

## TABLE OF CONTENTS

Committees	...	...	...	...	...	v
Editorial Preface	...	...	...	...	...	vii
Programme of the Conference	...	...	...	...	...	xi
Table of Contents	...	...	...	...	...	xvi
PART 1. STATUS AND RESULTS FROM EXPERIMENTAL FACILITIES						1
VEC at Calcutta						
A.S. Divatia	...	...	...	...	...	2
Preliminary Results of the Research on Few Body Problems at TRIUMF						
J. Reginald Richardson	...	...	...	...	...	14
Status of the C.P. Anderson Meson Physics Facility (LAMPF)						
Mahavir Jain, Louis Rosen	...	...	...	...	...	26
PART 2. INVITED AND CONTRIBUTED PAPERS AT PARALLEL SESSIONS						38
2.1. <u>Nuclear and Coulomb Interaction</u>						
An OBE-Model Including the N- $\Delta$ -Interactions, Two-Nucleon and Nuclear Matter Results						
K. Bleuler, R. Holinde, R. Machleidt	...	...	...	...	...	39
Completeness Relations in Scattering Theory for Non-Hermitian Potentials						
Y.E. Kim and A. Tubis	...	...	...	...	...	41
Ambiguities in Phase-Shift Analysis (Invited paper)						
L.P. Kok	...	...	...	...	...	43
Physical Properties Invariant for Phase Equivalent Potentials						
C.S. Warke	...	...	...	...	...	47
An Interpretation of the Tabakin Rank-One Potential						
M.J. Englefield	...	...	...	...	...	50
A Possible Phenomenological Form for the Two Body Local Potential						
A.V. Lagu	...	...	...	...	...	52
Two Body Bound State and Parametrization of Half-Off-Shell t-Matrix						
A.V. Lagu and C. Maheshwari	...	...	...	...	...	54
The Physical Basis of the Unitary Pole Expansion - Some Remarks						
A.N. Mantri, A.V. Lagu	...	...	...	...	...	56

# Parametrization of the Half-Shell t-Matrix When the Two Body Bound State is Delineated

V.S. Mathur, A.V. Lagu, C. Maheshwari ... 58

# A Simple Method of Calculating Scattering Parameters for Separable Potentials with Coulomb Interaction

H. Kumpf ... 60

# Analyticity Constraints on the Nucleon-Nucleon T-Matrix

S.K. Mukhopadhyay, P.U. Sauer ... 62

# A Few Applications of Coulombian Asymptotic States

H. van Haeringen ... 64

# Nuclear Three-Body Forces Arising from Triple-Boson Coupling

T. Ueda, T. Sawada, S. Takagi ... 67

# Consistent Calculation of Alpha-Alpha Interaction by the Resonating Group Method

S.A. Afzal, S. Ali ... 70

# Tensor Contribution to Nuclear Matter in the First Order Perturbation Theory

A.K. Deka, P. Mahanta ... 72

# Pairing-Plus-Surface-Tensor-Interaction and Structure of $^{51}\text{V}$

D. Banerjee ... 74

## 2.2. Dynamical Equations and Approximation Methods

# Local Strong and Coulomb Potentials in the Three-Nucleon System (invited paper) ...

E.O. Alt ... 76

# Dynamical Equations for the N-Particle Transit Operators (invited paper)

Gy. Bencze ... 81

# Generalized Faddeev Theory of Nuclear Reactions (invited paper)

E.F. Redish ... 86

# Three- and Four-Body Equations with Half-off-Shell Input (invited paper)

B.R. Karlsson, E.M. Zeiger ... 91

# Theory of the Three-Body Separable Expansion Amplitude (invited paper)

S. Oryu ... 94

# A New Dynamics of NN Scattering (invited paper)

D.D. Brayshaw ... 99

# Zero Range Covariant Three Body Equations (invited paper)

H. Pierre Noyes ... 104

The Three Body Problem with Energy Dependent Potentials					
Y.E. Kim, C.M. McKay, B.H.J. McKellar ...	...	...	...	...	109
Generalized Separable Expansion Method of the Two-Body and the Three-Body Scattering Amplitudes					
S. Oryu, T. Ishihara ...	...	...	...	...	111
How Different is the Resonating-Group Method from the Integral-Equation Approach to Few-Particle Scattering					
J. Schwager ...	...	...	...	...	113
Four-Body Equations					
T. Sasakawa ...	...	...	...	...	116
K-Matrix Formalism for the Four-Body Problem and Bound State Scattering Theory					
V.K. Sharma ...	...	...	...	...	118
Integral Equation for Three- and Four-Nucleon Problem in Resonating Group Approximation					
V.K. Sharma ...	...	...	...	...	120
On a Time-Independent Theory of Multichannel Quantum Mechanical Scattering					
C. Chandler, A.G. Gibson ...	...	...	...	...	123
2.3. <u>Few Body Bound States and Computational Techniques</u>					
Effect in Level Spectrum of Three Resonantly Interacting Particles (invited paper)					
V. Efimov ...	...	...	...	...	126
Trinucleon Properties with One-Boson-Exchange Potentials					
R.A. Brandenburg, P.U. Sauer, R. Machleidt ...	...	...	...	...	135
The Trinucleon System Bound by a One-Boson-Exchange Force					
E. Harper ...	...	...	...	...	138
Three-Body Unitary Transformation, Three Body Forces and Trinucleon Bound State Properties					
M.I. Haftel ...	...	...	...	...	141
Binding Energy Calculation of Triton with Realistic Potentials					
I. Zakia, S.A. Afzal ...	...	...	...	...	143
Analysis of the Shape of the Trinucleon Wave Function (invited paper)					
J.L. Ballot, M. Fabre de la Ripelle ...	...	...	...	...	146
Coulomb Energy of $^3\text{He}$					
H. Zankel, H. Zingl ...	...	...	...	...	151
Three-Alpha Model Calculation of $^{12}\text{C}$ in the Faddeev Formalism					
Y. Fujiwara, R. Tamagaki ...	...	...	...	...	154

A Study of $^6\text{He}$ with Two-Body Local Potentials in Faddeev Formalism					
H. Roy-Choudhury, V.P. Gautam, D.P. Sural	...	...	...	...	157
Structure of the Alpha Particle Based on Realistic Two- and Three-Body Interaction (invited paper)					
Y. Akaishi	...	...	...	...	160
Multi-Cluster Problem Based on the Microscopic Theory (invited paper)					
H. Horiuchi	...	...	...	...	165
The Deuteron Wave Function from ND Scattering Experiments and NN Potential (invited paper)					
V.V. Komarov	...	...	...	...	170
Three-Body Vertices with Two-Body Techniques					
A.N. Mitra, V.K. Sharma	...	...	...	...	177
2.4. <u>Scattering, Breakup Reactions and Polarization</u>					
Proton-Induced $^2\text{H}$ and $^3\text{He}$ Breakup at 156 MeV (invited paper)					
T. Yuasa	...	...	...	...	181
Proton Induced Deuteron Breakup at $E_p=12.5$ MeV					
Đ. Miljanić, E. Andrade, G.C. Phillips	...	...	...	...	186
Comparison of Deuteron Breakup Spectra at 8.5 MeV with Faddeev Calculations Using Different Separable Potentials					
B. Kühn, H. Kumpf, Y. Mössner, W. Neubert, G. Schmidt	...	...	...	...	189
The Breakup Reaction $p_0 + D \rightarrow p_1 + p_2 + n$ at $E_0=20$ MeV					
J. Doornbos, W. Krijgsman, C.C. Jonker	...	...	...	...	191
Three-Body Breakup Reactions (invited paper)					
R. Bouchez	...	...	...	...	194
A Test of the Proton Induced $^2\text{H}$ Breakup Study for Special Kinematic Conditions					
N. Fujiwara, E. Hourany, H. Nakamura, F. Reide, T. Yuasa	...	...	...	...	199
The N-P FSI Angular Distribution in Deuteron Breakup at 45 MeV					
E.L. Petersen, M.I. Haftel, R.G. Allas, L.A. Beach, R.O. Bondelid, P.A. Treado, J.M. Lambert	...	...	...	...	201
Off-Shell Effects in Nucleon-Deuteron Scattering					
J.H. Stuivenberg, R. van Wageningen	...	...	...	...	203
Nucleon-Deuteron Breakup Quantities Calculated with Separable Interactions Including Tensor Forces and Higher Partial Waves					
J. Bruinsma, R. van Wageningen	...	...	...	...	206
Determination of the Total Nucleon-Deuteron Breakup Cross Section at $E_d = 26.5$ MeV					
R. van Dantzig, B.J. Wielinga, G.J.F. Blommesteijn, I. Slaus	...	...	...	...	209

Study of Doublet Proton-Deuteron Breakup at $E_p = 50$ MeV G.J.F. Blommenstijn, Y. Haitzma, R. van Dantzig, I. Slaus ...	212
Neutron Experiments at LAMPF (invited paper) M. Jain ... ..	215
A New Experiment in the Interaction of 14 MeV Neutrons with Tritons S. Desreumaux, A. Chisholm, P. Perrin, R. Bouchez ...	220
Proton-Deuteron FSI in Proton Induced $^3\text{He}$ Breakup N. Fujiwara, E. Hourany, H. Nakamura-Yokota, F. Reide, V. Valkovic T. Yuasa ... ..	223
A Proposed Experiment for Determining the Neutron-Neutron Effective Range by Means of Doubly Quasi-Free Scattering in the D+D Reaction H. Kumpf ... ..	225
Quasifree Processes in the Reaction $^3\text{He} + ^3\text{He}$ for $E_{^3\text{He}} = 50, 65$ and 78 MeV and 78 MeV R.G. Allas, L.A. Beach, R.O. Bondelid, E.L. Petersen, P.A. Treado, J.M. Lambert, R.A. Moyle, L.T. Myers, I. Slaus ... ..	227
Double Spectator Process in the $^3\text{He} (^3\text{He}, dd)pp$ Reaction J.M. Lambert, P.A. Treado, L.T. Myers, R.O. Bondelid, R.G. Allas, L.A. Beach, E.L. Petersen, I. Slaus ...	229
Quasifree Processes in the $^2\text{H} + ^3\text{He}$ Reactions P.A. Treado, J.M. Lambert, R.A. Moyle, L.T. Myers, R.G. Allas, L.A. Beach, R.O. Bondelid, E.L. Petersen I. Slaus ... ..	232
Further Evidence of High Energy Deuterons in the Reaction $^3\text{He} + ^3\text{He}$ R.J. Slobodrian, R. Pigeon, M. Irshad, S. Sen, J. Asai ...	236
Production of High Energy Deuterons in the $^3\text{He} + ^3\text{He}$ Reaction and the Solar Neutrino Problem - a Comment Đ. Miljanić ... ..	238
Resonant Subsystems as a Challenge to Nuclear Reaction Theory (invited paper) H.H. Hackenbroich, W. Schütte, H. Stöwe ... ..	241
Reactions $^{10}\text{B} + d, ^9\text{Be} + ^3\text{He} \rightarrow 3\alpha$ and Excited States in $^{12}\text{C}$ R. Roy, R.J. Slobodrian, G. Goulard ... ..	246
Four-Body Description of $d + d \rightarrow p + t$ and $p + ^3\text{He} \rightarrow p + ^3\text{He}$ Reactions M. Sawicki, J.M. Namysłowski ... ..	249
Investigation of Few Nucleon Systems Using Polarized Deuterons (invited paper) W. Grüebler ... ..	252

Neutron Polarisation Studies on Reactions Between Light Nuclei  
(invited paper)

L.C. Northcliffe ... .. 258

Polarisation on Final State Interactions:  ${}^3\text{He}({}^3\text{He}, \vec{p})p\alpha$  and  
 ${}^6\text{Li}({}^3\text{He}, \vec{p})\alpha\alpha$ R.J. Slobodrian, M. Irshad, R. Pigeon, C. Rioux,  
J. Asai, S. Sen ... .. 263Excited States of  ${}^4\text{He}$  Studied with the Polarized Proton  
Capture Reaction (invited paper)S.S. Hanna, H.F. Glavish, G. King, Y.R. Calarco,  
D.G. Mavis, V.K.C. Cheng, E. Kuhlmann ... .. 266A Microscopic Description of Polarization Phenomena in the  
Four Nucleon System

S. Ramavataram, K. Ramavataram, C.L. Rao ... .. 271

A Study of the  ${}^6\text{Li}({}^3\text{He}, p\alpha)\alpha$  ReactionK. Ramavataram, R. Larue, R. Gagnon, G.C. Ball,  
W.G. Davies, A.J. Fergusson, R.E. Warner ... .. 2732.5. Few Body Reactions with Mesons and ResonancesUnitarity, Analyticity and the Relativistic Three Body  
Problem (invited paper)

I.J.R. Aitchison ... .. 275

## Resonance Amplitudes in Light Nuclei (invited paper)

G. Igo ... .. 282

 $N^*$ 's in the Deuteron Ground State (invited paper)

H.J. Weber ... .. 292

Structure in the Backward Proton-Deuteron Scattering in the  
40-1000 MeV Region

S. Morioka, T. Ueda ... .. 297

The Process  $pp \rightarrow dp^+$  in a Model of N and  $N^*$  Exchanges

J.S. Sharma ... .. 300

## Pion Production in Neutron-Proton Collisions (invited paper)

D.M. Wolfe, C. Cassapakis, B.D. Dieterle, C.P. Leavitt,  
W.R. Thomas, G. Glass, M. Jain, L.C. Northcliffe,  
B.E. Bonner, J.E. Simmons ... .. 303 $(\pi, NN)$  Reactions for Nuclear Structure Studies (invited paper)

B.K. Jain ... .. 308

On the Energy Dependence of  $(\pi^+, {}^4\text{He})$  and  $(\pi^-, {}^{12}\text{C})$  Backward  
Elastic Scattering Cross sectionsF. Balestra, E. Bollini, L. Busso, R. Garfagnini,  
G. Piragino, A. Zanini, C. Guaraldo, R. Scrimaglio,  
I.V. Falomkin, M.M. Kulyukin, R. Mach, F. Nichitiu,  
G.B. Pontecorvo, Yu.A. Shcherbakov ... .. 315

On Coherent Neutral Pion Photoproduction from the Deuteron K. Srinivasa Rao, K. Venkatesh, S. Srinivasa Raghavan ...	317
Models for Pion Production by Protons in Light Nuclei (invited paper) V.S. Bhasin ... ..	320
Current Algebra and Low Energy $\pi$ N Scattering (invited paper) M. Scadron ... ..	325
2.6. <u>Symmetries; Photon and Lepton Probes on</u> <u>Few Body System</u>	
Parity-Nonconservation Effects in the Two-Nucleon System- Sensitivity to the Short-Range Strong Nuclear Force B.A. Craver, E. <b>Fishbach</b> , Y.E. Kim, A. Tubis ... ..	331
The Parity Violating Asymmetry in the Radiative Capture of Polarized Neutrons by Proton B.A. Craver, Y.E. Kim, A. Tubis, P. Herczeg, P. Singer ...	333
Remarks on the Level Scheme of $F^{19}$ K. Bleuler ... ..	335
Electromagnetic Properties of Tri-Nucleon Systems with Separable Potentials (invited paper) V.K. Gupta and S.S. Mehdi ... ..	337
Integral vs Fractional Charges of Quarks - A View through Unified Gauge Theory (invited paper) G. Rajasekaran ... ..	341
Meson-Exchange Currents in Electron-Deuteron Scattering (invited paper) M. Gari, H. Hyuga ... ..	346
The Three Nucleon Bound State Problem as a Probe of the Internucleon Force (invited paper) M.I. Haftel ... ..	351
Neutron-Deuteron Collision and the Charge Form Factor of Triton S.N. Banerjee ... ..	356
Trinucleon Photoeffect Using Coupled Hyperspherical Harmonics K.K. Fang, J.S. Levinger, M. Fabre de la Ripelle ...	358
Total Cross Section of the ( $\gamma$ ,d) Disintegration of the Alpha Particle H.L. Yadav, B.K. Srivastava ... ..	361
Electron Scattering and Correlation Structure of Light Nuclei M.A.K. Lodhi ... ..	364

Possible Evidence for Enhanced  $\Delta S=0, \Delta T=2$  Weak Interaction in Parity Mixing in Nuclei

B.H.J. McKellar, K.R. Lassey, M.A. Box, A.J. Gabric ... 368

2.7. Few Electron Systems

## Application of the Channel Coupling Array Theory to Some Atomic Three-Body Systems (invited paper)

F.S. Levin ... 371

## The Optical Potential in the Channel Coupling Array Method: A Model Study (invited paper)

D.J. Kouri, R. Goldflam ... 378

## High Energy Electron Scattering from a Two Centre Potential

S.S. Chandel, S. Mukherjee ... 383

## Multimagnon Bound States (invited paper)

C.K. Majumdar ... 386

2.8. Nuclear Reactions and Scattering Few Body Aspects

## Solvable Few Body Models as Laboratories for Nuclear Reaction Theories

B.H.J. McKellar ... 390

## Few-Body Approaches to Direct Nuclear Reactions (invited paper)

V. Vanzani ... 394

## Nuclear Reactions and Scattering in the Three Body and Eikonal Formalism (invited paper)

J.M. Namysłowski ... 400

## Three-Body Approach to the Nucleon-Nucleus Optical Potential

P.C. Tandy, E.F. Redish, D. Bollé ... 405

## Three-Body K Operators and Unitary Approximations: Application to Model (d,p) and (d,n) Processes (invited paper)

F.S. Levin ... 408

## A Model for Deuteron Stripping and Breakup Reaction

Suproakash Mukherjee, S. Ray ... 415

## N-Body Integral Equations and Orthogonality Scattering (invited paper)

E.W. Schmid, H. Ziegelmann ... 418

## A Microscopic Approximation for Sequential Decay Processes in Light Nuclear Systems (invited paper)

P. Heiss ... 423

## On Theory of Deuteron Stripping Reaction (invited paper)

S.N. Mukherjee ... 428



Some Aspects of Studies of Interactions Between Two Light Nuclear Systems (invited paper)						
S. Ali	...	...	...	...	...	433
Scattering of Mass-3 Projectiles from Heavy Nuclei						
S. Mukhopadhyay, D.K. Srivastava, N.K. Ganguly	...	...	...	...	...	438
 <u>2.9. Workshop on Experimental Techniques</u>						
Introduction						
R.O. Bondelid	...	...	...	...	...	441
Survey of Few Nucleon Reactions for $A > 3$						
J.M. Lambert, P.A. Treado, L.T. Myers, E.I. Karaoglan	...	...	...	...	...	442
Neutron Physics Techniques						
Đ. Miljanić	...	...	...	...	...	449
The Study of Few Particle Systems with Photographic Emulsions						
B. Bhowmik	...	...	...	...	...	452
A Short Report on the Variable Energy Cyclotron at Chandigarh						
H.S. Hans	...	...	...	...	...	454
Some Techniques of Correlation - Experiments						
R.G. Allas	...	...	...	...	...	455
Detection Techniques at Intermediate Energies						
J.M. Cameron	...	...	...	...	...	462
Relevance of Few Nucleon Problems to Nuclear Power						
A.S. Divatia	...	...	...	...	...	469
 PART 3. INVITED PAPERS AND RAPORTEURS' TALKS AT PLENARY SESSIONS						...
						471
 <u>3.1. Nuclear and Coulomb Interactions</u>						
Some Topics on N-N Interaction (invited paper)						
R. Vinh Mau	...	...	...	...	...	472
Coulomb Problem and Separation of Electromagnetic Effects (invited paper)						
P.U. Sauer	...	...	...	...	...	488
Three-Body Forces in Nuclei (invited paper)						
B.H.J. McKellar	...	...	...	...	...	508
Relativistic Effects in Few Body Systems (invited paper)						
F. Gross	...	...	...	...	...	523
Discussion	...	...	...	...	...	538

### 3.2. Dynamical Equations and Approximation Methods

#### Introduction

W. Sandhas	...	...	...	...	...	540
------------	-----	-----	-----	-----	-----	-----

#### Rapporteur's Talk

Y.E. Kim	...	...	...	...	...	558
----------	-----	-----	-----	-----	-----	-----

Discussion	...	...	...	...	...	566
------------	-----	-----	-----	-----	-----	-----

### 3.3. Few Body Bound States and Computational Techniques

#### Rapporteur's Talk: Computational Techniques

J.A. Tjon	...	...	...	...	...	567
-----------	-----	-----	-----	-----	-----	-----

#### Rapporteur's Talk: Bound States

T. Sasakawa	...	...	...	...	...	577
-------------	-----	-----	-----	-----	-----	-----

Discussion	...	...	...	...	...	583
------------	-----	-----	-----	-----	-----	-----

### 3.4. Scattering, Breakup Reactions, Polarization

#### Breakup Processes - a Bridge (invited paper)

Ivo Slaus	...	...	...	...	...	584
-----------	-----	-----	-----	-----	-----	-----

#### Inclusive Reactions and the Few-Body Problem (invited paper)

R. Rajaraman	...	...	...	...	...	602
--------------	-----	-----	-----	-----	-----	-----

#### Polarization Phenomena in Few-Body Systems (invited paper)

H.E. Conzett	...	...	...	...	...	611
--------------	-----	-----	-----	-----	-----	-----

#### Remarks on Polarization in Few-Body Reactions

R.J. Slobodrian	...	...	...	...	...	622
-----------------	-----	-----	-----	-----	-----	-----

#### Rapporteur's Talk: Breakup Reactions

H. Pugh	...	...	...	...	...	625
---------	-----	-----	-----	-----	-----	-----

Discussion	...	...	...	...	...	630
------------	-----	-----	-----	-----	-----	-----

### 3.5. Few Body Reactions with Mesons and Resonances

#### Quark Physics (invited paper)

R.H. Dalitz	...	...	...	...	...	632
-------------	-----	-----	-----	-----	-----	-----

#### Rapporteur's Talk: Resonances

G. Shaw	...	...	...	...	...	659
---------	-----	-----	-----	-----	-----	-----

#### Rapporteur's Talk: Meson Reactions

I.R. Afnan	...	...	...	...	...	667
------------	-----	-----	-----	-----	-----	-----

### 3.6. Symmetries, Photon and Lepton Probes on Two Body Systems

#### Symmetries (invited paper)

E.M. Henley	...	...	...	...	...	677
-------------	-----	-----	-----	-----	-----	-----

Rapporteur's Talk						
M.K. Sundaresan	...	...	...	...	...	690
Discussion	...	...	...	...	...	695
3.7. <u>Few Electron Systems</u>						
The Few Charged Particle Problem in Atomic Physics (invited paper)	...	...	...			
E. Gerjouy	...	...	...	...	...	696
Rapporteur's Talk						
L. Spruch	...	...	...	...	...	715
3.8. <u>3.8. Nuclear Reactions and Scattering - Few Body Aspects</u>						
Rapporteur's Talk						
F. Levin	...	...	...	...	...	726
PART 4 . POSTDEADLINE PAPERS			...	...	...	735
Multiple Scattering Approach to the $\pi$ - $^4\text{He}$ Scattering at Intermediate Energies						
M. Bleszynski, T. Jaroszewicz, P. Osland				...	...	736
Three Nucleon Potential in Nuclear Matter						
S.A. Coon, B.R. Barrett, M.A. Scadron, D.W.E. Blatt, B.H.J. McKellar	...	...	...	...	...	739
Variational and Exact Studies of the Bound State of Three Helium Atoms						
T.K. Lim	...	...	...	...	...	741
Studies of the $^2\text{H}(p,2p)n$ Reaction for Constant NN Relative Energies						
W.T.H. van Oers	...	...	...	...	...	746
Nonlocality in (Helium-Helium) Interatomic Potentials						
Y.S.T. Rao	...	...	...	...	...	752
Three Body Problems with Local Potentials in Coordinate Space						
T. Sasakawa and T. Sawada	. . .	...	...	...	...	754
Contributor Index	...	...	...	...	...	756
List of Registrants	...	...	...	...	...	758
List of Observers	...	...	...	...	...	765