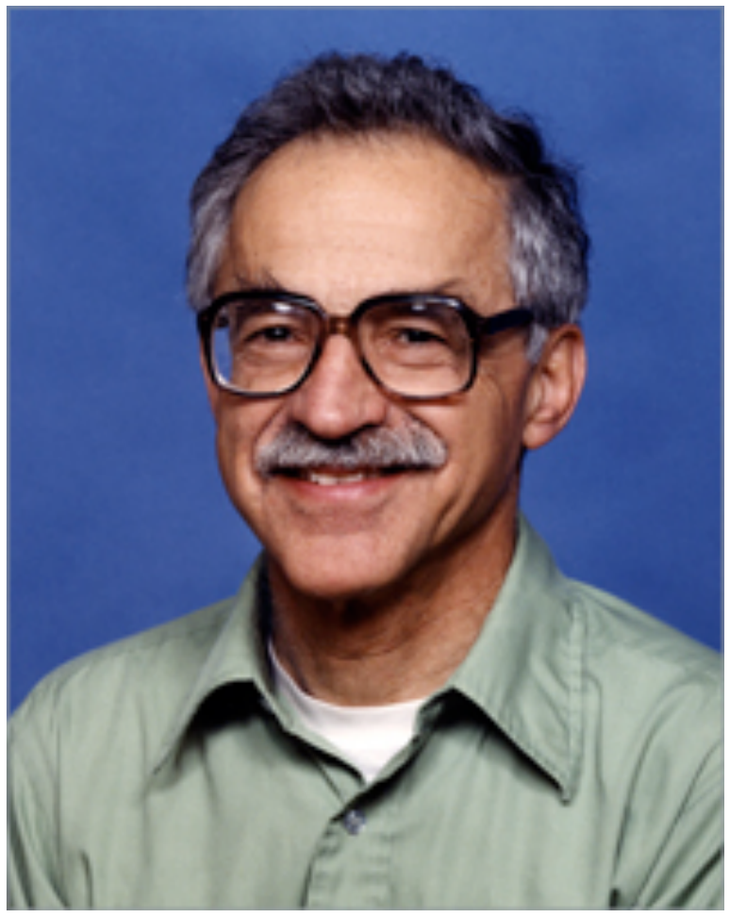
Ernest Henley and Isospin

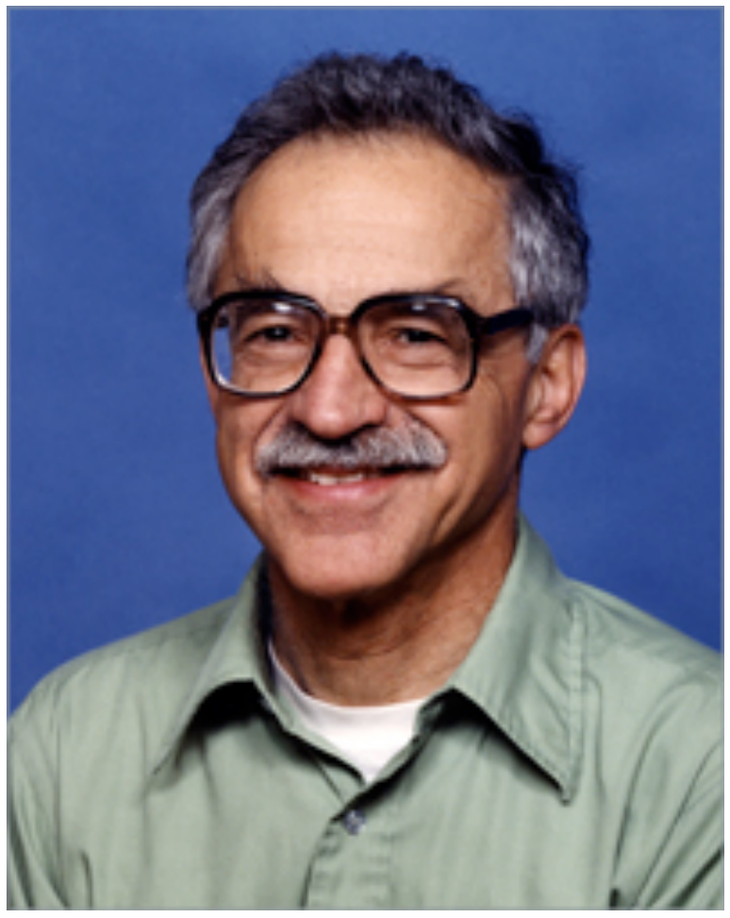


My first encounter with Ernest occurred about two years before I met him

I was a grad student, working on isospin violating hadronic corrections to the widths of isobaric analog states

John Negele told me that there was a new preprint on isospin violations from Henley in the Physics Library

Ernest Henley and Isospin



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Article was much more advanced than I had ever seen.
I thought: What is a man like that doing in Seattle?

Ernest Establishes the Field

from Isospin in Nuclear Physics
ed. by Wilkinson 1970

- paper established isospin as
- approximate symmetry
- collected the evidence
- defined the terms

CHAPTER 2

CHARGE INDEPENDENCE AND CHARGE SYMMETRY OF NUCLEAR FORCES

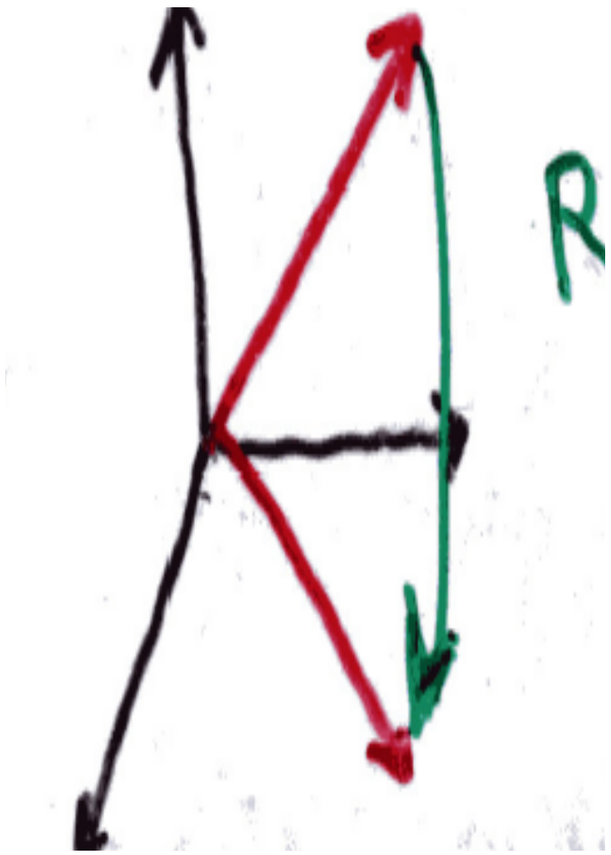
ERNEST M. HENLEY
University of Washington, Seattle, Washington

CONTENTS

Ernest organized the nuclear force

- Fact: np and nn nuclear forces are different, but still called charge independent
- Ernest: Charge independence defined: as pp, np and nn forces are equal to each other in the same space-spin state
- Charge symmetry - nn and pp forces are identical
- Generalized these statements to all hadrons
- Electromagnetic forces break these symmetries
- Catalogued the non-electromagnetic forces

Isospin invariance vs charge symmetry

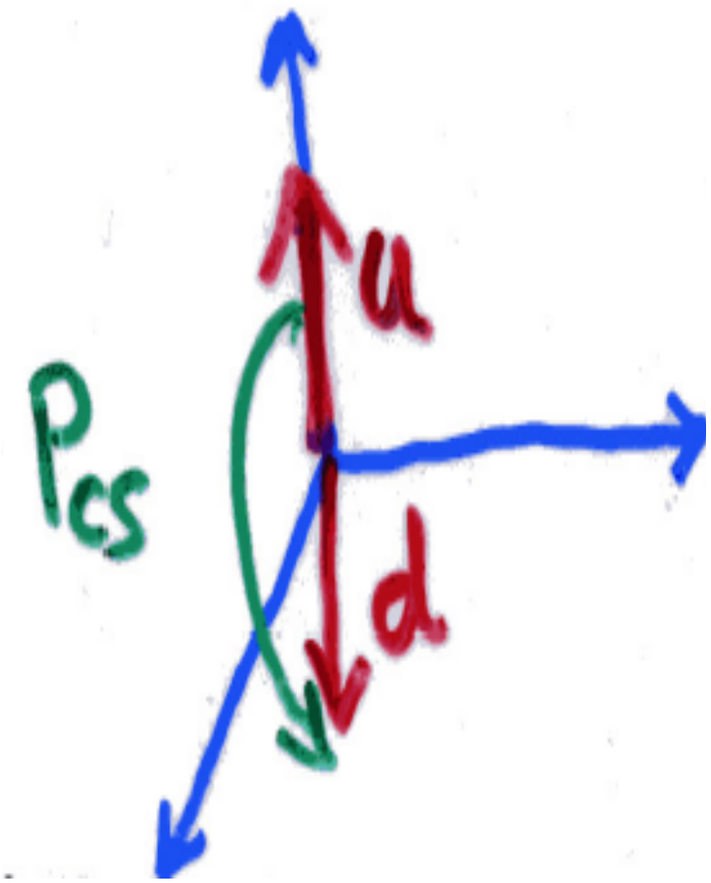


Isospin invariance:
Physics independent of any rotation in isospin space

$\text{needs } [H, T_i] = 0$

also called charge independence

Charge symmetry is invariance under a particular rotation



Charge symmetry does not imply isospin invariance

Ernest defined important future directions

- Theory:Unless an understanding of the hadronic NN force is possible, it will remain extremely difficult to make convincing theoretical calculations of non-electromagnetic hadron-hadron interactions

- Experiment: further work to accurately establish nn scattering length - $\pi^- + D \rightarrow nn + \gamma$

Theory carried out brilliantly by Gibbs, Gibson, Stephenson (1975)results still correct. Experiments showed that nn force more attractive than np in $^1S_0$ state

Ernest asked me to join

CIB well established, need to study CSB

Theory summary- CSB hard to calculate
serve to stimulate experiment

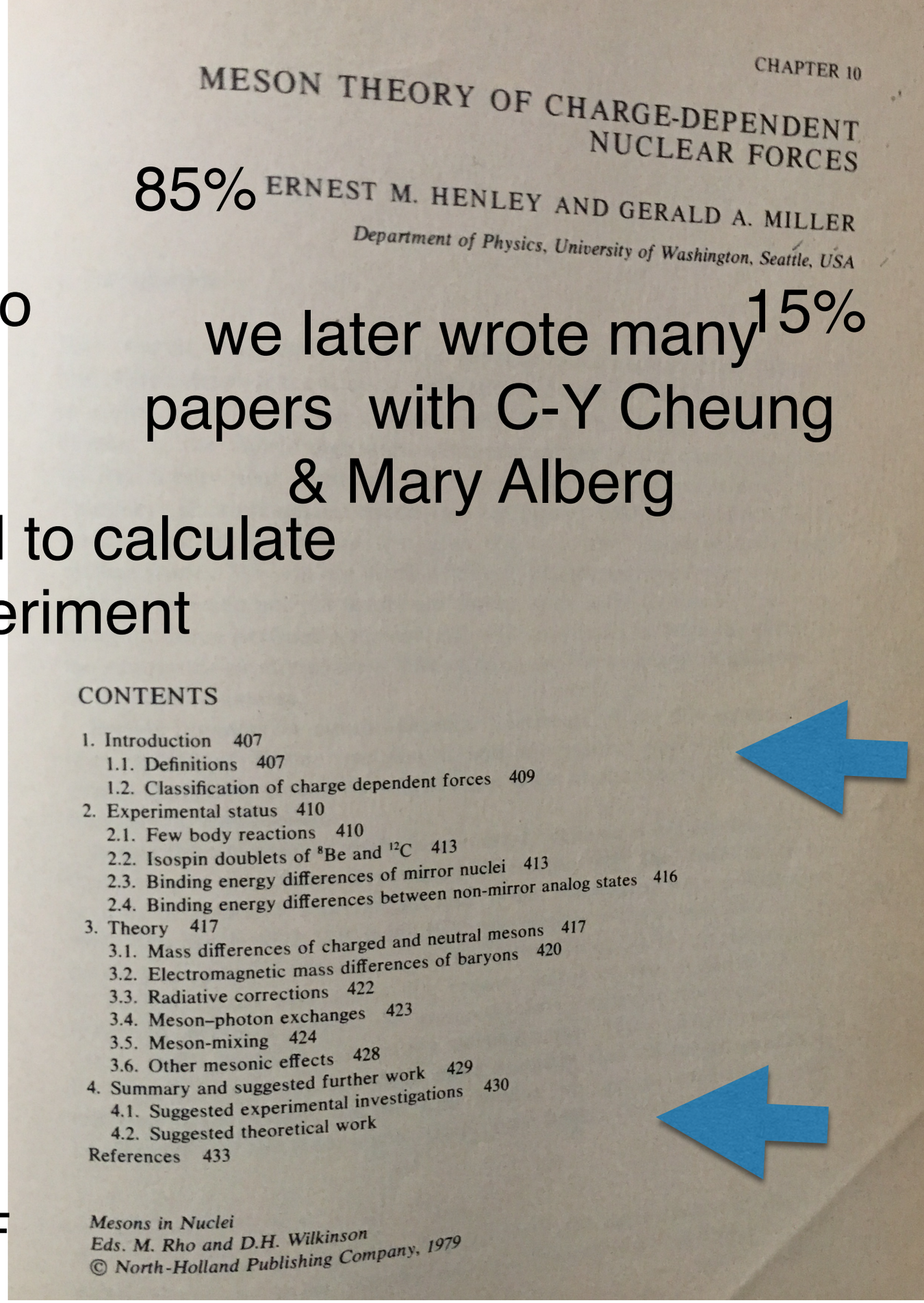
Experiment:
np scattering

$$P_n(\theta) = P_p(\pi - \theta)$$

$$dd \rightarrow {}^4\mathrm{He} + \pi^0$$

Angular asymmetry in np$\rightarrow d\pi^0$

Ernest worked with PACs all
all were done at TRIUMF & IUCF



CHAPTER 10

MESON THEORY OF CHARGE-DEPENDENT NUCLEAR FORCES

85%

ERNEST M. HENLEY AND GERALD A. MILLER

Department of Physics, University of Washington, Seattle, USA

15%

we later wrote many papers with C-Y Cheung & Mary Alberg

CONTENTS

Mesons in Nuclei
Eds. M. Rho and D.H. Wilkinson

Nucleon-nucleon force classification Henley-Miller 1977

Coulomb potential $V_c(1,2) = \frac{e^2}{r_{12}}[1 + (\tau_3(1) + \tau_3(2)) + \tau_3(1)\tau_3(2)]$

I: Isoscalar $A(r_{12}) + B(r_{12})\vec{\tau}_1 \cdot \vec{\tau}_2$

II: maintains CS, CIB, charge dep. $C(r_{12})\tau_3(1)\tau_3(2)$=+1 (pp,nn), -1 (np)

III: breaks CS and CI: $D(r_{12})(\tau_3(1)+\tau_3(2))$ - no isospin mixing in 2N system

IV: mixes isospin:

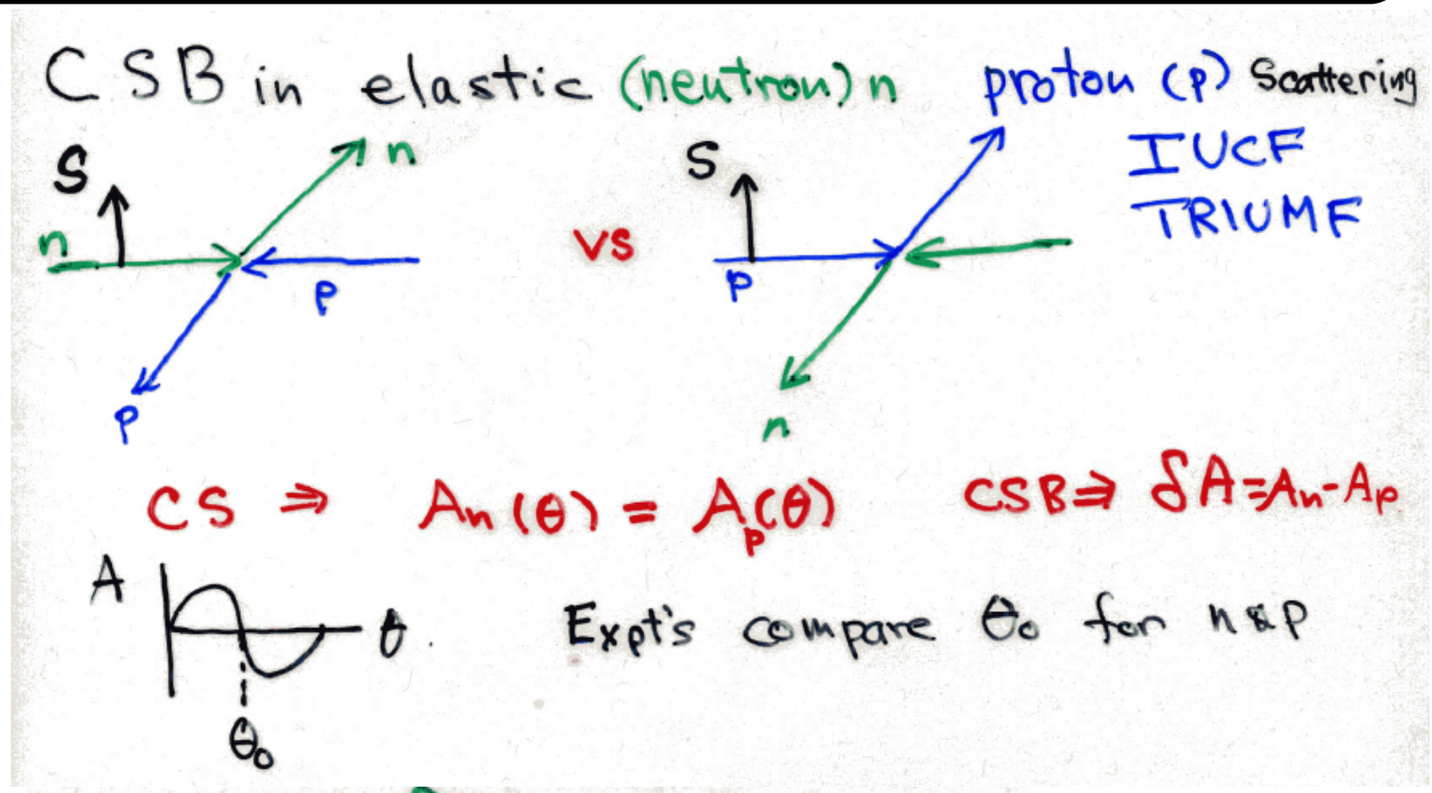
$V_{IV}(1,2) = E(r_{12})(\tau_3(1) - \tau_3(2))(\sigma(1) - \sigma(2)) \cdot \vec{L}$ +...

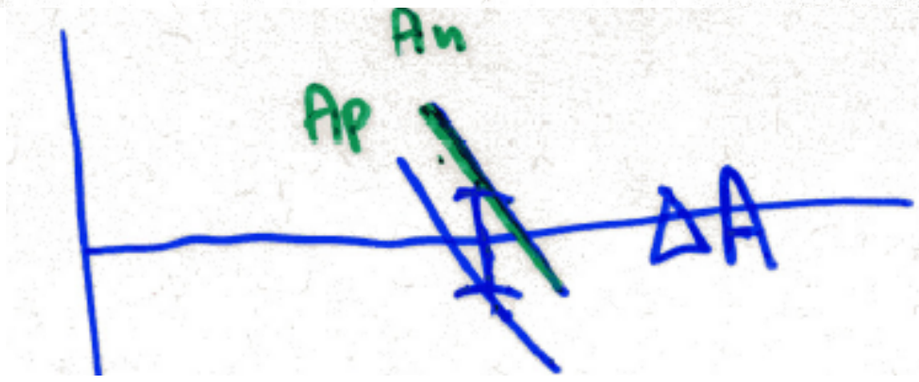
magnetic np force Class IV: $\vec{j}_p$ interacts with μ_n

spin flip ${}^3P_0 \leftrightarrow {}^1P_0$, ${}^1D_2 \leftrightarrow {}^3D_2$ in TRIUMF, IUCF experiments

Polarization difference

Search for class IV forces





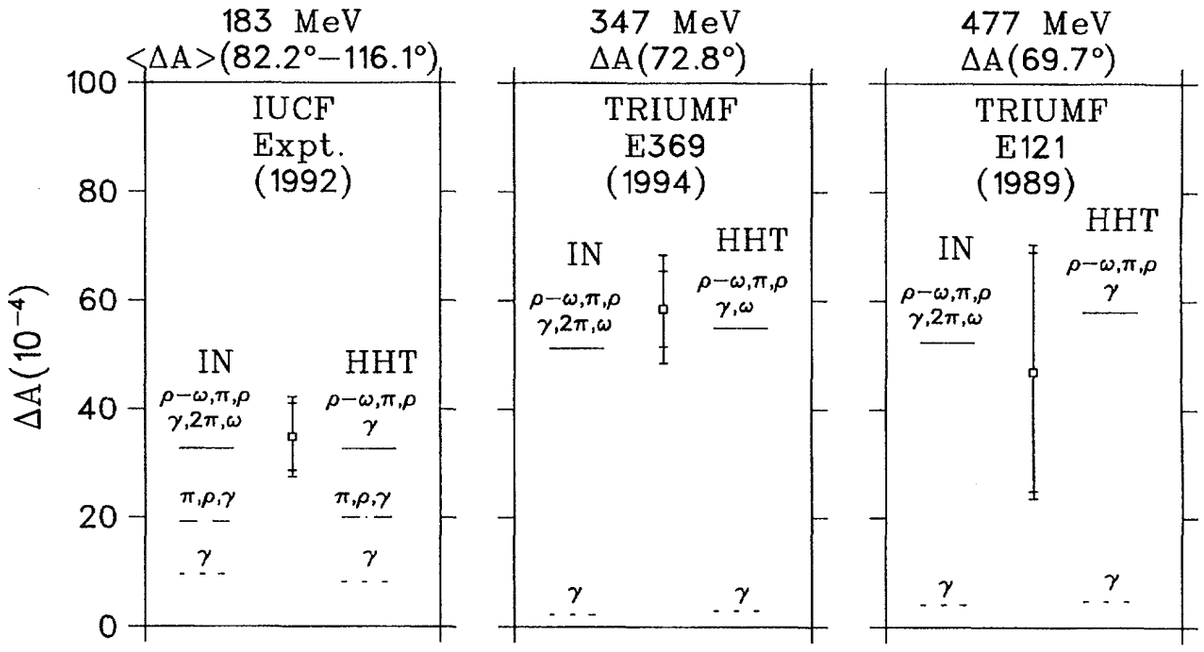
Δ A -see next slide

VOLUME 75, NUMBER 9 PHYSICAL REVIEW LETTERS 28 AUGUST 1995

Precision Measurement of Charge Symmetry Breaking in *np* Elastic Scattering at 347 MeV

R. Abegg,[1] A. R. Berdoz,[2,*] J. Birchall,[2] J. R. Campbell,[2] C. A. Davis,[1,2] P. P. J. Delheij,[1] L. Gan,[2] P. W. Green,[1,3] L. G. Greeniaus,[1,3] D. C. Healey,[1] R. Helmer,[1] N. Kolb,[3,†] E. Korkmaz,[3,‡] L. Lee,[2] C. D. P. Levy,[1] J. Li,[3] C. A. Miller,[1] A. K. Opper,[3] S. A. Page,[2] H. Postma,[4] W. D. Ramsay,[2] J. Soukup,[3] G. M. Stinson,[3] W. T. H. van Oers,[2] A. N. Zelenski,[1] and J. Zhao[2,§]

Third in series:



OPEP dominant
at 477 MeV
Miller Thomas Williams
PRL56, 2567

HHT Holzenkamp,Holinde Thomas
IN Iqbal Niskanen
Strong interaction parameters determined from np scattering data

from 1969 henley article

$$dd \rightarrow \alpha\pi^0$$

- “if isospin is conserved this reaction is forbidden, however contrary to all claims made in the literature, this reaction only tests charge parity (EH word for charge symmetry)

Observation of the Charge Symmetry Breaking $dd \to \alpha\pi^0$ Reaction Near Threshold

E. J. Stephenson, A. D. Bacher, C. E. Allgower, A. Gårdestig, C. M. Lavelle, G. A. Miller, H. Nann, J. Olmsted, P. V. Pancella, M. A. Pickar, J. Rapaport, T. Rinckel, A. Smith, H. M. Spinka, and U. van Kolck

Phys. Rev. Lett. 91, 142302 (2003)

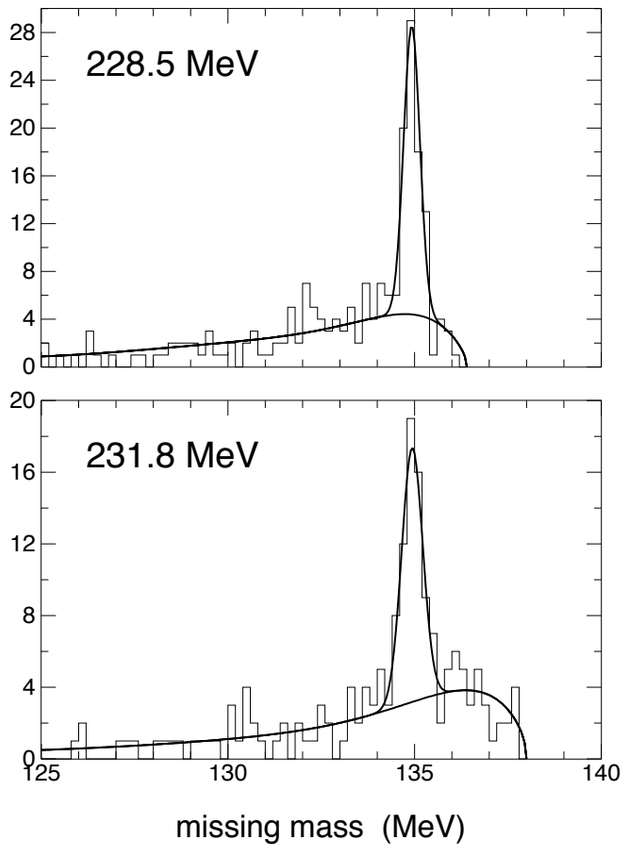


Figure 2: Historgrams of the candidate events at the two deuteron bombarding energies as a function of their missing mass value. The smooth curves show the reproduction of these histograms with a Gaussian peak and a continuum.

σ (pb)

12.7 +/- 2.2 pb

15.1 +/-3.1pb

Survey of charge symmetry breaking operators for $dd \to \alpha\pi^0$

A. Gårdestig, C. J. Horowitz, A. Nogga, A. C. Fonseca, C. Hanhart, G. A. Miller, J. A. Niskanen, and U. van Kolck

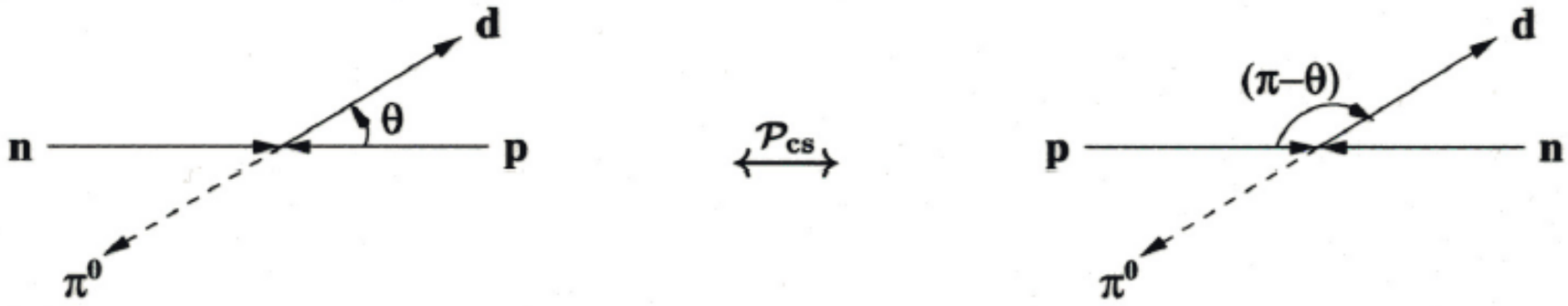
Phys. Rev. C 69, 044606 (2004)

total cross section; 23, 31 pb

$$np \to d\pi^0$$

Opper

er



$$A_{fb}(\theta) \equiv \frac{\sigma(\theta)-\sigma(\pi-\theta)}{\sigma(\theta)+\sigma(\pi-\theta)} \text{ in cm}$$

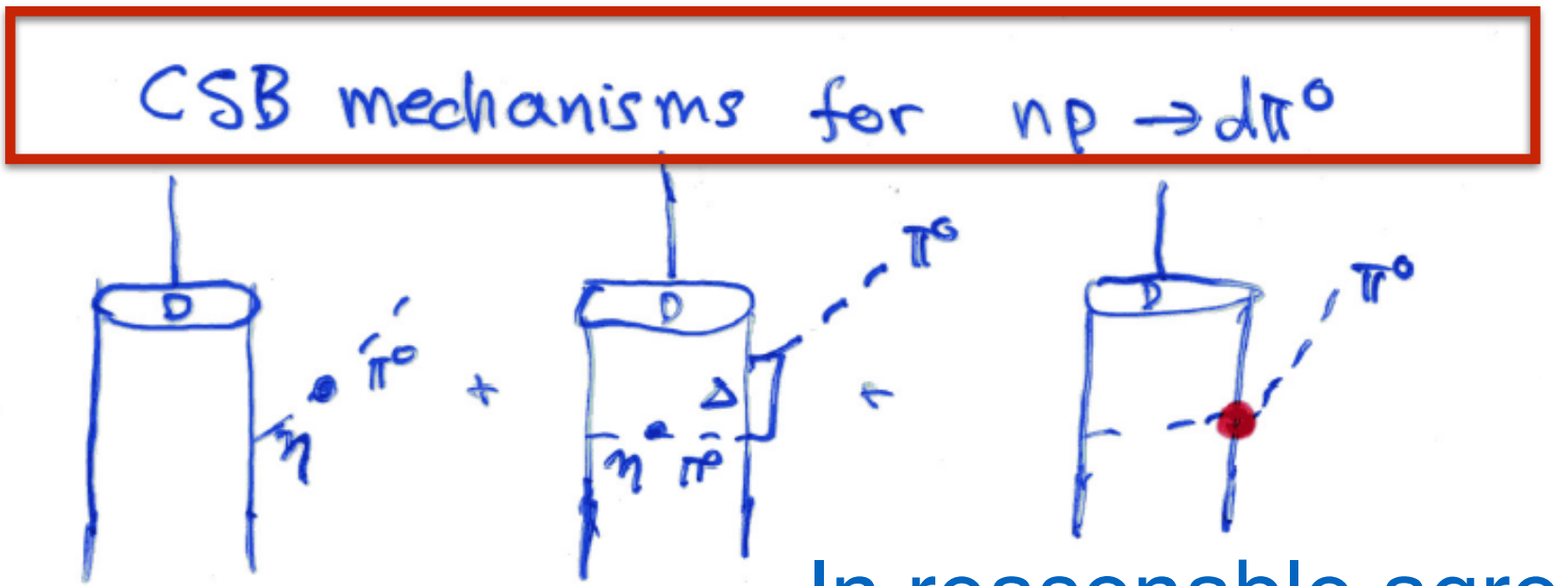
$$A_{fb} \neq 0 \leftrightarrow \text{CSB}$$

Charge symmetry breaking in $np \to d\pi^0$

A.K. Opper,[1,*] E. Korkmaz,[2] D.A. Hutcheon,[3,4] R. Abegg,[3,4,†] C.A. Davis,[4,5] R.W. Finlay,[1] P.W. Green,[3,4] L.G. Greeniaus,[3,4] D.V. Jordan,[1,3,‡] J.A. Niskanen,[6] G.V. O'Rielly,[2,§] T.A. Porcelli,[2] S.D. Reitzner,[1,¶] P.L. Walden,[4,7] and S. Yen[4]

PRL 91(2003) 212302

The forward-backward asymmetry in np→dπ0, which must be zero in the center-of-mass system if charge symmetry is respected, has been measured to be [17.2±8.0(stat) ±5.5(syst)]×10–4, at an incident neutron energy of 279.5 MeV.



In reasonable agreement

$$A_{\rm fb} = -0.28\% \times \left[\left(\frac{g_{\eta NN}}{\sqrt{4\pi(3.68)}} \right) \left(\frac{\langle \pi^0 | \mathcal{H} | \eta \rangle}{-0.0059 \text{ GeV}^2} \right) - \frac{0.87}{4 \text{MeV}} (\delta m_N - \frac{\bar{\delta} m_N}{2}) \right]$$

U. van Kolck, J.A. Niskanen, and G.A. Miller, Phys. Lett. **B493**, 65 (2000).

The field lived for a long time: further reading
Miller, Nefkens Slaus Phys. Rept. 194 (1990) 1
Miller, Opper, Stephenson ARNPS 56 (2006)253
many later experiments and theory papers

Summary

- Henley's isospin vision was carried out by a host of experimentalists and theorists- the program laid out in his reviews was carried out-

- Ernest always acted with grace

- He was a model of how to behave, I tried to emulate

- I am very grateful for having known him and will miss him forever