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MEASUREMENT OF PARITY VIOLATION IN PROTON-PROTON SCATTERING AT 13.6 MeV[1]

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Résumé - Nous avons mésuré le pouvoir d'analyse longitudinal $A_z = 1/P_z\ (\sigma^+-\sigma^-)\ /\ (\sigma^++\sigma^-)$ de la diffusion elastique proton-proton. L'énergie moyenne du faisceau était 13.6 MeV. Le résultat de plusieurs expériences donne $A_z = -(1.5 \pm 0.5)\ 10^{-7}$. Les erreurs systématiques sont supprimées en utilisant des techniques de correlation et du contrôle automatique. Les données brutes sont analysées en utilisant la régression multilinéaire. Cette méthode donne la plupart des erreurs systématiques et les corrections.

Abstract - At the Bonn Isochronous Cyclotron the longitudinal analyzing power $A_z = 1/P_z\ (\sigma^+-\sigma^-)\ /\ (\sigma^++\sigma^-)$ in proton-proton scattering is measured at 13.6 MeV. A_z is found to be : $A_z = -(1.5 \pm 0.5)\ 10^{-7}$. Systematic errors are suppressed by correlation techniques in the time domain and by automatic controls. A multilinear regression determines, by analyzing the noise of the system, the relevant systematic error contributions and corrects A_z for these contributions.

1 - INTRODUCTION

The existence of the parity violating longitudinal analyzing power A_z in proton-proton scattering clearly indicates the presence of the strangeness conserving ($\Delta S = 0$) purely hadronic part of the weak interaction. The quantity $A_z = 1/P_z\ (\sigma^+-\sigma^-)\ /\ (\sigma^++\sigma^-)$ is the relative difference of the proton beam helicity dependent cross sections σ^+ and σ^-, normalized to the longitudinal mean polarization P_z. Since for the purely hadronic part of the weak interaction the existence of neutral currents has not been proven unambiguously /1/, more independent and precise measurements should be performed.

The most precise measurement /2/ yielded at 45 MeV $A_z = -(1.5 \pm 0.22)\ 10^{-7}$. At 15, 45, 800 and 5100 MeV A_z was measured to be $-(1.7 \pm 0.8)\ 10^{-7}$ /3/, $-(1.63 \pm 1.03)\ 10^{-7}$ /4/, $+(2.4 \pm 1.1)\ 10^{-7}$ /5/ and $+(26 \pm 7)\ 10^{-7}$ /6/ respectively. A prediction /7/ using the "best" weak meson nucleon coupling constants of ref. /8/ and the one boson exchange Bonn potential yielded $A_z(13.6\ \text{MeV}) = -1.5\ 10^{-7}$. Another calculation /9/ yielded $A_z(13.6\ \text{MeV}) = -1.7\ 10^{-7}$. From the measurement in ref. /2/ at 45 MeV and the $\sqrt{E}$ energy dependence of A_z at low energies /10/ A_z at 13.6 MeV is extrapolated to be: $A_z = -(0.8 \pm 0.1)\ 10^{-7}$. This discrepancy gives an additional reason to measure A_z in proton-proton scattering at low energies.

Since the quantity of interest is of the order of 10^{-7}, special care has to be provided to find all relevant systematic errors and correct for them. Since σ^+ and σ^- cannot be measured simultaneuously, the definition of A_z suggests a correlation experiment in the time domain. In order to have a clear signature of A_z, all correlated changes of the proton beam phase space density distribution with the proton beam helicity have to be kept small. In case of the beam intensity, position- and

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angle deviations automatic controls care for stable conditions and reduce correlated changes.

The remaining correlated changes of the beam properties like intensity, position and angle, and other parameters like beam width, energy, polarization and position-polarization moments are measured with high precision by secondary electron monitors (SEM) /11/ or beam profile scanners (BPS) /12/ (cf. Fig. 1). These devices derive their signals whenever possible directly from measured currents with the underlying statistics of the incident proton beam.

The precision of this method allowed to deduce the corrections from the remaining fluctuations of the beam parameters by means of a multilinear regression analysis, since these fluctuations contain all informations of the relations among the measured quantities. Thus, all sensitivities and corrections of A_z with respect to helicity correlated modulations of the measured quantities are determined at the "operating" point of the experiment. Special measurements with artificially enhanced error amplitudes of specific beam parameters like for instance intensity, position- or angle modulations are only performed for control purposes.

2 - EXPERIMENTAL SET-UP

The polarized beam is prepared by the polarized ion source (P) with the ECR-ionizer (E) (cf. Fig. 1) and accelerated by the Bonn Isochronous Cyclotron (C) to 14.5 MeV. The longitudinal polarization is tuned by means of the polarized ion source, the Wien filter (W), the solenoid (So) the bending magnet A4 and the x-y polarimeter (POL). The secondary electron monitors SEM1/2 and the steering magnets SV1/2 and SH1/2 are part of a feedback system that stabilizes the position of the beam to a fraction of a µm. The SEM1/2 are comprised of two foils the first foil being split horizontally and the second one vertically. Since the slits of the SEM1/2 have a finite width of approximately 0.1 mm, the sums of the left and right SEM foil or up and down foil respectively are sensitive to the beam width. Moreover, the SEM current is about inversely proportional to the kinetic energy of the impinging protons. Therefore, a non-split SEM3 was implemented to disentangle these dependencies. The position and shape of the beam is determined independently by x/y beam profile scanners at two positions (BPS1/2), providing intensity- as well as polarization profiles. The beam intensity is measured with a Faraday Cup.

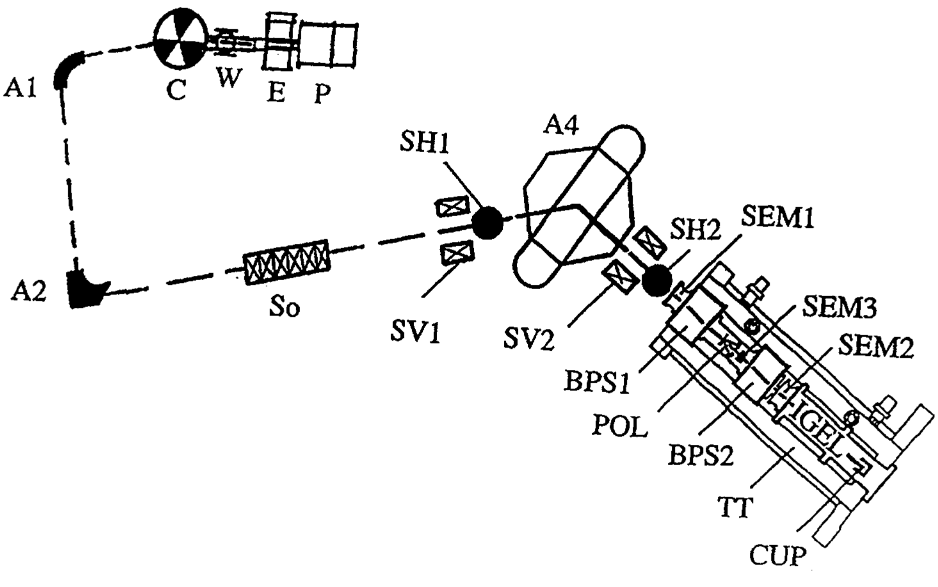

Fig. 1 - The experimental set-up (not on scale), showing the polarized ion source (P) with the ECR-ionizer (E), the Wien filter (W), the Cyclotron (C), the bending magnets A1, A2, and A4, the spin-precession solenoid (So), the horizontal and vertical fast steering magnets (SH, SV), the secondary electron monitors (SEM), the beam profile scanners (BPS), the x/y polarimeter (POL), the adjustable target table (TT), the target detector system (IGEL) and the Cup.

The combined target-detector system IGEL is filled with 12 bar hydrogen gas. Protons scattered in the target enter one of four (left, right, up, down) ionization chambers which surround the target volume of interest. In order to provide sufficient statistics the ionization chambers operate in current mode.

The currents provided by the SEM, BPS, detector and cup are converted to frequencies and integrated by 100 MHz CAMAC scalers. An on-line computer sorts these data according to the polarization state of the source, which is chosen randomly every 40 ms. Every two hours the solenoid field is reversed, in order to suppress all non helicity-dependent error contributions further.

3 - DATA ANALYSIS

During one week runtime some 10^6 measurements of A_z are collected. Every 40 ms A_z is measured together with the helicity correlated changes of the following parameters : i) the beam intensity measured by the cup current, ii) the beam position by the left/right (L/R) and up/down (U/D) asymmetries of the SEM1, SEM2 and the detector currents, iii) the width by the (L+R or U+D) sums of the currents of the SEM1 and SEM2, and iv) the energy by the SEM3 output current.

By means of a multilinear regression A_z is corrected for helicity correlated parameter changes. The relevance of these parameters has been determined by F-tests. All data are analyzed by the same set of n parameters. The multilinear regression analysis provides a symmetric correlation matrix C which consists of the $(n^2 - n) / 2$ correlations among these parameters. If there are significant correlations, the resulting error of A_z is reduced by the amount of $(R^2 - 1)^{1/2}$, with R being the usual multilinear regression coefficient. In addition, large elements of C point out how the experimental set-up or the tuning of the beam can be improved. An example is given in table 1.

Table 1
Example of a correlation matrix C

	SEM1 O/U	SEM1 L/R	SEM2 O/U	SEM2 L/R	Detector O/U	Detector L/R	Cup	SEM1 -SUM	SEM2 -SUM
SEM1-O/U	1.00								
L/R	−0.10	1.00							
SEM2-O/U	0.03	−0.11	1.00						
L/R	−0.04	0.30	0.03	1.00					
Det. - O/U	0.03	−0.02	0.21	0.02	1.00				
L/R	−0.06	−0.02	0.01	0.36	−0.04	1.00			
Cup	−0.24	−0.01	−0.19	−0.06	−0.06	−0.01	1.00		
SEM1-SUM	0.06	−0.04	−0.07	−0.01	−0.08	0.08	0.03	1.00	
SEM2-SUM	0.11	0.02	−0.09	0.02	−0.06	0.03	0.04	0.80	1.00

The matrix can be interpreted as follows: A coupling of the asymmetries of the detector and the SEM2 is evident. A coupling of the SEM1 with the SEM2 exists only horizontally. The cup-current increases if the beam moves down at the position of SEM1. This was a problem of a parasitic beam, hitting the entrance aperture of the detector. The information of the sums of the SEM currents is redundant (as it should be).

Other sources of systematic errors have been explored by separate experiments or with special analysis methods. A list of these error contributions is shown in table 2.

4 - RESULTS

During 6 different running periods about 600 runs have been accumulated. The result is presented in table 2.

Table 2
Summary of data, corrections and limits on systematic error contributions for A_z (in units of 10^{-7})

"Raw" asymmetry[a] A_z:	-1.95 ± 0.45
Corrections deduced from the multilinear regression analysis:	0.46 ± 0.29
Corrected asymmetry A_z:	$-1.49 \pm 0{,}54$
Limits on systematic effects (1σ)	
- Electronic crosstalk	0.05
- Background due to beam-target scattering	0.05
- Double scattering	0.037
- Uncertainty in beam polarization	0.03
- Beta decay asymmetry	0.01
- Gas impurities	0.001
- Gasheating	0.001

[a]Mean and standard deviation of measured asymmetries

This result is in good agreement with recent theoretical predictions of ref. /7/ and /9/ and in bare agreement with the extrapolation from the measurement at 45 MeV in ref. /2/.

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