THEORY SUMMARY

OR: ALL YOU EVER WANTED TO ASK ABOUT HYPERONS BUT WERE AFRAID TO KNOW.

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THE TALKS:

HOLSTEIN – OVERVIEW
- NON-LEPTONIC DECAYS [$\cancel{CP}$, $\Delta I = 1/2$, ..]
- SEMI-LEPTONIC DECAYS [$\cancel{SU3}$, CKM]
- RADIATIVE DECAYS [$\cancel{\text{Hara}}$]
- POLARISABILITIES
- SINGLE SPIN ASYMMETRIES

TANDEAN – $\Delta I = 3/2$ AMPLITUDES

KARL – SEMI-LEPTONIC & $\cancel{SU2}$

GARCIA – SEMI-LEPTONIC & $\cancel{SU3}$

ZENCZYKOWSKI – RADIATIVE DECAYS & $\cancel{\text{Hara}}$

LIPKIN – QCD $\longrightarrow$ REGGE

VALENCIA – NON-LEPTONIC & $\cancel{CP}$

LIPKIN′ – STATIC PROPERTIES
AKA JENKINS

GOLDSTEIN – $\Lambda_c^{\Uparrow}$

SOFFER – $\Lambda^{0\Uparrow}$

ABSENTEES: HYPERNUCLEI, "REAL"/PURE PQCD.

NATURALLY FRESH

CREAMY
ITALIAN
DRESSING
POUR IT ON

ING: SOYBEAN OIL, VINEGAR, WATER, EGGS, SUGAR, EGG YOLKS, GARLIC, SALT, ONION, RED BELL PEPPER, MUSTARD FLOUR, SPICES, ANNATTO TURMERIC COLOR.

STATIC PROPERTIES

MASSES & MAGNETIC MOMENTS

LIPKIN REMINDED US THAT

$$177 \text{ MeV} = m_\Lambda - m_N \simeq \frac{3(m_{K^*} - m_K) + (m_K - m_\pi)}{4} = 180 \text{ MeV}$$

AND

$$\frac{m_\Delta - m_N}{m_{\Sigma^*} - m_\Sigma} = 1.53 \qquad \frac{m_\rho - m_\pi}{m_{K^*} - m_K} = 1.61$$

$\Longrightarrow$ QUARKS IN MESONS ARE LIKE QUARKS IN BARYON

SIMILARLY

$$0.88 = \mu_p + \mu_n \simeq \frac{2 m_p}{m_N + m_\Delta} = 0.865$$

AND

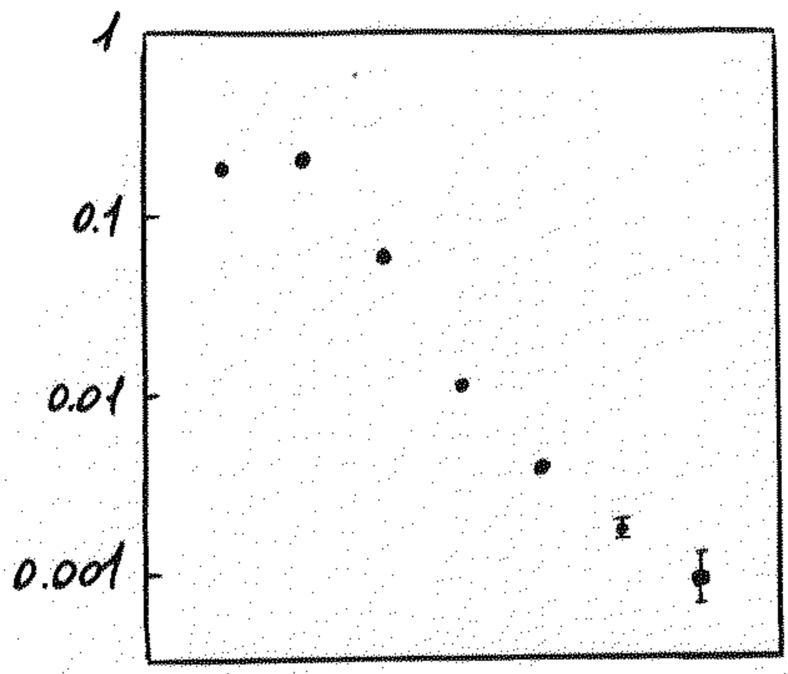
$$-0.61 = \mu_\Lambda = -\frac{1}{3}\mu_p \frac{m_{\Sigma^*} - m_\Sigma}{m_\Delta - m_N} = -0.61$$

JENKINS WOULD HAVE TOLD US ABOUT $1/N_c$.

$\Longrightarrow$ HIERARCHY OF RELATIONS

E.G., COLEMAN-GLASHOW IS $O(1/N_c)$ AND SO SHOULD BE BETTER THAN NAÏVE EXPECTATIONS:

$$(m_p - m_n) - (m_{\Sigma^+} - m_{\Sigma^-}) + (m_{\Xi^0} - m_{\Xi^-}) \simeq 0$$



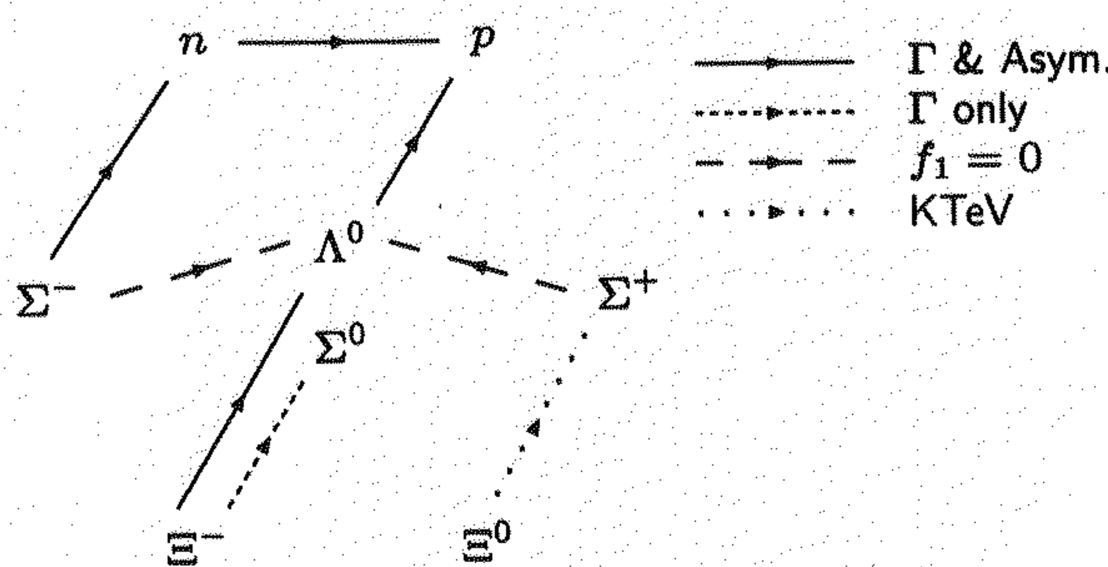
HIERARCHY IN $1/N_c$ AND SU3 BREAKING $\varepsilon \sim 0.3$, COMBINATIONS NORMALISED TO THE SUMS:

- $\mathcal{O}(1/N_c^2)$
- $\mathcal{O}(\varepsilon/N_c,\ \varepsilon/N_c^2,\ \varepsilon/N_c^3)$
- $\mathcal{O}(\varepsilon^2/N_c^2,\ \varepsilon^2/N_c^3)$
- $\mathcal{O}(\varepsilon^3/N_c^3)$

SIMILARLY FOR MAGNETIC MOMENTS: E.G., THE ISOVECTOR μ'S ARE DETERMINED UPTO CORRECTIONS $\sim \mathcal{O}(1/N_c^2)$ FOR $N_f = 2$.

AGAIN THE MAGNETIC MOMENT COMBINATIONS OBEY THE HIERARCHY DICTATED BY $1/N_c$.

The HSD Data



The present world data (the values for g_1/f_1 are extracted from angular correlations).

Decay $B \to B'\ell\nu$	Γ $(10^6\,\mathrm{s}^{-1})$ $\ell = e^-$	$\ell = \mu^-$	g_1/f_1 $\ell = e^-$	SU(3)
$n \to p$	1.1274 ± 0.0025		1.2601 ± 0.0025	$F + D$
$\Lambda^0 \to p$	3.161 ± 0.058	0.60 ± 0.13	0.718 ± 0.015	$F + D/3$
$\Sigma^- \to n$	6.88 ± 0.23	3.04 ± 0.27	-0.340 ± 0.017	$F - D$
$\Sigma^- \to \Lambda^0$	0.387 ± 0.018			$-\sqrt{\frac{2}{3}}\,D$
$\Sigma^+ \to \Lambda^0$	0.250 ± 0.063			$-\sqrt{\frac{2}{3}}\,D$
$\Xi^- \to \Lambda^0$	3.35 ± 0.37	2.1 ± 2.1	0.25 ± 0.05	$F - D/3$
$\Xi^- \to \Sigma^0$	0.53 ± 0.10			$F + D$

1. Γ for $n \to p$ in units of $10^{-3}\,\mathrm{s}^{-1}$.
2. Scale factor 2 for error on Γ in $\Xi^- \to \Lambda^0$ (PDG practice for discrepant data).
3. Absolute expression for g_1 in $\Sigma^\pm \to \Lambda^0$ given as $f_1 = 0$.
4. $\Xi^- \to \Lambda^0$ μ-mode data are not used in fits.
5. Values in green have precision 5% or better.

SEMI-LEPTONIC DECAYS

F & D OR G_A's (A ROSE BY ANY OTHER NAME ...)

THESE ARE RELATED TO THE SPIN STRUCTURE OF THE QUARKS AND THUS TO Δu, Δd & Δs OR COMBINATIONS THEREOF.

"ASIDE" ON PROTON SPIN

$$\Gamma_1^p = \int_0^1 g_1^p(x, Q^2)\, dx = \frac{1}{2}\left[\frac{4}{9}\Delta u + \frac{1}{9}\Delta d + \frac{1}{9}\Delta s\right] \times \left[1 + pQCD \ldots\right]$$

E.G., SMC MEASURES $\Gamma_1^p = 0.120 \pm 0.005 \pm 0.006$
$\propto F - \frac{1}{3}D + O(\Delta s)$ *

COMBINED WITH $G_A^n \sim 1.267$ & $F/D \sim 0.58$ THIS IMPLIES

$$\Delta s \simeq -0.1$$ (SPIN ~~CRISIS~~ ~~PROBLEM~~ PUZZLE

BUT! IF $F/D \sim 0.50$ THEN $\Delta s \sim 0$

SO DONOGHUE-HOLSTEIN-KLIMT 0.535 "HELPED" A LOT.

THE BOTTOM LINE IS THAT IT IS IMPORTANT TO KNOW HOW MUCH WE TRUST THE VALUES OF F & D FROM HSD <u>AND</u> JUST WHAT THEY ARE.

SO, TO SOME EXTENT, "PLAYING" WITH PARAMETRISATIONS IS LEGITIMATE, I.E., FOR PURPOSES OTHER THAN JUST UNDERSTANDING ~~SU3~~.

V_{us} (OR $\sin\theta_c$)

HSD SHOULD ALSO PROVIDE A MEASUREMENT OF $\sin\theta_c$ TO SOME LEVEL OF PRECISION, BUT IS IT COMPARABLE TO K_{e3}? (NB THE PROTON SPIN PROBLEM DOES NOT REQUIRE THE SAME HIGH PRECISION.)

DIFFICULTIES:

- FIRST (BUT NOT FOREMOST FOR HADRONIC PHYSICS PURPOSES) IS NEUTRON β-DECAY. CLOUDS THE ISSUE OF CKM UNITARITY.

- SECOND-CLASS CURRENTS – THESE HAVE NOT BEEN INVESTIGATED SUFFICIENTLY – THEY CAN HAVE A PROFOUND EFFECT ON g_A AND EVEN PUSH F/D BACK TO ITS SU(6) VALUE.

SU3 BREAKING ANALYSES IN THE LITERATURE ARE OFTEN: HIGHLY MODEL DEPENDENT, HIGHLY DATA SELECTIVE & EVEN BIASED BY A DESIRE TO SOLVE THE PROTON SPIN PUZZLE.

- THE DATA DO NOT SUFFICIENTLY OVERCONSTRAIN THE PROBLEM: NEED DIFFERENT COMBINATION OF F & D AND COVERING WELL BOTH $\Delta S=0$ & $|\Delta S=1|$ DECAYS.

COMMENTS ON THE $\Xi^0 \to \Sigma^+ e \bar{\nu}$ PREDICTIONS

PGR: ESSENTIALLY EQUIVALENT TO DHK BUT WITHOUT THE STRANGE WAVE-FUNCTION MISMATCH CORRECTION AND WITH NEWER DATA.

- ATTEMPT TO MOTIVATE THE FINAL SIMPLE FORM FROM QUARK MODEL CONSIDERATIONS.

- THE STRANGE WAVE-FN MISMATCH, AS CALCULATED BY DHK IS TOO BIG. THE UNCERTAINTY HERE ($|\Delta S = 1|$ DECAYS) HAS SERIOUS REPERCUSSIONS ON V_{us} EXTRACTION.

- N.B. AFTER THE CORRECTION IS APPLIED NO SINGLE DATA POINT STANDS OUT BADLY.

MANOHAR & JENKINS: APPLY THE $1/N_c$ EXPANSION BUT ALSO INCLUDE/COMBINE FITTING TO THE DECUPLET NON-LEPTONIC DECAYS.

- SU(3) BREAKING IS MUCH BIGGER IN THE DECUPLET SECTOR AND THE PULL ON PARAMETERS IS STRONG.

- A FIT TO HSD ALONE GIVES THE SAME RESULT AS PGR.

RADIATIVE DECAYS

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

MATRIX ELEMENT:

$$\langle B'\gamma | \mathcal{H}_w | B \rangle = \bar{u}(p') \Big(\underbrace{C\, \varepsilon_\mu \sigma^{\mu\nu} q_\nu}_{M1} + \underbrace{D\, \varepsilon_\mu \sigma^{\mu\nu} q_\nu \gamma_5}_{E1} \Big) u(p)$$

HARA'S THEOREM (1964)

U-SPIN INVARIANCE, TO THE EXTENT THAT SU(3) IS NOT BADLY BROKEN, IMPLIES THAT

$D = 0$ FOR $B, B' \in$ U-SPIN MULTIPLET

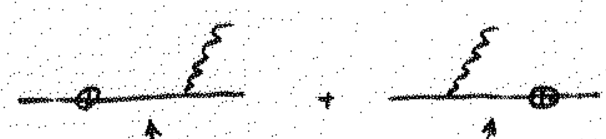
$\Rightarrow$ SMALL ASYMMETRY PARAMETER $\alpha = \dfrac{2 \mathrm{Re}\, C^* D}{|C|^2 + |D|^2}$

FOR $\Sigma^+ \to p\gamma$ & $\Xi^- \to \Sigma^- \gamma$

$\hookrightarrow$ EXP'T. $\Rightarrow -0.76 \pm 0.08$

HARD TO EXPLAIN CONSISTENTLY.

LE YAOUANC ET AL. (1979) SUCCESSFUL APPROACH



70, 1^-

REALLY NEED TO CROSS-CHECK WITH $\Xi^0 \to \Lambda^0 \gamma$

([illegible]) $\Rightarrow$ KEY TO HARA

$\cancel{CP}$ IN NON-LEPTONIC DECAYS

LOOK AT ASYMMETRY ARISING FROM A PRODUC
OF PHASES:

$$\mathcal{A}(\Lambda^0_-) \equiv \frac{\alpha+\bar{\alpha}}{\alpha-\bar{\alpha}} \simeq -\tan(\delta_p-\delta_s)\,\sin(\phi_p-\phi_s)$$

STRONG $\Delta I = \frac{1}{2}$ PHASES

WEAK PHASES

STRONG PHASES: WATSON'S THEOREM RELATES $A \to B\pi$ TO $B\pi$ sc

USEFUL FOR $\Lambda \to N\pi$ BUT NOT $\Xi \to \Lambda\pi$, $\Omega \to \Xi\pi$

GENERAL CONSENSUS SEEMS TO BE THAT THESE ARE ALL SMALL

WEAK PHASES: $\mathcal{H}_{\text{eff}}^{\Delta S=1} = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} \sum_{i=1}^{12} C_i(\mu)\, O_i(\mu) + h.c$

COEFFICIENTS WELL-KNOWN

OPERATOR MATR ELEMENTS – MOD

$\Rightarrow$ UNCERTAINTY IN $\phi_s - \phi_p \sim 100\%$ (χPT)

$$\Rightarrow \quad \mathcal{A}(\Lambda^0_-) \simeq (-3 \pm 2.6) \times 10^{-5}$$

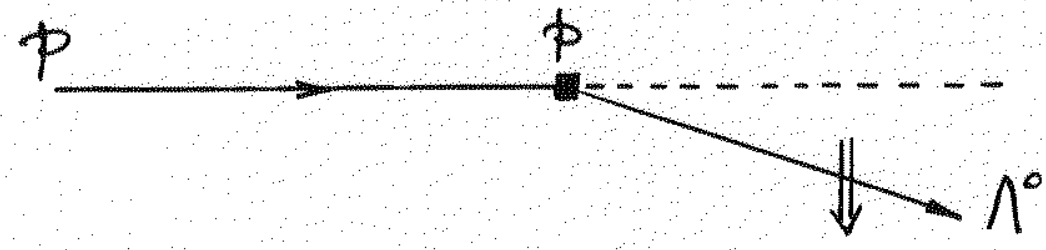
[LIKELY TO BE LARGER THAN $\mathcal{A}(\Xi^-_-)$]

IN SM + ($\sim$ SUSY) CAN BE LARGER $\sim 10^{-3}$

COMPLEMENTARY TO ε'/ε.

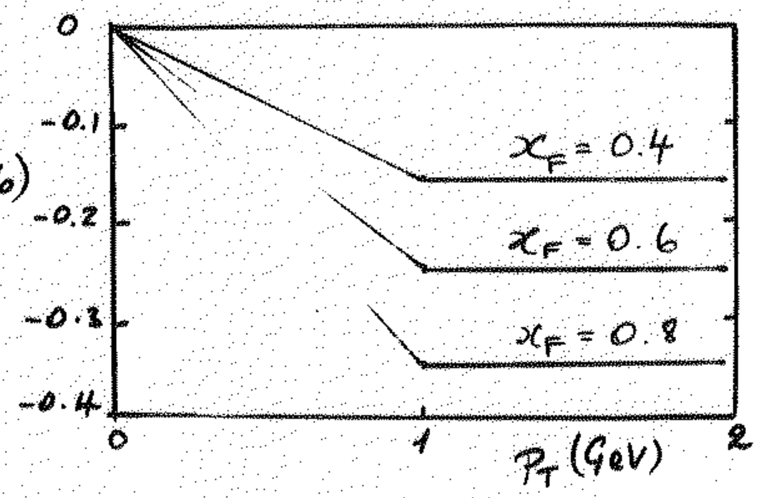
HYPERON POLARISATION

A LONG-STANDING AND EVER-GROWING PUZZLE.
THE POLARISATION APPROACHES 40%



SCHEMATICALLY

ROUGHLY SU(6)



SOME DATA POINTS GET OUT TO BIGGER p_T:
THE POLARISATION DOES NOT APPEAR TO DIE.

A PRESUMABLY RELATED EFFECT IS THE SO-CALLED PION ASYMMETRY: A LEFT-RIGHT ASYMMETRY WITH RESPECT TO A TRANSVERSE INITIAL-STATE POLARISATION.
THIS IS NOT MEASURED OUT TO SUCH LARGE p_T ($p_T \lesssim 1$ GeV) BUT THE OVERALL BEHAVIOUR APPEARS SIMILAR.

$$\text{SINGLE-SPIN ASYMMETRY} \propto \mathrm{Im}\left(\text{SPIN-FLIP}^* \cdot \text{NON-FLIP}\right)$$

IN GAUGE THEORIES WITH LIGHT FERMIONS THIS IS A PROBLEM:

- TREE-LEVEL DIAGRAMS ARE REAL
- SPIN-FLIP $\propto$ FERMION MASS

LOOP DIAGRAMS MEAN $O(\alpha_s)$ AND TYPICALLY LEAD TO COLOUR / KINEMATIC MISMATCH $\Rightarrow$

KANE, PUMPLIN & REPKO – DOOM & GLOOM FOR QCD IF $A_N^{\pi} \neq 0$

OF COURSE, IT WASN'T ZERO BUT QCD IS STILL VERY MUCH ALIVE AND KICKING.

THE "GET-OUT" CLAUSE (AS ALWAYS) IS P_T!
WHILE $P_T = 100$ GeV IS <u>NOT</u> NECESSARY, SIGNIFICANTLY LARGER THAN 1 GeV IS, FOR $\alpha_s(Q^2)$ TO BE ACCEPTABLE

SOFFER LISTED SOME SEMI-CLASSICAL (NON-PQCD) MODELS AND NAILED THE COFFIN ON ONE OR TWO. LET ME ADD ANOTHER NAIL TO THE LUND EXPLANATION

THE INITIAL MOTIVATION IS ANGULAR MOMENTUM CONSERVATION (ORBITAL vs. $s\bar{s}$ PAIR SPIN) BUT WHILE THE SPIN OF THE $s\bar{s}$ PAIR IS LIMITED TO $\frac{1}{2}+\frac{1}{2}=1$, THE ORBITAL CONTRIBUTION IS UNBOUND AS P_T INCREASES ($|\vec{L}| \propto p_T\sqrt{p_T^2+m^2}$).

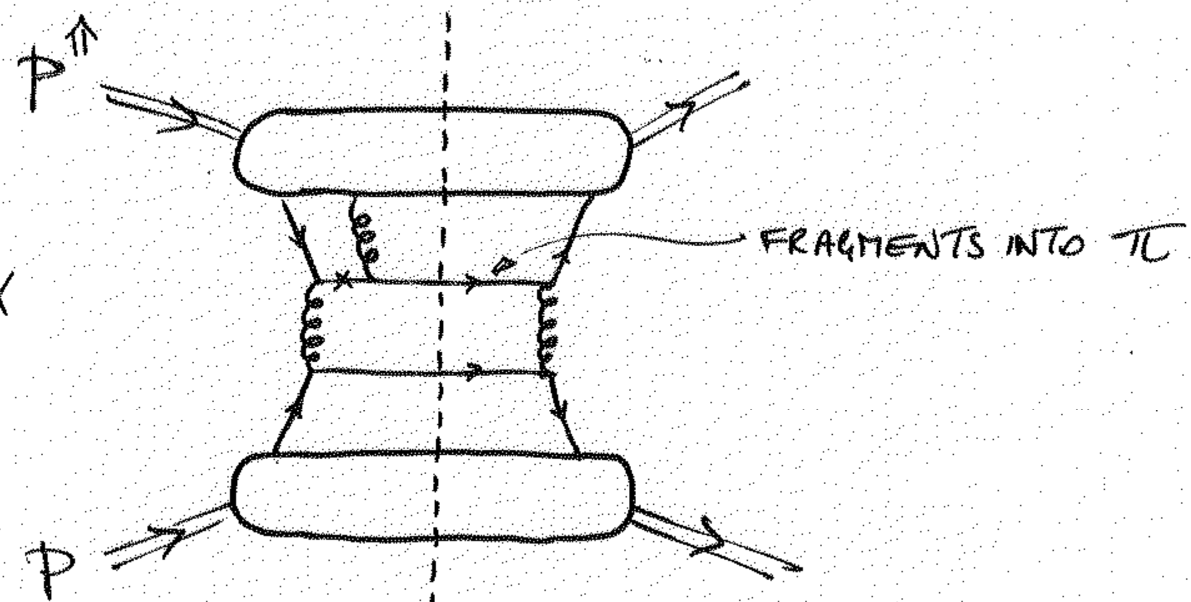
WHILE THE REGGE MODELS, TO SOME EXTENT, GIVE MORE INSIGHT, THEY CANNOT REALLY BE APPLIED FOR p_T AT ALL LARGE.

BESIDES WHICH, THEY CANNOT EXPLAIN ALL THE DATA (E.G., THE ANTIHYPERON POLARISATION).

IS PQCD REALLY IN SUCH BAD SHAPE?

NO! EFREMOV AND TERYAEV POINTED OUT NEARLY 15 YEARS AGO THAT TWIST-3 CONTRIBUTIONS MAY COME TO THE RESCUE:

$\uparrow$
$pp \to \pi X$



N.B. TWIST-3 IS <u>NOT</u> AN UNNECESSARY COMPLICATION WE <u>KNEW</u> BEFOREHAND THAT IT SHOULD BE SO BECAUSE OF THE SPIN-FLIP REQUIREMENT

$\Longrightarrow$ PROPORTIONALLITY TO A MASS $\Longrightarrow \tau = 3$.

$\longrightarrow$ QIU & STERMAN

NOW WHEN GOES SOFT ($x_g \to 0$) HITS A POLE IN THE PROPAGATOR:

$$\text{(iε PRESCRIPTION)} \qquad \frac{1}{x_g s + i\varepsilon} = P\,\frac{1}{x_g s} + \underbrace{i\pi\,\delta(x_g)}_{\text{IMAGINARY PIECE}}$$

(N.B. THIS DOES <u>NOT</u> MEAN GOES ON-SHELL AND PROPAGATES, IT IS JUST A STATEMENT ABOUT HOW TO DO CONTOUR INTEGRALS)

THE 3-LEGGED BLOB  IS JUST WHAT IS ENCOUNTERED IN g_2 THE TRANSVERSE SPIN STRUCTURE FUNCTION IN DIS. THIS IS ALREADY UNDER EXPERIMENTAL STUDY.

NOTE THAT THE APPARENT EXTRA LOOP IS SWALLOWED INTO THE DEFINITION OF g_2: GAUGE INVARIANCE FORCES THIS $\Rightarrow$
- NO EXTRA α_s FACTOR
- THE MASS IS <u>HADRONIC</u> <u>NOT</u> <u>QUARK</u>
- THERE IS NO COLOUR/KINEMATIC MISMATCH

DRAWBACKS: THERE ARE MANY POSSIBLE CONTRIBUTIONS AND THERE MAY BE A SHORTAGE OF STRUCTURE FUNCTION INFORMATION. NEEDS HIGH P_T.

ADVANTAGES: IT IS NOT A MODEL, JUST PURE PQCD. IT ALSO RELATES NATURALLY MANY DIFFERENT PROCESSES THROUGH THE SAME HARD SCATTERING DIAGRAMS. IT SHOULD ALSO BE APPLICABLE TO $\Lambda_c^{\uparrow}$ (GOLDSTEIN).

HYPERNUCLEI

ONLY MENTIONED BY HOLSTEIN

A Λ^0 (OR Σ^0) CAN MOVE IN A NUCLEUS LIKE A NEUTRON BUT FREE FROM PAULI EXCLUSION.

$\Longrightarrow$ A PROBE OF THE NUCLEAR POTENTIAL

AN OLD QUESTION STILL DEBATED IS WHETHER OR NOT Σ-HYPERNUCLEI EXIST.

A MORE RECENT PROBLEM REGARDS THE APPARENT VIOLATION OF THE $\Delta I = \frac{1}{2}$ RULE.

A Λ^0 BOUND IN A NUCLEUS DOES NOT HAVE ACCESS TO THE FREE DECAY $\Lambda^0 \to N\pi$ BUT DECAYS VIA INTERACTION:

$$\Lambda + p \longrightarrow n + p$$
$$\Lambda + n \longrightarrow n + n$$

FROM THE DATA ON ${}_{\Lambda}H^4$ & ${}_{\Lambda}He^4$ IT APPEARS THAT ONE HAS

$$\frac{A(\frac{1}{2})}{A(\frac{3}{2})} \sim 1$$

QUESTION: CAN A NUCLEAR ENVIRONMENT REALLY HAVE SUCH AN INFLUENCE ON HADRON INTS?

FINUDA AT THE FRASCATI ϕ FACTORY, DAΦNE WILL STUDY THESE ISSUES.