Richard H Dalitz (1925 – 2006)

Oxford Particle Theory Group

John Wheater

Conformal field theory and quantum gravity

Founded in 1963 by **Dick Dalitz**
Emeriti: **Jack Paton, Ian Aitchison, John Taylor, Chris Llewellyn-Smith, Frank Close, Graham Ross**

Supported by: STFC, EU, Royal Society …

Andrei Starinets

Gauge-string duality, holography, AdS-CFT

Andre Lukas

String theory and phenomenology

+ presently 12 postdocs & ~25 DPhil students

http://www2.physics.ox.ac.uk/research/particle-theory

Mike Teper

Lattice field theory

Jorge Casalderrey-Solana

Juan Rojo

Giulia Zanderighi

Uli Haisch

Phenomenology of electroweak and strong interactions

Joe Conlon

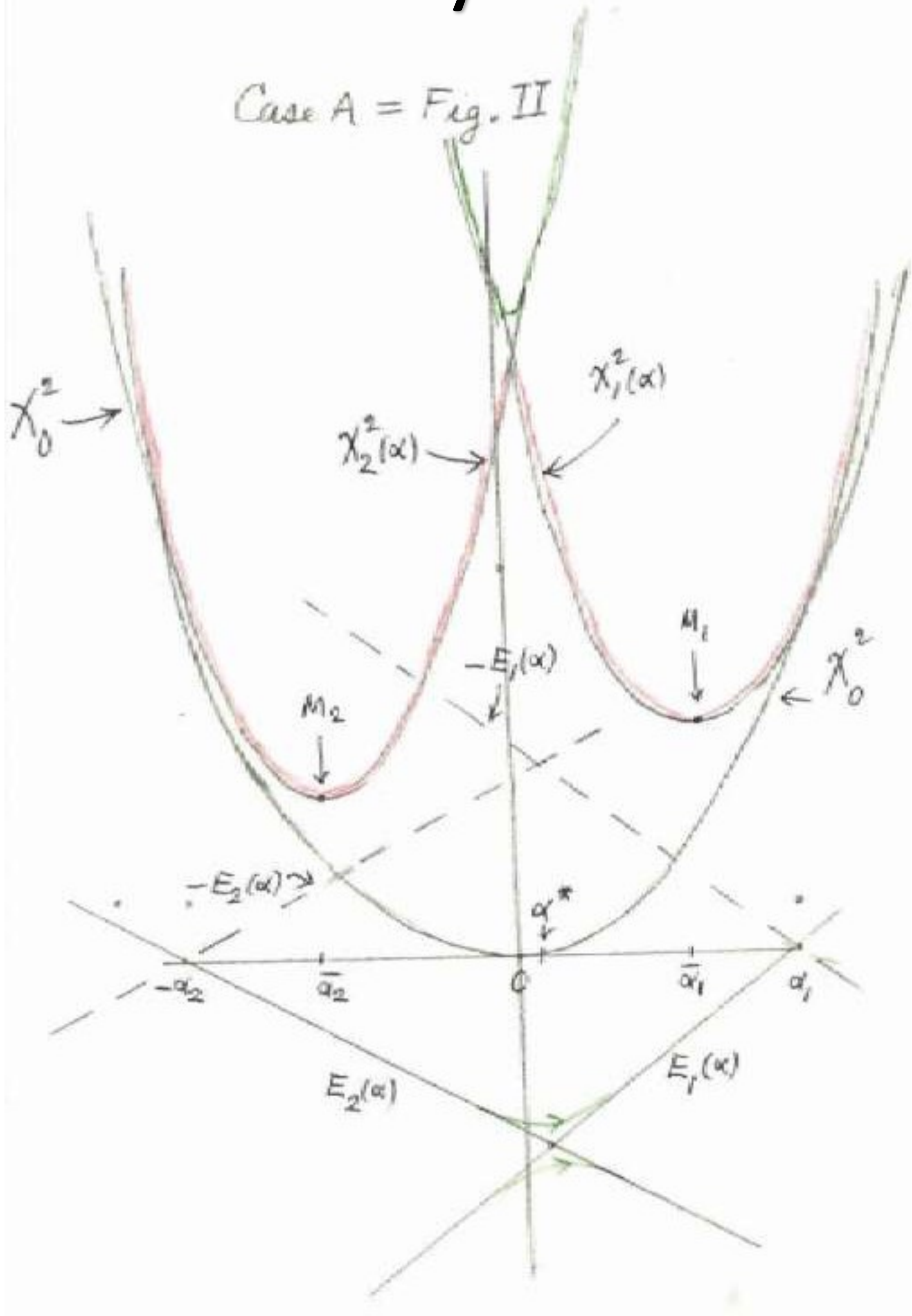
John March-Russell

Physics beyond the Standard Model

Subir Sarkar

Particle astrophysics and cosmology

A tribute by Frank Close



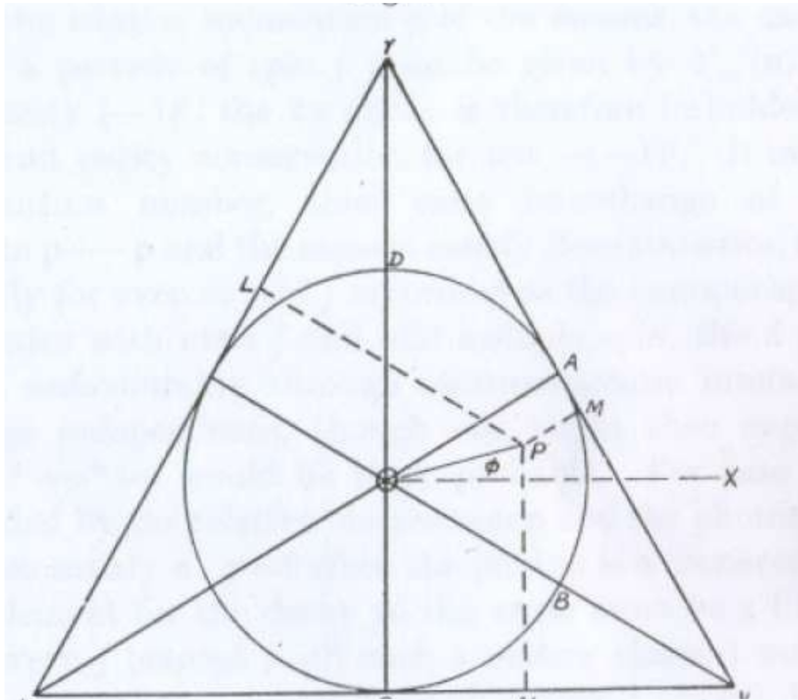


Fig. 2

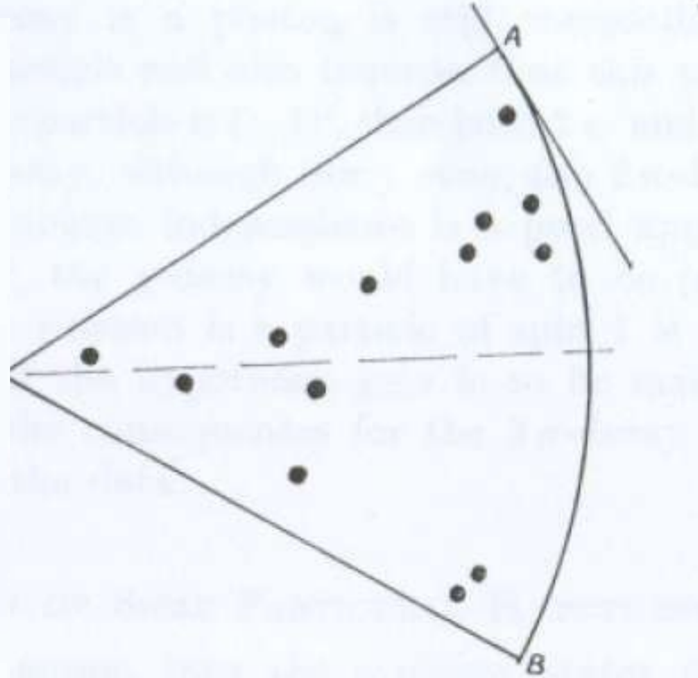

1955 PISA CONFERENCE

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

1956 | 2° Semestre | N. 2

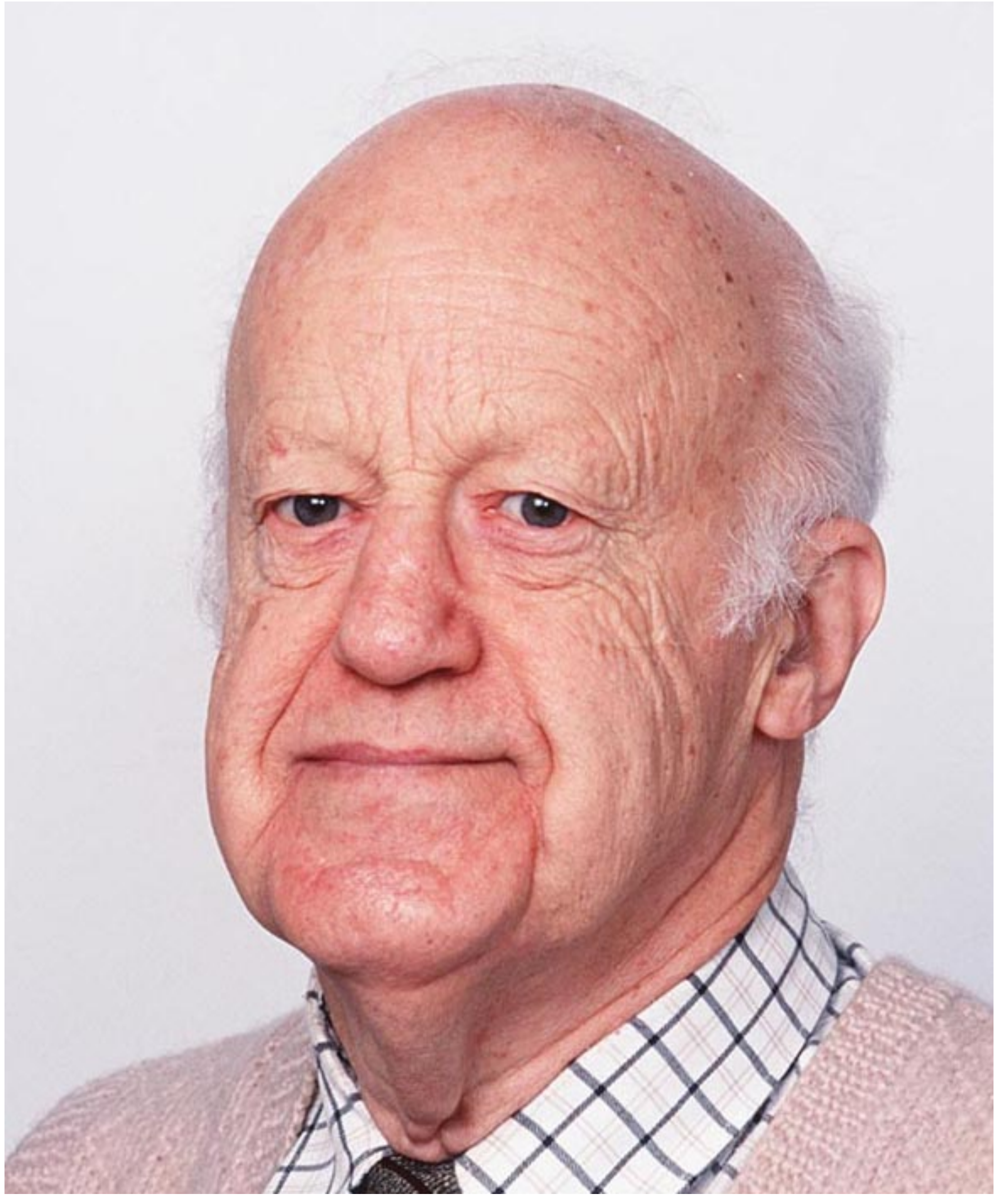
CELEBRAZIONE DEL CENTENARIO DEL GIORNALE
IL NUOVO CIMENTO

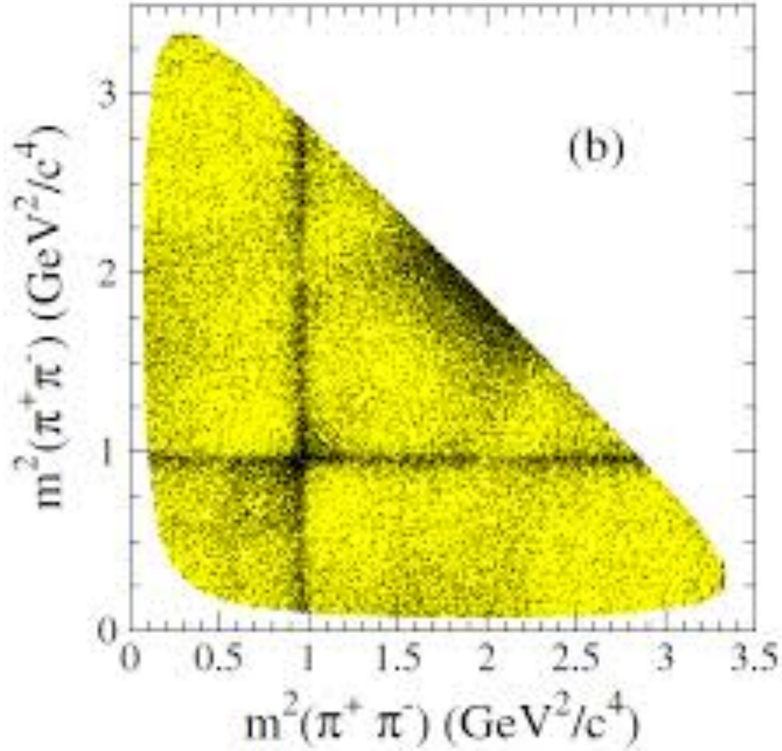
CONFERENZA INTERNAZIONALE
SULLE PARTICELLE ELEMENTARI



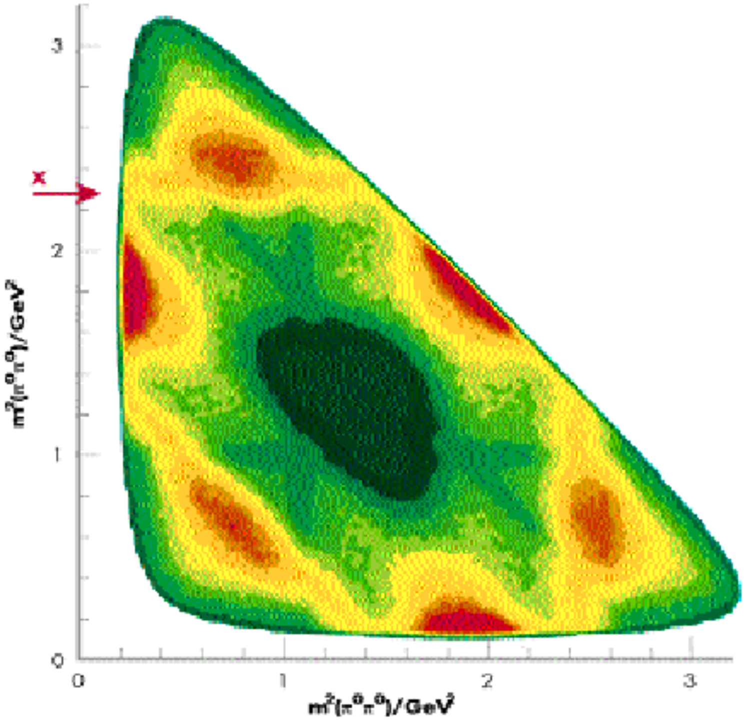
The data from 13 τ-meson decay events.

The First Dalitz Plot





(b)
m²(π⁺π⁻) (GeV²/c⁴)
m²(π⁺ π⁻) (GeV²/c⁴)
0
0.5
1
1.5
2
2.5
3
3.5



x
m²(π⁰π⁰)/GeV²
m²(π⁰π⁰)/GeV²
0
1
2
3

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

$$K^- + p \to \Lambda^0 + \pi^+ + \pi^- \qquad (1)$$

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)

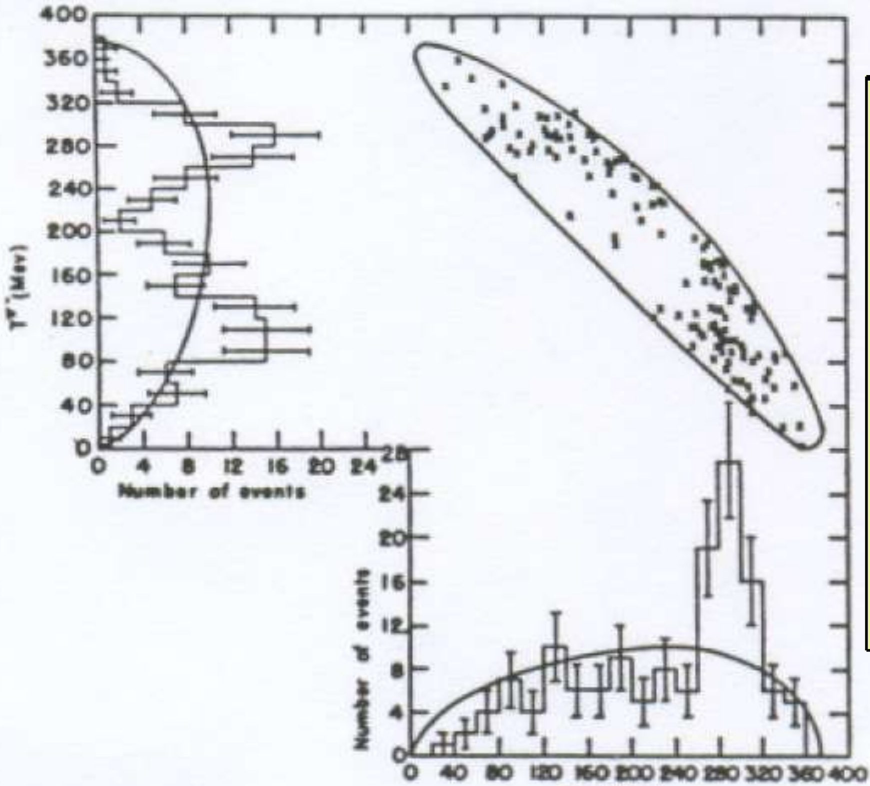


FIG. 1. Energy distribution of the two pions from the reaction $K^- + p \to \Lambda + \pi^+ + \pi^-$. Each event is plotted only once on the Dalitz plot, which should be uniformly populated if phase space dominated the reaction. The two energy histograms are merely one-dimensional projections of the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

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...."

Murray GellMann

1964

George Zweig

Also Peterman: CHLS narrate

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

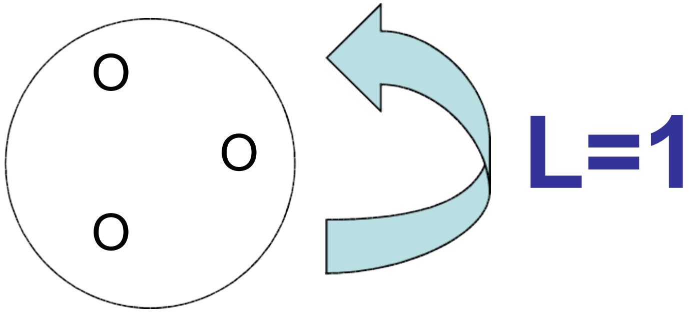
WICK	CHEW
GÜRSEY	DALITZ
FROISSART	JACKSON
OMNÈS	BELL

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. 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.



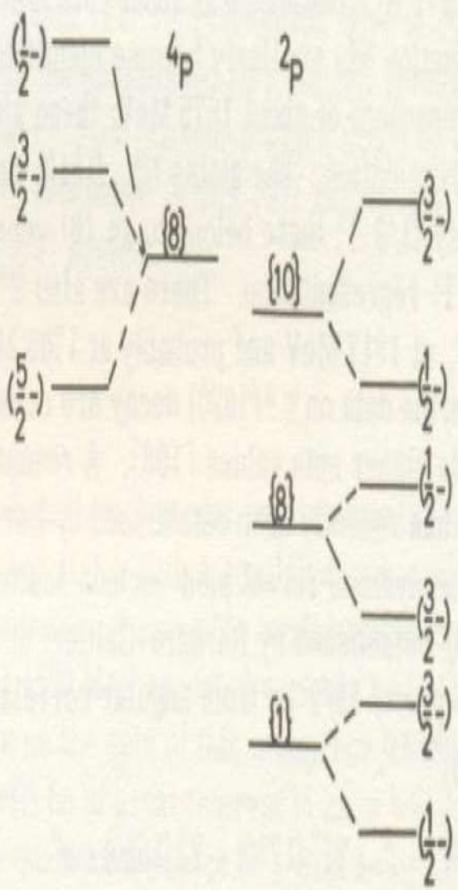


Fig. 6. The States belonging to the L = 1 Baryonic Supermultiplet on the three-quark model, for space wavefunction with [21] symmetry.

What Dalitz had proposed

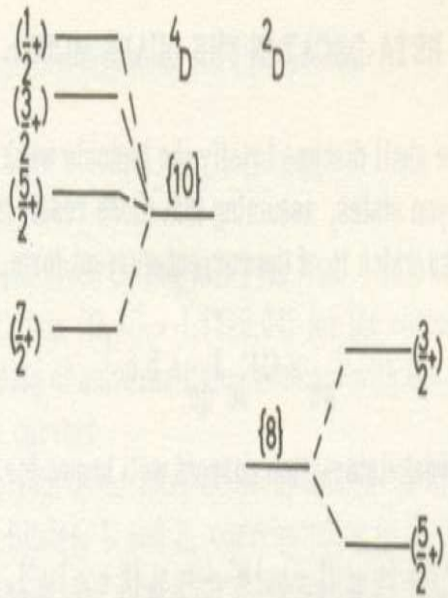
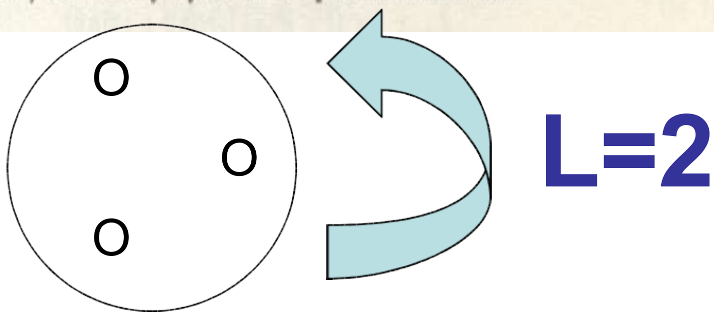


Fig. 7. The States belonging to the L = 2 Baryonic Supermultiplet on the three-quark model, for totally-symmetric space wavefunction.



PDG 2014 !!!

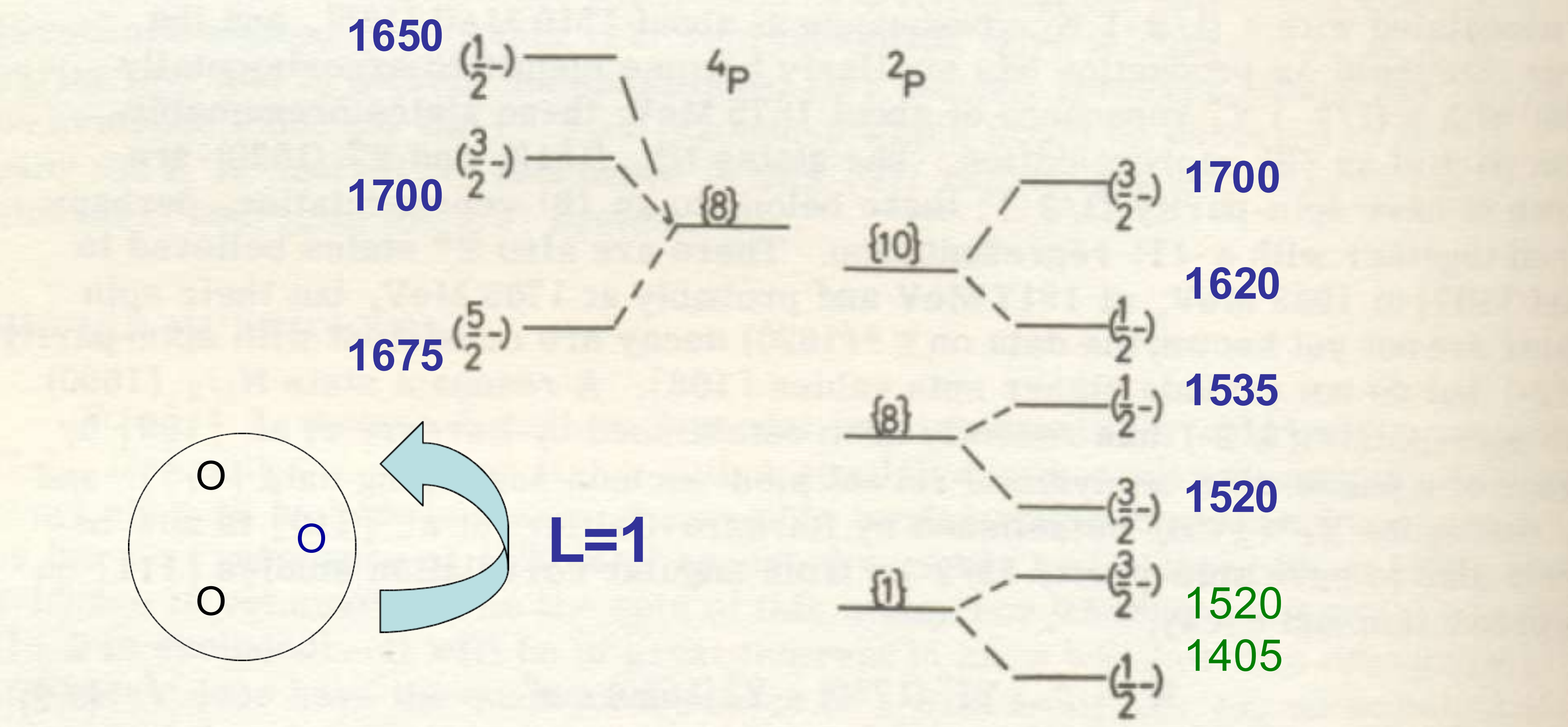


Fig. 6. The States belonging to the L = 1 Baryonic Supermultiplet on the three-quark model, for space wavefunction with [21] symmetry.

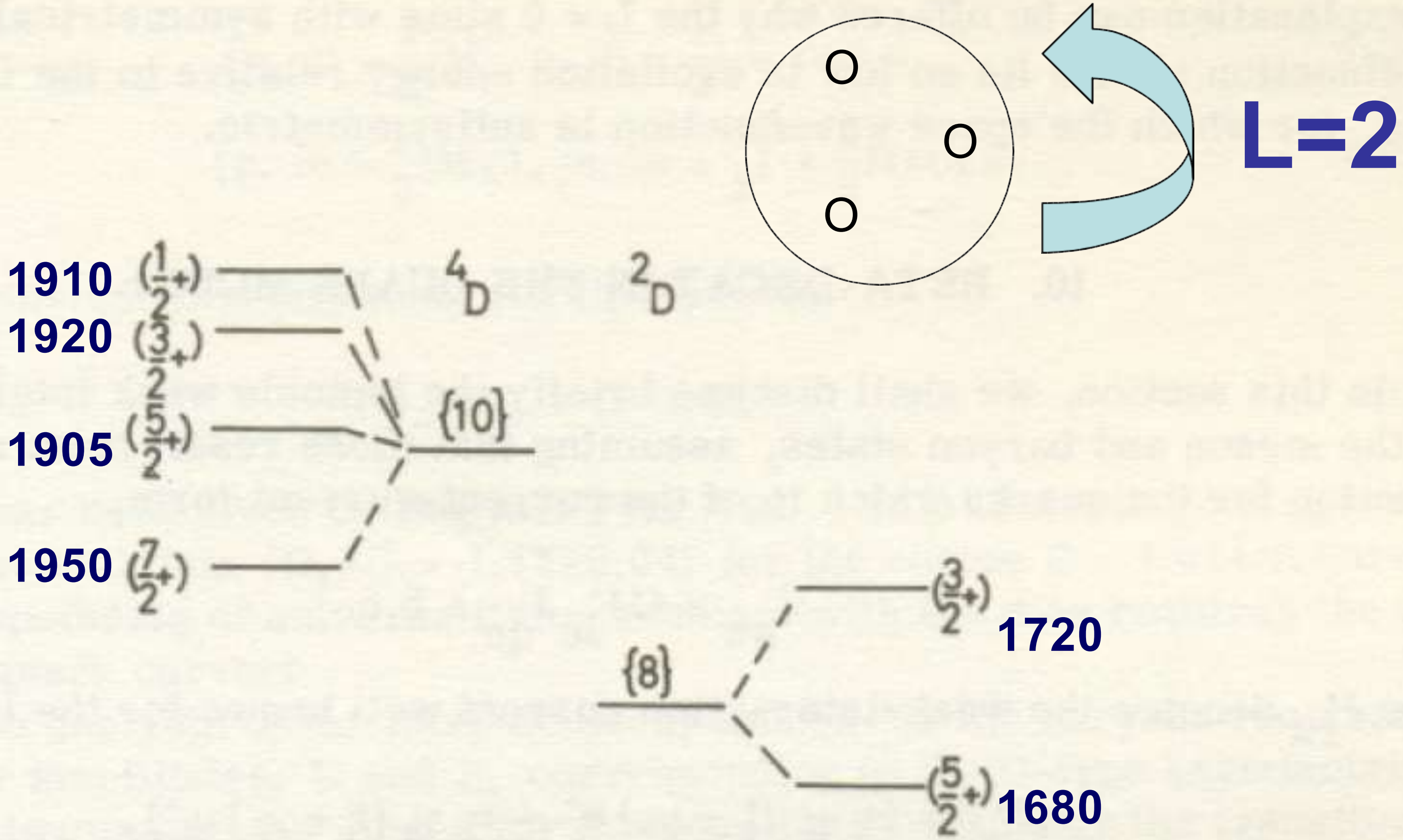


Fig. 7. The States belonging to the L = 2 Baryonic Supermultiplet on the three-quark model, for totally-symmetric space wavefunction.

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?

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

A student's dilemma in 1968

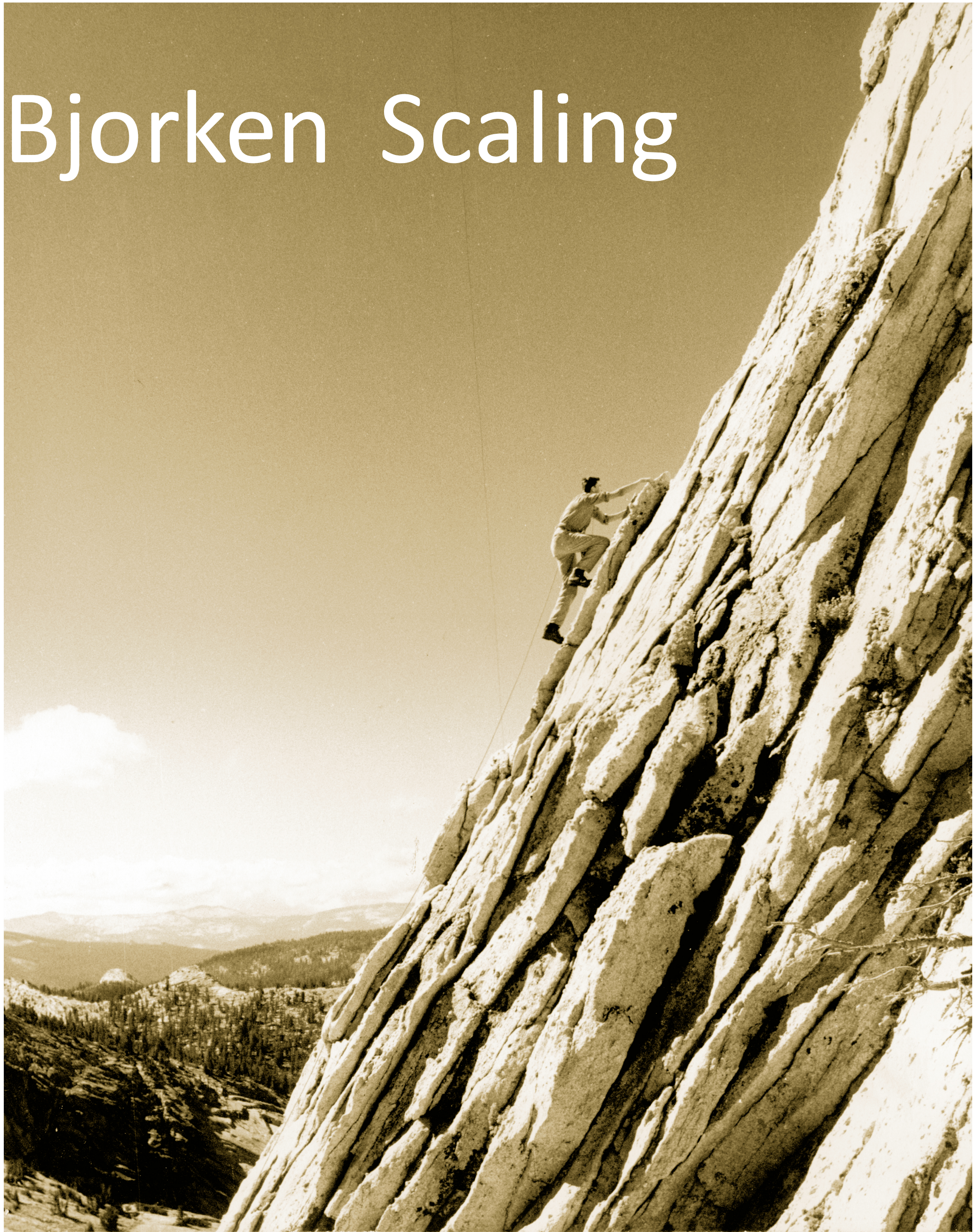
were fractionally charged particles that noone had ever seen REAL?

Or just figments of the imagination of people in Oxford?

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

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

Bjorken Scaling



bj on SE Arete – Cathedral Peak   Henry Kendall 1960

Bjorken DIS Quarks 1967

make any kind of careful statement. But the indication is that there does not yet seem to be any large cross sections which this model of point-like constituents suggests. Additional data is necessary and very welcome in order to completely destroy the picture of elementary constituents.

(Gottfried)

I also wanted to ask a question. I think Professor Bjorken and I constructed the sum rules in the hope of destroying the quark model. The electroproduction sum rule depends only on the assumption that the proton's charge is concentrated on three particles, and that these charges are given by the usual SU(3) quark model. Nothing need be assumed about forces, wave functions, etc. I wonder whether one of the experts, perhaps Professor Dalitz, would care to say how he would view a gross violation of the electroproduction sum rule at small q^2 ?

Dick’s response:

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

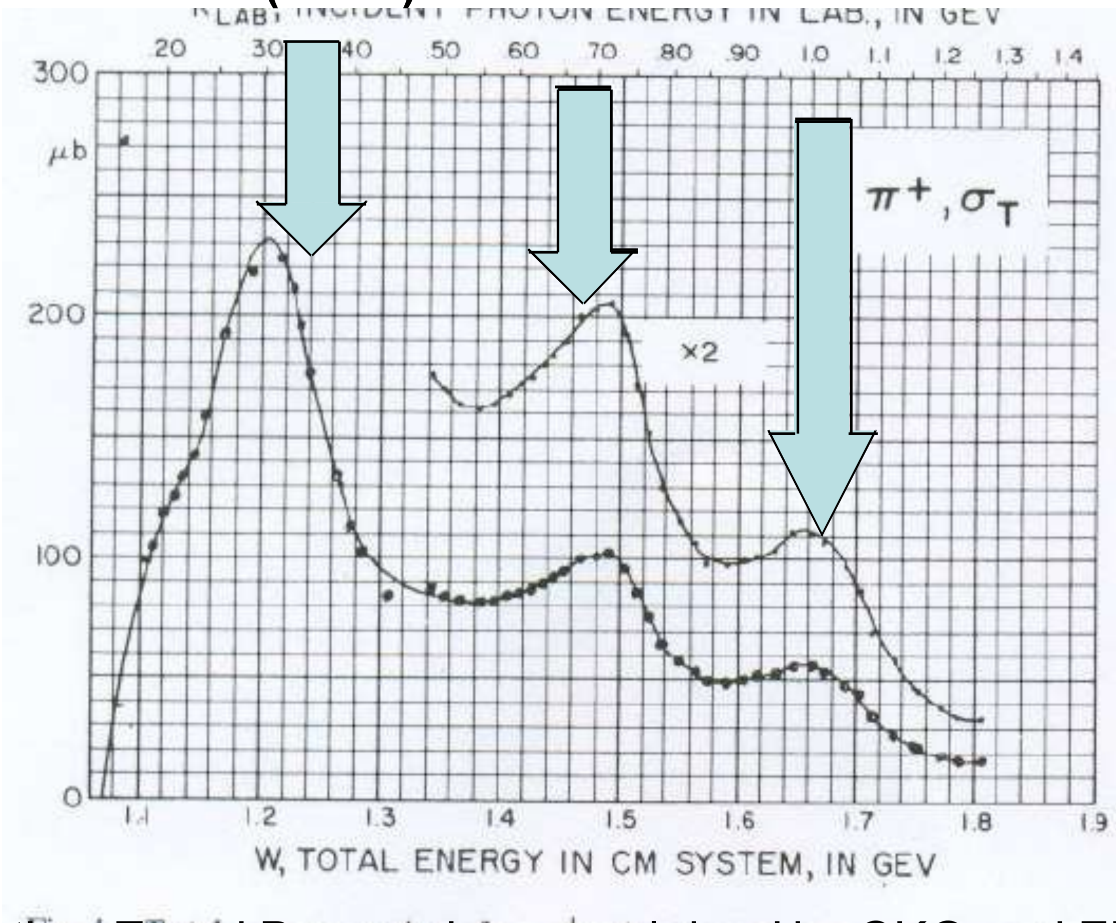
(Received 17 December 1970)

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?

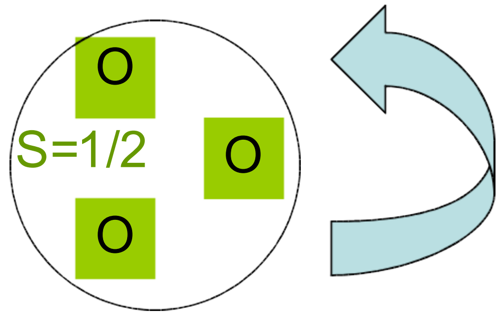
Empirically three prominent resonances

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



Photoproduction: E and B conspiracy explained by CKO and FKR

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



L=1 (2)

Photoexcitation

Magnetic - **Electric** = data

cancels

Catch 22:

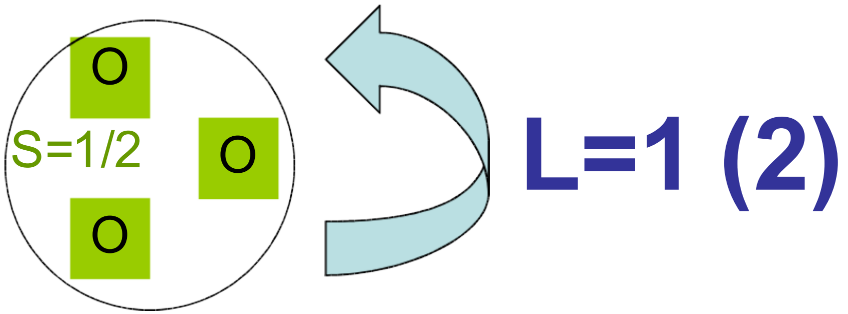
MGM symmetry:

can impose it by symmetry/clebsches

1972: Electroproduction

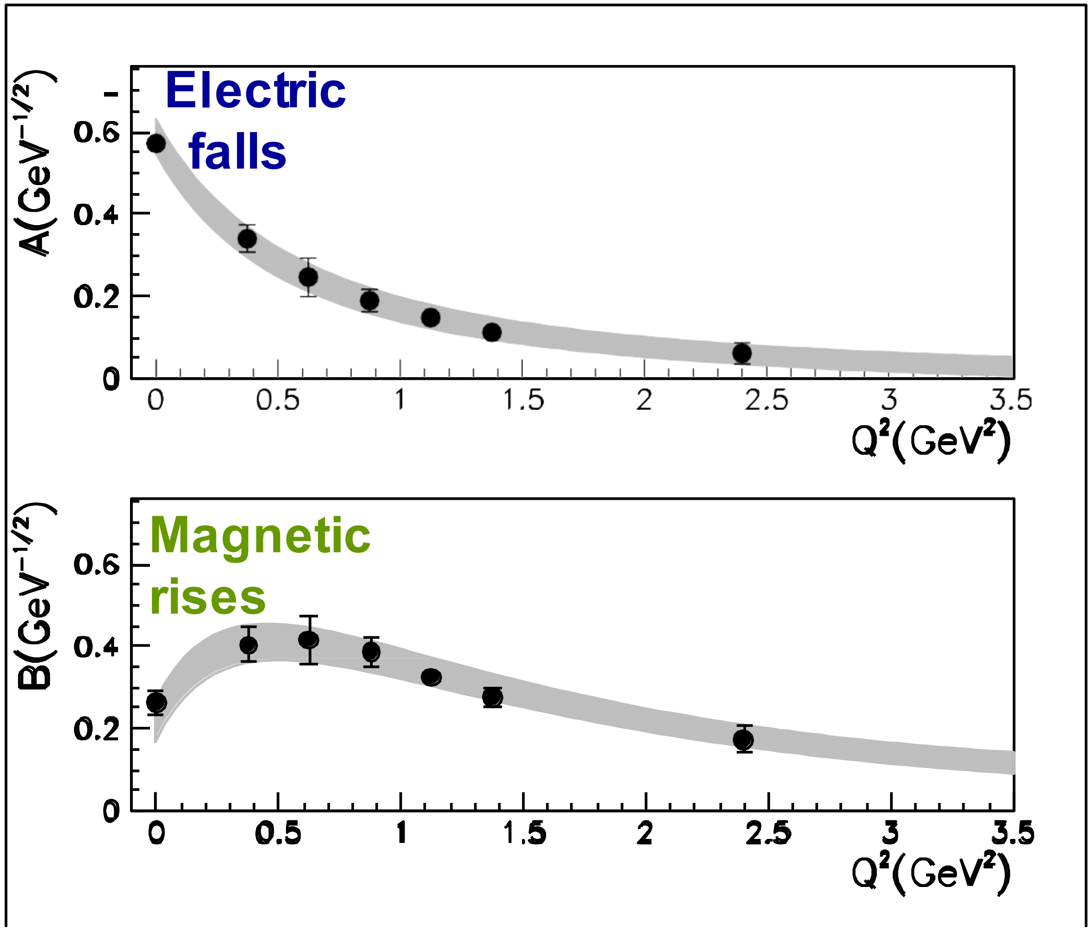
Changes magnetic/electric ratio

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



Electroexcitation
at small q^2

Magnetic rises - **Electric falls** = data



Response of "real" quarks

Dramatic change in spin data

Close+Gilman 1972

1973

Dick's notes on FC seminar

Photo to Electroprodn.

Constituent Quarks are "real"

Close νW_2 is a function of s/Q^2 only (essentially ω') Note: $s = M^2 + 2M\nu - Q^2$

Close connection between $\gamma N \to N^*$ (low q^2 region) and deep inelastic scattering (high q^2 region)

Bloom/Gilman — mean curve is that obtained from the deep inelastic region

$$\int \frac{d\omega}{\omega}(\nu W_2) A = Z; \quad Z^p - Z^n = \frac{1}{3}\frac{g_A}{g_V}$$

and SU(6) gives $Z^p = 5/9$, $Z^n = 0$

Z comes from considering $[V,V] \sim A$.

Conclude $A < 0$ for $\omega < 5$ to fit facts (SU(6)).

Note, $(\nu W_2) A \sim (\sigma_{1/2} - \sigma_{3/2})$.

$\gamma p \to N^*$ helicity analysis ① Mag Dipole excitation $\longrightarrow \frac{\sigma_{1/2}}{\sigma_{3/2}} = \frac{2J-1}{2J+1}$ ② Look at 0° or 180° Only $\sigma_{1/2}$ contributes

Resonance	1	2	3
Value of A			
$Q^2 = 0$	<0	<0	<0
$Q^2 < 0$			

Quark model explanation for this for 2- and 3-resonance regions.

Mom^{m} transfer dependence for $\sigma_{1/2}/\sigma_{3/2}$ predicted by Close + Gilman. Not found exptlly (Mancaster expts give $\frac{d\sigma}{d\Omega}$ at fixed q^2)

Multipole Approach (Devenish + Lyth)

$$\frac{A_{1/2}}{A_{3/2}} = \frac{1}{\sqrt{3}}\left(\frac{2M - E}{M + E}\right)$$

small for D(1520) and D(1688)

Both M and E have q^2 dependence. Numerator + Denom each vanish at some point.

Assume usual threshold behaviour

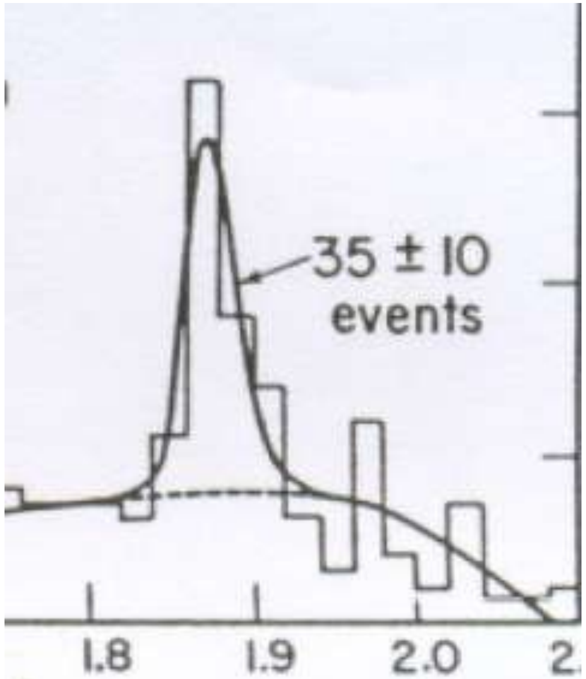
$M \sim q^3$, $E \sim q$ so $0 \leftarrow \frac{M}{E} \rightarrow \infty$ (small q ← , → large q.)

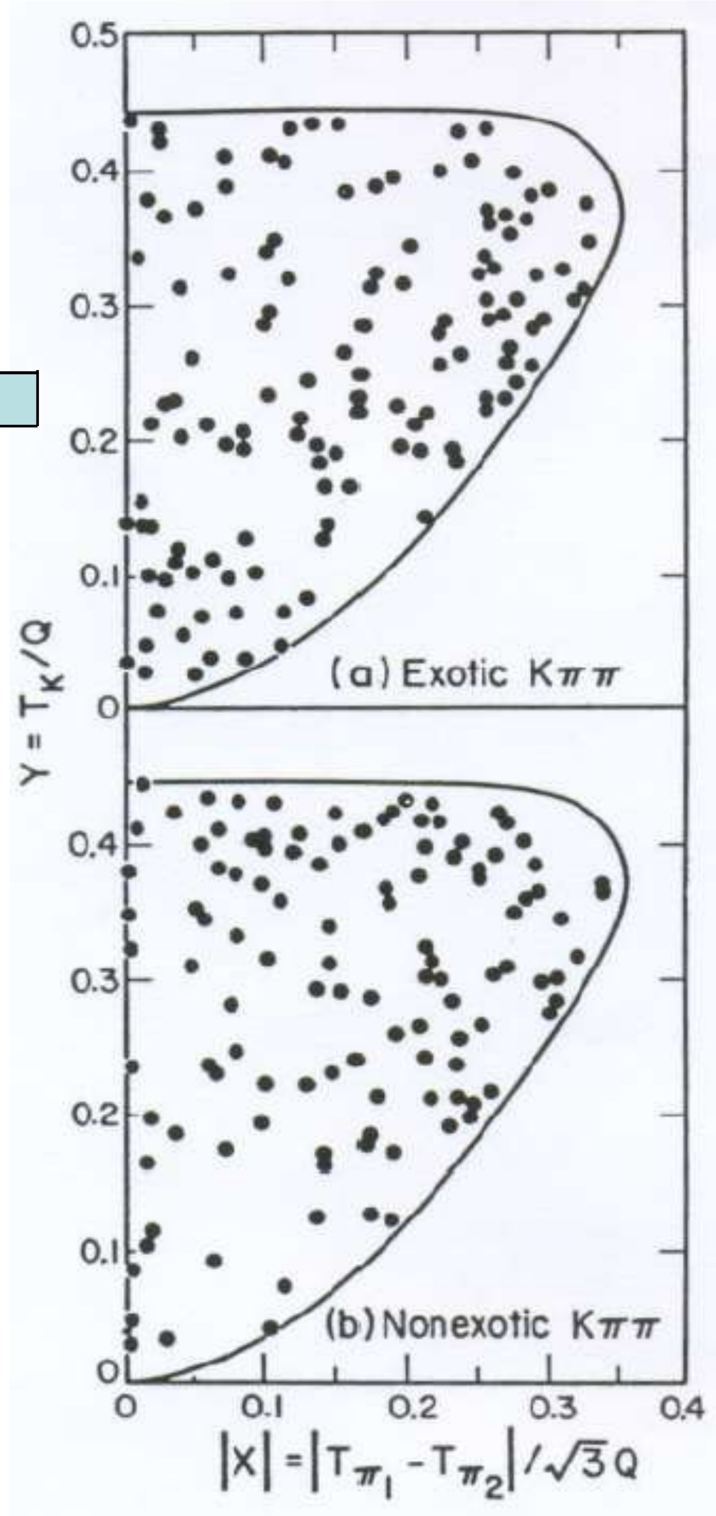
and $\sigma_{\frac{1}{2}}/\sigma_{\frac{3}{2}}$ → <1 (small q), → $\sqrt{3}$ (large q)

SHO quark model. gives

$\frac{\sigma_{1/2}}{\sigma_{3/2}} \to \infty$ (q large) and $\frac{\sigma_{1/2}}{\sigma_{3/2}} < 1$ (q small)

Elastic scattering must be included in Bloom/Gilman ~~✓ ✓~~ duality / arguments





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

1977: Dick extends 1965 idea to L=3

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

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)

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.

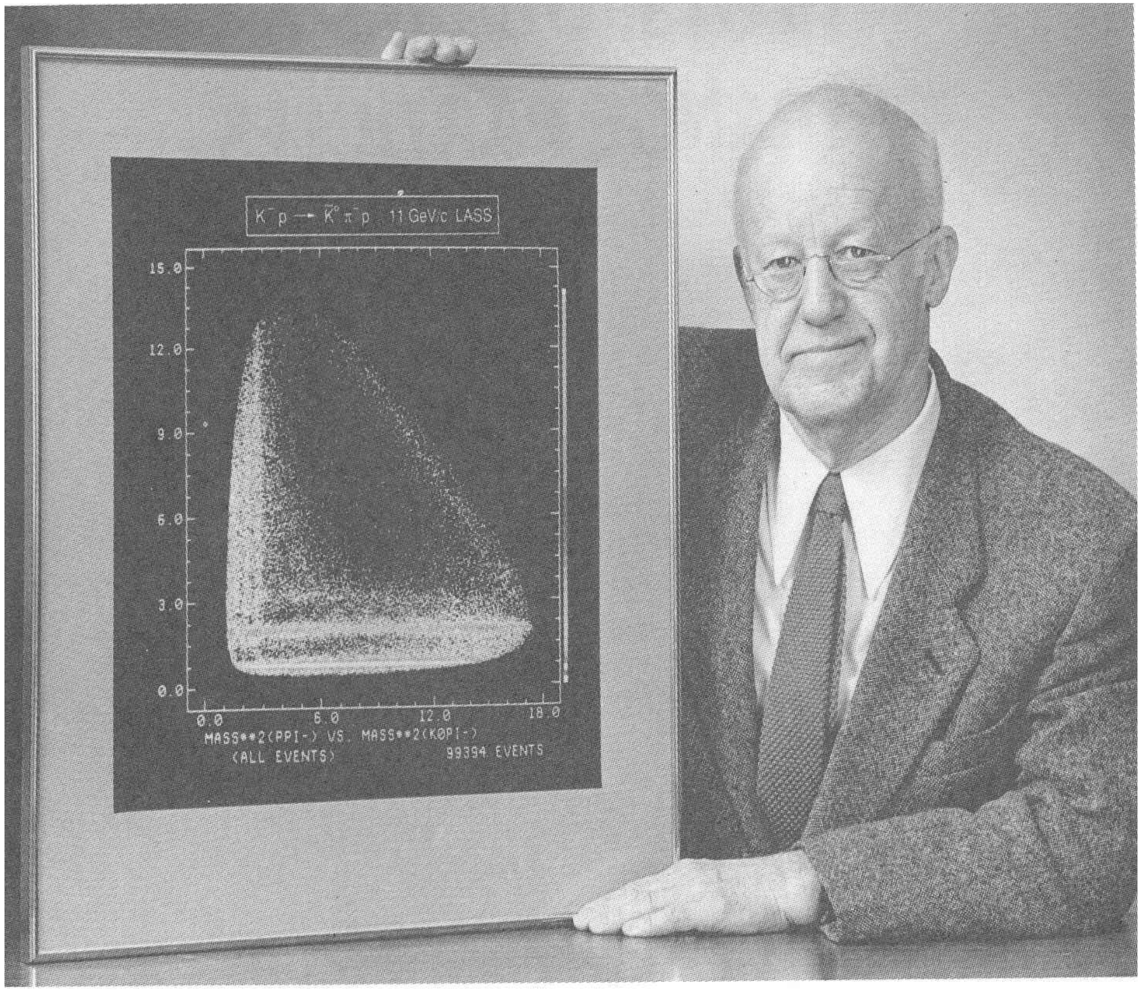
and then turned to
Spin+TOP quark
with Gary Goldstein

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

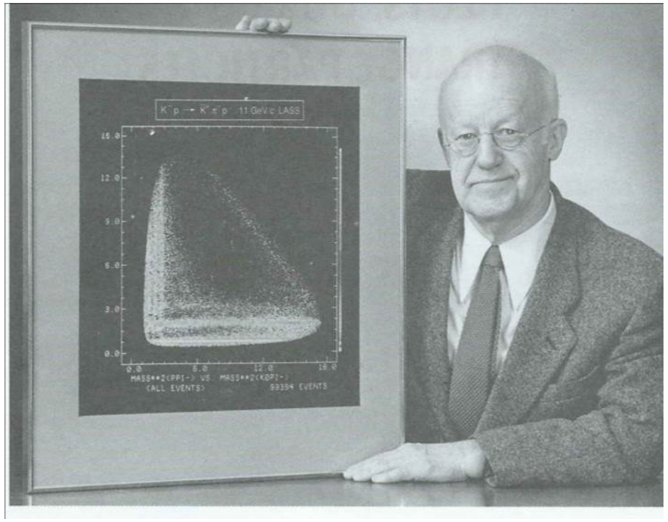


$K^- p \rightarrow \bar{K}^0 \pi^- p$ 11 GeV/c LASS
15.0
12.0
9.0
6.0
3.0
0.0
0.0
6.0
12.0
18.0
MASS**2(PPI-) VS. MASS**2(K0PI-)
(ALL EVENTS)
99394 EVENTS

Dick Dalitz

A Tribute to Dick Dalitz

28.2.1925 (Dimboola) – 13.1.2006 (Oxford)



Chris Llewellyn Smith

Director of Energy Research, Oxford University

President SESAME Council

Dalitz student: 1964-67

Dalitz colleague: 1974-93

Draft Abstract of Royal Society Memoir

I Aitchison and C H Ll S

Richard (Dick) Henry Dalitz was a theoretical physicist whose principal contributions were intimately connected to some of the major breakthroughs of the twentieth century in particle and nuclear physics. His formulation of the '$\tau - \vartheta$' puzzle led to the discovery that parity is not a symmetry of nature - the first of the assumed space-time symmetries to fail. He pioneered the theoretical study of hypernuclei, of strange baryon resonances, and of baryon spectroscopy in the quark model (at a time when many considered it 'naive'), to all of which he made lasting contributions. The 'Dalitz Plot' and 'Dalitz Pairs' are part of the vocabulary of particle physics. He remained throughout his career in close touch with many experimentalists, and he had an encyclopaedic knowledge of the data. Many of his papers were stimulated by experimental results, and were concerned with their analysis and interpretation, work which often required the forging of new phenomenological tools; many also indicated what new experiments needed to be done. As a consequence, he was a theorist exceptionally valued by experimentalists. He served on a number of scientific Boards and Committees, including the CERN Scientific Policy Committee. He created and ran a strong and flourishing particle theory group at Oxford, which attracted many talented students and researchers.

What to choose from the extensive menu?

- Dalitz pairs
- The Dalitz Plot
- Hypernuclei
- KN Interactions, CDD Poles and the K Matrix
- Quarks – covered by Frank Close
- Reminiscences and reflections

Brief Biography of R H D

- 1944 BA Mathematics, Melbourne
- 1945 BSc Physics, Melbourne
- 1946-48 PhD student Cambridge (PhD awarded 1950)
- 1948-49 Research Assistant, Bristol
- 1949-53 Research Fellow then Lecturer, Birmingham
- 1953-55* Research Associate , Cornell
- 1956-63* Associate then full Professor, Chicago
- 1963-90 Royal Society Research Professor (Emeritus from 1990) Oxford

* with visiting periods at Stanford, Institute for Advanced Studies, Brookhaven, Lawrence Radiation Lab, Seattle,..

Context

- **1946:** Elementary particles = p, n, e and a cosmic ray 'meson'* (Yukawa?) mass ~ 200 m_e + neutrino? (a postulate)

  *1947 – actually two particles: π and μ

- **1963**: 'Elementary' particles

  Leptons: e, ν_e, μ, ν_μ

  Hadrons: baryons N, Λ , Σ, Ξ, Σ

  mesons: π, K

  + Small number of 'resonances' Δ (1952) ρ, ω, η, K* (all 1961)… many discovered using Dalitz plots

- **Theory in the 1960s**

  S matrix, bootstrap…

  G Chew: "Field theory like an old soldier will not die but simply fade away"

Dalitz Pairs (1)

- Dick's thesis on "Zero- zero transitions in nuclei" focused on

  $^{16}O^*(0+,\ 6.05\ MeV) \rightarrow {}^{16}O\ (0+,\ \text{ground state})$

  He studied the decay via a virtual (longitudinal) photon → $e^+ + e^-$
  [emission of a single photon is forbidden]

- In 1951 members of Powell's group showed Dick some emulsion events, and said

  "Here are two peculiar pairs". In each of these cases, the outgoing pair of tracks were clearly identified as electronic. What was peculiar about them was that the origin of each pair could not be seen as separate from the centre of the cosmic ray star from which it emerged. What could give rise to these two pairs? On my way back to Birmingham, I suddenly realized that the π^0 itself could give rise to them by a direct decay to γe^+e^-, through the process of internal pair conversion of one of its product photons:

$$\pi^0 \rightarrow \gamma + \text{“}\gamma\text{”} \rightarrow \gamma + e^+ + e^-$$

Dalitz Pairs (2)

- Recalling his thesis work Dick

  "calculated the rate for the internal conversion of one of the γ-rays in $\pi^0 \to \gamma\gamma$ decay for a free π^0" and found a branching ratio of 1.185%, later increased to 1.195% by radiative corrections

  Today's value is (1.198 ± 0.032)%

  With just 2 events, the Bristol group did not claim discovery of decays to Dalitz pairs, which were established a year later

- Dalitz pairs proved to be a useful, e.g.

  - the decay $\Sigma^0 \to \Lambda^0 + \gamma$ (virtual) $\to \Lambda^0 + e^+ + e^-$ was used to establish that Σ^0 and Λ^0 have the same parity

  - Kroll and Wada extended Dick's work to the double-Dalitz process $\pi^0 \to e^+e^-e^+e^-$ which was used to determine the parity of the π^0

The τ-ϑ Puzzle and the Dalitz Plot

- **January 1953 Royal Society Discussion Meeting**

  11 events τ^+ (now called K^+) → $\pi^+\pi^+\pi^-$

  Dick later recalled "the time was ripe to give some serious consideration to their characteristics". He reported his considerations (in more detail in a paper already submitted) at the

- **July 1953 Bagnères-de-Bigorre conference**

  τ^+ well established, mass $(970 \pm 5)m_e$

  ϑ^0 (now called K^0)→ $\pi^+\pi^-$ reported, mass $(971 \pm 10)m_e$

  Question: given their similar masses, are τ^+ and ϑ^0 different states of the same particle? If so, they would have the same spin and parity

  Dick's analysis showed, when enough event had accumulated, that the $\pi^+\pi^-$ state from ϑ^0 decay and the $\pi^+\pi^+\pi^-$ state from τ+ decay have different party

  Either parity is not conserved (a revolutionary idea), or some unknown symmetry produces states with the same mass but opposite

The Dalitz Plot and the τ-ϑ Puzzle

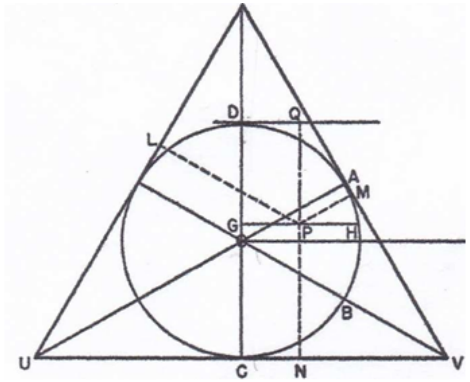
Dick later recalled:

It was my opinion that the amplitude for the decay mode $\tau^+ \rightarrow \pi^+\pi^+\pi^-$ should be largely calculable in form (although not in magnitude) in terms of angular momentum barrier considerations, apart from a few parameters necessary when the total angular momentum and parity could be apportioned to the internal orbital motions within the three-particle system in more than one comparable way. If so, it would then be possible to deduce the values of these internal angular momenta from the distribution of events and from them to reach some conclusions about the total spin-parity [of the τ-meson], at least to exclude some possibilities. First, a representation was needed to display the distribution of events pictorially……

The Dalitz Plot and the τ-ϑ Puzzle

- Dick's **'phase space plot'** is an ingenious way to display how the energy is shared between A, B and C in any decay X→ A + B + C ,which
  i) treats A, B and C on an equal footing, and
  ii) directly reflects physics (with kinematical factors removed)

- As they accumulated, the $\tau^+ \rightarrow \pi^+\pi^+\pi^-$ events populated the kinematically allowed domain (inside the circle) uniformly → no relative angular momenta→ parity opposite to that of ϑ !!



The original plot
Phys Rev 1954

- Dick (speaking in 1982) recalled the reaction:

"How was it possible that reflection invariance should not hold, people asked - was not left-right invariance inherent in our most fundamental conceptions about space-time? The only answer available was that the occurrence of both K → 2π and K → 3π decays actually did demonstrate this, but this answer did not have compelling force because it could not point to any *explicit* empirical demonstration of parity failure. . . . It required much less faith to suppose that . . . there existed two distinct K-meson charge doublets, labelled ϑ and τ , close in mass but with different spin-parities. . . . The mental obstacle [to accepting the parity violation explanation] arose from the fact that the $\tau - \vartheta$ puzzle did not provide an explicit demonstration of parity violation."

Hypernuclei = nulcei containing at least one strange baryon

- First observation (1952): a hyper-fragment event in a balloon-flown photographic emulsion (K + nucleus → π + hypernucleus with N replaced by Λ)
- In his first paper on hypernuclei (1955) Dick inferred that the nearly equality of the binding energies of ${}^4_\Lambda H$ and ${}^4_\Lambda He$ implies charge symmetry of the Λ-N interaction
- Soon after the discovery of parity violation, Dick realised that studies of the decays ${}^4_\Lambda H \to {}^4He + \pi^-$ and ${}^3_\Lambda H \to {}^3He + \pi^-$ could be used to determine the J^P of the parent hypernuclei
- He went on from simple s-shell cases to: p-shell and larger/more complex nuclei, including ΛΛ hypernuclei and Σ hypernuc;ei, and pioneered studies of non-mesonic weak decays in hypernuclei (ΛN→ NN) and γ decays of excited Λ hypernuclei
- Dick's work on light hypernuclei (in particular perhaps on ${}^3_\Lambda He$ and ${}^3_\Lambda H$, ${}^3_\Lambda N$)* honed expertise which he later used in his pioneering studies of three quark systems

******I= 0* ${}^3_\Lambda H$ *has small binding energy: Dick showed the iso-triplet state in not be bound*

$\bar{K}N$ Interactions, CDD Poles and the K Matrix

- **Pedagogical introduction:**

  Writing the scattering matrix $S = (1 - iK/2)/(1 + iK/2)$, then $SS^{\dagger} = 1 \rightarrow K^{\dagger} = K$, time reversal invariance → K real. Dick showed that parameterization of K is an excellent way to analyse data.

  With $S = 1 + iT$,setting $T = N/D$ where N [D] is analytic apart from a left-hand [right-hand] cut (N reflects particle exchanges = forces; D unitarity), was found in the 1950s to be a good way to solve model field theories, and formulate bootstrap models.

- **C**astillejo, **D**yson and **D**alitz (1956) pointed out that any solution of the N/D equation remains a solution if $D \rightarrow D + a/(s-s_0)$. Dick later pointed out that this leads to a resonance at $s \approx s_0 + a/\mathrm{ReD}(s_0)$ if $a/\mathrm{ReD}(s_0)$ is small.

- In a series of papers, with S F Tuan (later others) starting in 1959, Dick presented a masterly analysis of $\bar{K}N$ scattering, and developed the relativistic multi-channel K matrix formalism

Analysis of KN Scattering and the Λ (1405)

- **1st paper**: analysis of scattering lengths → one fit with pole below threshold in lower half (unphysical) complex plane (new idea phenomenology) "…the appearance of this maximum would correspond to the existence of a resonance . . . in pion-hyperon scattering [i.e. in $\pi\Sigma$] for a closely related energy value"

- Increasingly general/sophisticated K matrix analyses followed, while (following some bumps in the road) the predicted state – now known as the Λ (1405) – was confirmed (bump in $\Sigma\pi$ invariant mass distribution).

- Having predicted the state phenomenologically, Dick's attention then turned to its nature:
  - in the language of the time: elementary (CDD) or composite (dynamically generated by meson exchange)?
  - more recently: L = 1 three quark $½^-$ state? But why so much lighter than $3/2^-$ Λ(1520)?
  - Lattice QCD suggests KN molecule

Reminiscences and Reflections

- Scientific style
- Quarks
- Seen by students
- Hard work
- Professionalism

Dick's corrections to his own work

Autobiographical notes made by Richard Dalitz for Gerald Stone c. ~~1980~~ 1985–1990

My Childhood & Life in Australia

Dimboola, my birthplace, is a small town (population 2000) on the river Wimmera, which flows north from the Grampian mountains of western Victoria until it disappears in the sands of the semi-desert to the north. My grandfather Heinrich lived on the

in a district where there were many German settlers. A few years after Heinrich had married Anna Elizabeth Wuttke there, during which time my father Friedrich Wilhelm was born, Heinrich and his family left Robertstown to settle in the Wimmera district of Victoria, which involved a journey of some 350 km, mostly across semi-

It is worth saying a little about the later history of this family. Of the girls, one died young by accident, while the other two married, one to a Schulze, the other to a Tepper, both being from German families. Of the other 9 boys, two became local farmers, having married into German families (Möller and Hirthe) owning farmland locally, two became grocer's assistants locally, one died in France in

the work of others (Ron Horgan's 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. ~~We give the~~ The matrix elements for each of the SU(3) singlet and SU(3) octet operators are tabulated in Appendix IV_2 taken ~~listed above~~ between all the baryon states listed in Appendix I. ~~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-