HYPERON 99

Fermilab, Sep. 27-29, 1999

WEAK RADIATIVE HYPERON DECAYS QUESTIONING THE BASICS ?

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- FACTS
- OPINIONS ⟷ MODELS
  ⇑
  EXPERIMENTALLY TESTABLE

- WRHD's: 30-YEAR OLD

1964 - HARA's THEOREM → ASYMMETRY $\alpha(\Sigma^+ \to p\gamma)$ SMALL!
1969 - GERSHWIN et al, LBL → $-1.0^{+0.5}_{-0.4}$

[1964: a good year:
QUARKS
~~CP~~
QUANTUM NONLOCALITY

HARA'S THEOREM VS. DATA NOW

- Hara's theorem (HARA):

> PARITY VIOLATING (p.v.) AMPLITUDE A FOR $\Sigma^+ \to p\gamma$ (and $\Xi^- \to \Sigma^-\gamma$) SHOULD VANISH IN EXACT FLAVOUR SU(3)

assumptions: gauge-invariance
CP
local field theory (hadrons)

IN REALITY SU(3) BROKEN $\Rightarrow A \neq 0$
BUT:
IF p.c. AMPLITUDE B NOT SMALL ($A \ll B$)
$\Rightarrow \alpha = \frac{2AB}{A^2+B^2} \approx 2\frac{A}{B}$ → SMALL (±0.2?)

- DATA NOW:

	$\alpha(\Sigma^+ \to p\gamma)$	
1992	-0.72 ± 0.086	Foucher et al.
1998	-0.76 ± 0.08	PDG average

VIOLATION OF Hara's theorem ?

~~HARA~~ ≡ no HARA

ENTER ALL WRHD's

IMAGINE: WE MEASURED $\mu_p = +2.79$ $(\neq +1)$
BUT DON'T KNOW μ_n, μ_{Σ^+} etc.
IMPORTANT:
"LARGE CORRECTION TO DIRAC MOMENT"

BUT:
NO CONCLUSIONS ON QUARK/SU(6) POSSIBLE:

$$\frac{\mu_n}{\mu_p} = \begin{cases} -\frac{2}{3} & \text{SYMMETRIC SPIN-FLAVOUR} \rightarrow \text{COLOUR} \\ -2 & \text{ANTISYMMETRIC} \end{cases}$$

$\Rightarrow$ $\alpha = -0.76$ (& BRANCHING RATIO FOR $\Sigma^+ \rightarrow p\gamma$)
NOT SUFFICIENT

VIOLATION (?) of Hara's theorem should be viewed TOGETHER with data/theory on other WRHD's

$\Lambda \rightarrow n\gamma$, $\Xi^0 \rightarrow \Lambda\gamma$, $\Xi^0 \rightarrow \Sigma^0\gamma$; $\Xi^- \rightarrow \Sigma^-\gamma$, $\Omega^- \rightarrow \Xi^-\gamma$

IF WE SUCCEED IN CONSTRUCTING A MODEL WHICH DESCRIBES ALL WRHD's with a SMALL number of parameters, we may conclude with REASONABLE CERTITUDE that we REALLY HAVE the CORRECT description

when such a model available $\Rightarrow$ further, deeper questions

ASYMMETRIES & branching

THEORETICAL CONFLICTS(?)

MUST take into account that

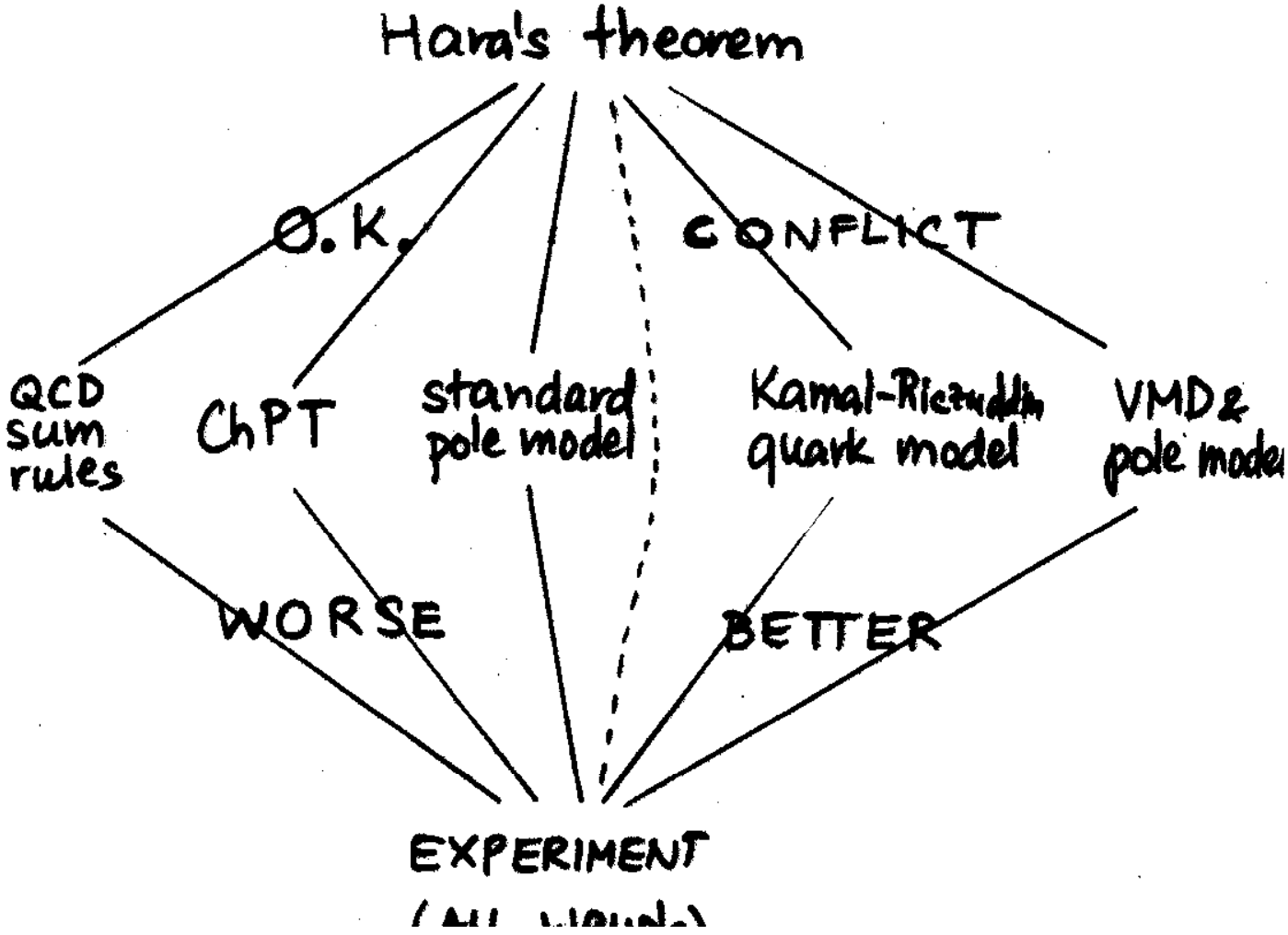
BARYONS ≡ COMPOSITES
made out of QUARKS

QUESTION IS:

HOW do we do it?

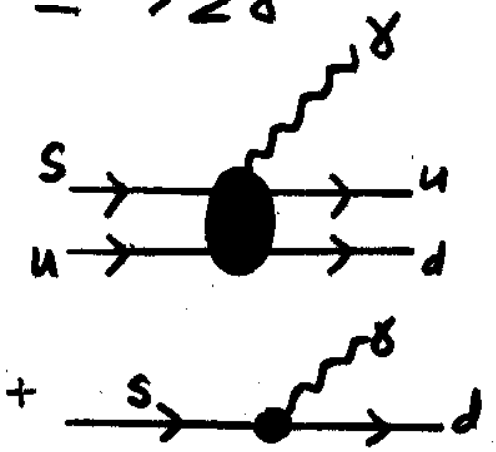
↑ the origin of "conflicts"

- SEVERAL WAYS (MODELS) in which quark degrees of freedom may be taken into account:

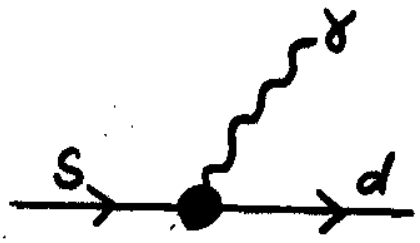


BASIC CONCLUSIONS FROM DATA ON QUARK-LEVEL TRANSITIONS

$\Sigma^+ \to p\gamma$
$\Lambda \to n\gamma$
$\Xi^0 \to \Lambda\gamma$
$\Xi^0 \to \Sigma^0\gamma$



$\Xi^- \to \Sigma^-\gamma$
$\Omega^- \to \Xi^-\gamma$

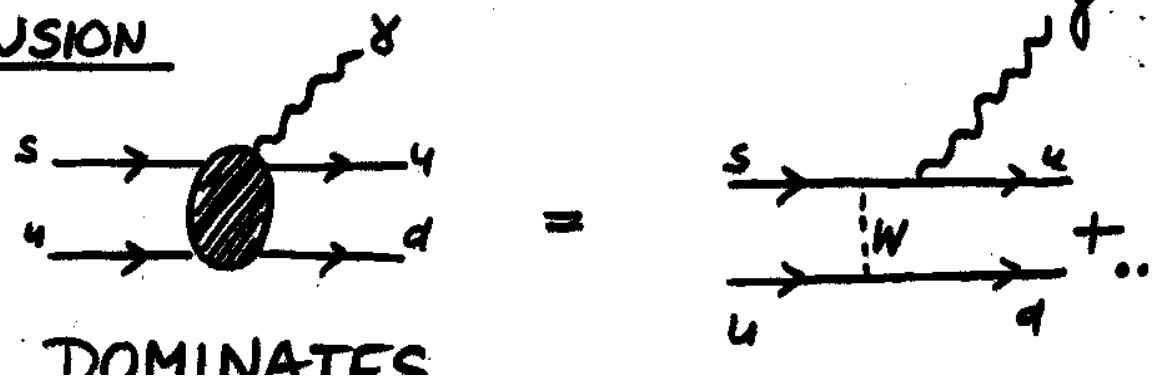


E761 $B.R.(\Xi^- \to \Sigma^-\gamma) = (0.128 \pm 0.023) * 10^{-3}$
VERY SMALL

assume $s \to d$ dominates
→ can estimate $B.R.(\Sigma^+ \to p\gamma)$ [Gilman, Wise]

$B.R._{\text{single quark}}(\Sigma^+ \to p\gamma) = 10^{-2} * \text{observed}$

CONCLUSION



DOMINATES

PARITY CONSERVING AMPLITUDES

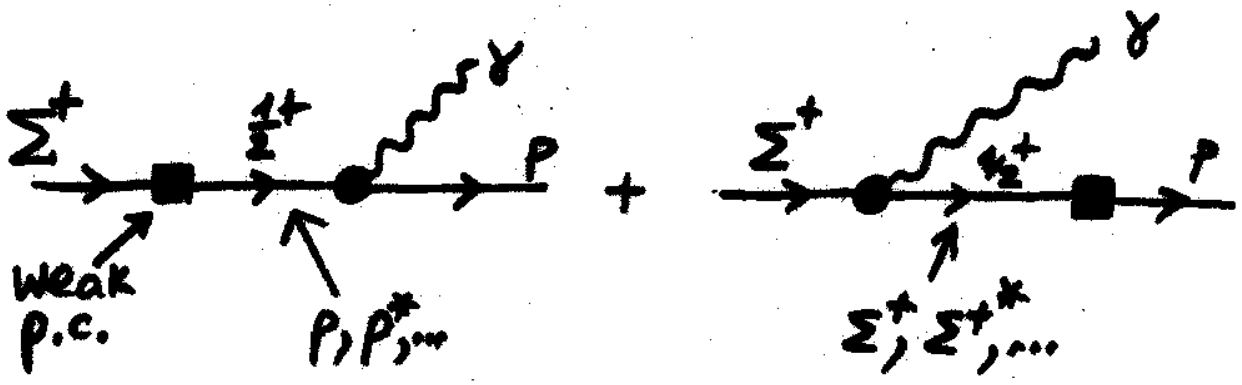
NO "CONFLICTS"

DESCRIPTION - STANDARD

ALLMOST ALL PAPERS AGREE QUALITATIVELY
(some non-conceptual differences
leading sometimes to numerical differenaes)

① BASIC:

HADRON-LEVEL POLE MODEL,
(very) similar to NONLEPTONIC DECAYS (NLHD)

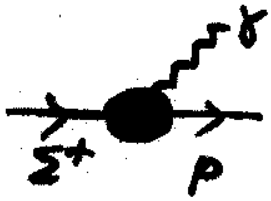


QUARKS: USED TO FIND SYMMETRY PROPERTIES OF HADRONIC BLOCKS

② ALTERNATIVE:

EVERYTHING EVALUATED AT
QUARK LEVEL
(no explicit hadronic poles)

ONE HADRONIC BLOCK



[predictions similar to ①]

QCD SUM RULES

sum rules:

asymmetry B.R.* 10^3	Khatsimovsky	Balitsky et al.	EXPERIMENT
$\Sigma^+ \to p\gamma$	+1 0.8	-0.85 ± 0.15* 0.5 to 1.5	-0.76 ± 0.08 1.23 ± 0.06
$\Lambda \to n\gamma$	$+0.10 \leftrightarrow +0.15$ $2.1 \leftrightarrow 3.1$		 1.65 ± 0.12
$\Xi^0 \to \Lambda\gamma$	+0.9 1.1		$+0.43 \pm 0.44$ 1.06 ± 0.16
$\Xi^0 \to \Sigma^0\gamma$			significantly negative 3.56 ± 0.43
$\Xi^- \to \Sigma^-\gamma$	+0.4		$+1.0 \pm 1.3$ 0.128 ± 0.023

*) ORIGINALLY POSITIVE

CHIRAL PERTURBATION THEORY Neufeld 92

small counterterms

- $\Sigma^+ \to p\gamma$ $\quad |\alpha| < +0.2$
  $\Lambda \to n\gamma$ $\quad \alpha = -0.7$ or -0.3
  $\Xi^0 \to \Lambda\gamma$, $\Sigma^0\gamma$ } DATA USED AS INPUT
  $\Xi^- \to \Sigma^-\gamma$ $\quad \alpha \in (-0.4, +0.3)$

" THE PREDICTIVE POWER OF ChPT IS LIMITED BY THE OCCURRENCE OF FREE PARAMETERS, WHICH ARE NOT RESTRICTED BY CHIRAL (OR OTHER) SYMMETRIES ALONE"

PARITY-VIOLATING E-M CURRENT

MOST GENERAL CURRENT:

$j^{(1)}$ ↙

$$j_5^\mu = g_{1,kl}(q^2)\,\bar{\psi}_k\left(\gamma^\mu - \frac{q^\mu \not{q}}{q^2}\right)\gamma_5\psi_l \qquad \text{"}\gamma\gamma_5$$

$$+ g_{2,kl}(q^2)\,\bar{\psi}_k(i\sigma^{\mu\nu}\gamma_5 q_\nu)\psi_l \qquad \text{"}\sigma\gamma_5$$

$j^{(2)}$ ↙

Hermiticity & CP-inv. of $A \cdot j_5$ require

- $g_{1,kl} = g_{1,lk} \qquad g_{2,kl} = -g_{2,lk}$ (and rea

Hara's theorem: $(k,l) \leftrightarrow (\Sigma^+, p)$

① no pole at $q^2=0$ (no exactly massless hadron)

$\Rightarrow g_{1,kl}(q^2) \propto q^2$

- ② for real, transverse photons

$q^2 = q\cdot A = 0 \Rightarrow$ ONLY $g_{2,kl}$ survives

③ SU(3)/U-spin $s \rightleftarrows d$

$\Sigma^+ = uus \rightleftarrows p = uud$

$\rightarrow g_{2,\Sigma^+p} = g_{2,p\Sigma^+} \longrightarrow \boxed{g_{2,\Sigma^+p} = 0}$

IF $g_{1,kl}(0) \neq 0 \Rightarrow$ ~~HARA~~

e.g. $g_{2,kl} \propto (m_k - m_l)$

STANDARD POLE MODEL HARA

Sequel to
LOPR 1979 successful description of NLHD (nonleptonic hyperon decays)

PARITY VIOLATING AMPLITUDES:

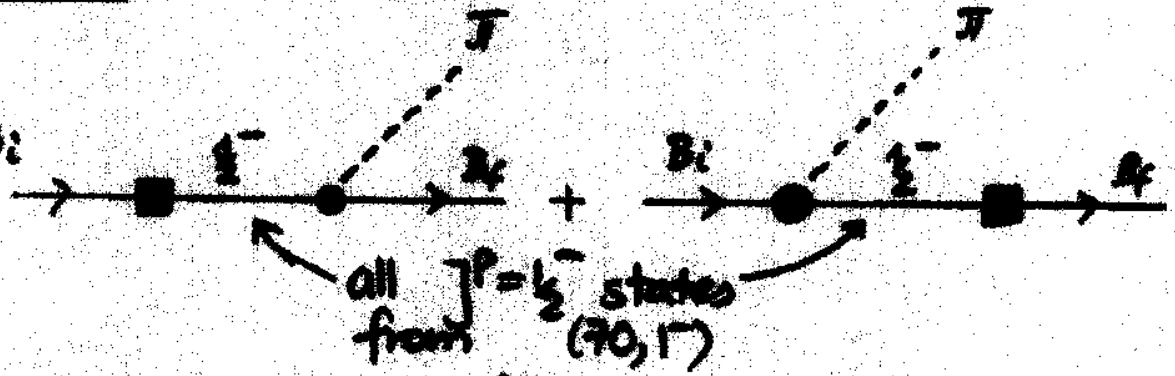
① A_{LOPR} = COMMUTATOR (NONZERO IN SU(3)) + CORRECTION from (70,1) VANISHING IN SU(3) ($\propto (m_s - m_u)$)

OR

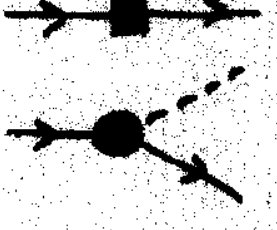
② SATURATE Current Algebra COMMUTATOR WITH (70,1⁻) STATES (the contribution from (70,1⁻) which does not vanish in SU(3))

THEN ① ⇒ FULL POLE MODEL WITH BROKEN SU(3)

NLHD's:



from QUARK MODEL:



$(1, \frac{1}{2})$	$\Lambda(1405)$
$(8, \frac{1}{2})$	$N(1535), \Lambda(1670), \Sigma(179$
$(8, \frac{3}{2})$	.....
$(R_{SU(3)}, S)$	(in average way)

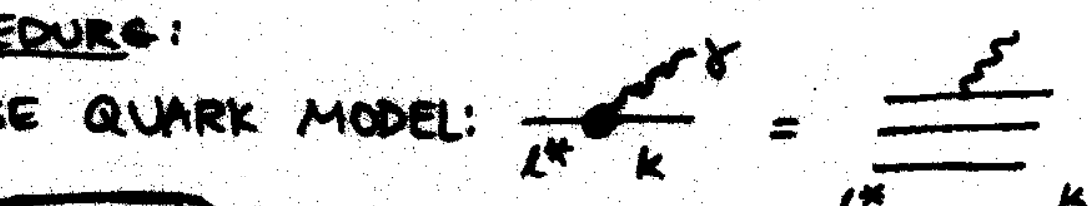
for WRHD's – analogous model

FULL POLE MODEL (version ②)

REASON: COMMUTATOR → ? "COMMUTATOR"
NLHD WRHD

for $\Sigma^+ \to p\bar{\nu}$ { "COMMUTATOR" = $\emptyset$
ONLY CORRECTION VANISHING IN SU3 EXPECTED TO APPEAR

PROCEDURE:

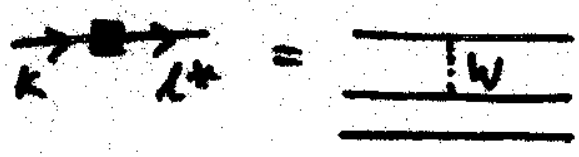
① USE QUARK MODEL: 

② (IDENTIFY) THE RESULT WITH

$$f_{2,kl}\ \bar{u}_{\frac{1}{2}^+,k}\ \sigma^{\mu\nu}\gamma_5 q_\nu\ u_{\frac{1}{2}^-,l^*}\cdot A^\mu$$

gauge-inv. p.c. photon coupling

$f_{2,kl^*} = f_{2,l^*k}$
CP, Hermiticit

③ USE QUARK MODEL 

$a_{kl^*} = -a_{lk^*}$
CP, Hermiticit

④ USE SYMMETRY TO GET 

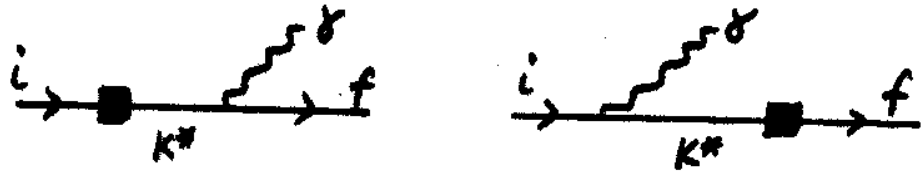
---

l^* = all $J^P = \frac{1}{2}^-$ states from (70,1)
as before

combining $\rightarrow\blacksquare\rightarrow$ and $\rightarrow\bullet\!\!\sim\rightarrow$ one gets

$$A \propto \sum_{K^*} \left\{ \frac{f_{2,fK^*}\, g_{K^*i}}{m_i - m_{K^*}} + \frac{g_{fK^*}\, f_{2,K^*i}}{m_f - m_{K^*}} \right\} * \bar{u}_f\, i\sigma^{\mu\nu} \gamma_5 q_\nu u_i \, (\epsilon$$

weight (b1) weight (b2)



- for $f=i$ (almost Hara's case) ← symmetric of g, f_2

$$f_{2,iK^*}\, g_{K^*i} = -\, g_{iK^*}\, f_{2,K^*i}$$

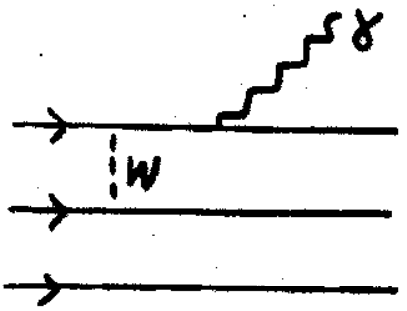
cancellation of (b1) and (b2)

	calculated in $SU(6)_W$ (b1)	calculated in $SU(6)_W$ (b2)	sign of asymmetry	GLOPR
$\Sigma^+ \rightarrow p\gamma$	$-\frac{1}{3\sqrt{2}}$	$-\frac{1}{3\sqrt{2}}$	— ~~SU(3)~~	$-0.80^{+0.32}_{-0.19}$
$\Lambda \rightarrow n\gamma$	$+\frac{1}{6\sqrt{3}}$	$+\frac{3}{6\sqrt{3}}$	—	-0.49
$\Xi^0 \rightarrow \Lambda\gamma$	0	$-\frac{1}{3\sqrt{3}}$	—	-0.78
$\Xi^0 \rightarrow \Sigma^0\gamma$	$\frac{1}{3}$	0	—	-0.96

HARA ⟷ (b1)−(b2) ⟷ (− − − −)

KAMAL-RIAZUDDIN 1983 KR

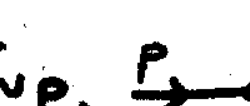
① QUARK MODEL CALCULATION of W-EXCHANGE (ONE BLOCK)



+ ... explicit ~~HARA~~

② AGREEMENT: KR is technically correct (Azimov, Holstein, P.Ż.,...)

③ DISAGREEMENT AS TO ORIGIN/MEANING

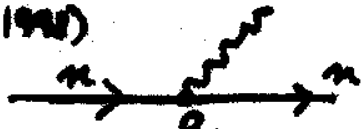
AZIMOV 1997 → 1. $\Sigma^+ \sim p$,  g_1

- TENTATIVELY IDENTIFY KR with $g_1 \neq 0$ $(\gamma_\mu \gamma_5)$ ⇒ ~~HARA~~

2. PERFORM γ_5-DEPENDENT RENORM "HIDE" $\gamma_\mu\gamma_5$ INTO γ_μ CURRENT.

3. ULTIMATELY no $\gamma_\mu\gamma_5$ ("p.v" ⇒ p.c.) (charge)

BUT: (P.Ż. 1998)

1. 

2. KR gives ANALOG of ~~HARA~~. $g_1 \neq 0$?

3. NO γ_μ (CHARGE Ø) piece to "HIDE" $\gamma_\mu\gamma_5$ INTO

⇒ KR NOT RELATED TO RENORM.

disagreement

HOLSTEIN } → ~~HARA~~ in KR
P.Ż }

DUE TO USE OF FREE QUARKS IN STATES OF DEFINITE MOMENTA

③ ASSUME ~~HARA~~ in KR is an artefact (due to quark freedom)

REPLACE quark model of KR by MODEL WITH THE SAME SPIN-FLAVOUR PREDICTIONS ELSEWHERE

BUT WITH QUARKS NOT TREATED AS COMPLETELY FREE PARTICLES

⇓

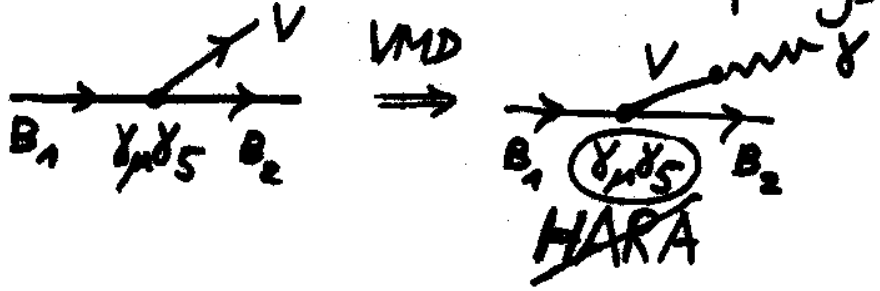
→ BAG MODEL (LO 1982)
seems: ~~HARA~~ still (P.Z.)
(should be more closely checked)

→ VMD ("always works")

– Schwinger: parameter-free prediction of baryon magnetic moments

– Kroll-Lee-Zumino: to ensure gauge-inv.

– Desplanques, Donoghue, Holstein 1980
weak vector-meson couplings

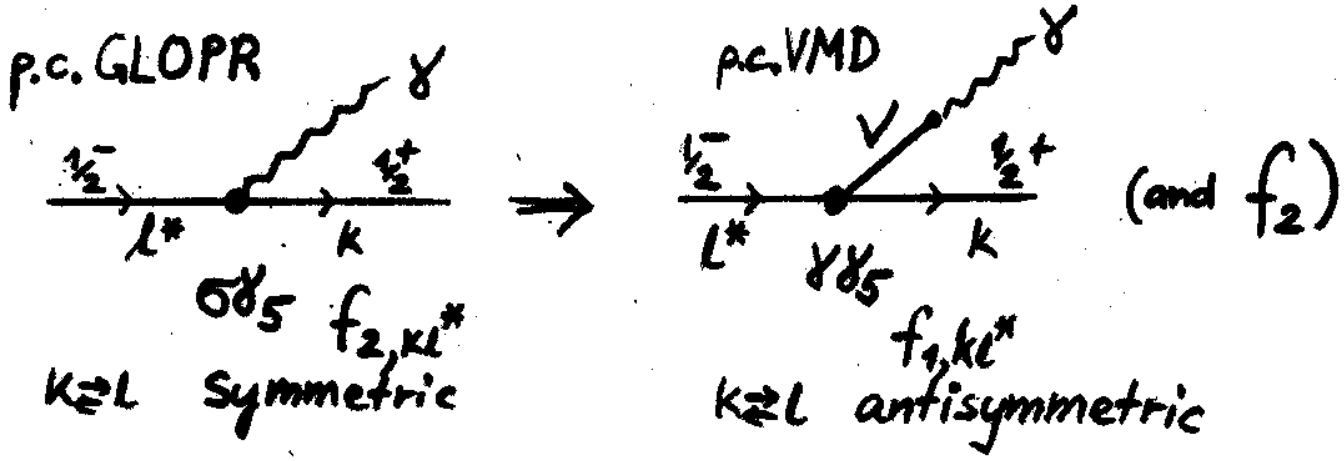


④ HINTS FROM EXPERIMENT

⇒ BELIEF THAT ~~HARA~~

~~HARA~~ - PATTERN OF ASYMMETRIES

VMD, KR



- $$A \propto \sum_{K^*} \left\{ \underbrace{\frac{f_{1,fK^*}\, q_{K^*i}}{m_i - m_{K^*}}}_{(b1)} + \underbrace{\frac{q_{fK^*}\, f_{1,K^*i}}{m_f - m_{K^*}}}_{(b2)} \right\} \bar{u}_f \gamma_\mu \gamma_5 u_i \cdot \epsilon^\mu$$

  $g_{1,fi}$ {fi}

for $f=i$ using antisym. of q_{K^*i} $\Rightarrow$ (b1) = (b2)
(relative sign dictated by symmetry with NLHD's)

$\Rightarrow$ ~~HARA~~, (b1) + (b2)

	sign of asymmetry	KR VS 1988	VMD LZ 1995	EXP	GLOPR
$\Sigma^+ \to p\gamma$	— pc. ~~SU(3)~~	−0.56	−0.95	−0.76 ± 0.08	$-0.80^{+0.31}_{-0.19}$
$\Lambda \to n\gamma$	+	−0.54	+0.8		−0.49
$\Xi^0 \to \Lambda\gamma$!	+	+0.68	+0.8	+0.43 ± 0.44	−0.78
$\Xi^0 \to \Sigma^0\gamma$	—	−0.94	−0.45	+0.60 ± 0.96 (2 significantly negative)	−0.96

SUMMARY

H99.19

① THE PROBLEM OF WRHD's IS WITH US FOR 30 YEARS

② DATA and SOME MODELS HINT AT VIOLATION OF HARA'S THEOREM

③ THE ISSUE OF VIOLATION OF HARA'S THEOREM MAY BE SETTLED EXPERIMENTALLY.

CRUCIAL ASYMMETRY:

$\alpha(\equiv^{\circ} \to \Lambda\gamma)$ $\gg 0$ ~~HARA~~ SOON

$\ll 0$ HARA

④ IF ~~HARA~~ THEN

1) CP ✓
   CURR. CONS. ✓
   LOCALITY ← SUSPECTED

2) QUARKS ⟷ HADRONS

3) DEEPER ISSUES WILL ENTER

⑤ IF HARA ✓

→ various hints were misleading

→ nothing really spectacular discovered, but should not regret the effort!

BUT:

FOR VERY MANY REASONS, (DEEP ARGUMENTS ESPECIALLY) I THINK THAT ~~HARA~~