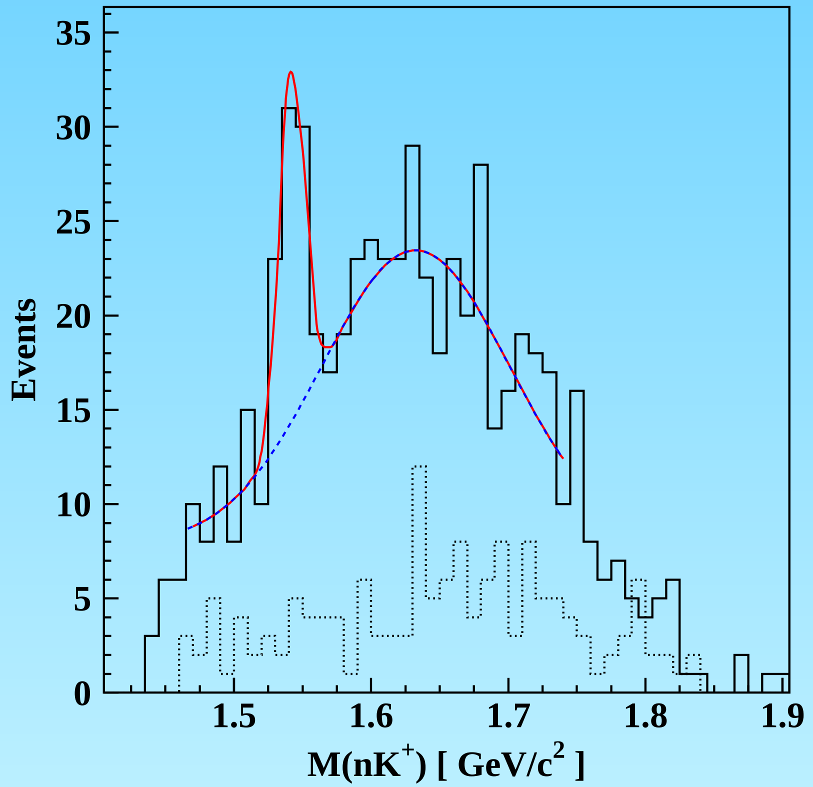
a narrow peak in $K^+ n$ invariant mass:



$$\gamma d \to p\, \underbrace{n K^+}_{\Theta^+} K^-$$

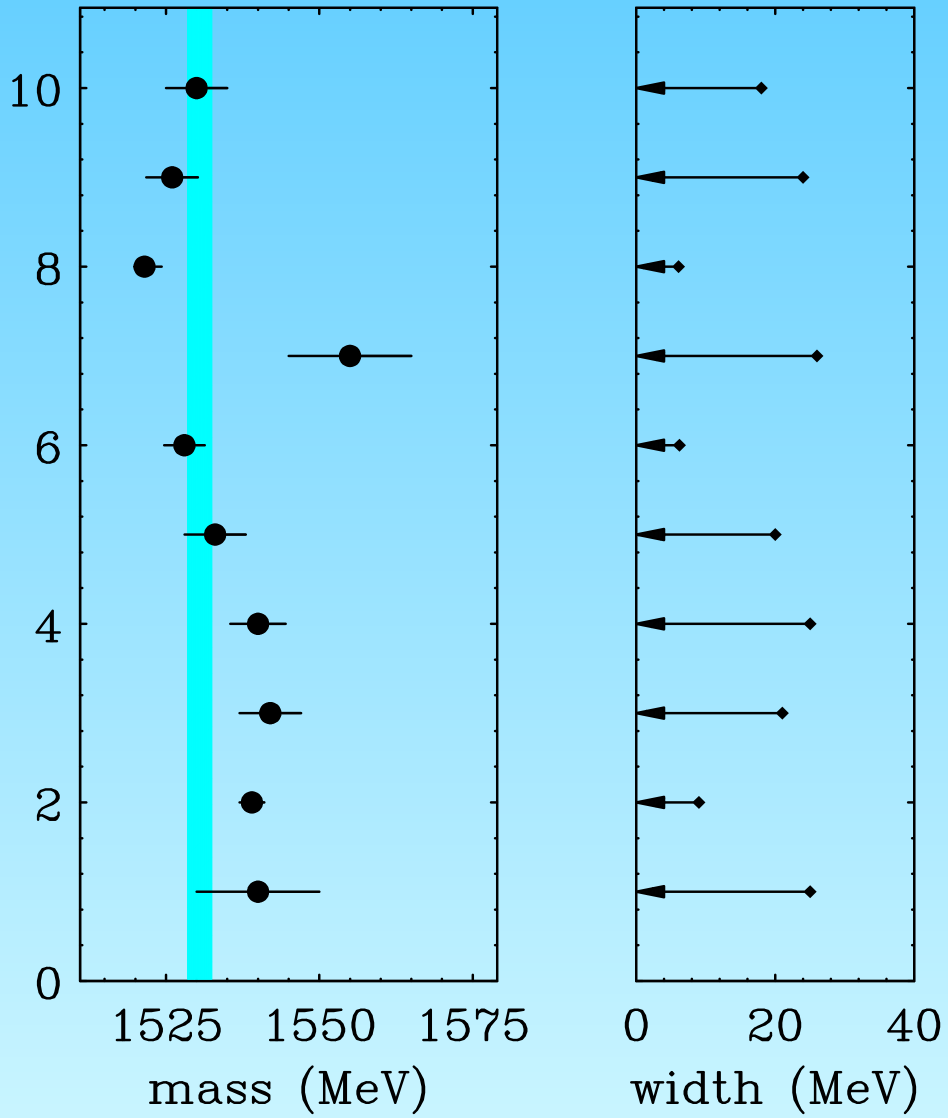
$\Longrightarrow$ **a pentaquark:** $\bar{s}u\,udd$, $S = +1$, **exotic baryon resonance**

distribution of $K^+ n$ invariant mass (CLAS/JLAB):



$m_{\Theta^+} = 1542 \pm 5$ MeV, $\Gamma_{\Theta^+} \leq 20$ MeV (CLAS, γD)

mass and width measurements of Θ^+

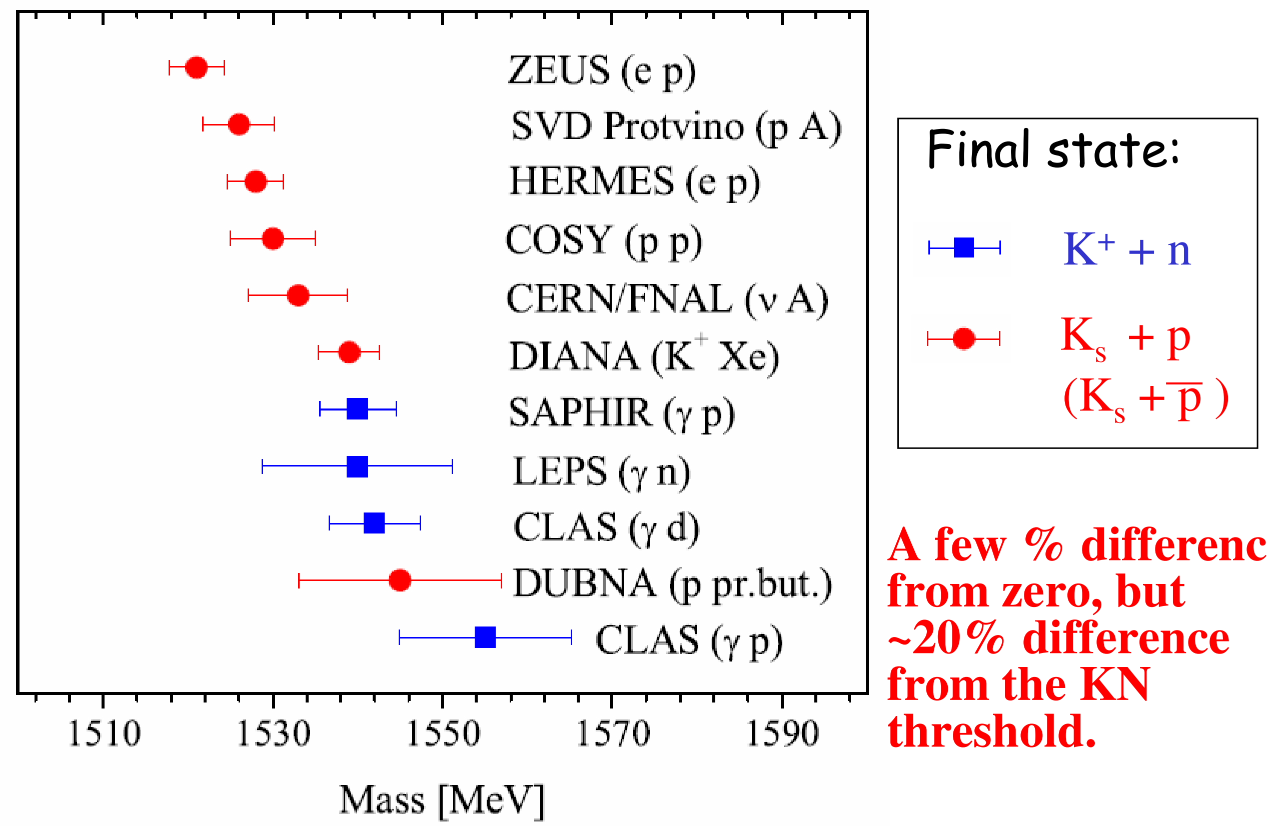


LEPS-2004 γD	**prelim.**
NOMAD: νN	**prelim.**
COSY: $pp \to \Sigma^+ K_s p$	$5\pm1\sigma$
SVD−2: pA	$5.6\,\sigma$
ZEUS: $\gamma^* p$ $\Theta^+ + \bar\Theta^-$	$(3.9\div4.6)\,\sigma$
CLAS 2: $\gamma\, p$	$7.8\pm1.0\,\sigma$
HERMES: $\gamma^* D$	$(4\div6)\,\sigma$
ITEP: $\nu A, \bar\nu A$	$6.7\,\sigma$
SAPHIR: $\gamma\, p$	$4.8\,\sigma$
CLAS: $\gamma\, D$	$\cancel{5}.2\pm0.6\,\sigma$ ↓
DIANA: $K^+ Xe$	$4.4\,\sigma$
LEPS: $\gamma\, ^{12}C$	$4.6\,\sigma$

World average: $m=1530.5\pm2.0$ MeV

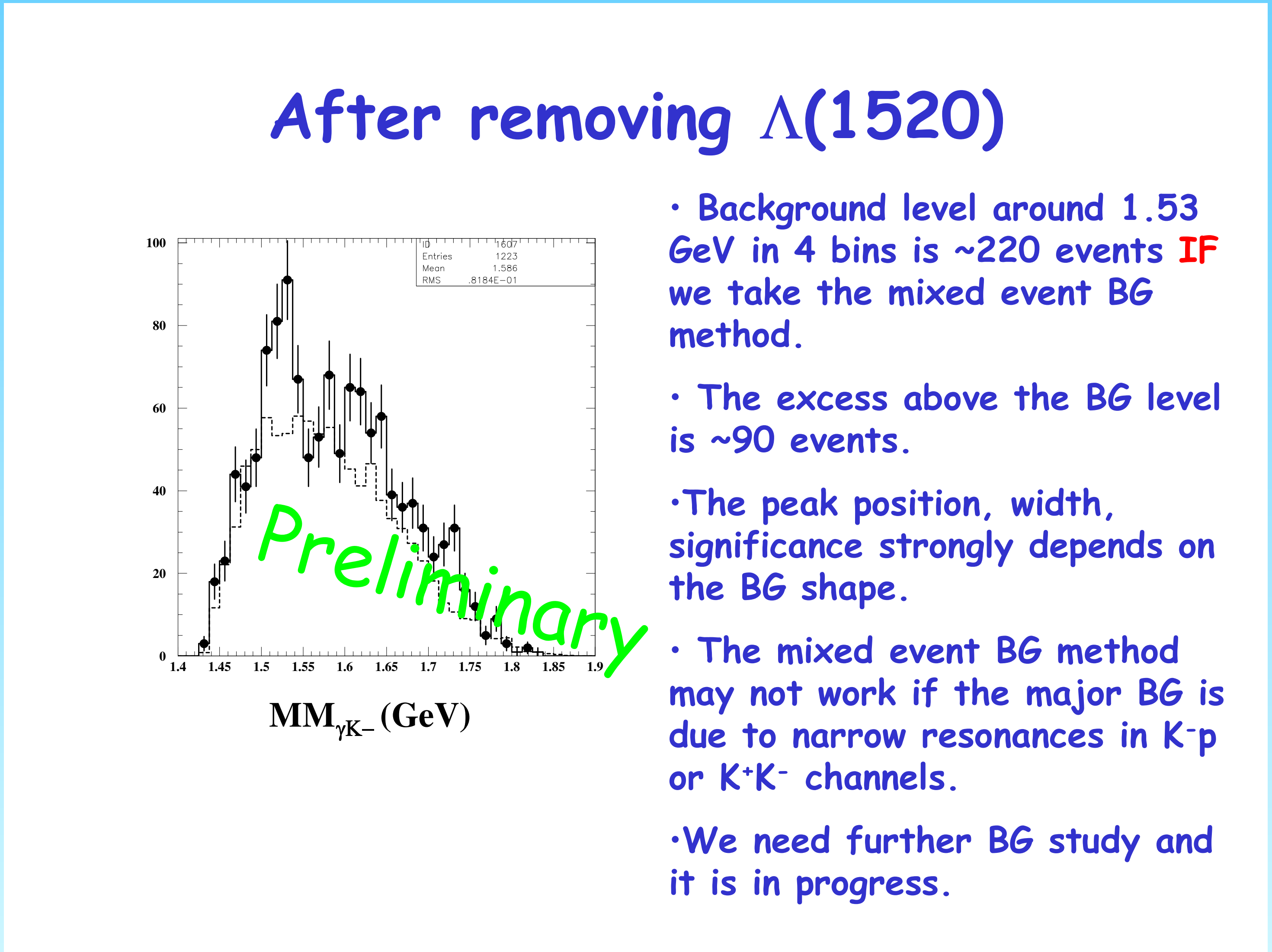
update from T. Nakano, Baryon 2004:

Mass



A few % difference from zero, but ~20% difference from the KN threshold.

preliminary new results from LEPS:



$MM_{\gamma K^-}$ (GeV)

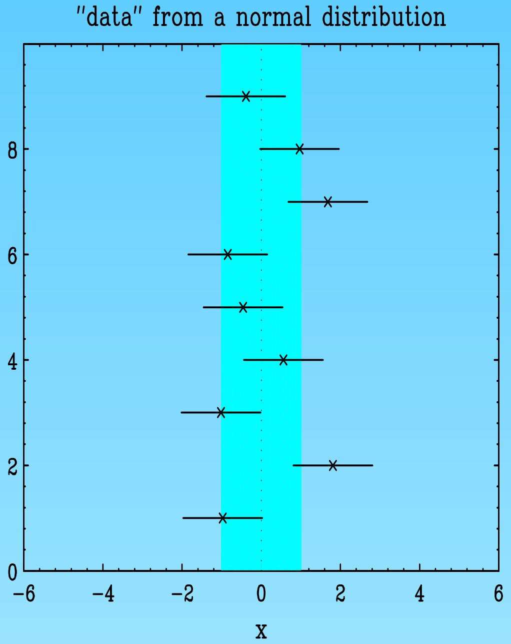
After removing Λ(1520)

- Background level around 1.53 GeV in 4 bins is ~220 events **IF** we take the mixed event BG method.
- The excess above the BG level is ~90 events.
- The peak position, width, significance strongly depends on the BG shape.
- The mixed event BG method may not work if the major BG is due to narrow resonances in K^-p or K^+K^- channels.
- We need further BG study and it is in progress.

caveats:

- consistency between experiments ?

cf. sample normal distribution:



possible reasons: systematics, statistical fluctuations, 2nd state

- final state: K^+n is $uudd\bar{s}$ but K_sp is $uudd\bar{s}$ or $uud\bar{d}s\,(\Sigma^*)$
- cross section $\sim \mu$-barns, so sophisticated cuts needed
- negative/null results

  $\cancel{\Theta}^+$: HERA-B, PHENIX, H1(?), DELPHI, ALEPH, SPHINX, CDF…

  $\cancel{\Xi}^{--}$: WA89, ZEUS, CDF, WA97

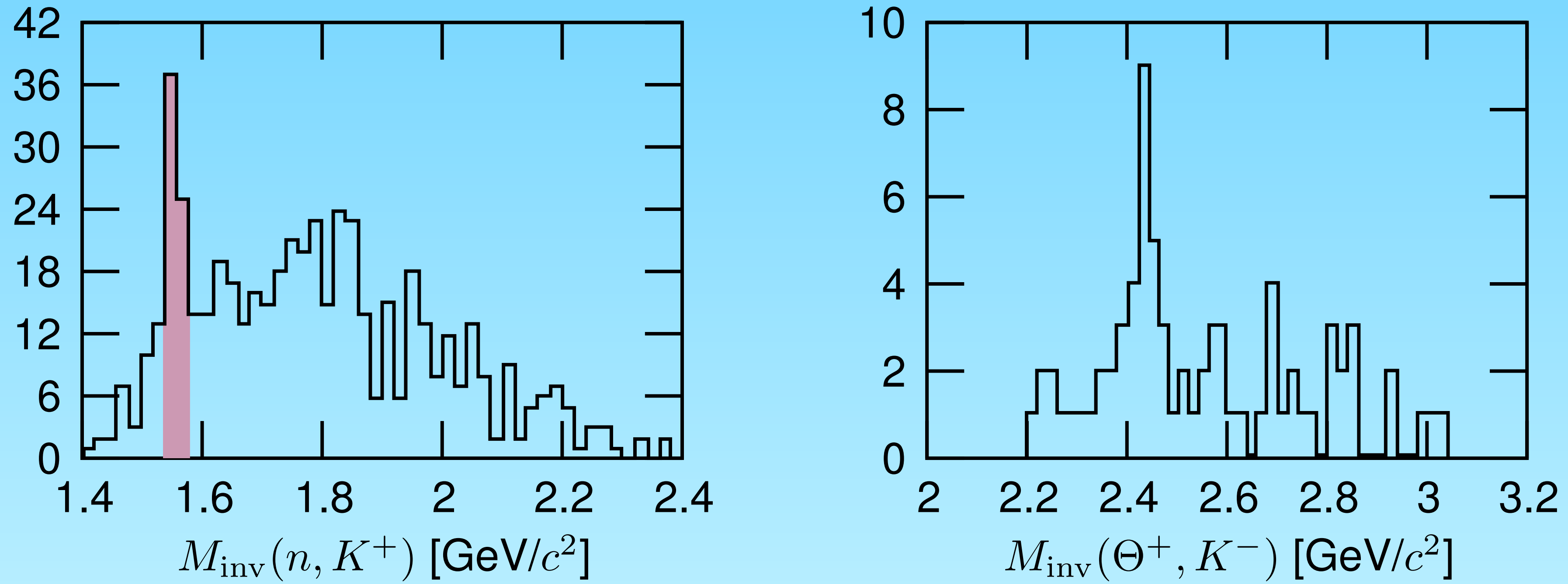
  $\cancel{\Theta}_c$: ZEUS, FOCUS, ALEPH, CLEO, BaBar, CDF

- new high stat. experiments at CLAS, first results in early 2005 (?)

Why some experiments see the Θ^+ and others don't ? – a possible explanation

Input from a second CLAS paper (arXiv:hep-ex/0311046)

Reaction: $\gamma p \to nK^+K^-\pi^+$



A resonance at m=2.4 GeV?

⇒ **Production of Θ^+ via decay of a cryptoexotic N^* resonance**

hep-ph/0405002

- HERA: $\bar{d}/\bar{p} \approx 5.0 \times 10^{-4}$. LEP: $\bar{p}/Z^0 \sim 1$. Where are LEP $\bar{d}$-s ?!T.Sloan

Θ^+ production cross section decreases with energy much faster than for 3 quark baryons, for both diffractive and fragmentation production (Titov et al.):

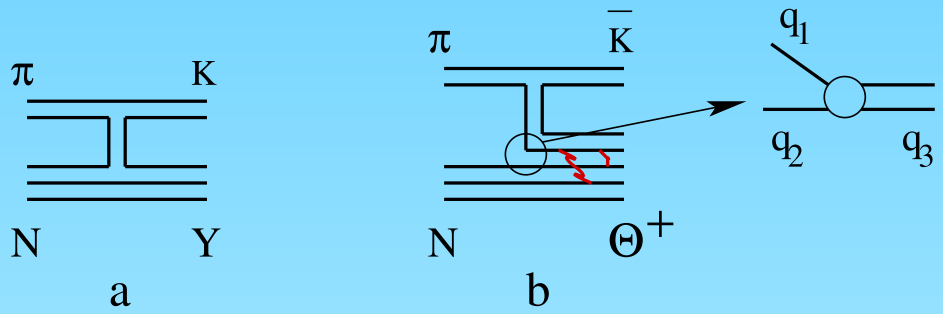


FIG. 1: The hyperon (a) and Θ^+ (b) -production in diffractive region.

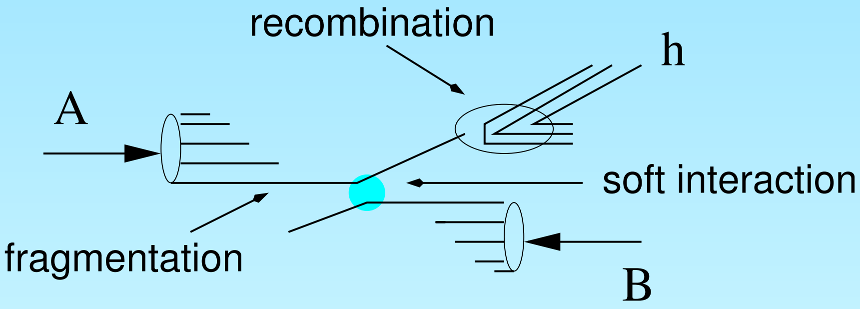


FIG. 3: Production of Θ^+ in inclusive reactions in the fragmentation region.

so far only upper bound on width,
because of experimental E resolution

but extremely narrow width from indirect analysis!

- re-analysis of old KN data:

  $\Gamma_{\Theta^+} \lesssim 1$ MeV (Nussinov, Arndt et al.)

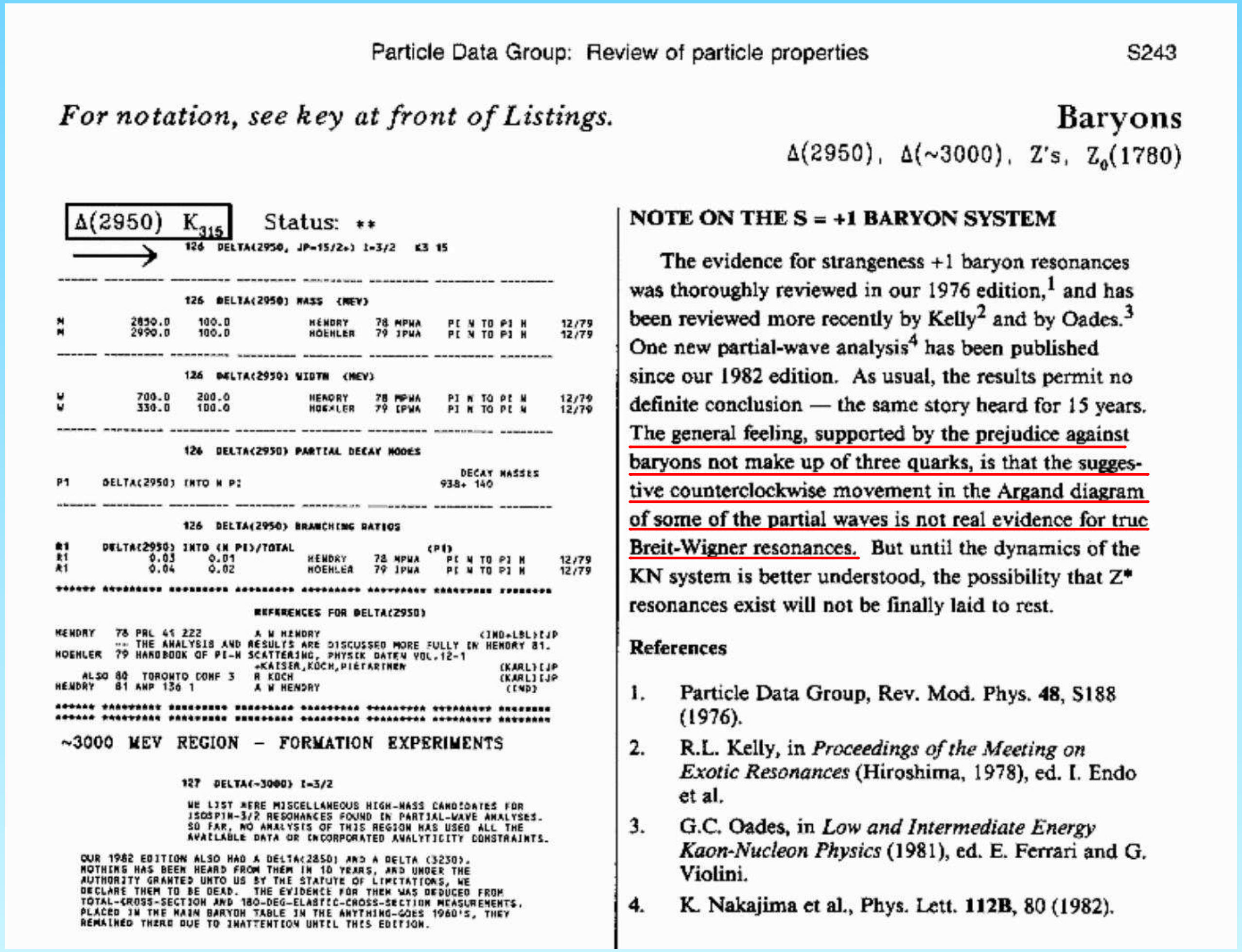
  but analysis indirect: no exp. coverage of relevant energy

  Cahn & Trilling: $\Gamma_{\Theta^+} = 0.9 \pm 0.3$ MeV from DIANA K^+Xe data

  $\Gamma_{\Theta^+} < \quad 1\text{–}4 \quad$ MeV from older exps

such a narrow width is unheard of in strong decays ?!...

1984 Review of Particle Properties:



For notation, see key at front of Listings.

Baryons

$\Delta(2950)$, $\Delta(\sim3000)$, Z's, $Z_0(1780)$

$\boxed{\Delta(2950)\ \ K_{315}}$ Status: **

$\longrightarrow$

```
                     126  DELTA(2950, JP=15/2+) I=3/2   K3 15

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                     126  DELTA(2950) MASS  (MEV)

M          2850.0     100.0            HENDRY     78 MPWA    PI N TO PI N     12/79
M          2990.0     100.0            HOEHLER    79 IPWA    PI N TO PI N     12/79

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                     126  DELTA(2950) WIDTH  (MEV)

W           700.0     200.0            HENDRY     78 MPWA    PI N TO PI N     12/79
W           330.0     100.0            HOEHLER    79 IPWA    PI N TO PI N     12/79

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                     126  DELTA(2950) PARTIAL DECAY MODES

                                                              DECAY MASSES
P1      DELTA(2950) INTO N PI                               938+ 140

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                     126  DELTA(2950) BRANCHING RATIOS

R1      DELTA(2950) INTO (N PI)/TOTAL                      (P1)
R1             0.03       0.01         HENDRY     78 MPWA    PI N TO PI N     12/79
R1             0.04       0.02         HOEHLER    79 IPWA    PI N TO PI N     12/79

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                          REFERENCES FOR DELTA(2950)

HENDRY    78 PRL 41 222         A W HENDRY                             (IND+LBL)IJP
             -- THE ANALYSIS AND RESULTS ARE DISCUSSED MORE FULLY IN HENDRY 81.
HOEHLER   79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
                                +KAISER,KOCH,PIETARINEN                  (KARL)IJP
    ALSO 80  TORONTO CONF 3     R KOCH                                   (KARL)IJP
HENDRY    81 ANP 136 1          A W HENDRY                                (IND)

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~3000 MEV REGION – FORMATION EXPERIMENTS

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                     127  DELTA(~3000) I=3/2

                      WE LIST HERE MISCELLANEOUS HIGH-MASS CANDIDATES FOR
                      ISOSPIN-3/2 RESONANCES FOUND IN PARTIAL-WAVE ANALYSES.
                      SO FAR, NO ANALYSIS OF THIS REGION HAS USED ALL THE
                      AVAILABLE DATA OR INCORPORATED ANALYTICITY CONSTRAINTS.

   OUR 1982 EDITION ALSO HAD A DELTA(2850) AND A DELTA (3230).
   NOTHING HAS BEEN HEARD FROM THEM IN 10 YEARS, AND UNDER THE
   AUTHORITY GRANTED UNTO US BY THE STATUTE OF LIMITATIONS, WE
   DECLARE THEM TO BE DEAD.  THE EVIDENCE FOR THEM WAS DEDUCED FROM
   TOTAL-CROSS-SECTION AND 180-DEG-ELASTIC-CROSS-SECTION MEASUREMENTS.
   PLACED IN THE MAIN BARYON TABLE IN THE ANYTHING-GOES 1960'S, THEY
   REMAINED THERE DUE TO INATTENTION UNTIL THIS EDITION.
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NOTE ON THE S = +1 BARYON SYSTEM

The evidence for strangeness +1 baryon resonances was thoroughly reviewed in our 1976 edition,[1] and has been reviewed more recently by Kelly[2] and by Oades.[3] One new partial-wave analysis[4] has been published since our 1982 edition. As usual, the results permit no definite conclusion — the same story heard for 15 years. The general feeling, supported by the prejudice against baryons not make up of three quarks, is that the suggestive counterclockwise movement in the Argand diagram of some of the partial waves is not real evidence for true Breit-Wigner resonances. But until the dynamics of the KN system is better understood, the possibility that Z^* resonances exist will not be finally laid to rest.

References

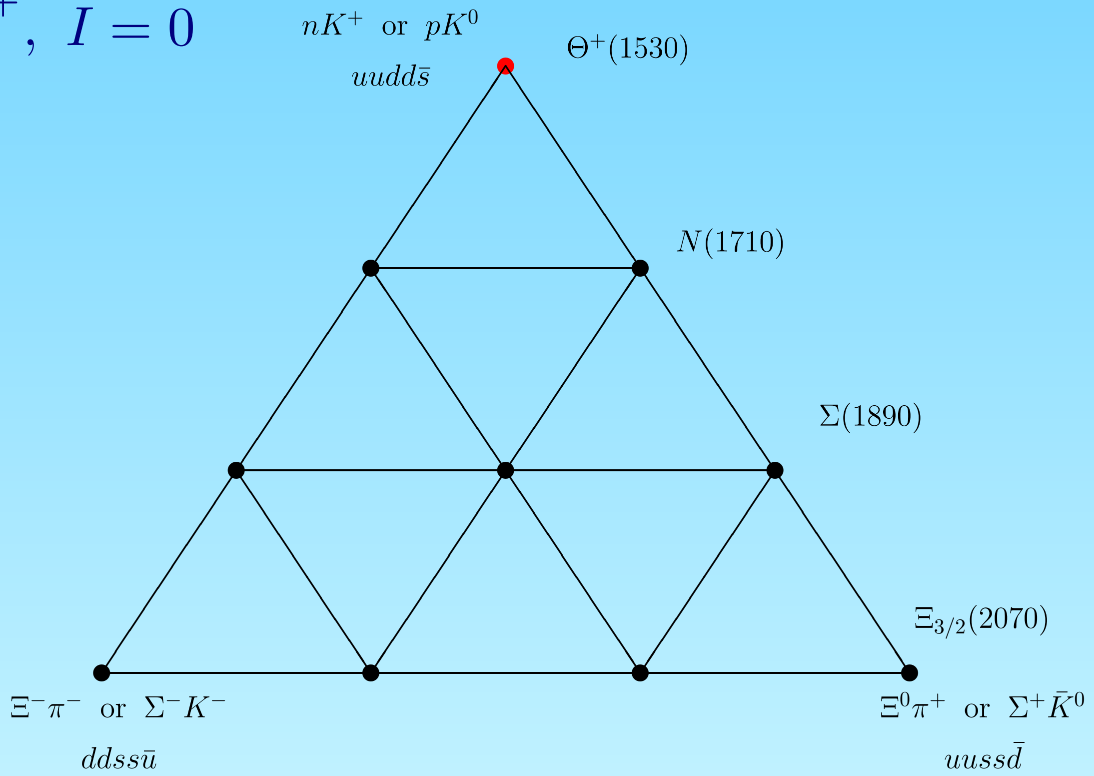
1. Particle Data Group, Rev. Mod. Phys. **48**, S188 (1976).
2. R.L. Kelly, in *Proceedings of the Meeting on Exotic Resonances* (Hiroshima, 1978), ed. I. Endo et al.
3. G.C. Oades, in *Low and Intermediate Energy Kaon-Nucleon Physics* (1981), ed. E. Ferrari and G. Violini.
4. K. Nakajima et al., Phys. Lett. **112B**, 80 (1982).

A beautiful prediction from Skyrme model:

Praszałowicz('87), Diakonov, Petrov & Polyakov('97): $m_{\Theta^+} \approx 1530$ MeV,

$\Gamma_{\Theta^+} < 15$ MeV, $J^P = \frac{1}{2}^+$, $I = 0$

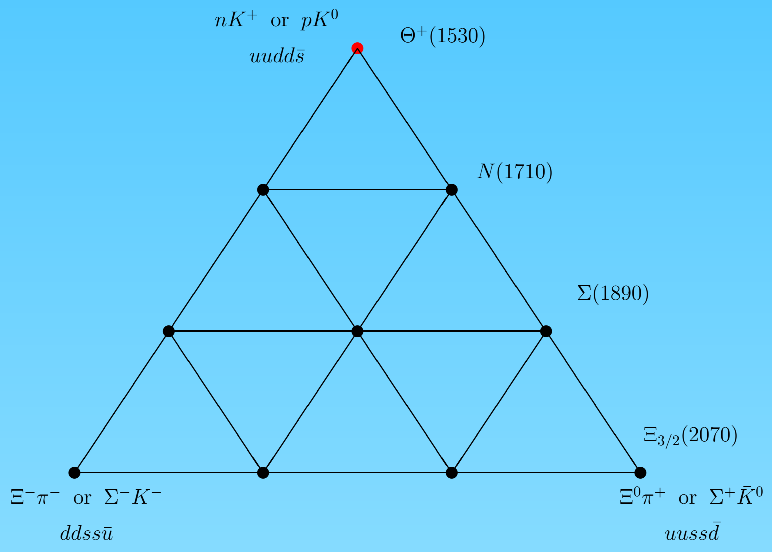
$\overline{10}$ of $SU(3)_f$:



important: $SU(3)$ breaking linear in $Y = B - S$

for $S < 0$, ordinary baryons – simple: counting s-quarks.

for $S > 0$, a bit subtle: need to understand quark WF first.

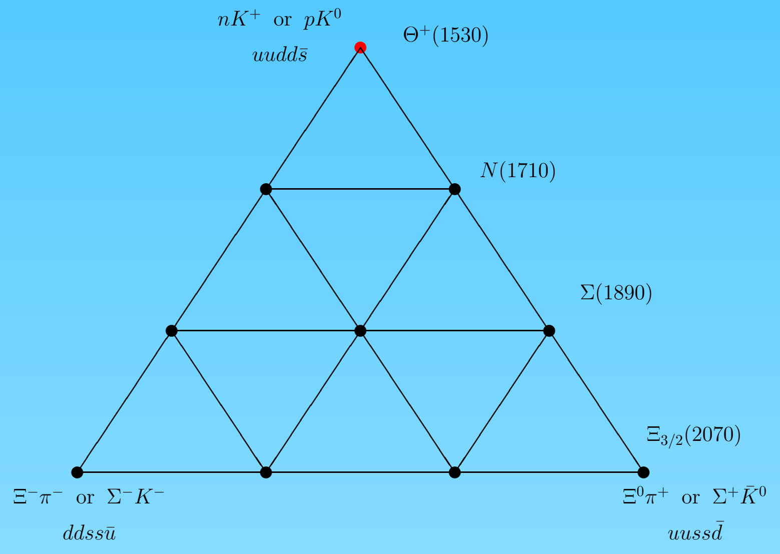


Quark content of the other states in $\overline{\mathbf{10}}$:

- start from $|\Theta^+\rangle = |uudd\bar{s}\rangle$
- apply U-spin lowering operator U_- repeatedly (cf. I_-):

$$\begin{array}{lll} I_-|u\rangle = |d\rangle & & U_-|d\rangle = |s\rangle \\ & \Longleftrightarrow & \\ I_-|\bar{d}\rangle = -|\bar{u}\rangle & & U_-|\bar{s}\rangle = -|\bar{d}\rangle \end{array}$$

- get the other states in each row applying I_-
- $|p^*\rangle = U_-|uudd\bar{s}\rangle = -\sqrt{\frac{1}{3}}\,|uud\,d\bar{d}\rangle + \sqrt{\frac{2}{3}}\,|uud\,s\bar{s}\rangle$



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- $|p^*\rangle = U_-|uudd\bar{s}\rangle = -\sqrt{\frac{1}{3}}\,|uud\,d\bar{d}\rangle + \sqrt{\frac{2}{3}}\,|uud\,s\bar{s}\rangle$ “crypto-exotic”
- “hidden strangeness” (like in ϕ)

$$\langle \#s + \#\bar{s}\rangle_{p^*} = 2 \times \left(\sqrt{\frac{2}{3}}\right)^2 = \frac{4}{3}$$

- $|\Sigma^{+*}\rangle = U_-|p^*\rangle, \qquad |\Xi^{+*}\rangle = U_-|\Sigma^{+*}\rangle = |uuss\bar{d}\rangle$
- $\Delta\langle \#s + \#\bar{s}\rangle = \dfrac{1}{3} \qquad \Longrightarrow \qquad \Delta M \sim \dfrac{m_s}{3}$!

But can't expect 1% precision for m_{Θ^+}

$\Longrightarrow$ Re-examine Skyrme/χSM predictions

hep-ph/0401127

- light $\overline{\mathbf{10}}$ a qualitative success
- realistic error estimate: $\delta m_{\overline{10}} \lesssim 100$ MeV
- DPP $m_{\Xi^{--}}$ off by 200 MeV: antiquated $\Sigma_{\pi N}$
- modern $\Sigma_{\pi N} \Longrightarrow$ central value of $m_{\Xi^{--}}$ ✓
- $\Gamma_{\overline{10}} \sim \mathcal{O}(1/N_c^2)$
- with realistic couplings hard to get $\Gamma_{\overline{10}} < 10$ MeV
- key prediction: light **27** with $J^P = \frac{3}{2}^+$

$\Rightarrow$ Θ-like $I = 1$ state within 100 MeV of $\Theta^+(I = 0)$

χSM & quark model: complementary description of hadrons

⇒ Need to understand Θ^+ in quark language

- QCD: nothing prevents $5q$ states
- but no direct QCD spectrum calculation yet (LC, lattice ?. . .)
- Constituent Quark Model:

$$M = \sum_i m_i - \underbrace{\sum_{i>j} V(\vec{\lambda}_i \cdot \vec{\lambda}_j) \frac{\vec{\sigma}_i \cdot \vec{\sigma}_j}{m_i \cdot m_j}}_{\text{hyperfine interaction}}$$

m_i : effective quark mass, $\vec{\lambda}$: $SU(3)_c$ generators, $\vec{\sigma}$: Pauli spin operators

$\Longrightarrow$ color-spin $SU(6)$ algebra:

symmetric in color × spin ⟷ attractive

antisymmetric in color × spin ⟷ repulsive

application: unravelling Θ^+ quark structure

- Θ^+: K^+n and $K^0p \iff \{uudd\bar{s}\}$
- Θ^+ is light! $\Rightarrow$ Goldstone-like component(s): minimize E_{int}

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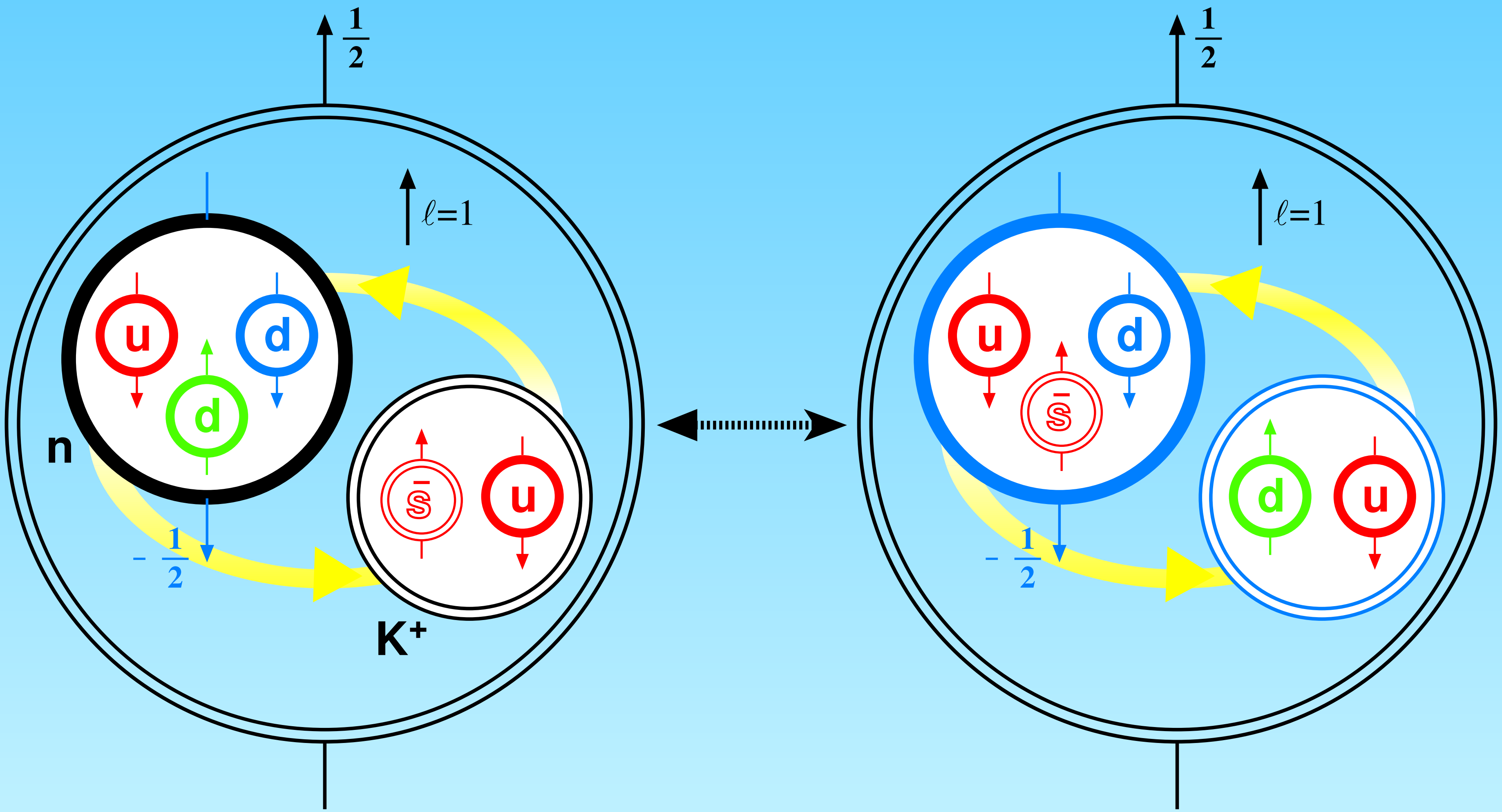
  color molecule of $\bar{\mathbf{3}}_c$ and $\mathbf{3}_c$ in a P-wave
- hyperfine int. short range ⟶ acts only *within* clusters

diquark-triquark configuration:



K n configuration **diquark – triquark configuration of the *uudd$\bar{s}$* pentaquark**

P-wave diquark-triquark molecule. No *S*-wave $\Longleftrightarrow$ h.f. repulsion

Θ^+ properties from diquark-triquark

- $|ud\ du\bar{s}\rangle$:
- ud diquark: $I = 0,\quad S = 0,\quad \bar{\mathbf{3}}_c$
- $ud\bar{s}$ triquark: $I = 0,\quad S = \frac{1}{2},\quad \mathbf{3}_c$ with ud in $S = 1$

$\Longrightarrow$ $J^P = \frac{1}{2}^+,\ I = 0,\ \overline{10}$ of $SU(3)_f$

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- estimate cost of P-wave excitation of $\{ud\}\{du\bar{s}\}$ system:

  reduced mass ≈ reduced mass of $c\bar{s}$ in D_s system

  $\Longrightarrow$ $\delta E^{P-wave} \approx 350 - (m_{D_s^*} - m_{D_s}) = 207$ MeV

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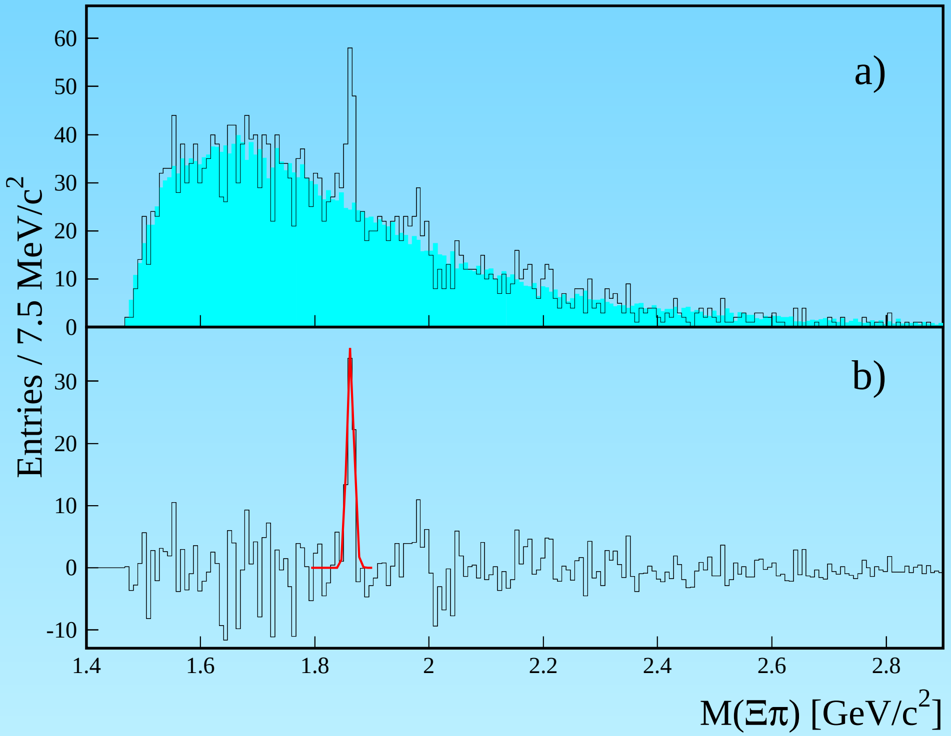
  $\Longrightarrow$ $\delta E^{P-wave} \approx 350 - (m_{D_s^*} - m_{D_s}) = 207$ MeV
- $m_{\Theta^+} \approx 1592 \pm 50$ MeV vs. 1542 ± 5 MeV (EXP).

analogous triquark-diquark configuration predicts

$m_{\Xi^{--}} = 1720 \pm 50$ MeV

vs exp, NA49:

$m_{\Xi^{--}} = 1862 \pm 2$ MeV, $\Gamma_{\Xi^{--}} < 18$ MeV



generic for all correlated quark configurations

but Ξ^{--}(1862) 400 MeV above $\Xi\pi$ threshold vs 100 MeV for Θ^+

$\Longrightarrow$ challenge for theory: additional degrees of freedom ?

a mass inequality for Ξ^{--*} and Θ^{+}

hep-ph/0402008

- **for unbroken** $SU(3)_f$**:**
  $M(\Xi^{--*}) = M(\Theta^{+})$ **as both in same** $\overline{10}$
- $SU(3)_f$ **breaking:** $m_s > m_u$
- **variational wave function for** Ξ^{--*} **:**
  $\Psi(\Theta^{+})$ **with** $u \to s$, $\bar{s} \to \bar{u}$

$\Rightarrow$ **upper bound on** $M(\Xi^{--*})$**:**

$$M(\Xi^{*--}) \leq M(\Theta^{+}) + m_s - m_u + \langle \delta V_{hyp}(\bar{s} \to \bar{u}) \rangle_{\Theta^{+}} + \langle \delta V_{hyp}(u \to s) \rangle_{\Theta^{+}}$$

$$M(\Xi^{*--}) - M(\Theta^{+}) \lesssim 300 \text{ MeV}$$

vs. EXP: 330 MeV

- **need confirmation of exp. mass values**
- **strong constraints on models of 5q structure**

a possible explanation for narrow Θ^+ width

hep-ph/0401072

- two almost degenerate $2q$-$2q$-$\bar{s}$ configurations: Θ_1 and Θ_2
- both can decay via quark rearrangement to isoscalar KN
- so they mix by a loop diagram: $\Theta_i \rightarrow KN \rightarrow \Theta_j$
- diagonalize the mass matrix: $M_{ij} = M_0 \langle \Theta_i | T | KN \rangle \langle KN | T | \Theta_j \rangle$

$$|\Theta\rangle_S \equiv \cos\phi \cdot |\Theta_1\rangle + \sin\phi \cdot |\Theta_2\rangle$$

$$|\Theta\rangle_L \equiv \sin\phi \cdot |\Theta_1\rangle + \cos\phi \cdot |\Theta_2\rangle$$

- the lower eigenstate, Θ_L, decouples from the KN channel

destructive interference !

width suppression in presence of Θ_1, Θ_2 splitting

$$\frac{\Gamma_{\Theta_L}}{\Gamma_{\Theta_S}} \leq \frac{\Delta M^2}{4\Gamma^2_{\Theta_S}}$$

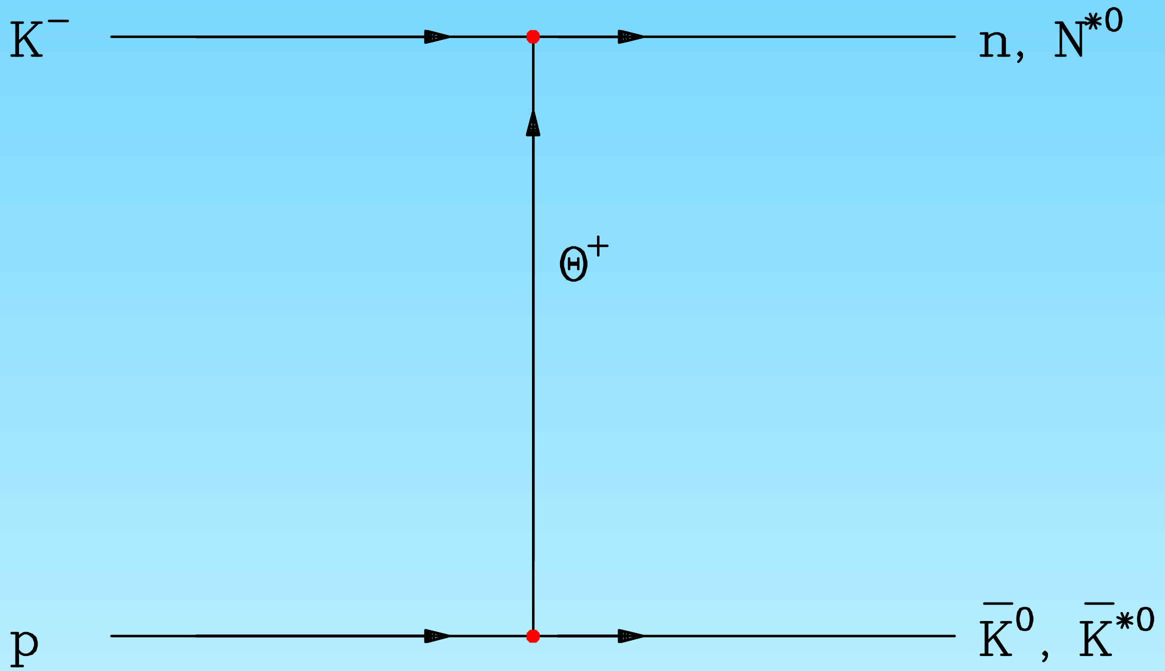
e.g. for $\Delta M = 40$ **MeV and** $\Gamma_{\Theta_S} = 120$ **MeV**

suppression factor = 1/36

$$\Longrightarrow \quad \Gamma_{\Theta_L} \lesssim 3\ \textbf{MeV}$$

couplings to K^*N channel <u>not suppressed</u>
so look at

baryon-exchange K^-p reactions with K going backward in CM:



$K^-p \to \bar{K}^o n$; $K^-p \to \bar{K}^{*o} n$; $K^-p \to \bar{K}^o N^{*o}$ **suppressed**

$K^-p \to \bar{K}^{*o} N^{*o}$ **unsuppressed**

experimental challenges

- confirmation of Θ^+ and Ξ^{*--}
- parity measurement
  (a) $K^+p \to \Theta^+\pi^+$ vs. $K^+D \to \Theta^+p$
  (b) polarization asymmetry in $\vec{p}\,\vec{p} \to \Sigma^+\Theta^+$, $\vec{p}\,\vec{n} \to \Lambda\Theta^+$
  (c) polarization asymmetry in $\vec{\gamma}\,n \to K^-\Theta^+$
- search for new states:
  (a) $\bar{s} \to \bar{c}, \bar{b}$
  (b) Θ^+: $J = \frac{1}{2}$ with $L = 1$, $S = \frac{1}{2}$ $\Longrightarrow$ $\overline{\mathbf{10}}$ with $J = \frac{3}{2}$
  (c) higher reps: **27**, **35**, . . .

a new spectroscopy !

enhancing signal-to-noise in Θ^+ production on nucleon at rest:

- resonance of given $J^P \Longrightarrow$ definite ang. dist. in CM
- in particular: $J = \frac{1}{2} \Longrightarrow$ isotropic in CM

  $\Longrightarrow$ forward-backward symm.
- vs background:

  eg. peripheral scattering forward-peaked in CM
- transform to LAB
- can use existing kinematical info:
- look at dist. of $\Delta p^2 \equiv |\vec{p}_K|^2 - |\vec{p}_N|^2$ in LAB

  vs $\Delta p_\perp^2$ which corresponds to 90^o scattering in CM
- might help decide if peaks due to genuine resonance
- can also test for kinematic reflections
- warm-up exercise: $\Lambda(1520)$

Predictions: Θ_c and Θ_b^+

- $\Theta^+ : \{ud\}\,\{du\bar{s}\}$ - a narrow resonance

- $\bar{s} \to \bar{c}: \quad \Longrightarrow \quad \Theta_c : \{ud\}\,\{du\bar{c}\} \qquad J^P = \frac{1}{2}^+,\, I = 0$

  $$M_{\Theta_c} = 2985 \pm 50 \text{ MeV}$$

  $$\Gamma(\Theta_c \to DN) \;\sim\; (1 \div 2) \times 21 \text{ MeV}\,.$$

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$\implies$ look for unexpectedly narrow peaks
in D^-p, $D^{*-}p$, $\bar{D}^0n$, $\bar{D}^{*0}n$, B^0p, $B^{*0}p$, B^+n and $B^{*+}n$.

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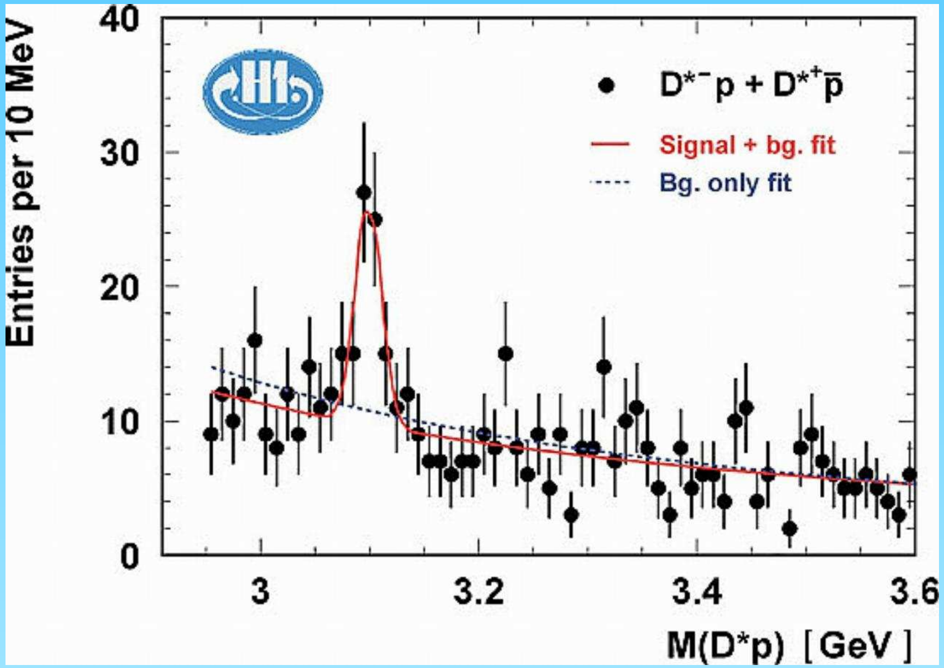
$\Longrightarrow$ look for protons coming out of charm/bottom decay vertex

Evidence for Θ_c from H1?



- a narrow resonance in $D^{*-}\,p$ and $D^{*+}\,\bar{p}$ channels: $uudd\bar{c}$ and $\bar{u}\bar{u}\bar{d}\bar{d}c$:

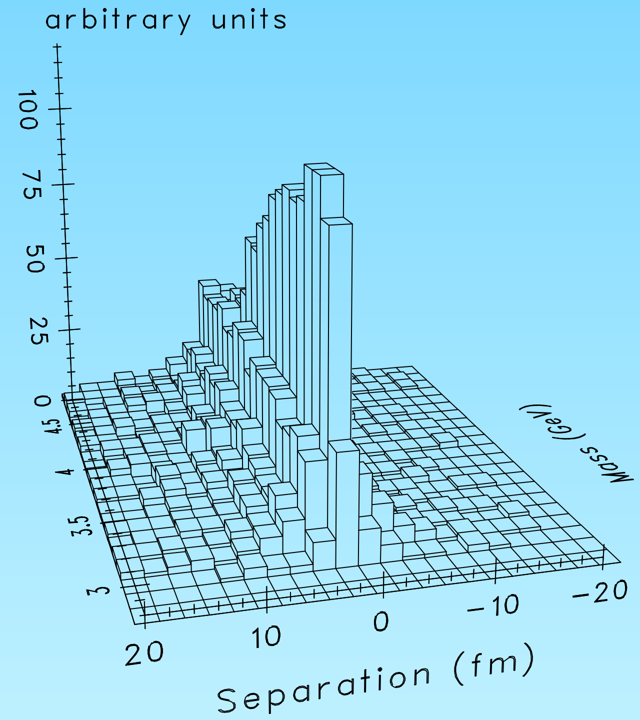
$$m = 3099 \pm 3 \pm 5 \text{ MeV} \qquad \Gamma = 12 \pm 3 \text{ MeV} \qquad 5.4\ \sigma$$

- not seen by ZEUS, despite larger data sample
- $D^{-}p$: more phase space. Suppressed? (cf. KN vs $K^{*}N$ couplings of Θ_s^+)
- if $\Gamma(\Theta_s^+) > 2 \div 3$ MeV then $\Gamma(\Theta_c(3099)) \gtrsim 20 \div 30$ MeV

Coalescence model for Θ_c formation

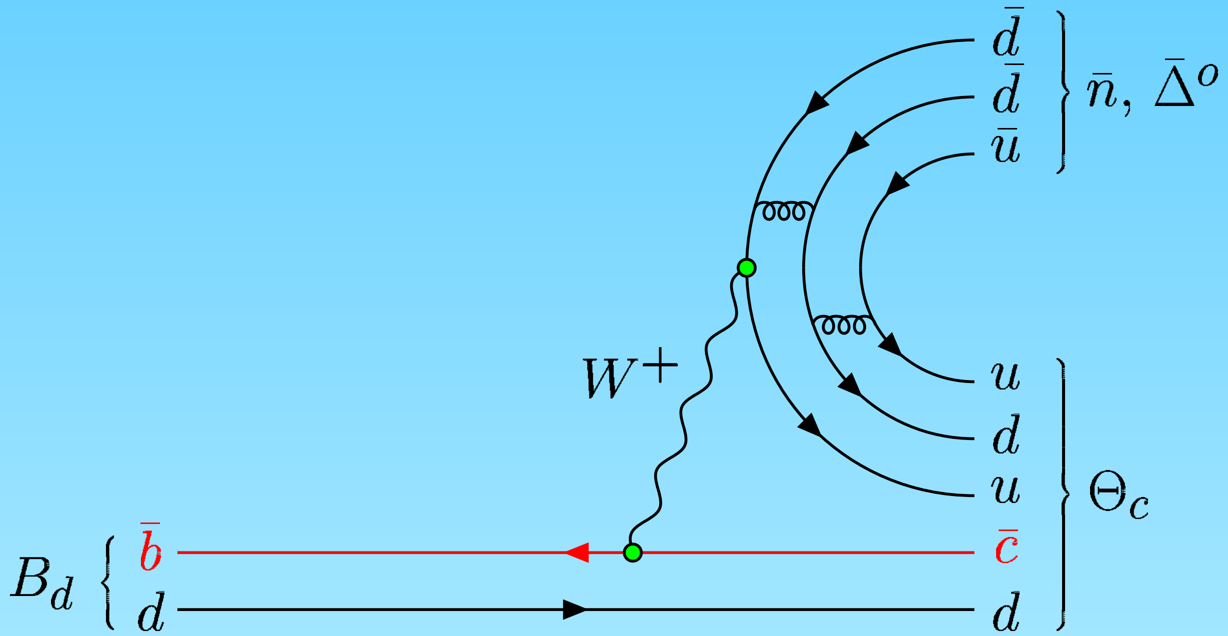
B.R. Webber & MK, hep-ph/0409121

- Θ_c formed by coalescence of p and D^{*-}
- $\sigma(\Theta_c) = F_{\rm co} \times$ number of pD^{*-} pairs
  $3050 < M(D^{*-}p) < 3150$ MeV, spacelike $0 < \Delta x < 2$ fm
- HERWIG MC:



- compare with H1 data $\Longrightarrow F_{\rm co} \lesssim 10$
- apply to LEP: should have seen 25-40 Θ_c events per experiment
- apply to Tevatron: should have seen at least few $\times 10^4$ events

Pentaquark production in B decays



- expect reasonable BR for $B \to$ baryon $+$ antibaryon
- a striking signature: $B \to \Theta^+ +$ charmed antibaryon
- E and $\vec{p}$ conservation in B CM frame:
  unlike multihadron reactions, no kinematical ambiguities!
- in $\Theta^+ \to K_s\, p$ decay, K_s flavor tagged by antibaryon

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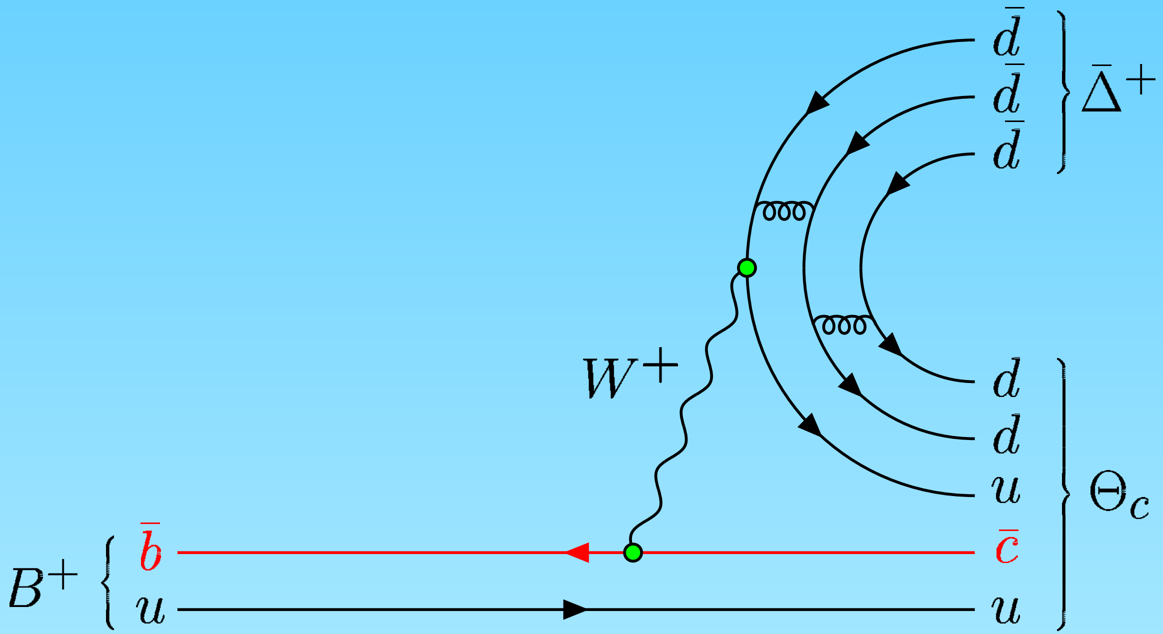

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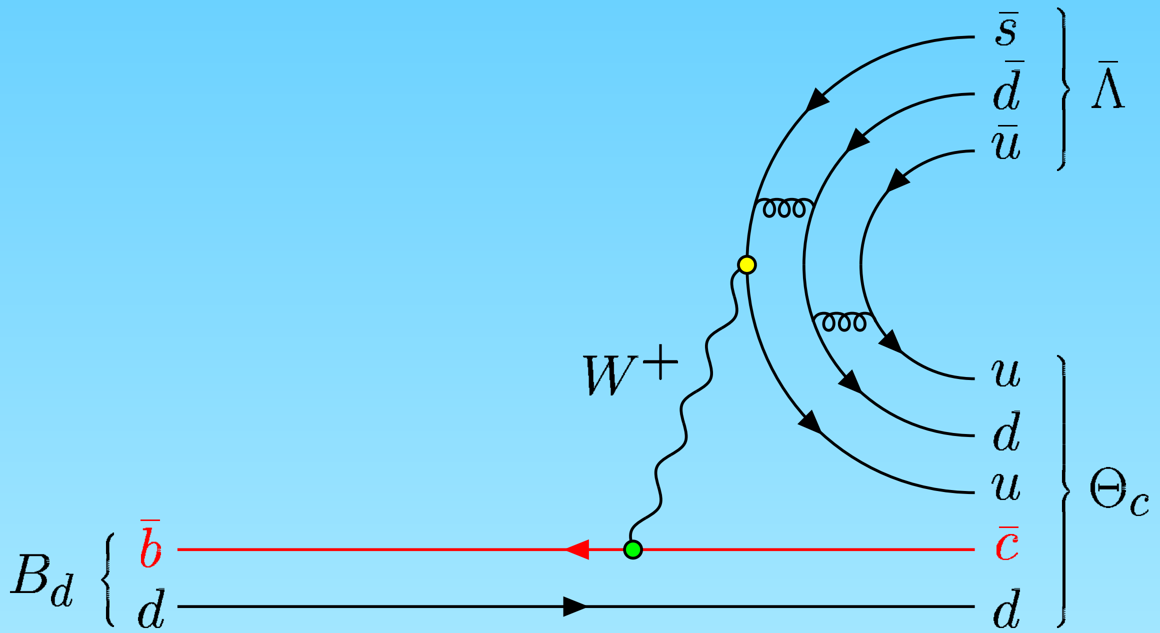

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Cabibbo hierarchy: 🟢 preferred 🟡 suppressed 🔴 doubly suppressed

- 🟢 $P^o(\bar{c}suud)$ – the “original pentaquark”: $B_s(\bar{b}s) \rightarrow P^o + \bar{n}$

and in charm factories

$$\psi' \rightarrow \Theta^+ + X$$

A possible tetraquark cousin of Θ^+

- **If $\exists$ narrow Θ^+, likely $ud\bar{s}$-ud component**
- $ud\bar{s}$-ud **binding mechanism** $\Longleftrightarrow$ $ud\bar{s}$-$\bar{s}$ **binding**
- **isoscalar $\mathcal{M}^+_{\bar{s}\bar{s}}$ with $S = +2$:**

  $M(\mathcal{M}^+_{\bar{s}\bar{s}}) - M(KK) \approx M(\Theta^+) - M(KN) + 300$ **MeV**
- $\mathcal{M}_{\bar{s}\bar{s}}$ **if $ud\bar{s}$ and $\bar{s}$ in P-wave:**

  1^-: **large width to K^+K^0**

  0^- **or** 2^-: **still large phase space to $KK\pi$**
- **what if $\mathcal{M}^+_{\bar{s}\bar{s}}$ has positive parity?**

  a striking experimental signature:

  sel. rules from generalized Bose stat. for K^+K^0

  $\mathcal{M}^+{}_{\bar{s}\bar{s}}$ **with $I = 0$, 0^+ can't decay to anything below $KK\pi\pi$**

  - **a narrow four-body resonance; never looked for**
  - $K^+p \to \Lambda\,\mathcal{M}^+_{\bar{s}\bar{s}} + X$, $K^+p \to \Sigma\,\mathcal{M}^+_{\bar{s}\bar{s}} + X$, $K^+p \to \Sigma^+\,\mathcal{M}^+_{\bar{s}\bar{s}}$