NUCLEAR STRUCTURE STUDIES AT INTERMEDIATE ENERGIES

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Progress Report

July 1990 through July 1991

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In Memorium

We were much grieved by the deaths of Noby Tanaka, in February 1991, and Magdy Gazzaly in May of 1991.

Noby had been a LAMPF Staff Member since 1969. He made many contributions to the smooth operation of the laboratory, and to numerous experiments. Noby was patient, seemingly tireless, and very meticulous. He played a major role in the design, construction and operation of the High Resolution Spectrometer as well as being a participant (or spokesman) on many experiments. Noby was a wise, humorous and sensitive individual and a talented physicist.

Magdy was the Senior Research Associate with this group from 1979 to 1989. He was deeply involved in all of our work from proposal writing to publication. Magdy originated this group's participation in the nucleon-nucleon program, at LAMPF and elsewhere, and was a co-spokesman (along with Noby and Gianni Pauletta) on many of the proposals, most of which were approved with high priority. His long bibliography (over 85 papers, on many of which he was a senior author) speaks for his excellence as a physicist. He possessed a quiet independence and integrity which sometimes isolated him and concealed his true ability.

It was a tragedy to lose two such splendid individuals in this comparatively early years. Their loss will be deeply felt by all of us who have worked with them.

Table of Contents

PROGRESS REPORT 90-91

I. Introduction and Summary

The period covered in this report is approximately July 1990 through July 1991. This constitutes a final report, to date, for the one year grant ending 31 Dec. 1991. A summary report for the period July 1987 through July 1990 accompanies this report for reference. A separate document presents a proposal and a request for renewal of the grant for the period 1 January 1992 through 31 December 1993.

The group at present consists of Norton M. Hintz (Principal Investigator and Prof. of Physics); Anil Sethi, Xin-hua Yang and Michael Franey (part time), Research Associates; Dimitris Mihailidis, graduate Research Assistant. Anthony Mack, a Research Assistant, completed his M. A. and left the group in September, 1990. Most of the experimental work reported here was done at the Los Alamos Meson Facility (LAMPF). Experiment numbers refer to LAMPF experiments unless otherwise noted.

An active collaboration, involving sharing of scientific staff and computer facilities, exists with the Minnesota group under Prof. Dietrich Dehnhard. In addition, we have collaborated with theorists at Minnesota (Bayman, Ellis) and elsewhere (G. Brown, SUNY; W. G. Love, Univ. of Georgia; A. M. Lallena, Univ. of Granada).

In a departure from our usual format, the main body of this report (Sect. III) consists of copies of papers that were published, written, or completed during the period of the report. We have included only papers written (or written in part) by the Minnesota group. Title pages of papers based on experiments with Minnesota participation are included in the bibliography, Sect. IV.E.

Our main activities during the past year were:

A. Experimental

1. Two development runs at MRS on Minnesota experiment E1201, a two-arm (p,2p) coincidence experiment to measure σ and A_y in the quasi-elastic continuum region. (Sept. and Oct. 1990). (See Sect. III.A).

2. MRS development (June 90), consisting mainly of focal plane polarimeter studies in preparation for E1145 and E1131U (both with Minnesota participation).

3. Final runs on E973U, "A Search for dibaryon resonances using the reaction $\vec{p} + {}^3He \rightarrow d + X$" (Minnesota co-spokesman, HRS, Sept. 90).

4. Participation in HRS tuneup and preparation for E1133U. (June, July 1991)

5. Participation in:

(a) E1131U, "Measurements of polarization transfer for 800 MeV inclusive proton scattering at the MRS". (July 1990).

(b) E1079U, "Precision measurements of proton-nucleus elastic scattering cross sections". (Aug. 90, HRS)

(c) E1080, "The longitudinal/transverse decomposition of the enhanced nucleon spin response in ${}^{40}Ca$" (June 90, HRS)

(d) IUCF-E338, "High momentum studies of 200 MeV inelastic proton scattering on ${}^{10}B$". (Nov. 1990, K600 spectrometer)

B. New Proposals and Updates (Minnesota spokesmen)

1. IUCF E352, "High spin states in the ${}^{58}Ni$ and ${}^{208}Pb$ (p,t) reaction". Approved (C^+ priority), Nov. 90 PAC.

2. E1133U (LAMPF), "Inelastic scattering from ${}^{182,184}W$ and the IBA model". Update approved (B priority), Jan. 91 PAC.

C. Papers

The following papers were written (all or in part) or completed by the Minnesota group during the past year. Copies are included in Sect. III and constitute the major part of this report. The Minnesota authors are underlined.

1. "$^{194,198}Pt(\vec{p},\vec{p}')$ reaction and the interacting boson model", A. Sethi, F. Todd Baker, G. T. Emery, W. P. Jones and M. A. Grimm, Jr., Nucl. Phys. A518, 536 (1990). (This paper was written by A. Sethi.)

2. "Measurement of spin observables in the ^{28}Si $(\vec{p},\vec{p}')$ reaction at 500 MeV and comparison with the distorted-wave impulse approximation", E. Donoghue, C. Glashausser, N. Hintz, A. Sethi, J. Shepard, R. Fergerson, M. Franey, M. Gazzaly, K. Jones, J. McClelland, S. Nanda and M. Plum, Phys. Rev. C43, 213 (1991). The theoretical analysis was done by the Minnesota group. The data are from Minnesota experiment E451 and Rutgers E623U (with Minnesota participation).

3. "Dressed quarks and proton's spin", Xin-hua Yang, Chun Wa Wong and Keh-Cheng Chu, Mod. Phys. Lett. A13, 1155 (1991). (Largely written by Xin-hua Yang.)

4. "Determination of neutron and proton multipole matrix elements in ^{208}Pb from π^- and π^+ scattering at 180 MeV", N. M. Hintz, X. H. Yang, M. Gazzaly, S. J. Seestrom-Morris, C. L. Morris, D. C. Cook, A. M. Mack, J. W. McDonald, D. S. Oakley, C. F. Moore, M. Lynker and J. D. Zumbro. Accepted for publication, Phys. Rev. C (1991). (Written by Xin-hu Yang and N. M. Hintz.) The data are from Minnesota E601.

5. "Quantum solitons in a Hamiltonian framework," J. A. Parmentola, Xin-hua Yang and I. Zahed, Ann. Phys. 209, 124 (1991).

6. "Inelastic proton scattering from Pt isotopes and the interacting boson model", A. Sethi, N. M. Hintz, D. N. Mihailidis, A. M. Mack, M. Gazzaly, K. W. Jones, G. Pauletta, L. Santi, and D. Goutte. In press, Phys. Rev. C, August 1991. (Written by A. Sethi.) The data are from Minnesota E903U.

7. "Modifications of the tensor and spin-orbit interactions and the stretched states of ^{208}Pb", N. M. Hintz, A. Lallena and A. Sethi, to be submitted, Phys. Rev. C. (Written by N. M. Hintz and A. Lallena.) This paper is a new analysis of data from Minnesota E686.

8. "Quadrupole moments in the Pt-Os region and the Interacting Boson Model", A. Sethi and N. Hintz, to be submitted, Phys. Rev. Lett. (Written by A. Sethi.) This paper uses data from Minnesota E903.

9. "Proton-Nucleus Scattering and density dependent meson masses in the nucleus", G. E. Brown, A. Sethi and N. M. Hintz. This paper was extensively revised and resubmitted to Phys. Rev. C in 1991.

D. Invited Talks

1. "Nuclear structure studies at intermediate energy", N. M. Hintz, The 9th Nordic Meeting on Intermediate and High Energy Nuclear Physics, Gräftåvallen, Sweden, 5-11 Jan. 1991.

2. "Medium modifications of the NN interaction and (p,p') scattering", N. M. Hintz, International Conference on Spin and Isospin in Nuclear Interactions, Telluride, Colo., 11-15 Mar. 1991.

3. "Coincidence studies of quasi-elastic scattering at medium energies at MRS at LAMPF", D. Mihailidis, National Nuclear Physics Summer School, Univ. of Wisconsin, Madison, Wisc., 17-29 June 1991.

A complete Bibliography is given in Sect. IV including additional papers with Minnesota authors.

II. Approved Experiments in Scheduling Queues

A. Minnesota Spokesmen

1. E1031U, ^{58}Ni and ^{208}Pb (p,t) reaction (any energy, 200-400 MeV). N. Hintz, spokesman; 112 hrs approved (HRS), A^- priority. This experiment is awaiting the availability of 200-400 MeV beam at HRS.

2. E1133U, "Inelastic proton scattering from ^{182,184}W and the IBA model", A. Sethi spokesman; 72 hrs approved, B priority. This experiment is scheduled to run Aug 1991.

3. E1201, "Coincidence Study of quasielastic proton scattering", N. Hintz, A. Sethi spokesmen. 130 hrs approved, B^+ priority. Development runs are scheduled at HRS and P^3, summer 1991.

4. IUCF E352, "High spin states in the ^{58}Ni and ^{208}Pb (p,t) reaction", N. M. Hintz, spokesman. 144 hrs approved, C^+ priority. This experiment is expected to run at IUCF in early 1992.

B. Minnesota Participation Expected

1. E823U, "Study of the IVGMR in ^{90}Zr, ^{208}Pb via the (n,p) reaction", LANL, U. Colorado spokesmen, 192 hrs approved, A^- priority, MRS.

2. E1079U, "Precision measurement of proton-nucleus elastic scattering cross sections", U. Texas, LAMPF spokesmen. 150 hrs approved, A priority; scheduled at HRS for Aug. 1991 (HRS).

3. E1131U, "Measurements of polarization transfer for 800 MeV inclusive proton scattering at the MRS", Rutgers, Texas, LAMPF spokesmen. 370 hrs approved, B^+ priority.

4. E1145, "Measurement of complete spin observables in the quasi-free region", U. Colorado spokesman, 325 hrs. approved, A priority (500 MeV at MRS). Some development runs expected summer 1991.

5. E1205, "Precision Dnn data for $^{13}C(p,p')$ at 500 MeV", U. Texas, LANL, Rutgers spokesman, 293 hrs approved, B^+ priority (HRS).

6. E1206, "Polarized proton elastic scattering from polarized ^6Li at 500 MeV", U. Texas, NMSU, LANL spokesman, 560 hrs. approved, B^+ priority, 500 MeV, (HRS/MRS).

III. Experiments and Analysis

Our main experimental activities in the past year have been to participate in MRS development at LAMPF, to assist in the first MRS experiments (E1131U) and in HRS experiments E973U (Minnesota co-spokesman), E1079U and E1080. In addition we participated in IUCF-E338 to gain familiarity with the K600 spectrometer to be used in Minnesota IUCF-E352.

Finally there were two development runs at MRS to prepare for E1201 (Minnesota spokesman), a two-arm coincidence experiment to study the (p,2p) reaction in the quasi-free region.

In Sections III.A and B. we summarize work on E1201, and some new analysis of the data from E903U. Sect. III. C is a brief summary of computer code development.

A large fraction of our time in the past year was spent writing or completing papers on Minnesota experiments or theoretical work. Copies of these papers constitute Sects. III. D-L.

A. E1201, development of (p,2p) coincidence studies at MRS

1. Introduction and motivation

In recent years there has been a growing interest in intermediate energy nucleon-nucleus, electron-nucleus and pion-nucleus scattering to the continuum, to study the nuclear response as a function of energy, momentum, spin and i-spin transfer.[(1)]

The basic quasielastic (QE) process allows us to study p-nucleon interactions in medium, with some separation of off- and on-shell interactions, by doing coincidence studies (for example (p,2p)).

Relativistic Dirac theory predicts NN amplitudes to be substantially altered in the nucleon medium, compared to the free values, due to the presence of large scalar and vector potentials in the nucleus, which results in dramatic changes in the predicted QE spin observables.[2] Most of the experiments to date have been inclusive (single-arm), and the quantitative understanding of proton QE data is not completely satisfactory. The magnitude and shape of the cross section ($\frac{d^2\sigma}{dEd\Omega}$) is not well reproduced in either non-relativistic (NR) calculations with RPA correlations or in the best currently available relativistic PWBA treatments.[3] The analyzing power (A_y) is even more poorly reproduced.[1]

The availability of the Medium Resolution Spectrometer (MRS)[4,5] at LAMPF, makes feasible not only inclusive but also coincidence studies at proton intermediate energies. There are several advantages of doing a coincidence (p,2p) experiment, detecting both protons in the final state. One can, with appropriate choice of coincidence detection geometry and energy selection, enhance the signal for a specific process and reduce the background due to unwanted events from nearby overlapping resonances or multi-step processes. One can also enhance various kinematic regions, for example, selecting preferentially low or high momentum components of the target proton momentum distribution.

With the approved EXP.1201,[6] we will develop coincidence techniques with the newly built MRS and obtain data for σ and A_y at the QE peak to test the current theories.

The target we proposed to study is ^{40}Ca with the use of CH_2 for normalization and calibration.

2. Preliminary data for development of E1201

a. Set up

In the summer of 1990 we worked on the assembly of the recoil proton arm, and later (Sept. 1990), we took some preliminary data, with a total running time of about 5 days.

The recoil proton arm will be an array of four CsI (pure) crystals 3"x3"x12" in the configuration shown in Figure 1. The dimensions of the array are thus 6"x6"x12". Our development data were taken using only two crystals in an array 3" (high) x 6" (thick) x 12" (long). Since that was the first attempt at coincidence studies at MRS we needed to assemble the hardware, the appropriate electronics, and also write the software for the data taking. We had the help of LAMPF staff (Dr. K. Koch and Dr. L. Rybarcyk) and researchers from other institutions (U. of Rutgers).

Each CsI crystal has a phototube at each end (Fig. 1) to allow us to make both energy and position measurements. The position measurements will give us the angle of the recoil proton. The energies and angles of the recoil protons from a ^{40}Ca target, at a given MRS angle, will vary because of their Fermi motion. A good calibration of the second arm and also good timing between the spectrometer (MRS) and the second arm is very important. That has been the aim of the preliminary runs made last fall, which have been analyzed during the past winter (1990-1991). The experimental set up is shown in Figure 1. In front of the two crystal array we used a "screen" plastic scintillator (3/18 inch thick), which defined the solid angle. Coincidence between the plastic scintillator and the CsI crystals were required. The second proton arm was about 70 cm away from the target. For these calibration data we ran in open air (energy resolution and multiple scattering effects are minimal) in order to avoid complications with the photomultiplier bases in vacuum. The incident beam was 800 MeV polarized protons and the target was CH_2 (as a proton target). This allowed us to do free p-p scattering at 800 MeV, detecting both protons. The CsI angle (56.4^{o}) was determined from p-p relativistic kinematics, corresponding to a spectrometer angle of 25°. The reason for using a 6" thick CsI array was that we want to detect proton recoil energies up to 250 MeV.

b. Timing

The timing between the spectrometer signals and the second arm signals, was carefully adjusted. It was necessary to delay the second arm signals by more than 20 ns in order to form coincidences with the spectrometer signals. The trigger in the spectrometer was defined by three scintillators in the focal plane and we required coincidence between these and the second arm array. Particle identification (PID) - dE/dx and time of flight, were used to isolate the useful proton events.

c. Second arm position and energy calibration

Considerable time was spent on the electronics and software for the second proton arm, before the preliminary development data were taken. Our goal is to develop a complete software package for coincidence experiments at MRS, since E1201 is the first such experiment. We used both timing and pulse height information from the second arm counters. Timing information allowed us position (angle) measurements and pulse height information allowed both position and energy measurements. Timing information from each end of both counters was used to form time differences and convert them into position information as follows:

For one counter (Fig. 1), (D and U label upstream and downstream ends):

$$\text{LOCX} = (\text{TXD-TXU})\text{xA1+A0} \qquad \text{(in cm)} \tag{1}$$

where LOCX is horizontal position on the counter, TXU, TXD are the time information of each phototube, A1 is the scale calibration parameter, and A0 is the offset parameter. The pulse heights are assumed to have the following dependence on the position of the event:

$$\begin{aligned} \text{PHU} &= G_u E \exp\left(\frac{-L-X}{\lambda}\right) \\ & \qquad\qquad\qquad\qquad \text{(in channels)} \\ \text{PHD} &= G_d E \exp\left(\frac{-L+X}{\lambda}\right) \end{aligned} \tag{2}$$

where E is the energy deposited in the counter (in MeV), G_u, G_d are the gain factors of PM tubes, L is the half length of the counter (in cm), λ is the attenuation length in the counter material (in cm); the center is taken as x=0.

The geometric mean of the two pulse heights is then:

$$\text{PH} = \sqrt{\text{PHU}\cdot\text{PHD}} = E\sqrt{G_u G_d}\ \sqrt{\exp\left(\frac{-2L}{\lambda}\right)}\ , \tag{3}$$

independent of X. We can also determine position from pulse height information:

$$X = -\frac{\lambda}{2}\ \ell n\left(\frac{\text{PHU}}{\text{PHD}}\right) + \frac{\lambda}{2}\ \ell n\left(\frac{G_u}{G_d}\right) \tag{4}$$

Again we parameterize the above as follows:

$$E = C1\ (PH\text{-}C0) \qquad \text{(in MeV)}$$

$$X = XLOC = B1\ \ell n\ (\frac{PHU}{PHD}) + B0 \qquad \text{(in cm)} \qquad (5)$$

The A,B,C parameters in Eqs. 1 and 5 are to be determined by various calibration techniques discussed briefly below.

First we corrected the raw pulse heights from each tube for the ADC offsets ("pedestals"). This guarantees the independence of E from x. The subtraction of "pedestals" was done with software arrangements for the pulse heights. Then we selected only second arm triggered events where the whole counter was illuminated with protons. The LOCX (Eq. 1) and XLOC (Eq. 5) distributions were then used to determine A1,A0,B1,B0. A1 and B1 were taken to be the FWHM (in channels) of LOCX and XLOC respectively, normalized to 30 cm, which is the physical length (12"≃30 cm) of the counter. A0 and B0 were chosen such that the scaled position distributions were centered at X = 0. Figure 2 shows the above calibration for one of the CsI counters. The shape of these position distributions are complicated because they result from folding of the rectangular shape of the counter with the shape of the pulse height distributions and the angular distributions of events. Two dimensional correlations between LOCX (time difference method) and XLOC (pulse height method) are shown in Figure 3. If the calibration is done consistently with both methods, the correlation should be a straight line with a 45° slope as seen in the figure.

Next comes the energy calibration and determination of the energy and position resolution. For energy calibration we used two techniques. First we looked at correlation of geometric mean pulse heights between the plastic scintillator and the first CsI and then between the first CsI and the second

CsI (Fig. 1). Figure 4 shows the correlation bands, which for the case of the plastic and the first CsI can also be used as a PID-ΔE-E signature. These bands correspond to energy deposited in one counter versus the energy deposited in the other. With an accurate knowledge of range and energy loss vs. energy for these materials (we used a computer code), one can use the turning points as energy calibration points. For example, in Fig. 4a, a proton of 170 MeV stops in the CsI, which is the Y coordinate of the turning point. This gives the C1 factor in Eq. 5, in MeV/channel. This method of calibration assumes C0 is very small.

A better way of calibrating the second arm is to use the hydrogen peak and free p-p kinematics. We looked at (p,2p) coincidence events with software cuts on the scattering angle of the spectrometer PHITGT, to select a specific p-p energy (and angle) through the spectrometer and therefore through the second proton arm. Since the CH_2 target contains also C, the same kinematics favor the QE process from C. To eliminate these events, we gated on the missing mass (MM) H peak. This eliminates most of the C events which contribute as a broad background under the H peak. Other cuts on several focal plane angle and momentum quantities were included along with PID, to define a "good MRS" event. This event, in coincidence with a second arm event, defined a good (p,2p) event on free hydrogen.

Three angle cuts of ± 0.25° around 23°,25° and 27° on PHITGT gave three energies in the second arm (164 MeV, 189 MeV, 216 MeV), and finally three position measurements. The FWHM (cm) of these position distributions, with ± 0.25° MRS cuts, gave the position resolution of the second arm (~ 3.2 cm or 2.6^{o}). Figure 5 shows the FWHM position resolution and also the position measurements that correspond to PHITGT cuts at 23° and 28°. For a distance of 70 cm from the target, the difference in position between the two should be about 5.9 cm. We measured 7.3 cm. The measurement depends strongly on how accurately we know the distance target-second arm, and how well the angular calibration of MRS is done.

We used once more the range tables to determine the energy deposited at each counter for each of the above recoil energies. Thus for each counter we had three energies corresponding to three geometric mean pulse heights. A least square fit program gave us the parameters C1 and C0 for each counter. We found that the C0 are between 1.5 and 3.5 MeV.

Having the energy calibration of the second arm, we can generate a summed energy histogram (sum of MRS and CsI arm). For free p-p scattering we expect a single peak at E_{tot}=800 MeV. The FWHM of this histogram gives the first measurement of the energy resolution of the complete system (Figure 6). It is important to note that the summed energy spectrum is free of kinematic correlations and so reflects the true overall energy resolution of the system. Here we report ΔE = 7.4 MeV. We expect to do considerably better when our techniques are refined.

3. Conclusions and further work

In order to perfect (p,2p) techniques at MRS, at LAMPF, more development time is required to supplement the five days we had last year. More work needs to be done on the energy resolution both of the spectrometer and the second arm. For this reason we have requested a few shifts of development time at P3 (West or East) where we can have a monoenergetic proton beam with a small beam spot and an energy range of few MeV to 200 MeV. The request has been approved and we expect to run some time in cycle-60 (Aug.-Sept. 1991). This proton beam will enable us to get a better understanding of the intrinsic resolution of each crystal separately and to test the energy resolution and position resolution of the whole array. It is important to test how the energy and position resolution varies along the crystal length. There is also some testing of these crystals that we can do with cosmic rays especially for ADC and TDC offsets. Later in cycle-60 (Sept. 1991) we expect to set up the array for more (p,2p) development, this time using all four CsI crystals (Fig. 1) which are needed in E1201 for out of plane events. The handling of four crystals and two screen detectors is complicated since it involves twelve signals.

Predictions for double differential cross section and analyzing power for ^{40}Ca (p,2p)^{39}K at T_p=800 MeV can be made using the code THREEDEE[(7)] (spin orbit version). This is a factorized DWIA[(7,8)] code which requires either input of optical potential parameters, or a global prescription for these (from the code), for the incident and outgoing proton distortions.

References

1. See for example, O. Hausser, et al., Phys. Rev. Lett. 61, 822 (1988).
2. C. J. Horowitz and D. P. Murdoch, Phys. Rev. C37, 2032 (1988).
3. See for example, R. D. Smith, Los Alamos Report LA-UR88-1604 and Proceedings of the International Conference on Spin Observables of Nuclear Probes, Telluride, CO, March 13-17, 1988, for current reviews.
4. R. L. Boudrie, "Planning Experiments With MRS," LAMPF, April 1989 (unpublished).
5. K. M. Koch, "MRS performance," MP-10-LAMPF, December 1989 (unpublished).
6. N. M. Hintz, A. Sethi, Exp. 1201 proposal LAMPF, January 1990.
7. N. S. Chant, code THREEDEE, University of Maryland, College Park.
8. P. Kitching, et al., Chapter 2, Advances in Nuclear Physics (Plenum).

Figure Captions

Fig. 1. Schematic (p,2p) coincidence set up (not to scale). Free p-p energies and angles are shown.

Fig. 2a. Position on CsI from time difference in units of 0.01 cm.

Fig. 2b. Position on CsI from pulse height ratio in units of 0.01 cm.

Fig. 3. Correlation between position from time difference and position from pulse height ratio.

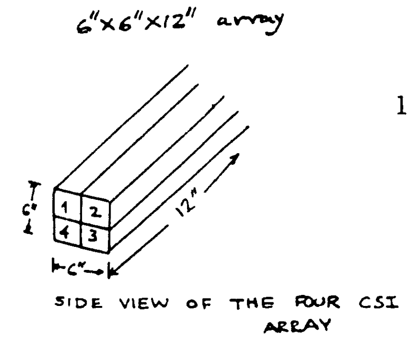
Fig. 4a. Pulse height in plastic scintillator vs. pulse height in the first CsI showing the 170 MeV turning point.

Fig. 4b. Pulse height in the first CsI vs. pulse height in the second CsI.

Fig. 5a. Time difference position histogram for first CsI detection (x2) showing 3.2 cm (2.6°) resolution for $\theta_{MRS}=25° \pm 0.25°$.

Fig. 5b. Same as Fig. 5a, but for $\theta_{MRS}=23°$ and 28° (± 0.25°) giving position calibration.

Fig. 6. Summed energy spectrum.



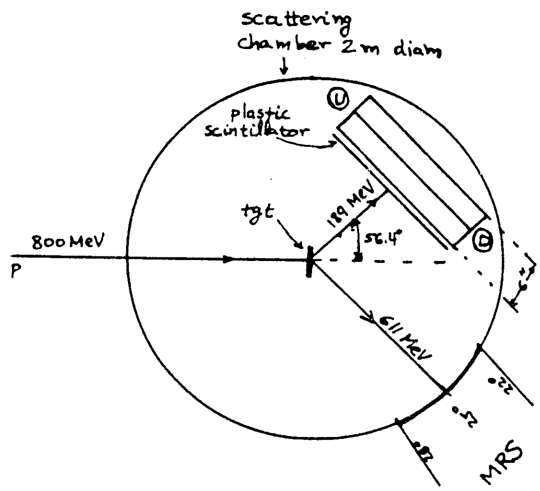


Fig. 1

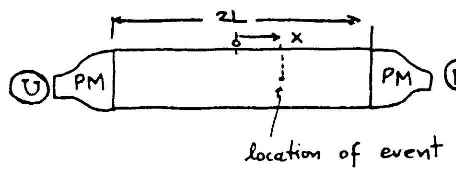


Fig. 1

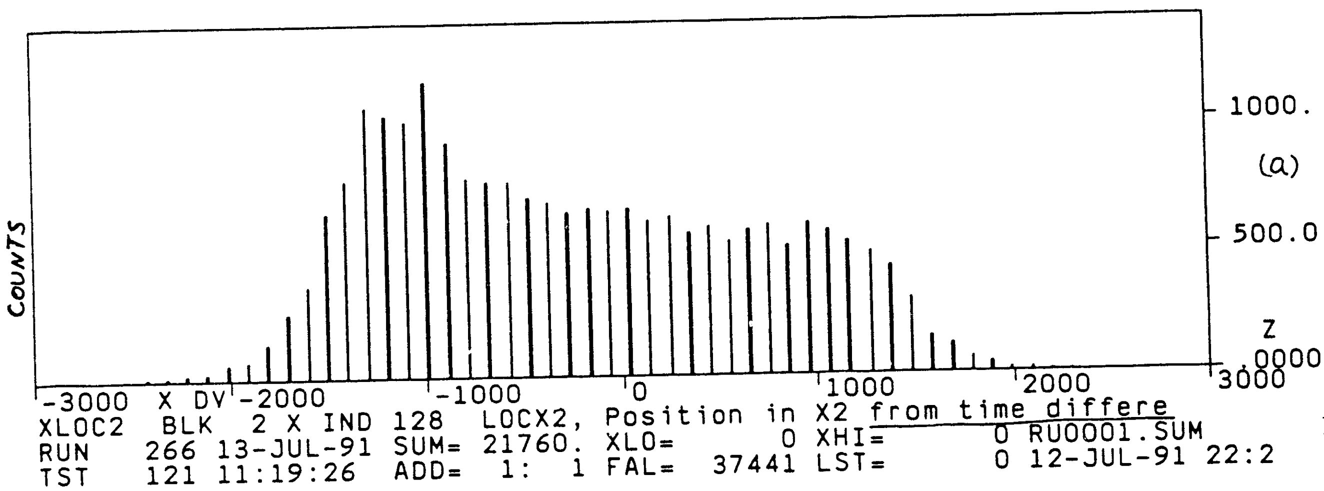


Fig. 2

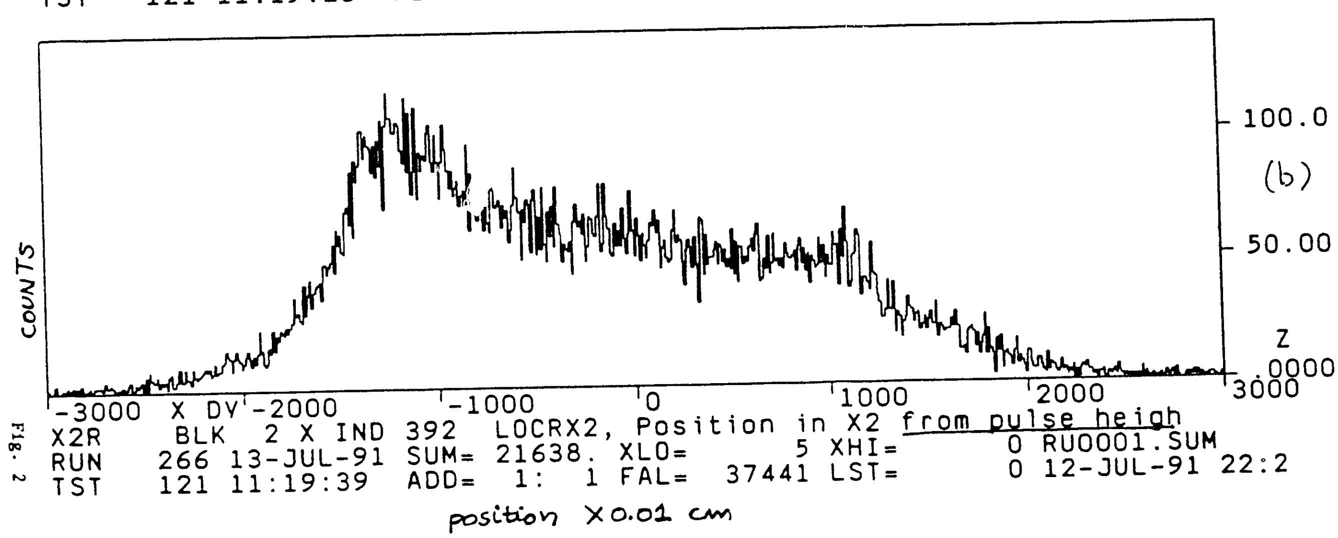
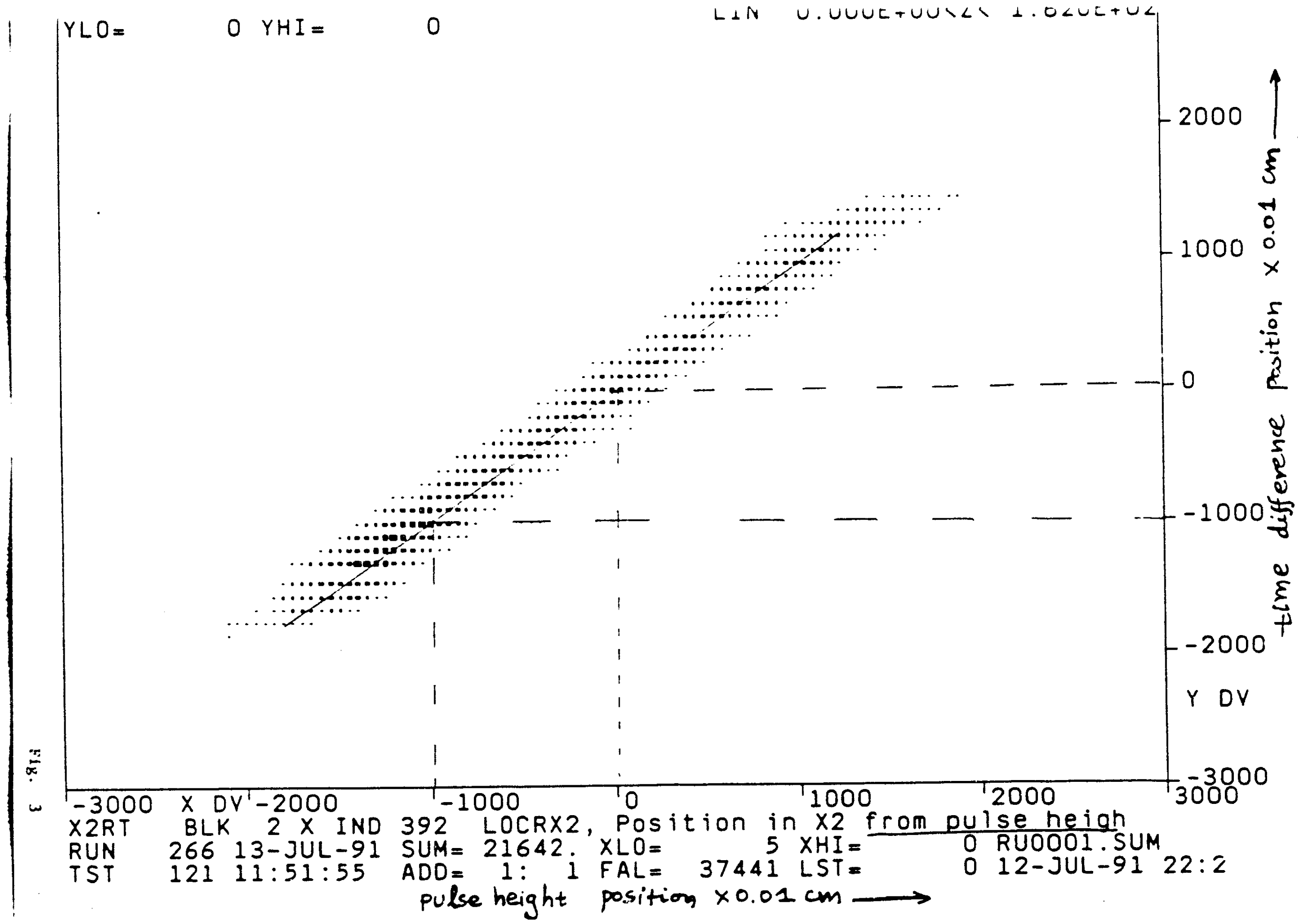


Fig. 2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-2000
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-3000 X DV -2000 -1000 0 1000 2000 3000
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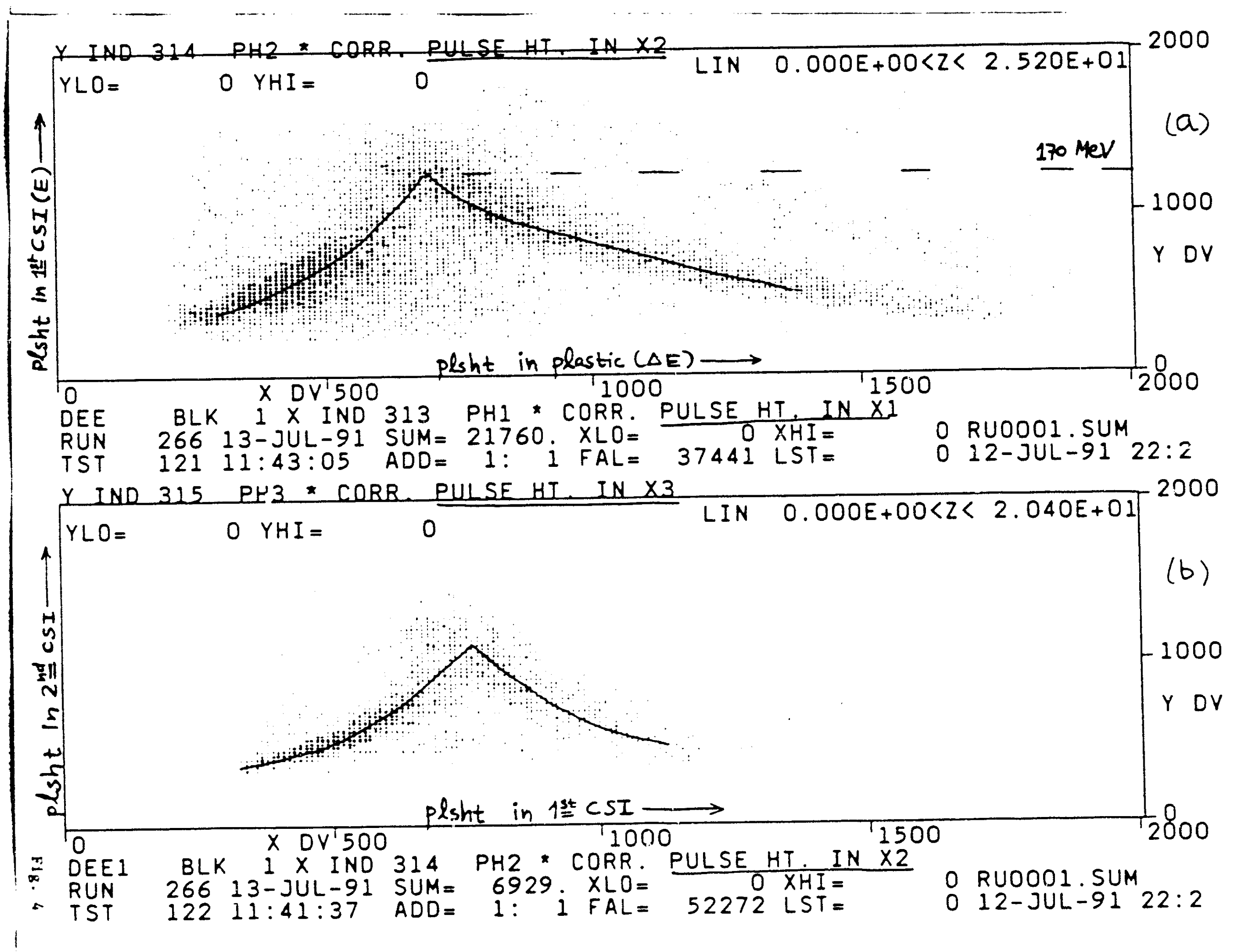
pulse height position x0.01 cm

Fig. 3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(a)
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1000
Y DV
0
plsht in 1st CsI (E)
plsht in plastic (ΔE)
0 X DV 500 1000 1500 2000
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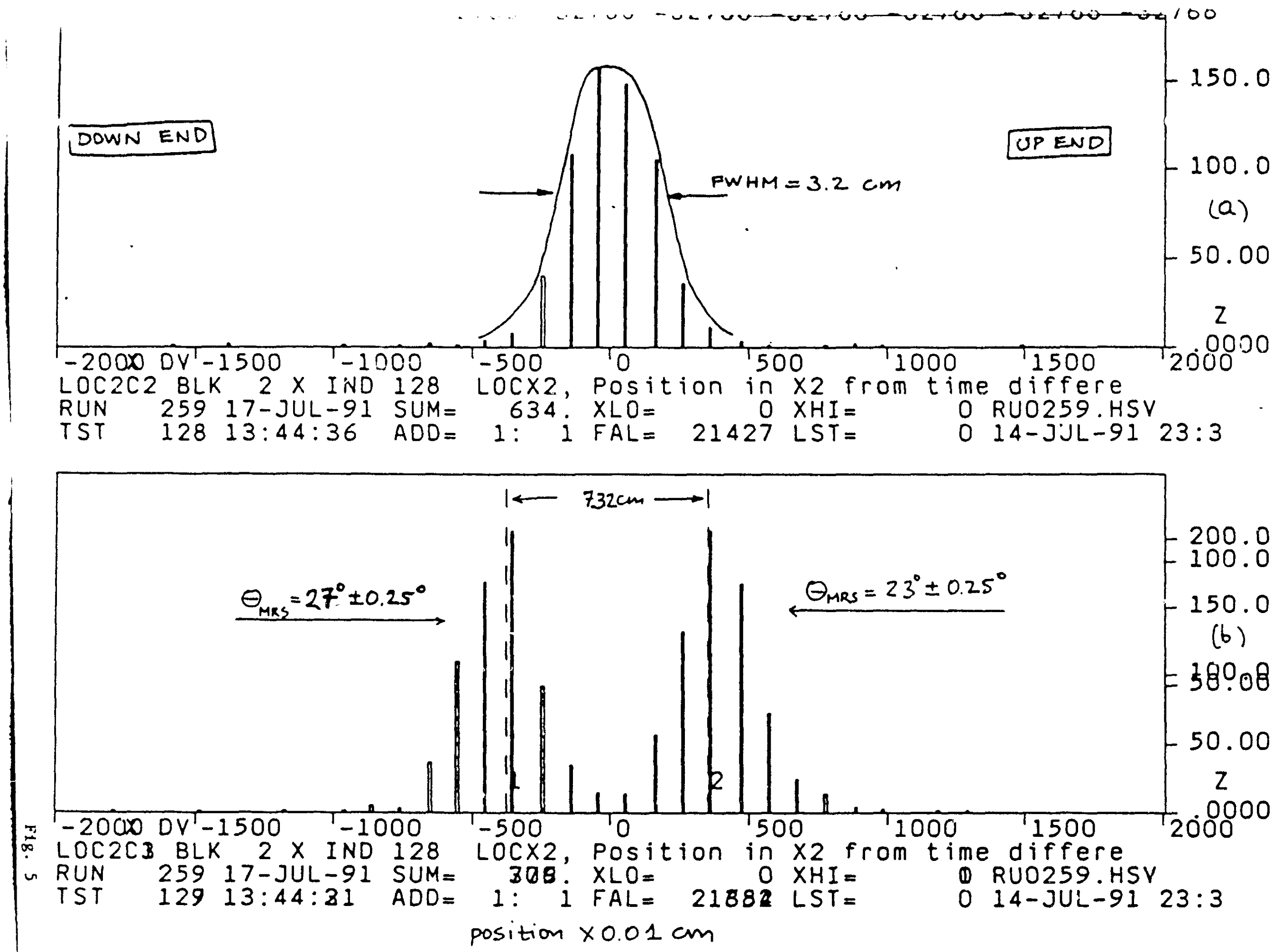
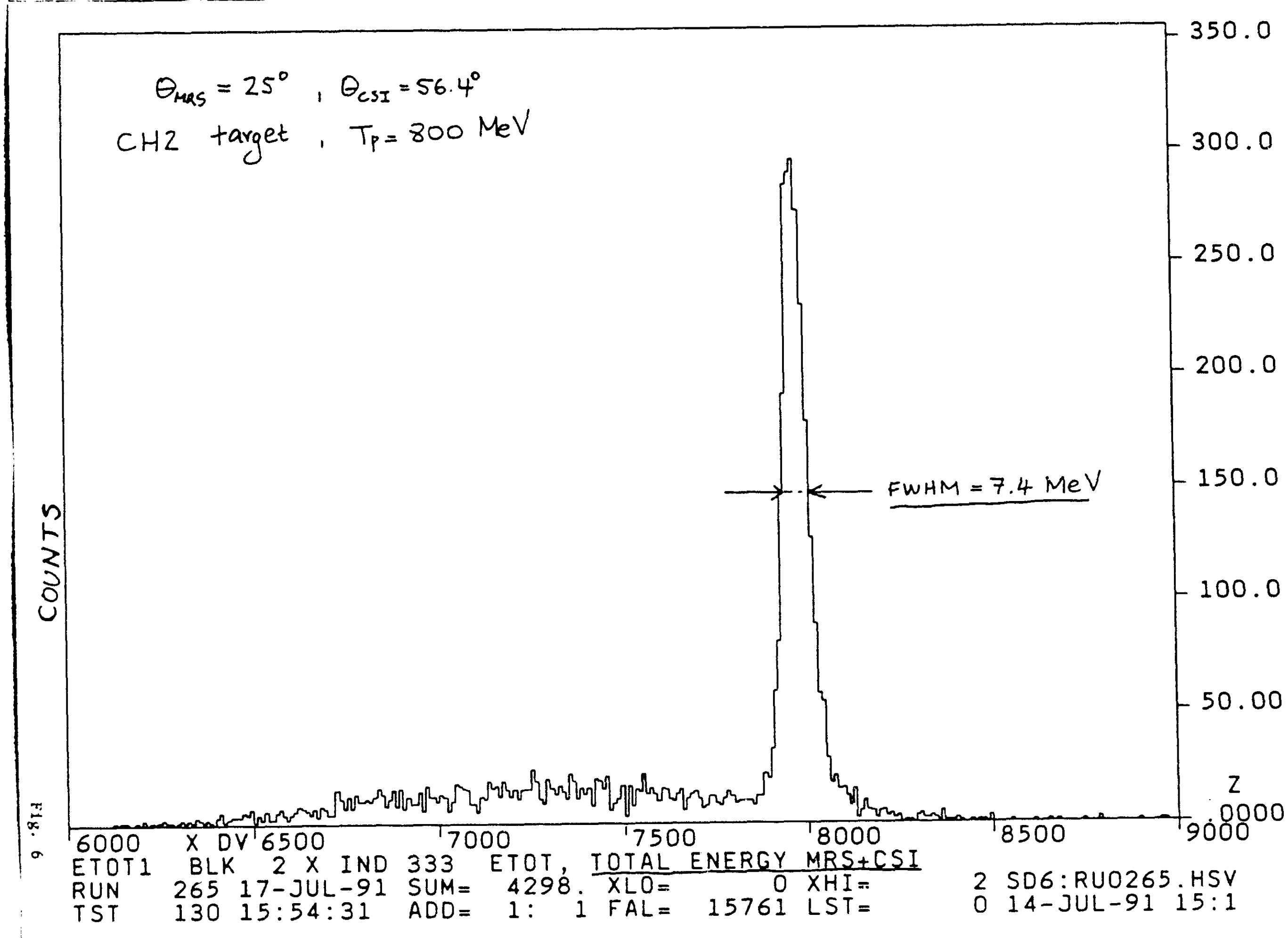
Fig. 4



DOWN END
UP END
FWHM = 3.2 cm
(a)
150.0
100.0
50.00
Z
.0000
-2000 DV -1500 -1000 -500 0 500 1000 1500 2000
LOC2C2 BLK 2 X IND 128 LOCX2, Position in X2 from time differe
RUN 259 17-JUL-91 SUM= 634. XLO= 0 XHI= 0 RU0259.HSV
TST 128 13:44:36 ADD= 1: 1 FAL= 21427 LST= 0 14-JUL-91 23:3
732cm
Θ_{MRS} = 27° ± 0.25°
Θ_{MRS} = 23° ± 0.25°
(b)
200.0
150.0
50.00
Z
.0000
1
2
-2000 DV -1500 -1000 -500 0 500 1000 1500 2000
LOC2C3 BLK 2 X IND 128 LOCX2, Position in X2 from time differe
RUN 259 17-JUL-91 SUM= XLO= 0 XHI= RU0259.HSV
TST 129 13:44:31 ADD= 1: 1 FAL= LST= 0 14-JUL-91 23:3
position × 0.01 cm

Fig. 5



Θ_{MRS} = 25° , Θ_{CsI} = 56.4°
CH2 target , T_p = 800 MeV
FWHM = 7.4 MeV
COUNTS
350.0
300.0
250.0
200.0
150.0
100.0
50.00
Z
.0000
6000 X DV 6500 7000 7500 8000 8500 9000
ETOT1 BLK 2 X IND 333 ETOT, TOTAL ENERGY MRS+CSI
RUN 265 17-JUL-91 SUM= 4298. XLO= 0 XHI= 2 SD6:RU0265.HSV
TST 130 15:54:31 ADD= 1: 1 FAL= 15761 LST= 0 14-JUL-91 15:1

Fig. 6

III. B. Analysis of $^{206,207,208}Pb$ data from E855

We have begun to analyze the elastic scattering data from E855 at T_p = 650 MeV. The purpose of the experiment was to obtain accurate (< ± 1%) cross section and analyzing power (A_y) data so as to derive neutron density differences. Information on the $^{207-208}Pb$ (and ^{208}Pb-^{209}Bi) neutron and proton differences can be used to obtain isoscalar and isovector nuclear compressibilities (K_0,K_1). In a preliminary analysis of charge density differences, Co' and Speth[1] conclude that $K_0 \simeq$ 350-460 MeV, larger than the presently accepted value of K ≃ 200 MeV. The neutron density difference in the lead isotopes is expected to be an order of magnitude larger than the proton and so should lead to a more reliable value of K_0. The nuclear compression moduli are of interest for theories of dense nuclear matter and the giant monopole resonance.

As a by-product of E855, considerable inelastic data were obtained. These have been analyzed using a phenomenological optical potential and collective form factors to obtain neutron-proton transition matrix element ratios (See 1987-90 Summary Progress Report, Sect. II.C.)

We have just begun an analysis of the elastic data using the non relativistic impulse approximation but with various modifications of the N-N interaction. At 650 MeV the real central potential is nearly zero so the imaginary central and the spin-orbit (Re and Im) dominate. This is very nice as "standard" medium modifications affect mainly the real central interaction.

As a first step we are exploring the effects of simple density independent modifications of the Franey-Love[2] t-matrix of the form successfully used by Hoffmann et al. 500 MeV[3],

$$\tilde{t}(q) = f(q)\ t(q)$$

where

$$f(q) = (b-a)\ \bar{q}/q + a \text{ for } 0 \leq q \leq \bar{q}$$

and

$$f(q) = (c-b)\ (q/\bar{q}-1) + b \text{ for } q > \bar{q} \qquad (1)$$

(but with $f(q)$ set to zero if $f(q) < 0$).

Two types of reasonable density distributions are being tried to see the effects of $f(q)$:

1) Theoretical HFB densities of Decharge[4], ρ_n^D and ρ_p^D.

2) Proton densities, ρ_p derived by unfolding the proton charge form factor from model independent (e,e) charge densities, and neutron densities from the "scaling" prescription,

$$\rho_n = N/Z\ \rho_p + (\rho_n^D - N/Z\ \rho_p^D)$$

Our initial strategy is to determine effective force parameters (a,b, and c) to give a good average fit to the data using "reasonable" densities. The next step will be to vary the densities for each isotope for a best fit to the (e,e) and (p,p') data for each isotope so as to obtain density <u>differences</u>.

A few initial results are shown in Figs. 1 - 5 using theoretical (1, above) or "scaled" (2) densities and with f(q) = 1, or with f(q) as given above with $\bar{q}$ = 1.0 fm, a = 1, b = 0.75, c = 0.15. (In the latter calculations, with f(q) = 1, we have modified only the spin-orbit interaction with the parameters the same for the real and imaginary and IS, IV parts). It is surprising that a reasonable fit to A_y can be found for parameters which correspond to a <u>reduction</u> of the spin-orbit interaction, contrary to what was found by Hoffmann[3].

The results so far indicate the need to modify the central parts of the force, and/or to include a density dependence as suggested by ideas on meson and nucleon mass decrease in medium which have been shown to fix the phase of the calculated cross sections (See Sect. III.H below).

References

1. G. Co' and J. Speth, Phys. Rev. Lett. <u>57</u>, 547 (1986).

2. M. A. Franey and W. G. Love, Phys. Rev. <u>C31</u>, 488 (1985).

3. G. W. Hoffmann, L. Ray, <u>et al</u>., Phys. Rev. Lett. <u>47</u>, 1436 (1981).

4. J. Decharge and D. Gogny, CEA-N-2260, Centre d'Etudes de Bruyères-le-châtel, 1982, unpublished.

Figure Captions

Fig. 1. Elastic cross sections for ^{208}Pb at T_p = 650 MeV. The curves represent DWIA calculations for Decharge's densities (1). The dashed curve is for t(q) unmodified (f(q) = 1, Eq. (1)). The solid

curve shows the results for $a = 1.0$, $b = 0.75$, $c = 0.15$ and $\bar{q} = 1.0$ in Eq. 1 for $f(q)$.

Fig. 2. Same as Fig. 1 but with scaled densities (2).

Fig. 3. Same as Fig. 1 but for A_y and scaled densities (2).

Fig. 4. Comparison of Decharge (1) and scaled densities (2) for A_y using $t_{LS}(q)$ modified as in Fig. 1.

Fig. 5. Same as Fig. 1 but for ^{206}Pb and A_y.

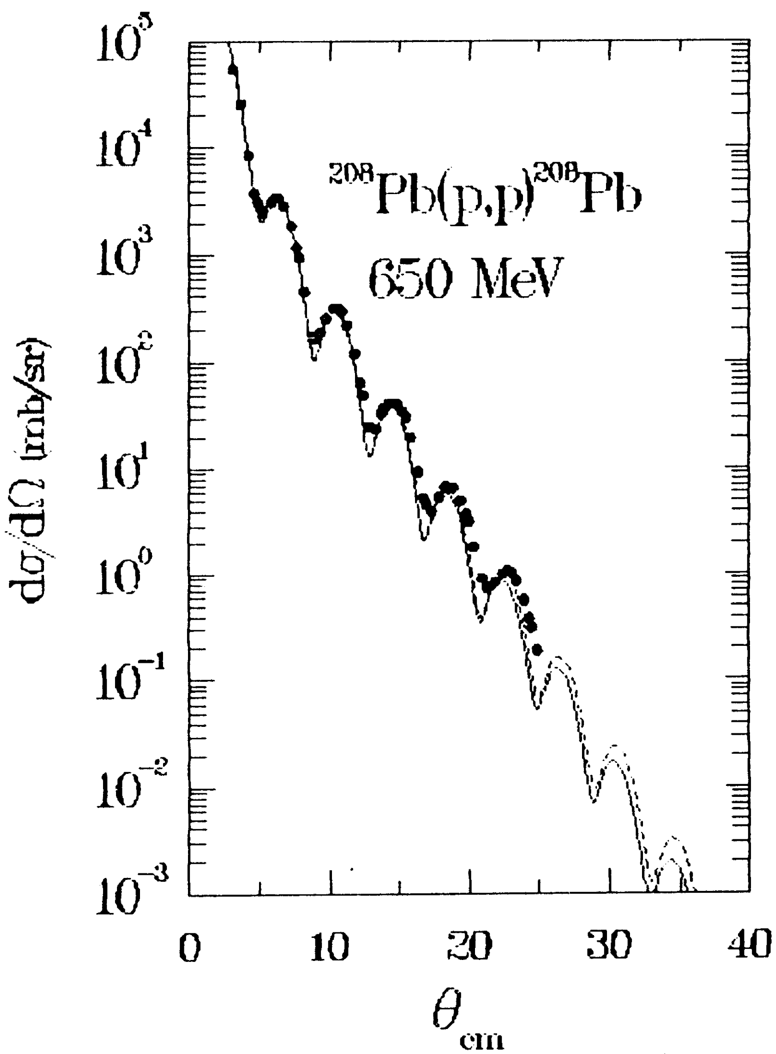

^{208}Pb(p,p)^{208}Pb
650 MeV
dσ/dΩ (mb/sr)
θ_{cm}
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
0
10
20
30
40

Fig. 1

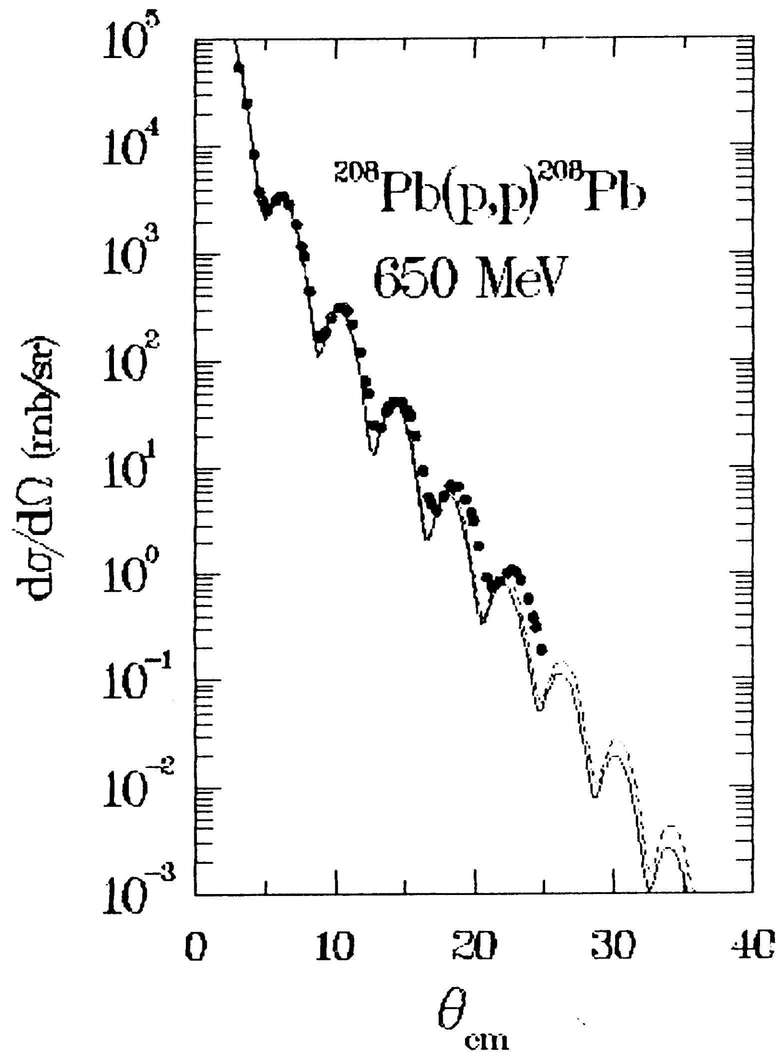
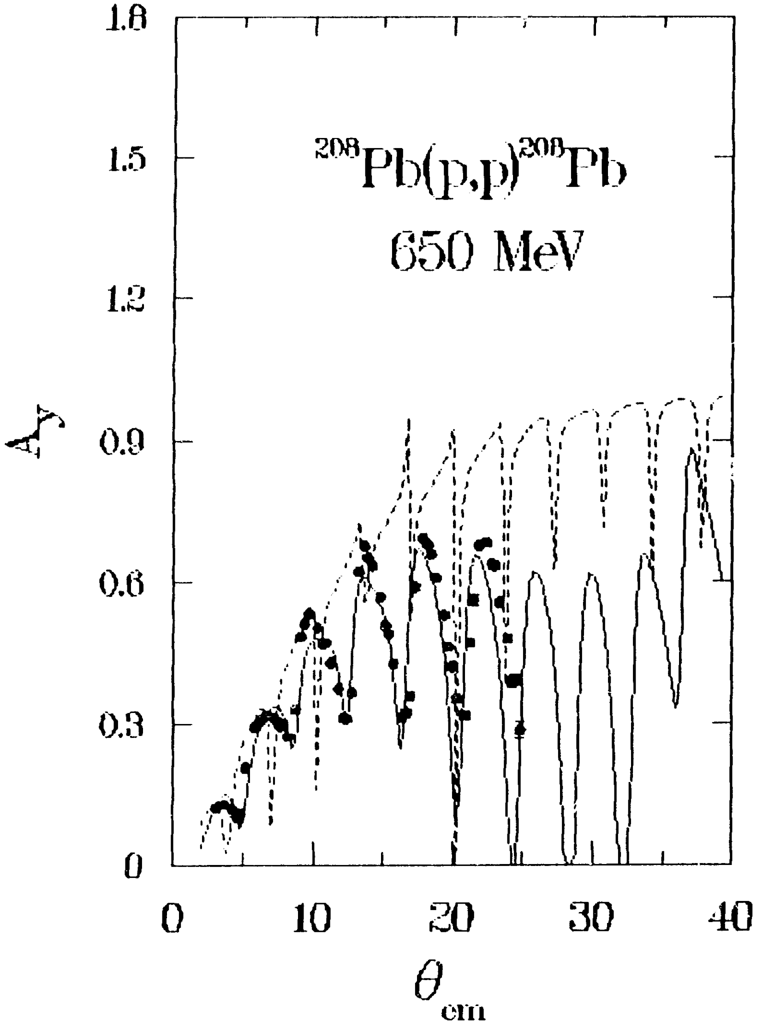
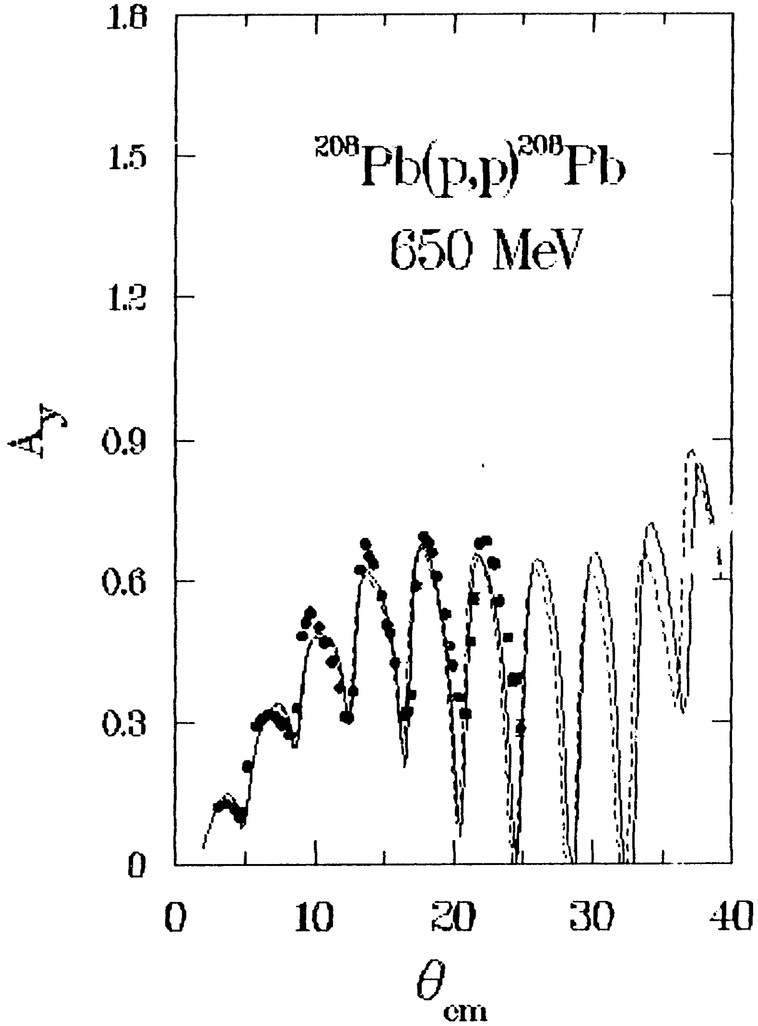

^{208}Pb(p,p)^{208}Pb
650 MeV
dσ/dΩ (mb/sr)
θ_{cm}
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
0
10
20
30
40

Fig. 2



^{208}Pb(p,p)^{208}Pb
650 MeV
A_y
1.8
1.5
1.2
0.9
0.6
0.3
0
0
10
20
30
40
θ_{cm}

Fig. 3



^{208}Pb(p,p)^{208}Pb
650 MeV
A_y
1.8
1.5
1.2
0.9
0.6
0.3
0
0
10
20
30
40
θ_{cm}

Fig. 4

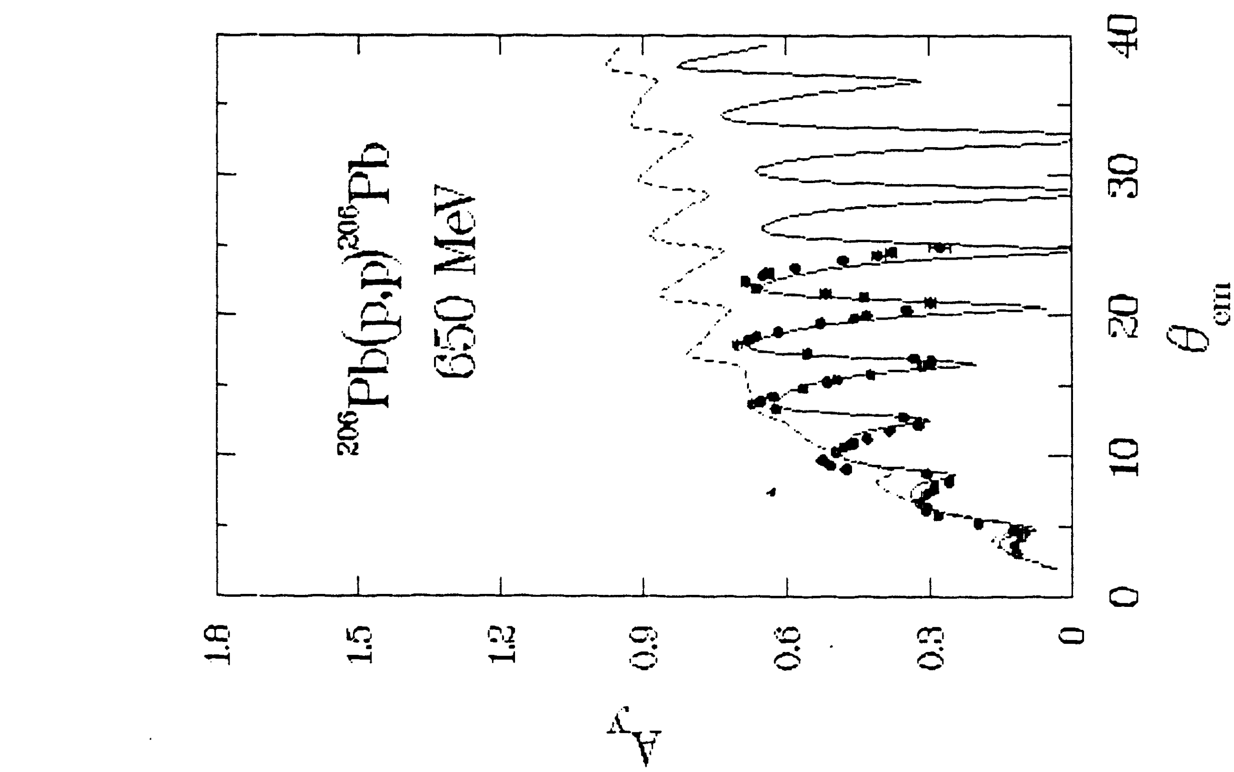


Fig. 5

III. C. Computer Program Development

1. Electron Scattering

a) The program HEIMAG[1] calculates inelastic electron scattering cross sections for magnetic transitions in the DWBA. The bound state wavefunctions are calculated in a Woods-Saxon potential. We have expanded the program to combine up to 20 orbitals in 19 configurations. This is very useful for wave functions from large basis RPA calculations such as those described in Sect. III.J for the 14^- and 12^- states of ^{208}Pb. To ensure consistency with the phase convention in the RPA and (p.p′) calculations the program has been fixed to ensure that all particle and hole orbitals are positive near the origin.

b) An additional program, UNFOLD, has been written which unfolds the proton charge form-factor from a given nuclear charge distribution. The program allows unfolding of Gaussian, exponential and Yukawa type form factors for the proton.

2. IBM Nuclear Structure Programs

We have updated our IBM programs on the CRAY. Preliminary work has been done on modifying these to include an f-boson (L=3) in addition to the s- and d-bosons. These programs will be needed to study the negative parity states in the transition nuclei (Sec. III. G.).

3) Pion Scattering

To analyze date on pion-nucleus inelastic scattering, two programs have been modified: DWPI (coordinate space) and HL (momentum space). DWPI was expanded to allow angular momentum transfers up to J=8.

END

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