EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/89-115
September 5th, 1989

π^-p Elastic Scattering from 295 to 450 MeV/c

OMICRON Collaboration

A. Filipčič [1)], G. Kernel [1)], D. Korbar [1)], P. Križan [1)], M. Mikuž [1)], F. Sever [1)],
A. Stanovnik [1)], M. Starič [1)], D. Zavrtanik [1)], C.W.E. van Eijk [2)], R.W. Hollander [2)],
W. Lourens [2,*)], E.G. Michaelis [3)], N.W.Tanner [4)], S.A. Clark [5,**)], J.V. Jovanovich [6)],
J.D. Davies [7)], J. Lowe [7)] and S.M. Playfer [7,***)]

Abstract

Differential cross-sections for π^-p elastic scattering were measured for nine incident pion momenta from 295 to 450 MeV/c. The measurements cover π^- CMS scattering angles from 40^0 to 120^0. Preliminary results have statistical and systematical accuracy of 5 - 6 % and 3 %, respectively. Agreement between the data and the phase-shift analysis of Koch and Pietarinen is good.

Presented at the Third International Symposium on Pion-Nucleon and Nucleon-Nucleon Physics, Gatchina, USSR, April 17 - 22, 1989. (to appear in the proceedings).

---

1) J. Stefan Institute and Department of Physics, E Kardelj University, YU-61111 Ljubljana, Yugoslavia
2) Delft University of Technology, Delft, The Netherlands
3) CERN, CH-1211 Geneva 23, Switzerland
4) Nuclear Physics Laboratory, Oxford University, Oxford OX1 3RH, UK
5) Rutherford and Appleton Laboratory, Chilton, Didcot OX11 0QX, UK
6) Department of Physics, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada
7) Department of Physics, University of Birmingham, Birmingham B15 2TT, UK

*) Present address: State University Utrecht, Utrecht, The Netherlands
**) Present address: DEC, RDL 2B Queens House, Forbury road, Reading RG1 3JH, UK
***) Present address: PSI,SIN, CH-5234 Villigen, Switzerland

1. INTRODUCTION

Experimental study of differential cross-sections for pion-nucleon scattering at low energies is essential for the understanding of the interaction of pions with free nucleons as well as for evaluating the results of pion-nucleus experimental data. There have been many previous measurements of differential cross-sections for $\pi^- p$ elastic scattering. A complete bibliographical study up to 1980 can be found in ref. [1]. The best accuracy on differential cross-sections (typically 2%) for data below 450 MeV/c was obtained by Bussey et al. [2]. In addition, the recent $\pi^- p$ experimental data of Brack et al. [3] cover the incident pion momentum range from 152 to 240 MeV/c with an accuracy of 3 to 19%.

We report here of measurements of the differential cross-section for $\pi^- p$ elastic scattering at incoming pion laboratory momenta of 296, 315, 334, 354, 375, 394, 413, 432 and 450 MeV/c. Our data cover the π^- CMS scattering angle range from 40° to 120° with a 2° resolution.

2. EXPERIMENTAL DETAILS AND DATA

The experiment was carried out at the CERN 600 MeV Synchro-cyclotron with a large solid angle magnetic spectrometer OMICRON. The apparatus and the analysis procedures were described in details in refs. [4,5,6]. Here we recapitulate their main features.

The beams were of variable momentum and had a typical momentum spread of 7% FWHM. The incoming pion momentum was measured with five MWPC with a resolution of approximately 1%. An atmospheric-pressure freon gas Čerenkov counter was used to discriminate against electrons in the beam. Muon contamination of the beam was determined by a separate measurement on the spent beam and was described elsewhere [5]. The target vessel was a 80 cm long cylinder with a diameter of 15 cm. It was made of 250 μm thick mylar reinforced with kevlar fibres and filled with gaseous hydrogen at 1.2 MPa. Trajectories and momenta of particles emerging from the target were measured in two secondary arms consisting of two sets of three drift chambers placed at the left and right hand side of the beam, supplemented by scintillator hodoscopes.

The fast trigger signal required an incoming particle (pion or muon) and one secondary particle in each spectrometer arm defined by a hit in left and right scintillation hodoscope counter. In addition, a minimal number of hits in drift chambers was required in order to ensure the analysability of secondary tracks [6]. Data satisfying the trigger conditions were written to magnetic tapes. The off-line analysis consisted of track finding procedures and a fit of three tracks to a common vertex.

The criteria for the selection of events belonging to $\pi^- p$ elastic scattering were based on geometrical and kinematical properties of this reaction. Events originating in the target walls were eliminated by restricting the fiducial target volume to a radius of 5 cm and a length of 60 cm. Since the experimental set-up was designed for detection of low momenta $\pi^-\pi^+$ pairs produced in the reaction $\pi^- p \to \pi^-\pi^+ n$, the momentum resolution for relatively high momenta of scattered pions and protons was rather poor. Thus, we based our selection criteria on experimentally well defined angles of scattered particles. $\pi^- p$ elastic scattering events are coplanar. In addition, we have three constraints which allow us to calculate the proton scattering angle $\vartheta_p{}^c$ from the measured beam-particle momentum vector $\mathbf{p_o}$ and the measured scattering angle of π^- and to compare it to the measured one ($\vartheta_p{}^m$). Combining both features we defined the quantity Ψ as :

$$\Psi^2 = \left(\frac{\vartheta_p{}^m - \vartheta_p{}^c}{\sigma_{\Delta\vartheta}}\right)^2 + \left(\frac{\varphi_{ac} - \pi/2}{\sigma_{\varphi_{ac}}}\right)^2$$

where φ_{ac} is the acoplanarity angle defined as $\cos\varphi_{ac} = [\mathbf{p_o}\cdot(\mathbf{p_\pi}\times\mathbf{p_p})]/[p_o\cdot|\mathbf{p_\pi}\times\mathbf{p_p}|]$. $\sigma_{\Delta\vartheta}$ and $\sigma_{\varphi ac}$ are the r.m.s. experimental resolutions typically 1.8^o and 0.8^o, respectively. A cut on $\Psi \leq 4$ eliminated most of the background originating in multibody final state reactions. The contributions of background processes to the measured differential cross-sections for $\pi^- p$ elastic scattering were determined by Monte Carlo simulation and were found to be negligible at all incoming pion momenta.

Differential acceptance of the apparatus $\varepsilon(\vartheta)$ was obtained from simulated data. $\pi^- p$ elastic scattering events were generated isotropically in CMS. The simulation was performed by using beam track parameters obtained during the measurements with a special trigger. Secondary tracks were followed through the magnetic field taking into account multiple Coulomb scattering, energy loss, decay of particles as well as resolutions and efficiencies of detectors. In addition, spurious hits in drift chambers obtained from analysis of beam trigger sample were added to the output data which was analysed with the same off-line computer programmes as experimental data. A typical differential acceptance which includes the efficiency of the off-line computer programmes is shown in fig. 1.

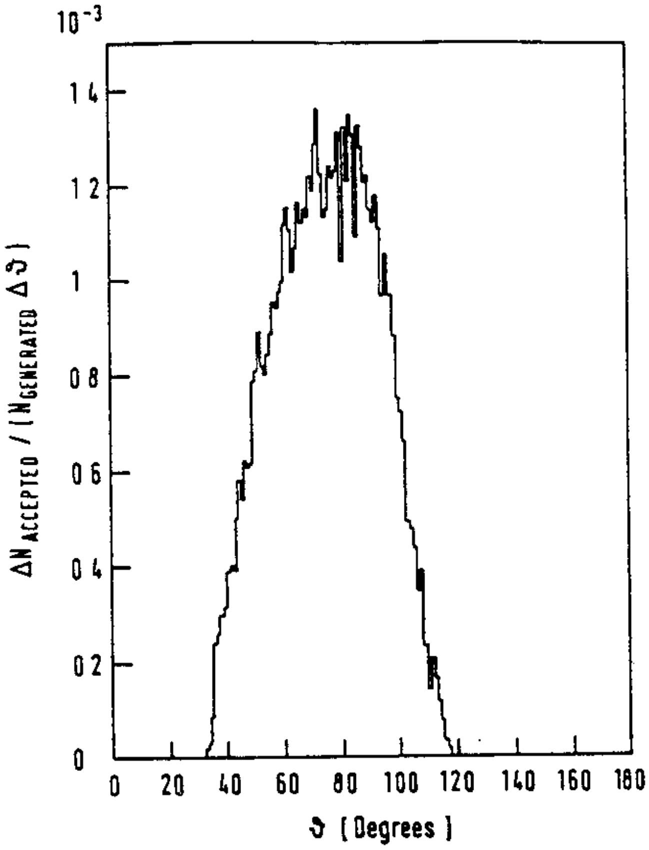


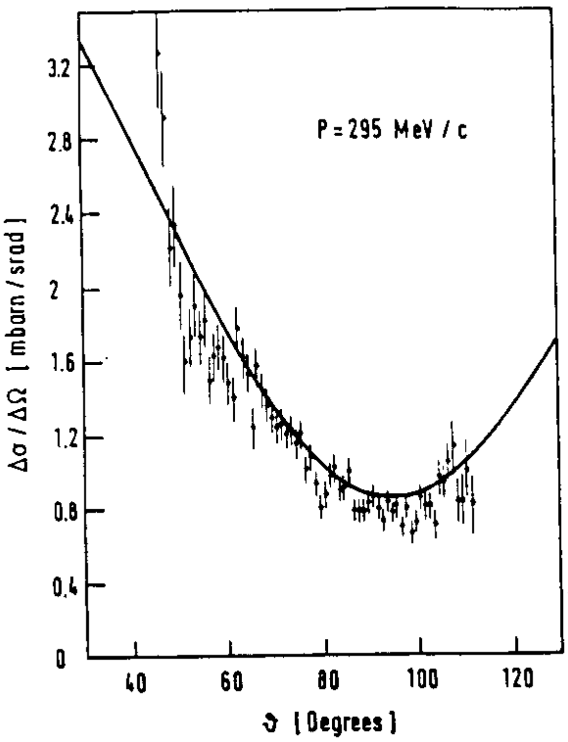
Figure 1. Acceptance of the apparatus determined by analysing simulated $\pi^- p$ elastic scattering events at incoming pion momentum 394 MeV/c.

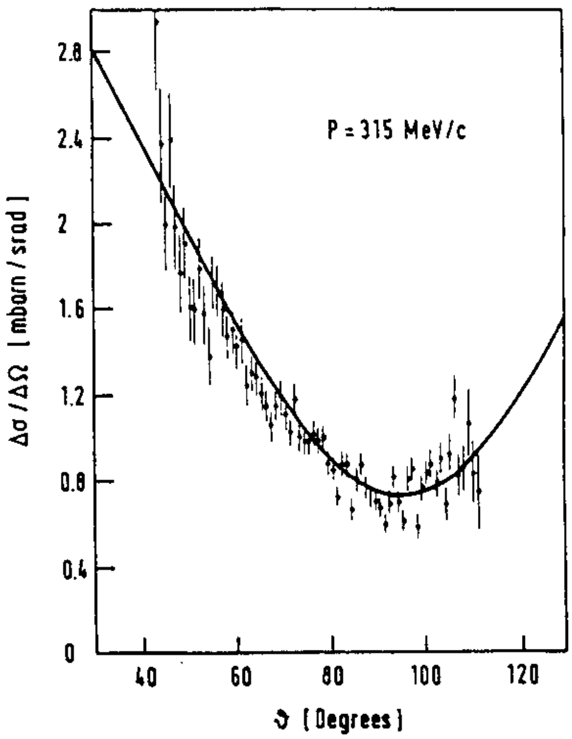
3. RESULTS

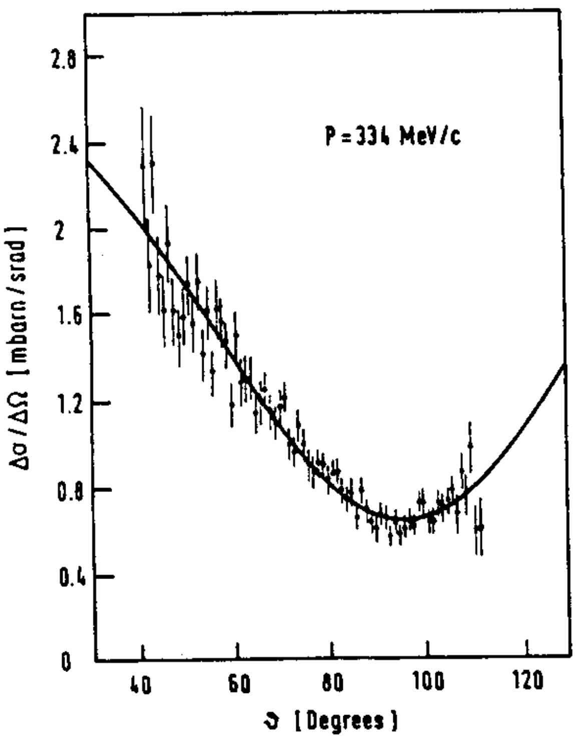
The differential cross-section was determined from the relation

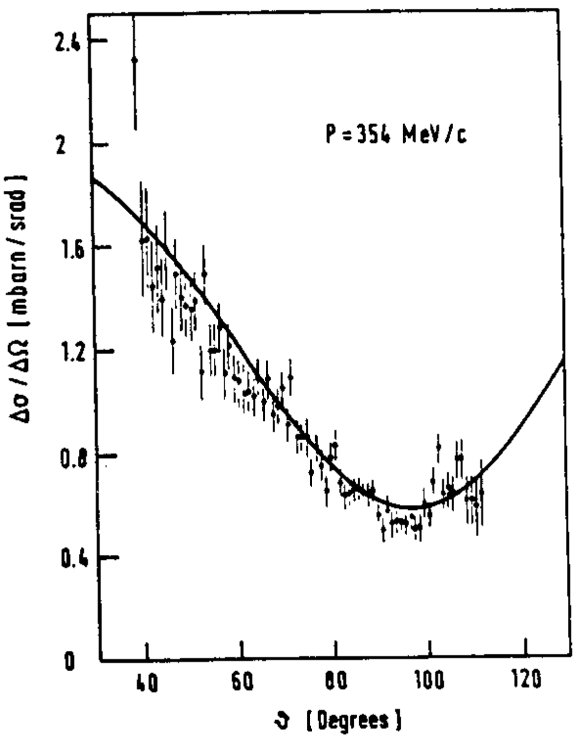
$$\frac{\Delta\sigma}{\Delta\Omega} = \frac{\Delta N_m/\Delta\vartheta}{\Delta N_a/\Delta\vartheta} \, \frac{N_g}{4\pi \, N_\pi H}$$

where H is the surface density of protons in the target, N_π the number of incoming pions, N_g the number of generated events by M.C. simulation and $\Delta\vartheta$ the CMS proton scattering angle bin. ΔN_m and ΔN_a represent the number of measured and simulated events which survived the analysis, respectively. Differential cross-sections at different incoming pion momenta are shown in fig. 2. The normalization includes corrections due to muon contamination of the beam, efficiency of Čerenkov counter as well as the loss of events


P = 295 MeV / c
Δσ / ΔΩ [mbarn / srad]
ϑ [Degrees]
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
40
60
80
100
120


P = 315 MeV/c
Δσ / ΔΩ [mbarn / srad]
ϑ [Degrees]
0
0.4
0.8
1.2
1.6
2
2.4
2.8
40
60
80
100
120


P = 334 MeV/c
Δσ / ΔΩ [mbarn / srad]
ϑ [Degrees]
0
0.4
0.8
1.2
1.6
2
2.4
2.8
40
60
80
100
120


P = 354 MeV/c
Δσ / ΔΩ [mbarn / srad]
ϑ [Degrees]
0
0.4
0.8
1.2
1.6
2
2.4
40
60
80
100
120

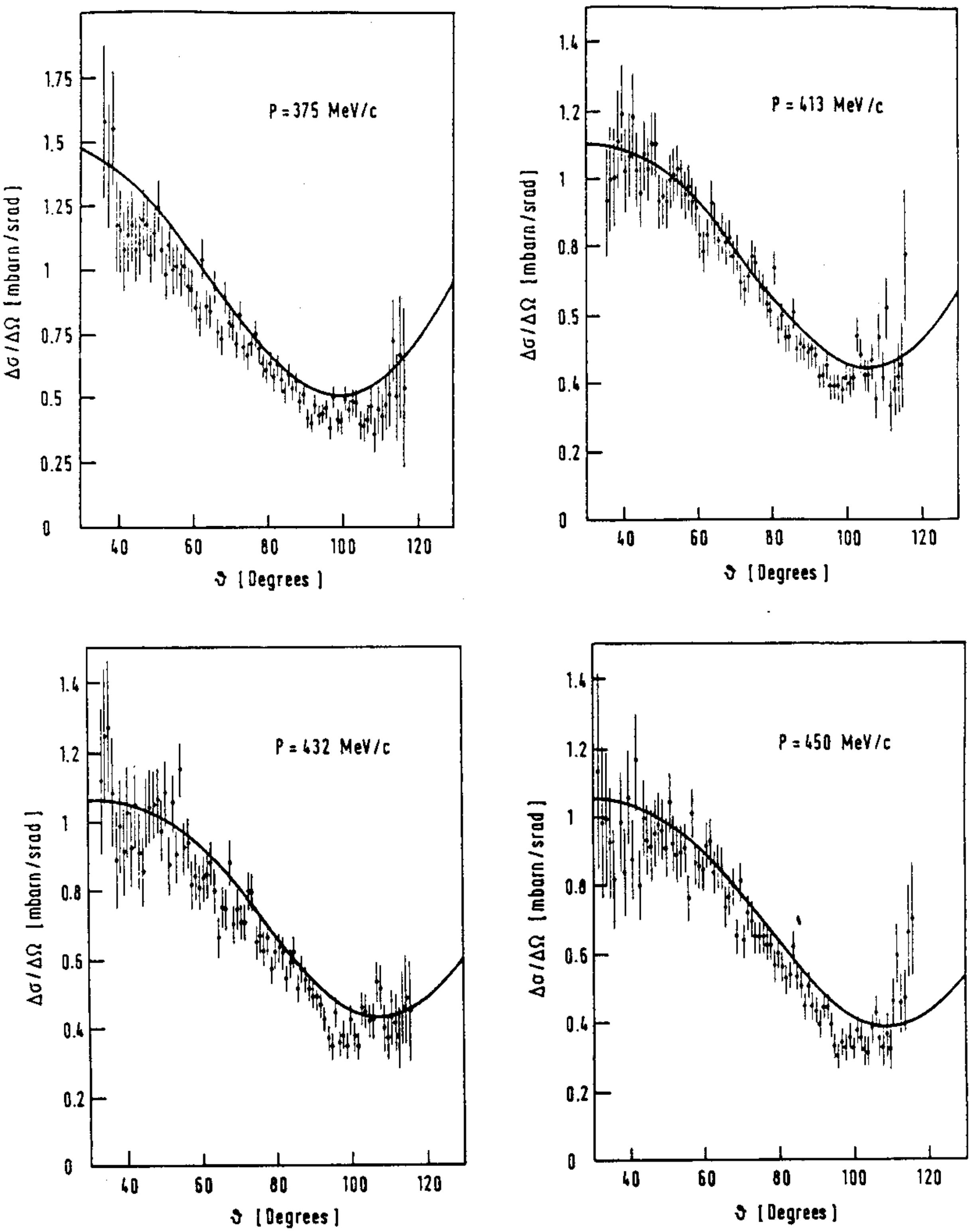


Figure 2. Differential cross-section for π^-p elastic scattering at different incoming pion momenta. Error bars include statistical errors on measured and simulated data. Solid curves represent results of phase shift analysis of Koch and Pietarinen [7].

caused by nuclear interactions and Rutherford scattering of particles in target walls. The error bars represent the statistical uncertainities on measured and simulated data. As can be seen from fig. 2. the agreement between measured differential cross-sections and results from phase shift calculations of Koch and Pietarinen [7] is very good in the whole range of angles and incoming pion momenta covered by this experiment.

The major contribution to systematic errors was the uncertainity on the number of incident pions. The number of muons in the beam and Čerenkov efficiency for electrons yields an error of 1.5% and 2%, respectively. The efficiency of track-finding of beam tracks was known with an accuracy better than 1.5%. Other sources of systematic errors considered were those on the hydrogen density in the target (< 0.5%) and uncertainities in calculating the number of lost events due to Rutherford scattering and nuclear interactions in target walls (< 1%). Various contributions were considered uncorrelated and added in quadrature which resulted in a total systematical error of 3%.

4. CONCLUSIONS

We have performed a full-kinematics and high-statistics measurement of $\pi^- p$ elastic scattering at nine incoming pion momenta ranging from 295 to 450 MeV/c. The differential cross-sections cover the CMS proton scattering angles between 40°c and 120° with an angular resolution of approximately 2°. The preliminary results are in very good agreement with the results of phase shift analysis. The statistical error is mainly due to the lack of simulated data and is expected to be improved to approximately 2%.

REFERENCES

[1] Pion Nucleon Scattering: 1)Tables of Data, 2)Methods and Results of Phenomenological Analysis, G. Höhler (ed. H. Schopper), Landolt-Börnstein New Series Volumes **I/9 b1** (1982), **I/9 b2** (1983), Springer - Verlag, Berlin.

[2] J.T. Brack, J.J. Kraushaar, J.H. Mitchell, R.J. Peterson, R.A. Ristinen, J.L. Ullmann, D.R. Gill, R.R. Johnson, D. Ottewell, F.M. Rozon, M.E. Sevior, G.R. Smith, F. Tervisidis, R.P. Trelle, E.L. Mathie, Phys. Rev. **C34** (1986) 1771.

[3] P.J. Bussey, J.R. Carter, D.R. Dance, D.V. Bugg, A.A. Carter, A.M. Smith, Nucl. Phys. **B58** (1973) 363.

[4] G. Kernel, D. Korbar, P. Križan, M. Mikuž, F. Sever, A. Stanovnik, M. Starič, D. Zavrtanik, C.W.E. van Eijk, R. Hollander, W. Lourens, S.A. Clark, J.D. Davis, N.W. Tanner, E.G. Michaelis, S.M. Playfer, J. Lowe, J.V. Jovanovich, Nucl. Instr. and Meth. **A244** (1986) 367,
P. Križan, G. Kernel, F. Sever, Nucl. Instr. and Meth. **A248** (1986) 451.

[5] D. Zavrtanik, F. Sever, M. Pleško, M. Mušič, G. Kernel, N.W. Tanner, E.G. Michaelis, A. Stanovnik, Nucl. Instr. and Meth. **A227** (1984) 237.

[6] G. Kernel, P. Križan, M. Mikuž, A. Stanovnik, D. Zavrtanik, C. Engster, E.G. Michaelis, A.G. Zephat, J. Harvey, K.O.H. Ziock, Nucl. Instr. and Meth. **A214** (1983) 273,

[7] R. Koch, E. Pietarinen, Nucl. Phys. **A336** (1980) 331.