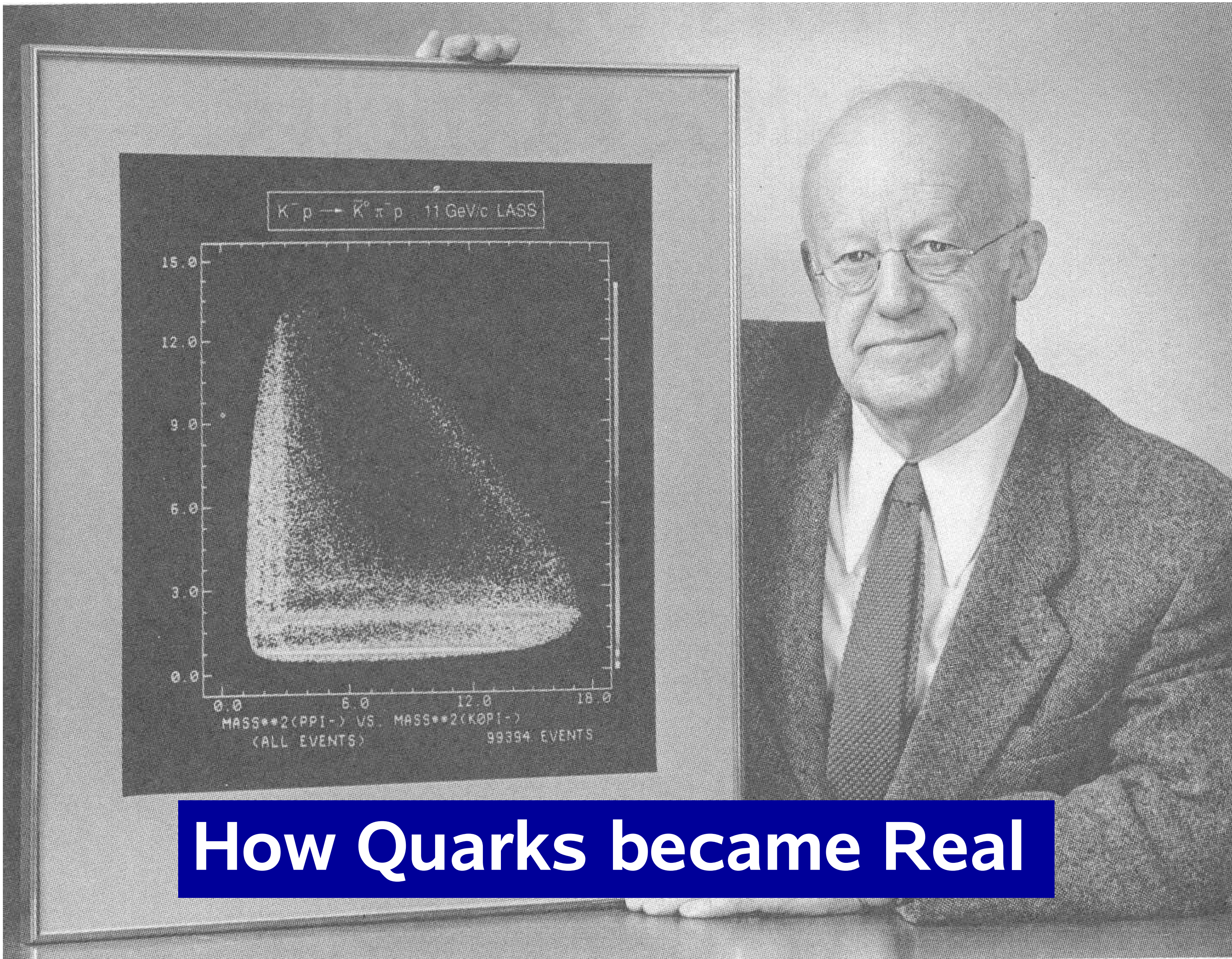


How Quarks became Real

The first Dalitz Plot

Fig. 1

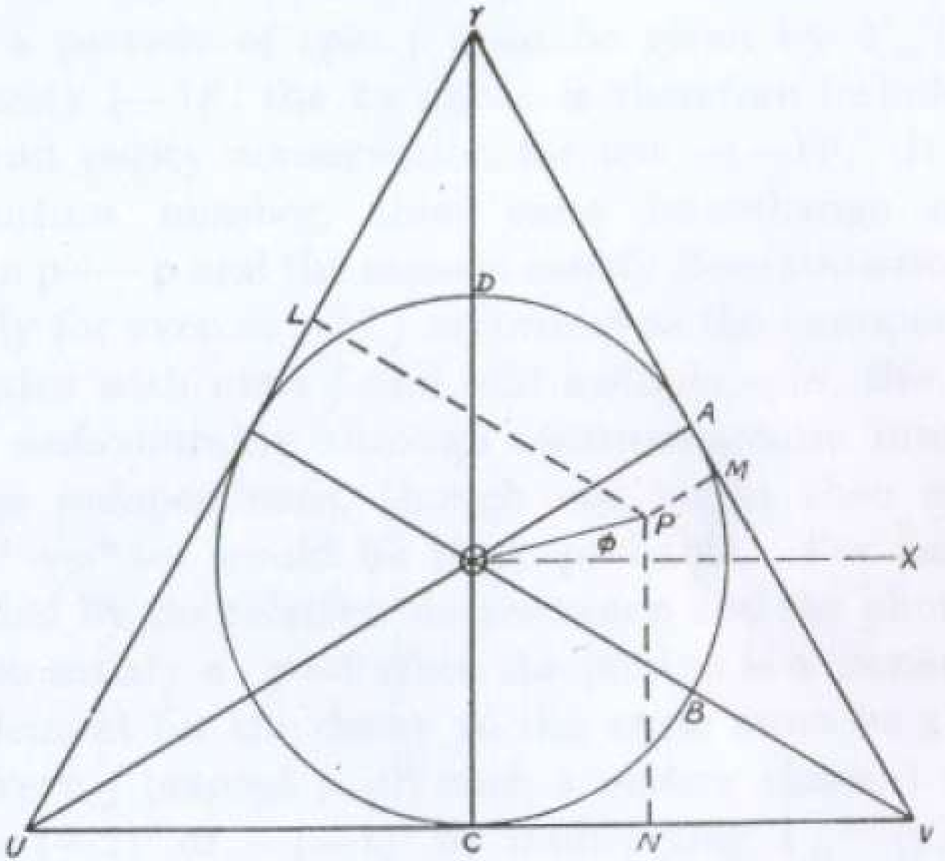
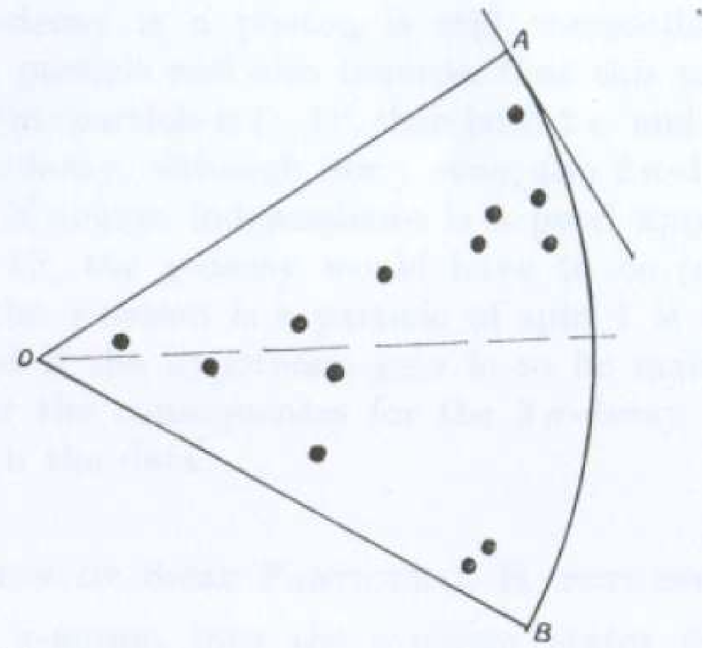


Fig. 2



The data from 13 τ-meson decay events.

VOLUME 94, NUMBER 4 MAY 15, 1954

Decay of τ Mesons of Known Charge*†

R. H. DALITZ‡
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York

(Received February 9, 1954)

The experimental data on the 3π decay of τ mesons is summarized on a convenient two-dimensional plot, both (a) when the π-meson charges are known and (b) when they are not. Some events may be included in plot (a) only if the parent τ meson is assumed positive and arguments supporting this identification for τ mesons decaying in an emulsion are discussed. The dependence of this plot on the τ-meson spin (j) and parity (w) is discussed in general terms and those features depending particularly on w and on its relation with j are emphasized—for example, if the density of events does not vanish at the bottom of the plot, the τ meson must have odd parity and even spin. Simple estimates of the distribution, using only the lowest allowable angular momenta and a "short range" approximation, may be modified by final-state meson-meson attractions, whose effects are discussed qualitatively. The available data are insufficient for any strong conclusion to be drawn but rather suggest even spin and odd parity for the τ meson; the need for careful assessment of geometrical bias in the selection of experimental material is stressed.

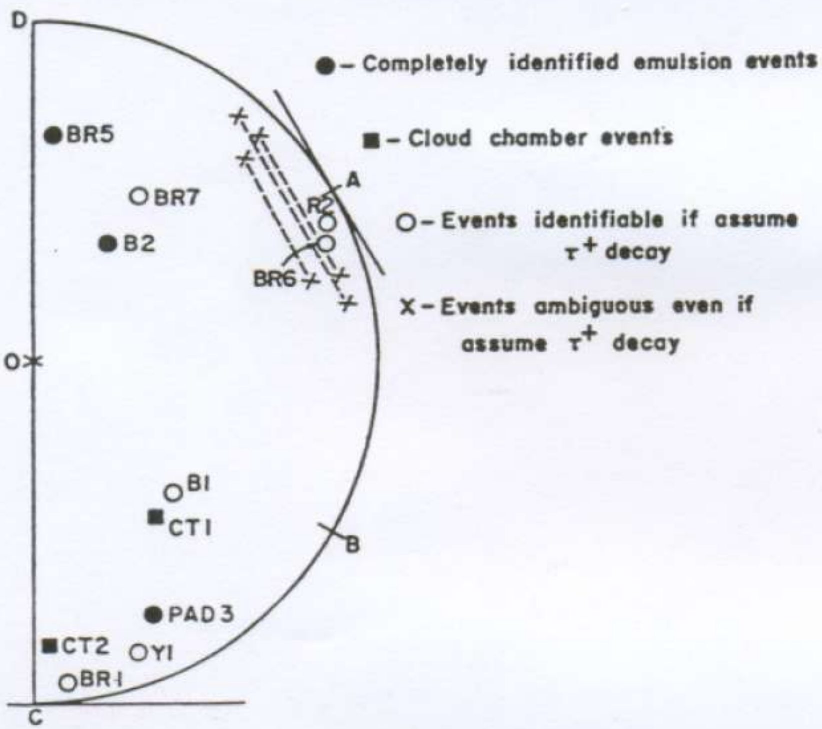


FIG. 3. The data on τ-meson decay events in which the signs of π-meson charges are established.

The first Dalitz Plot

1954 tau-theta analysis

1955: tau decay Dalitz plots in Cloud chamber……..and emulsion

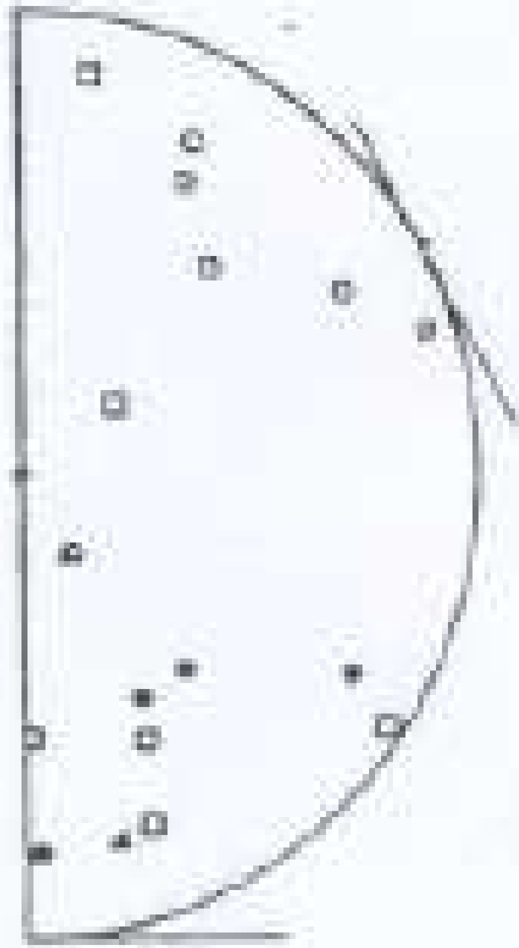
1955 PISA CONFERENCE

SUPPLEMENTO
AL VOLUME IV, SERIE X, DEL
NUOVO CIMENTO
A CURA DELLA SOCIETÀ ITALIANA DI FISICA

1956 | 2° Semestre | N. 2

CELEBRAZIONE DEL CENTENARIO DEL GIORNALE
IL NUOVO CIMENTO

CONFERENZA INTERNAZIONALE
SULLE PARTICELLE ELEMENTARI



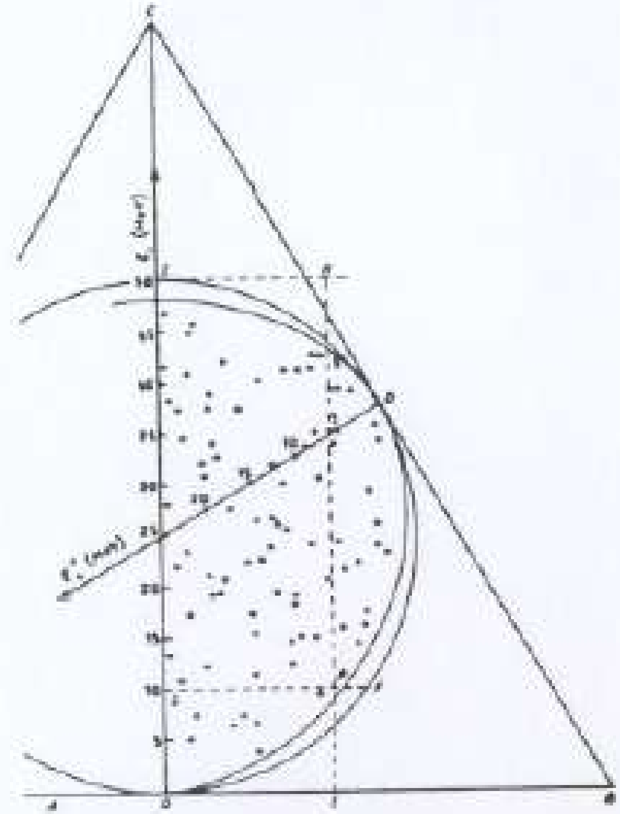


Fig. 3. – Representation of τ-meson decays observed in emulsions.

Fig. 4. – Representation of τ-meson decays observed in cloud chamber (DALITZ, private communication).

1960 A “new” application of Dalitz plots

VOLUME 5, NUMBER 11 PHYSICAL REVIEW LETTERS DECEMBER 1, 1960

RESONANCE IN THE $\Lambda\pi$ SYSTEM*

Margaret Alston, Luis W. Alvarez, Philippe Eberhard,† Myron L. Good,‡
William Graziano, Harold K. Ticho,§ and Stanley G. Wojcicki
Lawrence Radiation Laboratory and Department of Physics, University of California, Berkeley, California
(Received October 31, 1960)

We report a study of the reaction

$$K^- + p \rightarrow \Lambda^0 + \pi^+ + \pi^- \quad (1)$$

produced by 1.15-Bev/c K^- mesons and observed in the Lawrence Radiation Laboratory's 15-in. hydrogen bubble chamber. A preliminary report of these results was presented at the 1960 Rochester Conference.[1]

Strong interaction resonances = discovery of Sigma*(1385)

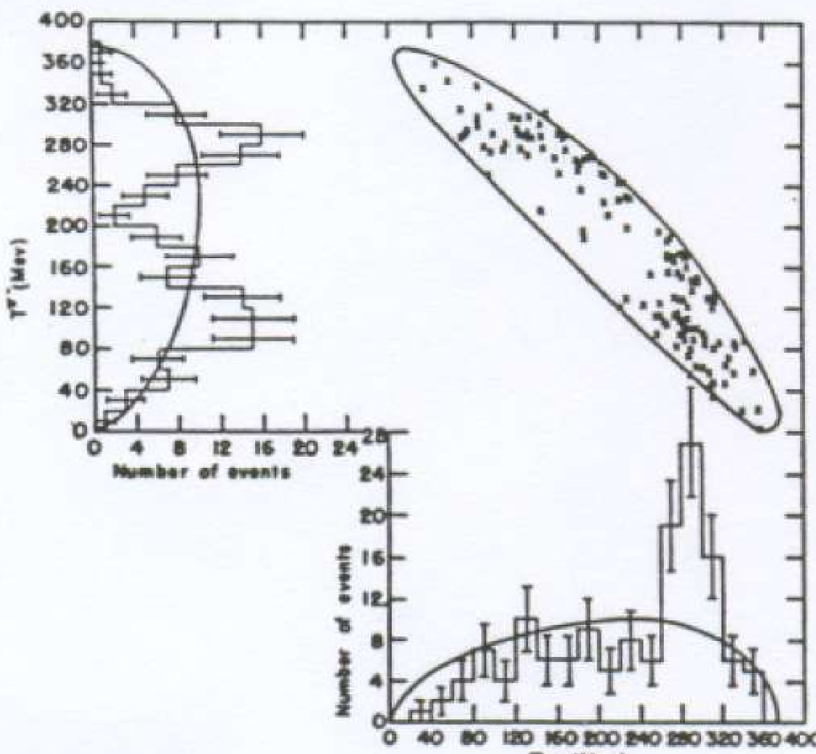


FIG. 1. Energy distribution of the two pions from the reaction $K^- + p \rightarrow \Lambda + \pi^+ + \pi^-$. Each event is plotted only once on the Dalitz plot, which should be uniformly populated if phase space dominated the reaction. The two energy histograms are merely one-dimensional projections of the two-dimensional plot, and each event is represented once on each histogram. The solid lines superimposed over the histograms are the phase-space curves.

Partner of Delta(1230)

Beginning of the Decuplet….

Soon followed by Csi*(1530)…..

And MGM Eightfold Way

… and so Gell Mann invented the Eightfold Way

with **octets** and **decuplets**

and first spoke about it in **1961**

at TIFR summer school in Bangalore

…. with **Dick Dalitz** in the audience

…. as recalled in 30 May email by G Rajasekran

Email from G Rajasekran on origin of quark model: physics/0602131

During one of the lectures,

Dalitz questioned him about the triplets.

Why is he ignoring them?

Email from G Rajasekran on origin of quark model: physics/0602131

During one of the lectures,

Dalitz questioned him about the triplets.

Why is he ignoring them?

Gell-Mann managed to evade it,

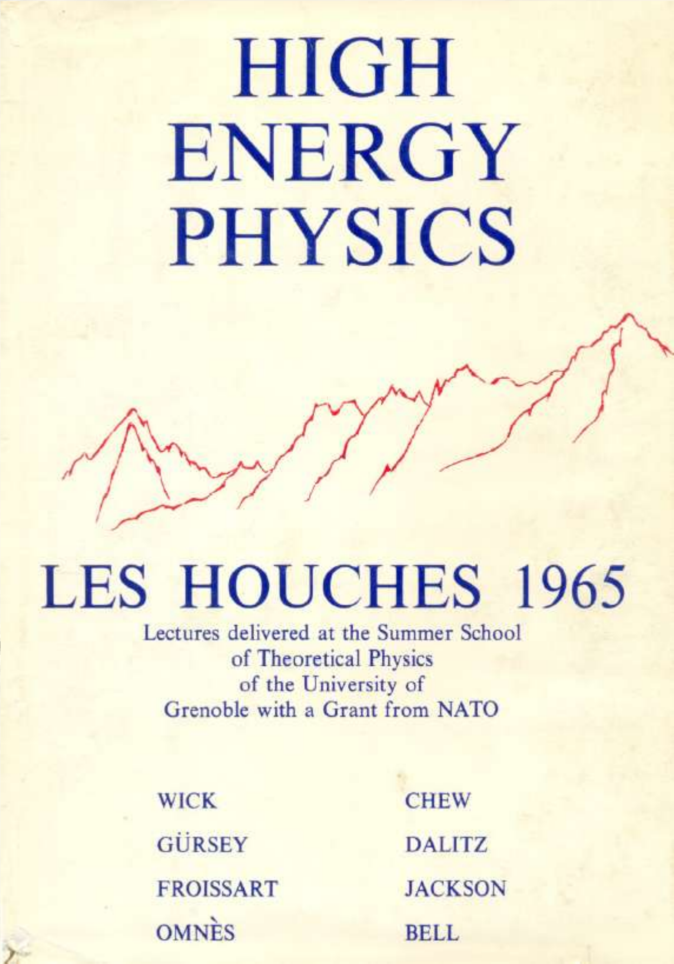
inspite of Dalitz's repeated questioning.

If Gell-Mann had answered the question directly, quarks would have been born in Bangalore in 1961 instead of having to wait for another three years…."

Quark Models for the "Elementary Particles"

R. H. Dalitz

Clarendon Laboratory, Oxford


HIGH ENERGY PHYSICS

LES HOUCHES 1965

Lectures delivered at the Summer School of Theoretical Physics of the University of Grenoble with a Grant from NATO

WICK CHEW

GÜRSEY DALITZ

FROISSART JACKSON

OMNÈS BELL

R. H. DALITZ

Clarendon Laboratory, Oxford.

1. HISTORICAL INTRODUCTION

The type of model for the strongly-interacting "elementary particles", or hadrons, which I wish to discuss in these lectures has a very long history, beginning with the model discussed by Fermi and Yang [1] for the pion, as a bound state of the nucleon-antinucleon system. These bound-state models have never been considered fully respectable, perhaps not even today.

R. H. DALITZ

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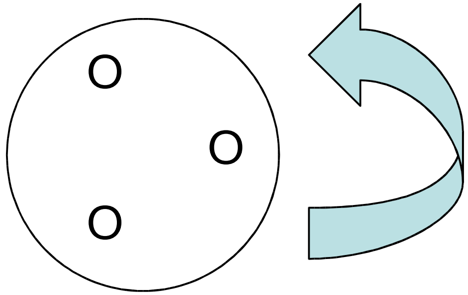
1. HISTORICAL INTRODUCTION

The type of model for the strongly-interacting "elementary particles", or hadrons, which I wish to discuss in these lectures has a very long history, beginning with the model discussed by Fermi and Yang [1] for the pion, as a bound state of the nucleon-antinucleon system. These bound-state models have never been considered fully respectable, perhaps not even today. Indeed, it is not really possible to meet all the objections to such models which can be made from the field-theoretic standpoint. Yet the models are instructive and suggestive, and have at present rather more contact with the experimental data than do the more formal considerations based on group theory. They are explicit representations of the group-theoretical approach, of course, and so they are able to reproduce the group-theoretical results, but in a more pedestrian and comprehensible manner; however, they involve dynamical assumptions going beyond the group-theoretical structure and lead to further predictions which can be tested experimentally.

What Dalitz had proposed



L=1

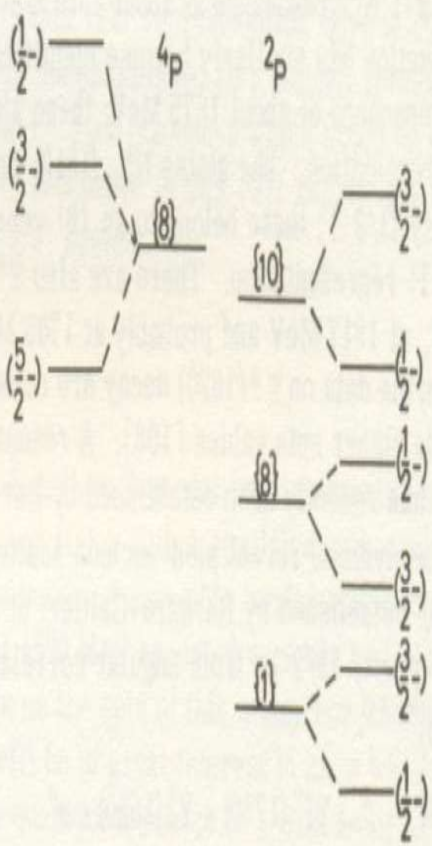


Fig. 6. The States belonging to the L = 1 Baryonic Supermultiplet on the three-quark model, for space wavefunction with [21] symmetry.

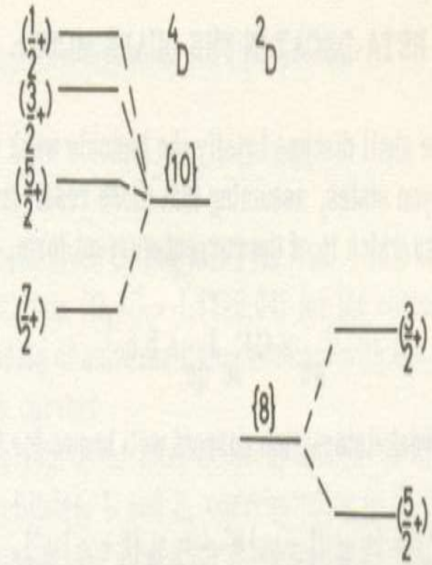
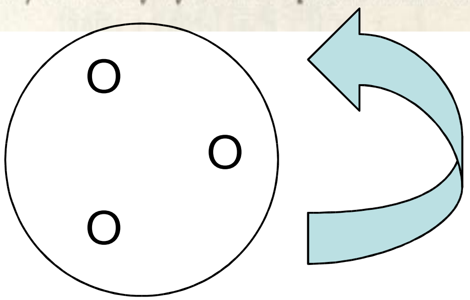


Fig. 7. The States belonging to the L = 2 Baryonic Supermultiplet on the three-quark model, for totally-symmetric space wavefunction.



L=2

PDG 2006 !!!

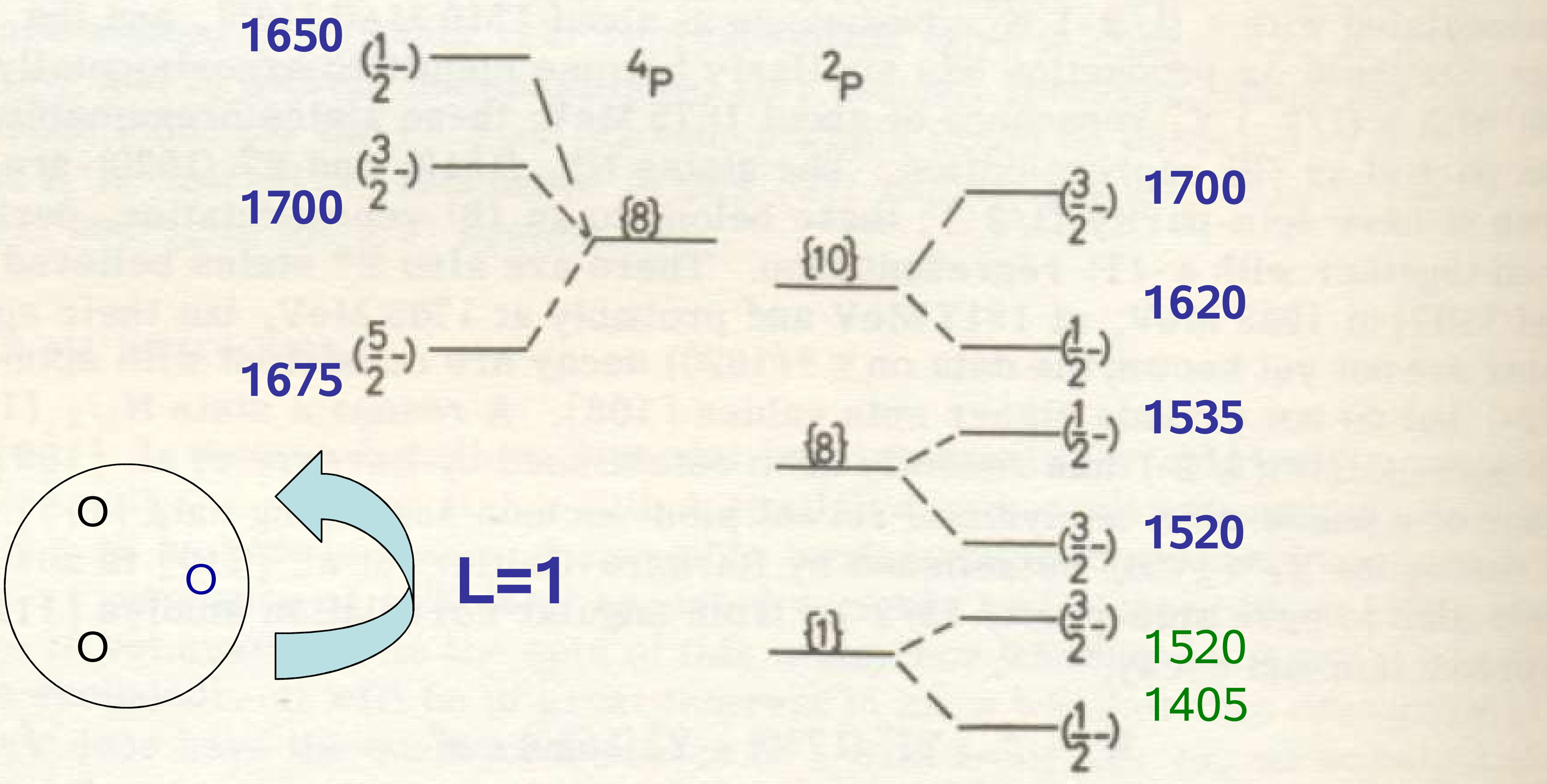
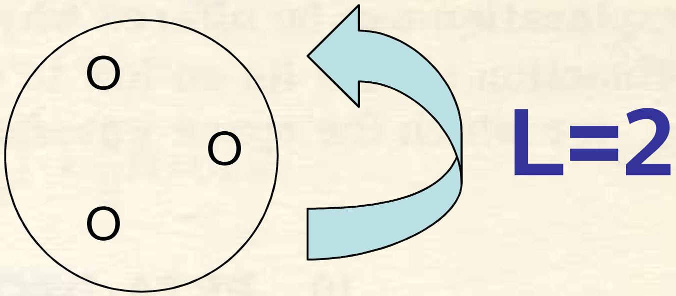


Fig. 6. The States belonging to the L = 1 Baryonic Supermultiplet on the three-quark model, for space wavefunction with [21] symmetry.



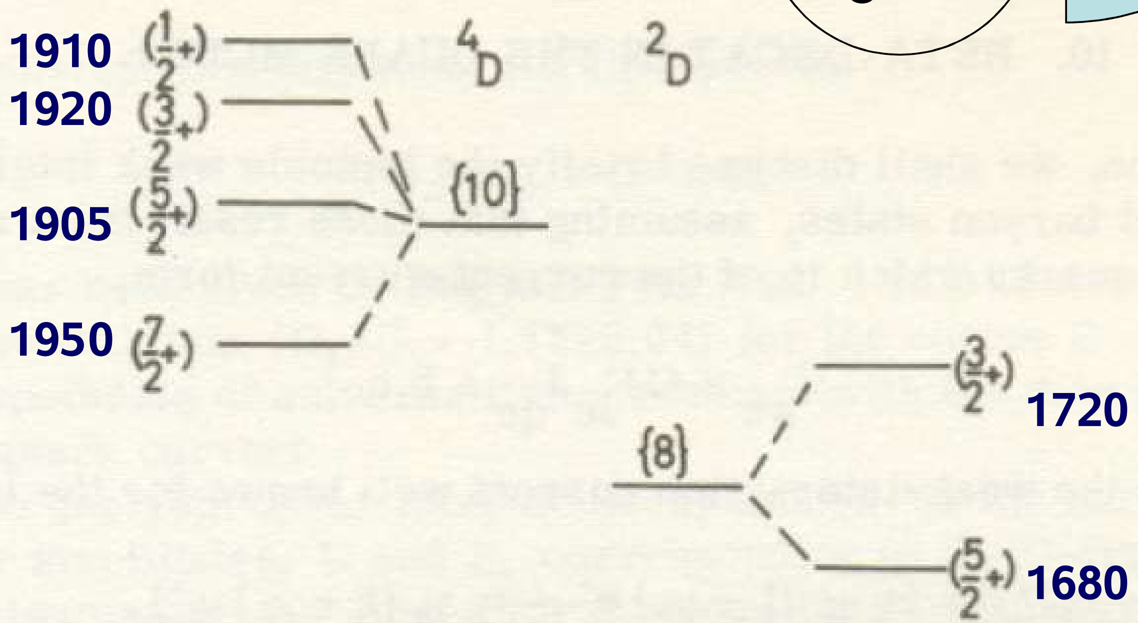


Fig. 7. The States belonging to the L = 2 Baryonic Supermultiplet on the three-quark model, for totally-symmetric space wavefunction.

1977 : L=3 levels identified

J. Phys. G: Nucl. Phys., Vol. 3, No. 9, 1977. Printed in Great Britain. © 1977

LETTER TO THE EDITOR

The new resonance ΔD35(1925) and the $(56, 1_3^-)$ baryonic supermultiplet

R H Dalitz, R R Horgan† and L J Reinders

Department of Theoretical Physics, University of Oxford, 1 Keble Road, Oxford OX1 3NP, UK

Received 13 July 1977

By 1974+ charm had established quarks as real even for sceptics
But there are some quirks of quarks prior to that “November revolution” that Dalitz stimulated. Were light constituent quarks “REAL”?

A student’s dilemma in 1968

were fractionally charged particles that noone had ever seen REAL?

Or just figments of the imagination of people in Oxford?

A student's dilemma in 1968

were fractionally charged particles that noone had ever seen
REAL?

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MGM 2 FEC @ R(HE)L 1968/9

A student’s dilemma in 1968

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MGM 2 FEC @ R(HE)L 1968/9

“The quark model is a convenient way for keeping track of the group theory labels”

DALITZ CONFERENCE, OXFORD 1990

Gillman & Soame OXFORD

RHD

CLARENDON LABORATORY

UNIVERSITY OF OXFORD

SINGLE PION PHOTOPRODUCTION IN THE QUARK MODEL

by

L. A. Copley, G. Karl and E. Obryk*
Department of Theoretical Physics,
12, Parks Road,
Oxford, England.

1969

PHYSICAL REVIEW D VOLUME 3, NUMBER 11 1 JUNE 1971

Current Matrix Elements from a Relativistic Quark Model*

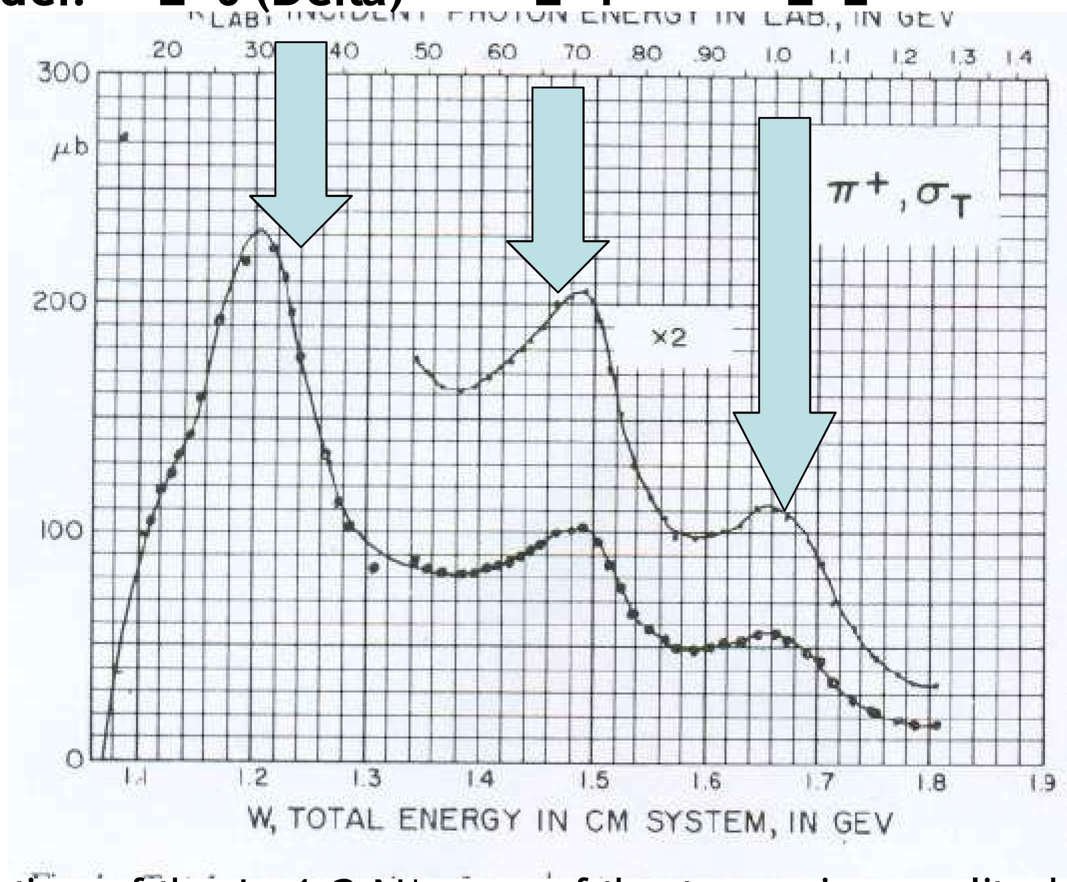
R. P. Feynman, M. Kislinger, and F. Ravndal
Lauritsen Laboratory of Physics, California Institute of Technology, Pasadena, California 91109
(Received 17 December 1970)

A relativistic equation to represent the symmetric quark model of hadrons with harmonic interaction is used to define and calculate matrix elements of vector and axial-vector currents. Elements between states with large mass differences are too big compared to experi-

What had they done?

Empirically three prominent resonances

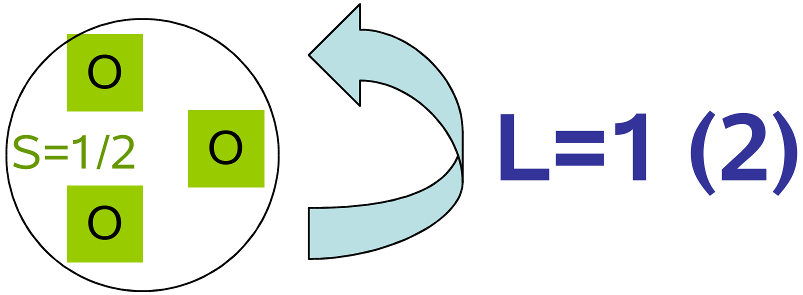
Dalitz model: L=0 (Delta) L=1 L=2



Photoproduction of the L=1,2 N*: one of the two spin amplitudes vanishes for proton

No algebraic reason. CKO explain in quark model

Quark Model: N* J=3/2 (5/2) =



Photoexcitation

Magnetic - Electric vanishes = data

1969 Lepton Photon Conf at Liverpool: Walker (Caltech) devotes review to CKO

SINGLE PION PHOTOPRODUCTION IN THE RESONANCE REGION

R. L. Walker
California Institute of Technology, Pasadena, California, U.S.A.

1. INTRODUCTION

In this talk I would like to discuss three general topics. The first is a brief review of the more conspicuous features of pion photoproduction in the resonance region, the second is a discussion of how all of these features can be more or less predicted by a simple quark model,

This is the same conference
which is dominated by DIS

But on return to Caltech,
Walker impresses Feynman
with the quark model results
And it is this that Feynman takes up

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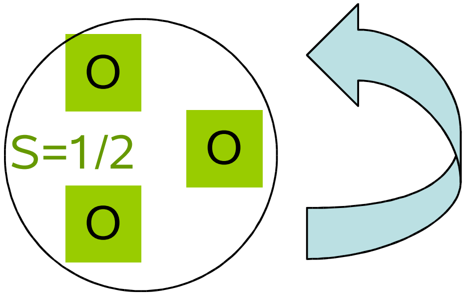
Quark Model: N* J=3/2 (5/2) =



L=1 (2)

Photoexcitation

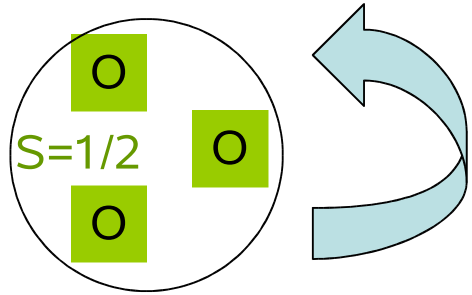
Magnetic - Electric vanishes = data

Catch 22:

MGM symmetry:

can impose it by symmetry/clebsches

Quark Model: N* J=3/2 (5/2) =



L=1 (2)

Photoexcitation

Magnetic - Electric vanishes = data

Catch 22:

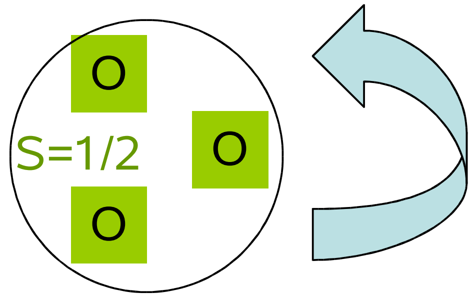
MGM symmetry:

can impose it by symmetry/clebsches

1972: Electroproduction q^2

show it IS dynamic constituent quarks

Quark Model: N* J=3/2 (5/2) =



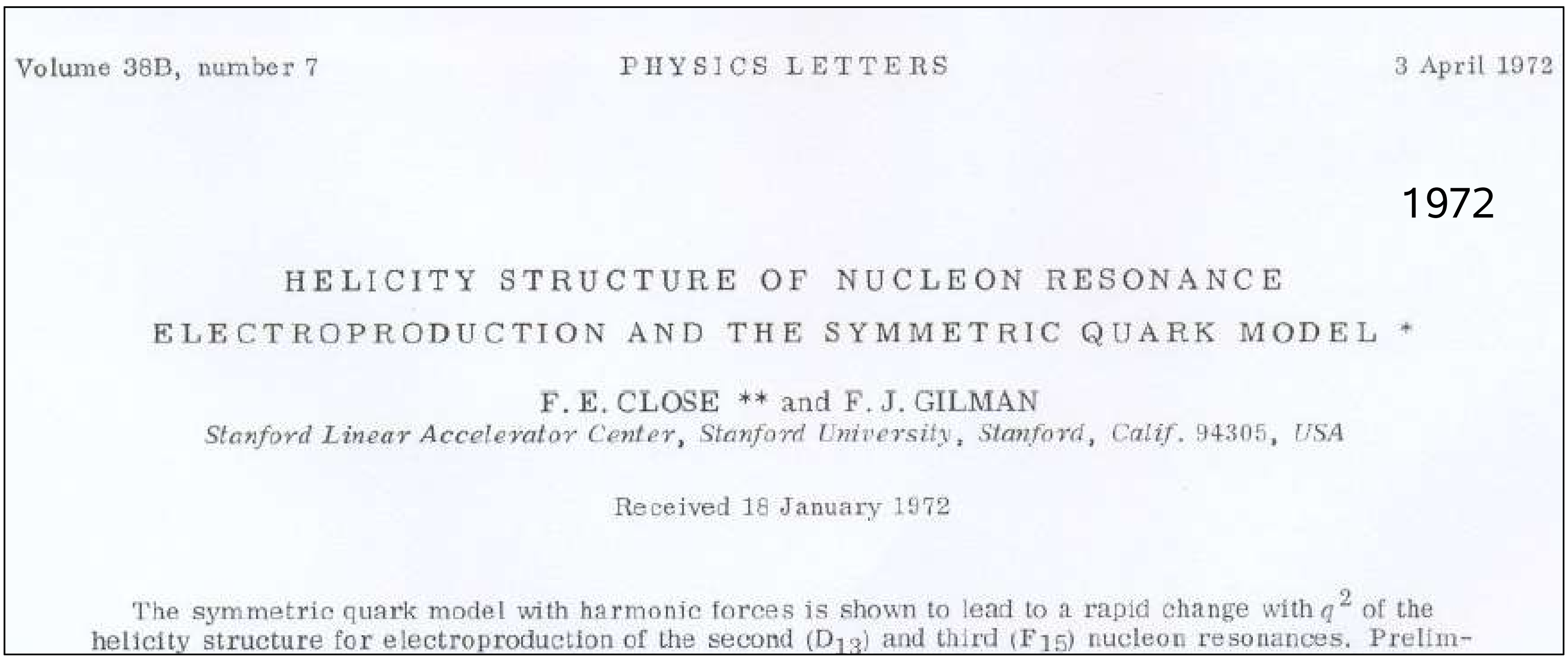
L=1 (2)

Electroproduction

Magnetic rise and then fall

Electric fall

= dramatic q^2 effect


Volume 38B, number 7 PHYSICS LETTERS 3 April 1972

HELICITY STRUCTURE OF NUCLEON RESONANCE ELECTROPRODUCTION AND THE SYMMETRIC QUARK MODEL *

F. E. CLOSE ** and F. J. GILMAN
Stanford Linear Accelerator Center, Stanford University, Stanford, Calif. 94305, USA

Received 18 January 1972

The symmetric quark model with harmonic forces is shown to lead to a rapid change with q^2 of the helicity structure for electroproduction of the second (D_{13}) and third (F_{15}) nucleon resonances. Prelim-

1972

Devenish and Lyth p. wave analysis confirmed the phenomenon;

The data at the time seemed to rule out the quark model!!

This was very worrying until clearer data on pi0 electroproduction and Devenish and Lyth's analysis and confirmed the predictions

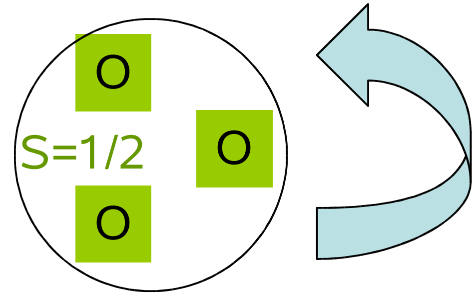
The dramatic change in Helicity (poln asymmetry) as predicted by FEC + Gilman in constituent quark model was verified:

This confirmed that CKO and FKR analyses of photoproduction imply

Constituent Quarks are real dynamical entities

(whatever constituent quarks actually are!)

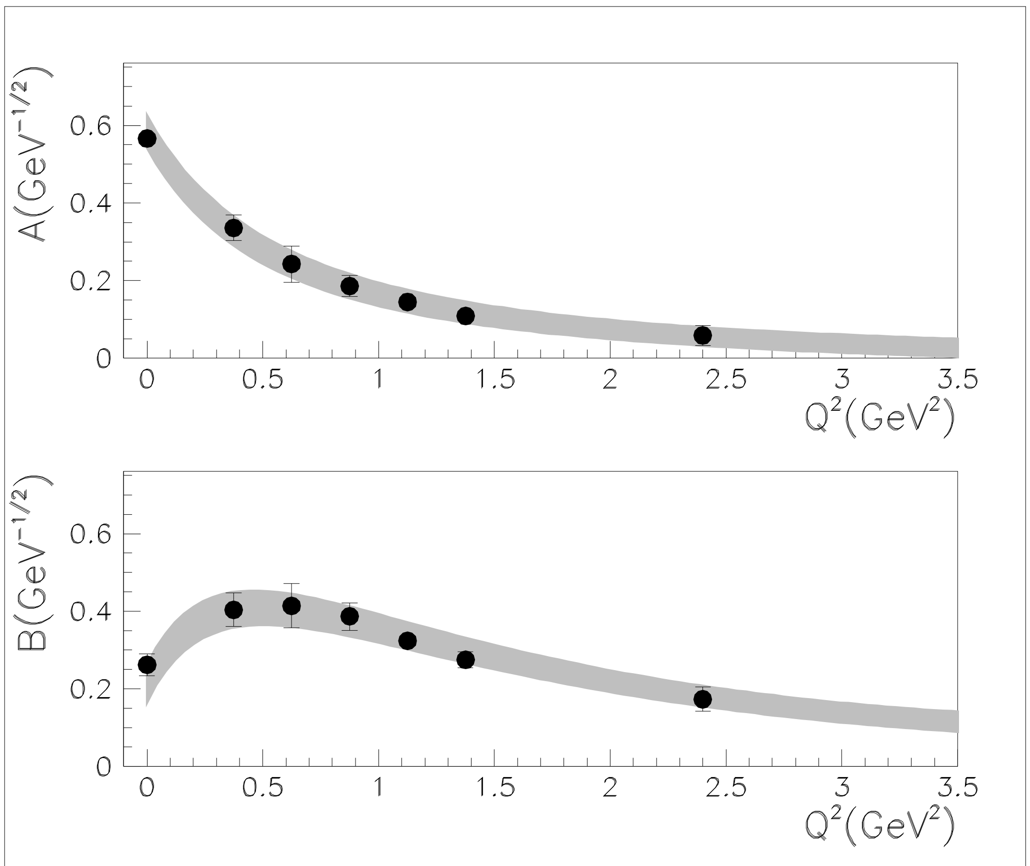
Quark Model: N* J=3/2 (5/2) =



L=1 (2)

Electroproduction

Magnetic - Electric

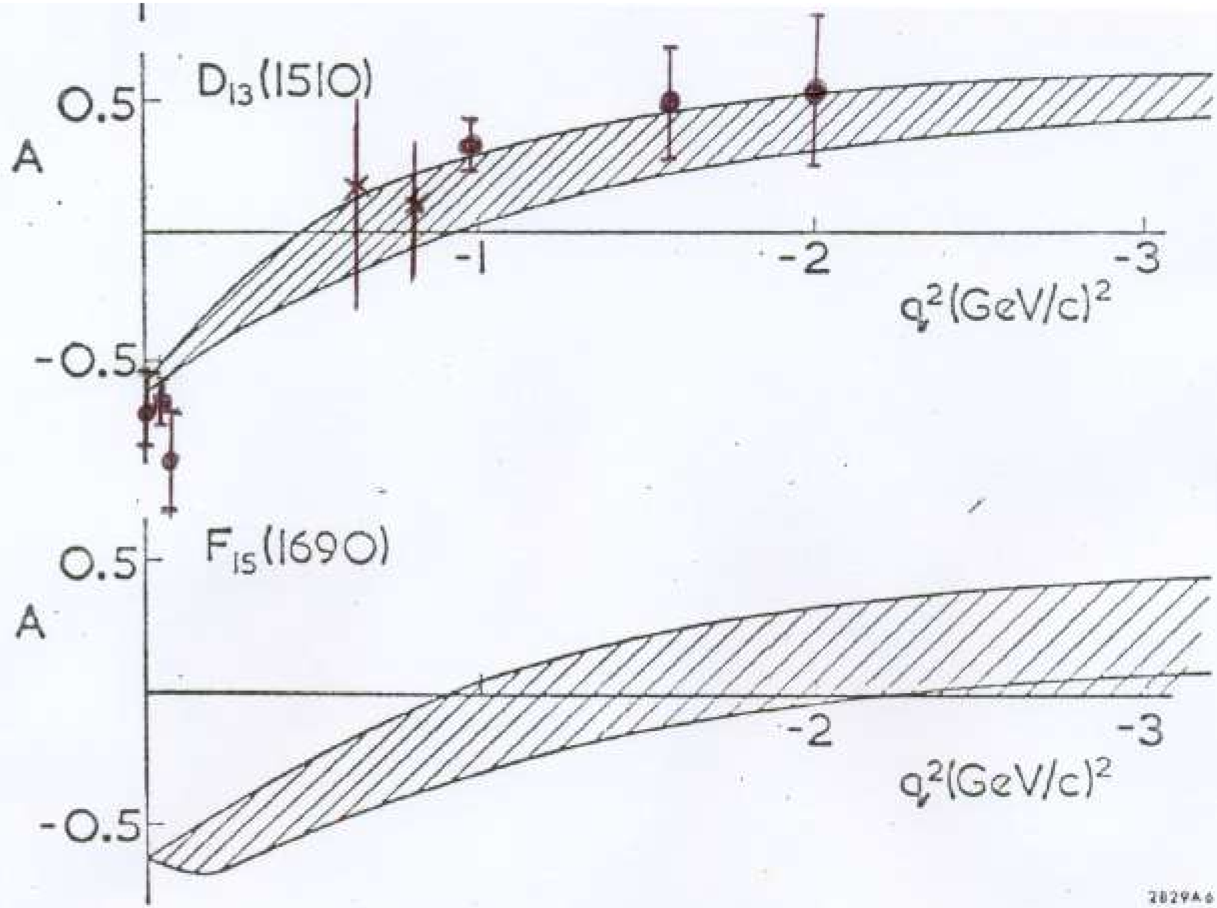


Electric falls

Jefferson Lab 2006

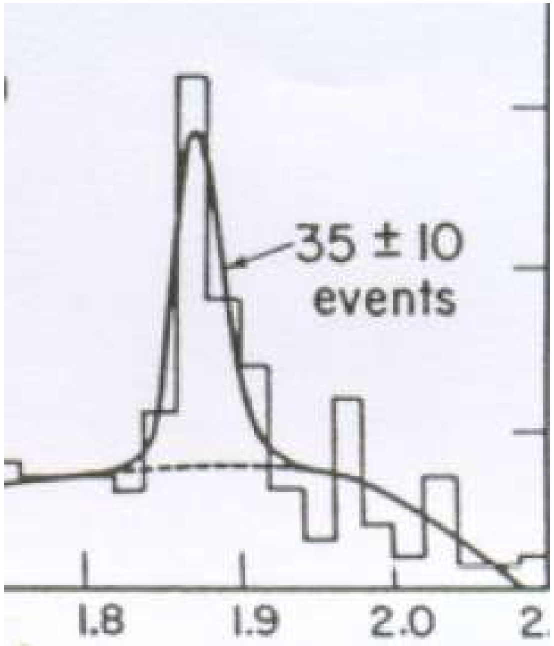
Magnetic rise then falls

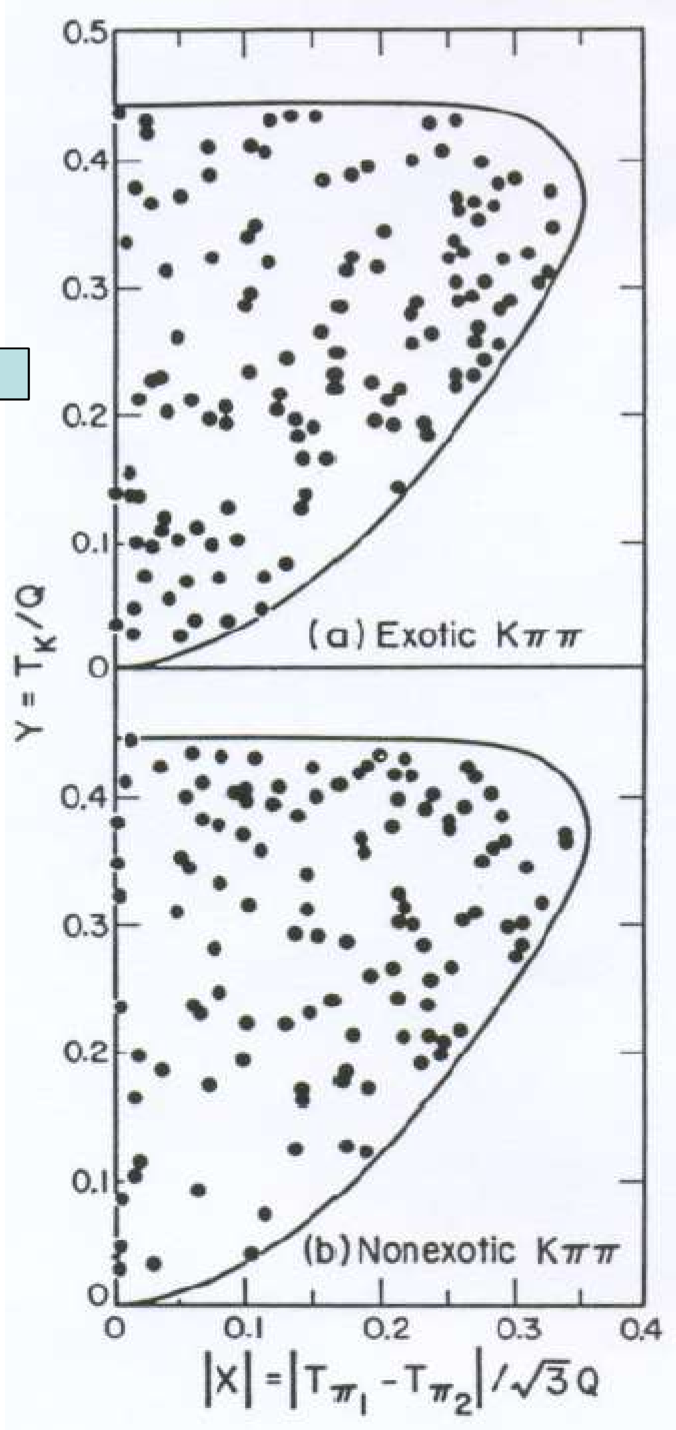
Original evidence from Donncahie review 1975



The helicity asymmetry $a = (\sigma_{1/2} - \sigma_{3/2}) / (\sigma_{1/2} + \sigma_{3/2})$ in the first, second and third resonance regions. (Asymmetry is only for the resonance amplitude.)

Fig. 2 From A. Donnachie 490
Proceedings of the 1975 International Symposium on Lepton and Photon Interactions at High Energies, Stanford University, August, 1975, p. 473.





1974 psi and charmonium confirmed quarks

RHD didn’t work on this

But Dalitz plots were again central in establishing charmed D mesons in 1976

1973-7

Nuclear Physics B66 (1973) 135–172. North-Holland Publishing Company

Classified baryon spectrum with Horgan and Jones

BARYON SPECTROSCOPY AND THE QUARK SHELL MODEL (I). THE FRAMEWORK, BASIC FORMULAE, AND MATRIX-ELEMENTS

R. HORGAN[+] and R.H. DALITZ
Department of Theoretical Physics, Oxford University

Received 29 June 1973

....his only formally journal-published work on the baryon quark model ideas

Nuclear Physics B129 (1977) 45–65

RE-ANALYSIS OF THE BARYON MASS SPECTRUM USING THE QUARK SHELL MODEL

Michael JONES * ‡
Serin Physics Laboratory, Rutgers University, Piscataway, NJ 08854, USA

R.H. DALITZ and R.R. HORGAN **
Department of Theoretical Physics, Oxford University

Received 27 May 1977
(Revised 22 July 1977)

Dalitz Horgan and Jones correspondence: Dick's beautiful handwriting

Theoretical Physics ~~Group~~ Department,
BNL AUI
BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC., UPTON, L.I., N.Y. 11973

DEPARTMENT OF PHYSICS

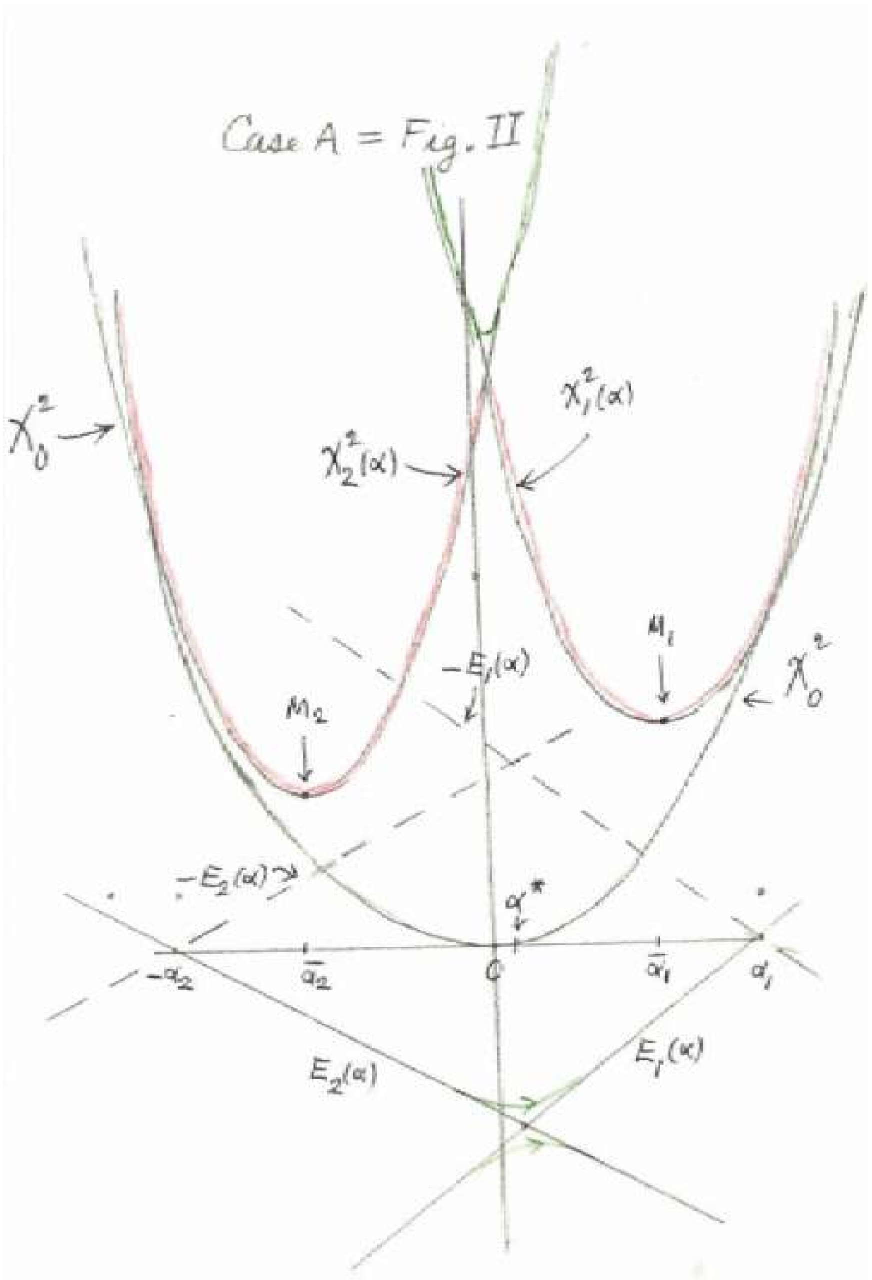
TELEPHONE: (516) 345- 3852

1 August 1972

Dear Dr Jones,

I enclose a copy of my Purdue talk. Ron Horgan was back at Oxford for some days in July, + he was able to run his programs again. He confirmed that he found many local minima in his fitting of the (70,1−) and (56,0+) states alone. When the data on (56,2+) and (70,2+) were included, there was found only one deep minimum. The new matrix-elements in (56,2+) also occur in (70,2+), and the additional matrix-elements needed for (70,2+) are the same as those already occurring in (70,1−). Hence the inclusion of the higher + parity states introduces some very strong constraints in the fitting, and this is what leads to the uniqueness of his fit.

His hand drawn Figures looked as if prepared by an engineer or artist.



The discovery of the psi in November 74 changed everything….

UNIVERSITY OF OXFORD

Telephone 53281

DEPARTMENT OF THEORETICAL PHYSICS

12 PARKS ROAD · OXFORD OX1-3PQ

14th January, 1975.

Dr. M. Jones,
Department of Physics,
Rutgers College,
New Brunswick,
New Jersey 08903,
U.S.A.

Dear Dr. Jones,

We are sorry to have taken so long to respond to your letter of 30 October 1974. Other excitements in physics have been taking our attention, and we could not sit down quietly to examine the situation.

With best greetings,

Yours sincerely,

R. H. Dalitz

R. H. Dalitz

R R Horgan

R. R. Horgan

Even when typewritten, last minute corrections were the norm

DEPARTMENT OF THEORETICAL PHYSICS

12 PARKS ROAD · OXFORD OX1–3PQ

Telephone (0865) 53281

29th October, 1975

Dr. M. Jones
Dept. of Physics
Rutgers University
New Brunswick
New Jersey 08903, U.S.A.

(i.e. starting from the solution 1 minimum, we cannot get to the solution 2 minimum)

Dear Michael

We were most interested to receive your output, especially your solution 2. We believe that our procedures (as they now stand) would not allow us to reach this minimum in a systematic way. We could reach it only following a lucky

given by (ii)

(c) The entry (−14/3) for $(\Lambda(8,2)|T_L.s|\Lambda(1,2))$ with J = 1/2, in Divgi's Table, does not bear the correct ratio (−1)/(+1/2) to the entry for J = 3/2, as ~~given~~ required by (ii). Probably it is the (−14/3) which is incorrect. The values you obtained from our

required

Editing is so much easier nowadays: (examples of Dick's precise logic and insistence on perfection from Ron Horgan thesis)

by the usual symbols. In each case the $SU(3) \otimes SU(2)_\sigma$ multiplet is ~~given~~ *indicated,* as well as the $SU(6)_\sigma \otimes O(3)$ multiplet concerned. ~~N.B. where~~ *Note that, whenever* a matrix element is not tabulated, ~~then~~ it ~~is~~ *has value* zero.

A3(ii). *Appendix VI. The*

~~We give the~~ matrix elements for each of the *SU(3) singlet and SU(3) octet* operators listed ~~above~~ *in Appendix IV, taken* between all the baryon states listed in Appendix I. *are tabulated*

~~2(ii).~~

The matrix elements of the ~~spin-independent~~ *spin-scalar* operators ~~(i.e. transform as scalars under $SU(2)_\sigma$ rotations)~~ do not depend on the angular momenta *J* of the baryons concerned. Hence, for a given $SU(6)_\sigma$ multiplet, these matrix elements are the same irrespective of the orbital angular momentum involved. The listings for these particular operators are ~~accordingly~~ *therefore* only labelled by the $SU(6)_\sigma$ multiplet di-

I didn’t realise Dick had read my thesis
until in 1981 he produced a paper himself out of the blue using it
and insisted he include my name on it

His final paper on light quark hadrons in 1981

THE ANTISYMMETRIC SPIN-ORBIT INTERACTION BETWEEN QUARKS

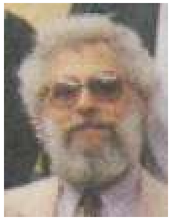
F.E. Close
Theoretical Physics Division, Rutherford and Appleton Laboratories - Chilton, Didcot

R.H. Dalitz
Theoretical Physics Department - Oxford University

411

E. Ferrari and G. Violini (eds.), Low and Intermediate Energy Kaon-Nucleon Physics, 411–418.

and then turned to Spin+TOP quark with Gary Goldstein



CONSTITUENT QUARKS ARE REAL;
Its just that we don't know what they are

Last word from Feynman (allegedly in response to MGM)

THE NON RELATIVISTIC QUARK MODEL IS RIGHT
(it describes so many data).

IT IS FOR THEORISTS TO EXPLAIN WHY

Dick Dalitz