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SPIN PHYSICS AT LEAR

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1. Introduction

This talk will focus on the most recent results on spin observables in $N\bar{N}$ scattering as measured at LEAR. The LEAR data are unique, and constitute a major step forward in our knowledge of $N\bar{N}$ interaction. Since the reaction $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ is covered in a different talk, I will speak only of the $\bar{p}p \rightarrow \bar{p}p$ elastic and $\bar{p}p \rightarrow \bar{n}n$ charge-exchange channels, and I will also show some new preliminary results for the last reaction.

After a brief review of the physics objectives of this field, I will illustrate all the work which has come out of LEAR. For completeness I will comment also on the scattering data with unpolarized particles, but clearly I will focus mostly on the new data on spin observables. In the final part of this talk I will try to compare the experimental finding with theory, and I will comment on the theoretical work which is going on. Of course, I would have by far preferred that these final comments be done by R. Vinh Mau, as originally anticipated in the Scientific Program of the conference, but he is not here and I feel authorized to proceed.

By now many reviews exist on the LEAR results¹⁾, and the Proceedings of the many LEAR Workshops²⁾ constitute the best reference for this activity. I myself have reviewed the field recently^{3,4)}, so necessarily what I will say is not very different from what I said last year in Stockholm or in Paris. Still, I have to stress a major difference, namely in this talk I will not mention perspectives, or future outlook. Following the recommendations of the Cogne Meeting in September '90 to give low priority to $N\bar{N}$ reaction dynamics studies, the CERN SPSLC Committee has not approved the new measurements which had been proposed⁵⁾, which were

- a. Measurement of A_{0n} for $\bar{p}n \rightarrow \bar{p}n$;
- b. Measurement of K_{k00k} for $\bar{p}p \rightarrow \bar{n}n$;
- c. Measurement of D_{0n0n} for $\bar{p}p \rightarrow \bar{p}p$;
- d. Measurement of $\Delta\sigma_T$ for $\bar{p}p$.

This means that no new information can be expected in the near future, and all we can conclude in this field must be inferred from the data which have already been taken and which I am about to review.

2. Physics Objectives

To study the $N\bar{N}$ interaction at low energy it is common practice to consider separately the long-range and the short-range parts of the interaction (see Fig. 1). At large distances the interaction is believed to proceed via exchange of mesons, and the traditional nuclear physics description of the antinuclear force⁶⁾ is generally considered to be adequate. At short distance the dominant process is annihilation which can be correctly described only involving microscopic degrees of freedom. Since the nucleons are not point-like particles, annihilation occurs at distances comparable to the nucleon r.m.s. charge radius, or to the quark core r.m.s. radius in the nucleon bag. $N\bar{N}$ interaction thus sits at the intersection between nuclear and particle physics and the ambitious goal of the people working in this field is just to provide a bridge between two

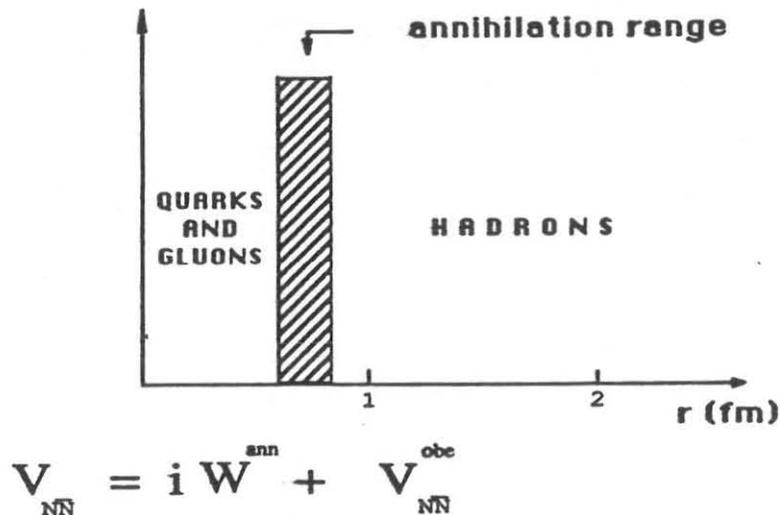


Fig. 1- Hybrid description of the $N\bar{N}$ potential.

well-established and successful theories, i.e. the meson-exchange potential (MEP) models and QCD. Microscopic degrees of freedom probably show up also in other low-energy phenomena: in N-N interaction the observed hard-core repulsion is sometimes interpreted in terms of the Pauli principle at the quark level⁷⁾, and not necessarily as due to the exchange of heavy vector mesons (like ω). In the $N\bar{N}$ system annihilation is a much more violent phenomenon than NN core repulsion, so it is likely that $N\bar{N}$ is better suited to explore distances of the order of ~ 0.5 fm, i.e. the intersection between nuclear and particle physics.

In practice, non-perturbative QCD cannot yet describe annihilation, and QCD-inspired

hybrid models are used. Alternatively, annihilation is treated in baryon exchange models, using the meson-nucleon vertices as determined in the MEP models and annihilation in two mesons as intermediate step. The simplest and most widely used approach is, however to parametrize annihilation with an optical potential⁸⁾, with both real and imaginary part, Wood-Saxon or Gaussian shape, and eventually energy, spin, and isospin dependent.

The long-range part of the interaction can be derived from the MEP model by applying the G-parity rule,

$$V_{\overline{N}N}^{\text{OBE}} = \sum_{i=\pi \rho \omega \dots} G_i V_{NN}^{(i)\text{OBE}}$$

which says that the contribution of odd G-parity mesons should change sign when going from NN to $\overline{N}N$. Thus the $\overline{N}N$ data should allow mainly to determine the parameters of the annihilation potential W^{ann} . In practice the nuclear force resulting from the application of the G-parity rule is quite different from the usual N-N force, and surely it deserves a check of its own. The basic notion here is coherence⁹⁾, i.e. the fact that the contributions of the various mesons add up coherently in some parts of the potential. Owing to the G-parity rule coherence in $\overline{N}N$ occurs in different terms than in NN, which makes the comparison of NN with $\overline{N}N$ interaction quite interesting. In the NN system, scalar (ϵ) and vector (ω) meson exchanges add coherently in the spin-orbit term, while they tend to cancel in the central part of the potential. In the $\overline{N}N$ potentials coherence occurs in the central ($\omega+\epsilon$), tensor ($\pi+\rho$) and quadratic spin orbit contributions. This coherence leads to a strong $\overline{N}N$ attraction, which was the starting point for the predictions for $\overline{N}N$ bound states (baryonium), and which has very striking consequences for the spin observables.

Summarizing, the study of $\overline{N}N$ interaction should allow us

- to check the validity of the MEP model description of the long-range part of the interaction, in particular of the G-parity rule and of the strong coherence among the various meson exchanges
- to determine the global properties of the annihilation potential.

3. Status of LEAR experiments

Table 1 summarizes the contribution of LEAR to $\overline{N}N$ scattering. Most of the results are published by now, and all of the experiments are over. The only experiment which is still on the floor is PS 199, which had its last run in December 1990.

Although I will focus on the measurements of spin-observables, let me just remind briefly the main features of the cross-section data

- the $\overline{p}p$ total cross-section and annihilation cross-section are very smooth with energy, and no narrow peaks are seen, thus confirming the KEK and BNL results demonstrating the non-existence of a narrow "baryonium" peak at 500 MeV/c, the S(1936), previously seen in several experiments.

Table 1

| | Experiment | Measured Momenta (MeV/c) | Reference |
|---|------------|------------------------------------|-----------|
| Cross Sections: | | | |
| $\sigma_{\text{tot}} (\bar{p}p)$ | PS 172 | 220 \rightarrow 600, 74 momenta | 10,11 |
| $\sigma_{\text{ann}} (\bar{p}p)$ | PS 173 | 180 \rightarrow 600, 53 momenta | 12 |
| $\sigma_{\text{tot}} (\bar{n}p)$ | PS 178 | 100 \rightarrow 350 MeV/c | |
| $\bar{p}p \rightarrow \bar{p}p$ Elastic scattering: | | | |
| ρ | PS 172 | 233, 272, 550, 800, 1100 | 13,14 |
| | PS 173 | 181, 219, 239, 261, 287, 505,590 | 15, 16 |
| $d\sigma/d\Omega$ | PS 173 | 181, 287, 505, 590 | 16, 17 |
| | PS 172 | 529 \rightarrow 1550, 15 momenta | 18, 19 |
| | PS 198 | 439, 544, 697 | 20, 21 |
| A_{0n} | PS 172 | 529 \rightarrow 1550, 15 momenta | 18, 19 |
| | PS 198 | 439, 544, 697 | 20, 21 |
| D_{0n0n} | PS 172 | 988, 1089, 1291, 1359 | 22 |
| | PS 198 | 697 | |
| $\bar{p}p \rightarrow \bar{n}n$ Charge exchange: | | | |
| $d\sigma/d\Omega$ | PS 173 | 183, 287, 505, 590 | 23 |
| | PS 199 | 546 \rightarrow 1280, 8 momenta | 24 |
| A_{0n} | PS 199 | 546 \rightarrow 1280, 8 momenta | 24 |
| D_{0n0n} | PS 199 | 546, 875 | |

- the annihilation cross-section at low momenta is about twice the elastic cross-section, indicating that annihilation is not just absorption by a black disc. This is due to the fact that the meson exchange potential is so strong and attractive in the $N\bar{N}$ system, that it pulls the $N\bar{N}$ wave function into the annihilation region, and effectively increases the absorption radius.
- the differential cross-sections have been measured with good precision down to low momenta (180 MeV/c) both in the elastic and in the charge-exchange channels. The main feature of the elastic channel is the strong P-wave enhancement (again due to the strong $N\bar{N}$ nuclear potential), which manifests itself as the forward peak present even at the lowest energies.

Fig. 2 shows typical differential cross-sections for the elastic and the charge-exchange channel at two momenta.

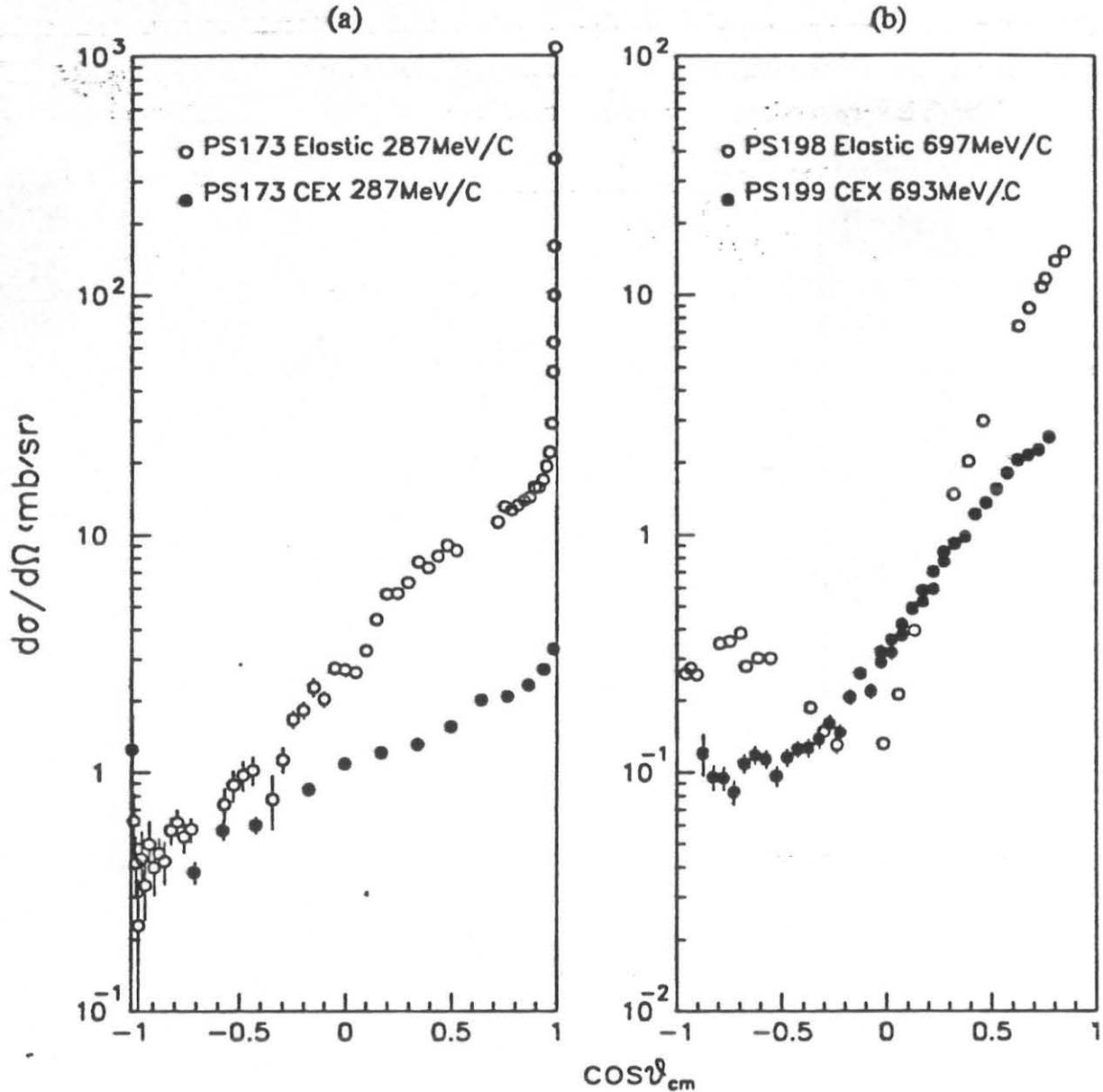


Fig. 2 - Differential cross-section for $\bar{p}p \rightarrow \bar{p}p$ elastic (open points) and $\bar{p}p \rightarrow \bar{n}n$ charge-exchange (full points) as measured from Experiment PS173 at 287 MeV/c (a), and from PS198 and PS199 at about 695 MeV/c (b).

4. Comparison with theory

All the cross-sections data in Table 1 can be described surprisingly well by a variety of potential models: apart from the original Bryan and Phillips model, popular names are the Bonn model²⁵⁾, the Dover-Richard²⁶⁾ model (in its two versions), the Dalkarov-Myhrer²⁷⁾ model, the Kohno-Weise²⁸⁾ model, the Nijmegen model²⁹⁾, and the Paris model³⁰⁾. All these models differ either in the parametrization of the boson exchange part or in the treatment of annihilation (or in

both ingredients), but the predictions for the cross-sections are rather stable, which is an indication that the $N\bar{N}$ process is dominated by absorption. As an example Fig. 3 compares cross-section data and calculations with the Khono-Weise model: a local and state independent annihilation potential was used, and a fit to the data allows to fix the annihilation parameters. The quality of the fit is very good, as apparent from the figure.

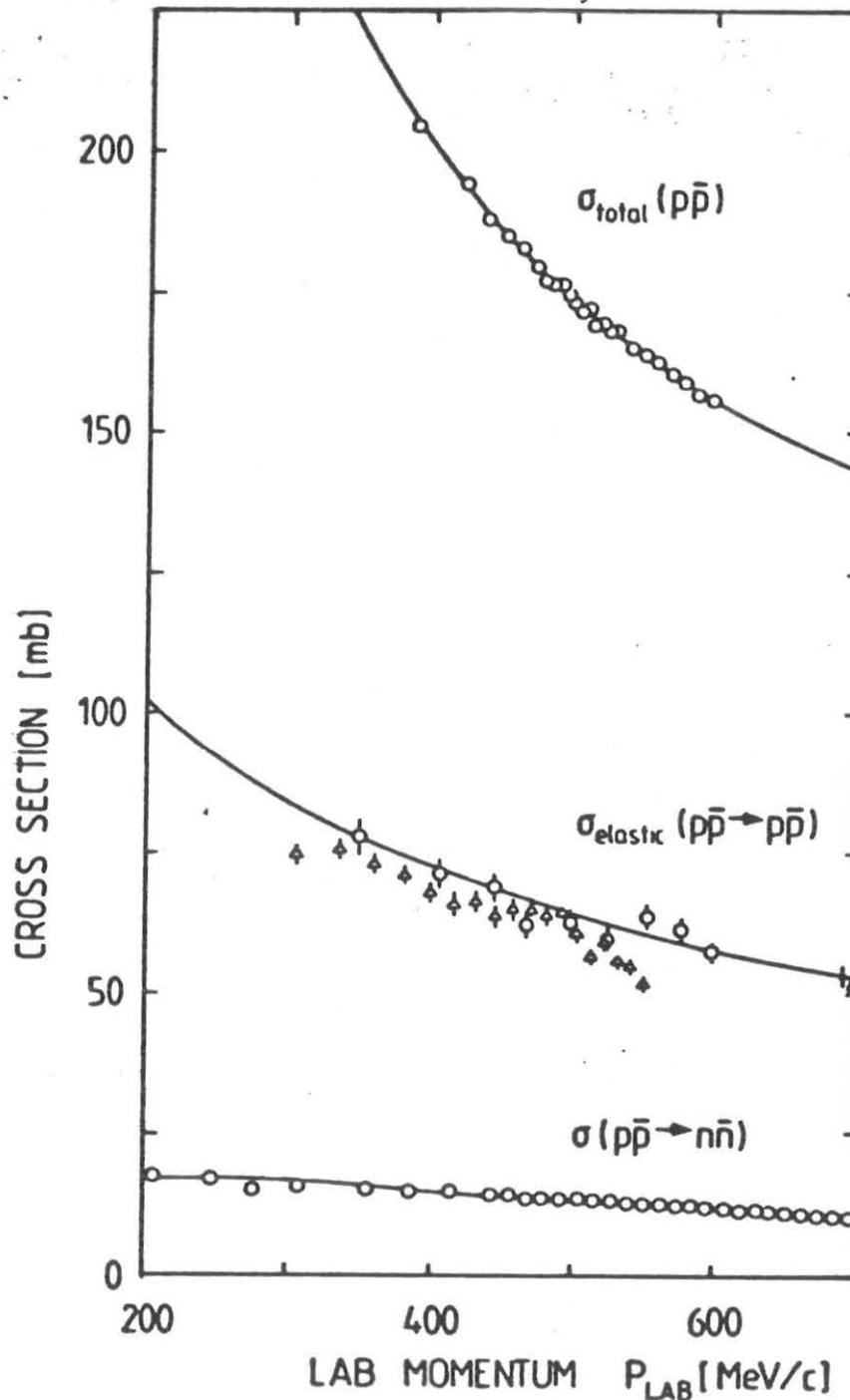


Fig. 3 - Total, elastic, and charge exchange $\bar{p}p$ cross-sections as a function of \bar{p} laboratory momentum. For references and details of the calculation see Ref. 28.

Actually, to fit the cross-section data, the MEP model does not need a high degree of sophistication: only π -exchange and a suitably parametrized annihilation potential, with an annihilation radius of ~ 0.8 fm, already give a satisfactory description of the data. For instance, a Wood-Saxon type annihilation potential, with

$$\text{Re } V_{\text{ann}} = \frac{-c_0}{1 + \exp[(r-r_0)/a_0]}, \quad \text{Im } V_{\text{ann}} = \frac{-c_1}{1 + \exp[(r-r_1)/a_1]},$$

and no energy, spin, or isospin dependence, already gives very good fits with $c_0 = c_1 = 500$ MeV, $r_0 = r_1 = 0.74$ fm, and $a_0 = a_1 = 0.2$ fm³¹).

The conclusion is that cross-sections data are only sensitive to the gross features of the interaction, namely to the strength and to the range of the potential describing the annihilation. To learn about the details of the interaction more sophisticated data are needed, i.e. data on spin observables.

5. The elastic $\bar{p}p$ channel

The analyzing power A_{0n} has been measured over most of the angular range by experiment PS172¹⁸) at fifteen momenta, ranging from 530 to 1550 MeV/c. The measurements are shown in Fig. 4 and compared with the predictions of the Dover-Richard model (up to 1 GeV/c) and of the Paris model. At momenta large than 1 GeV/c, the Paris model reproduces the trend of the data surprisingly well. At low momentum the agreement is not too good. Experiment PS198 has measured A_{0n} over the entire angular range at 497, 523 and 697 MeV/c. The data at the two lowest momenta are shown in Fig. 5, together with previous data from experiment PS172 and predictions from the Paris, the Dover-Richard, and the Nijmegen models. The agreement between the two sets of experimental data is good.

The analyzing power exhibits a lot of structure with angle and momentum, and the trend of the data at these low energies is reproduced satisfactorily by the model, apart from the very backward direction. The most remarkable feature of the data is the very large positive polarization observed in the forward hemisphere. This can be accommodated by $V_{\bar{N}N}^{\text{OBE}}$ alone, and can be interpreted as another manifestation of coherence among the various meson exchanges, as stressed in Ref. 32). This does not imply that W^{ann} has no spin dependence: it is just an illustration of the fact that $V_{\bar{N}N}^{\text{OBE}}$ has enough spin dependence to generate large polarization effect in $\bar{p}p$ elastic scattering. As pointed out by Dover and Richard, unlike the pp case, the polarization is due to the tensor component of the potential (V_T), and practically not at all to the spin-orbit one (V_{LS}), as illustrated in Fig. 6 from Ref. 32. In the backward direction, the polarization is very model-dependent, and a more sophisticated analysis is needed.

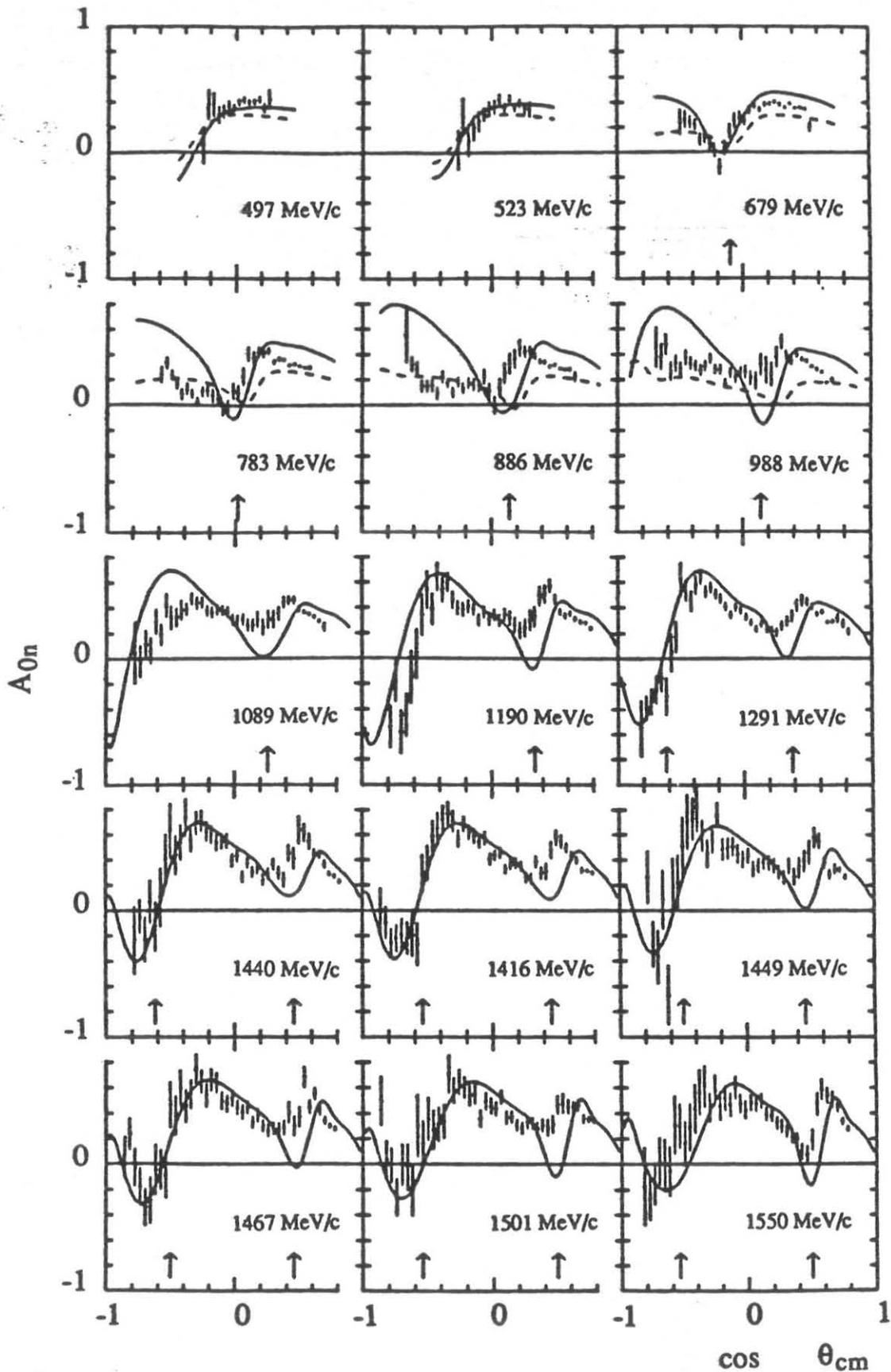


Fig. 4 - Analyzing power for $\bar{p}p$ elastic scattering at fifteen momenta from experiment PS172. The dashed and full curves are predictions from the Dover-Richard²⁶⁾ and Paris³⁰⁾ models respectively.

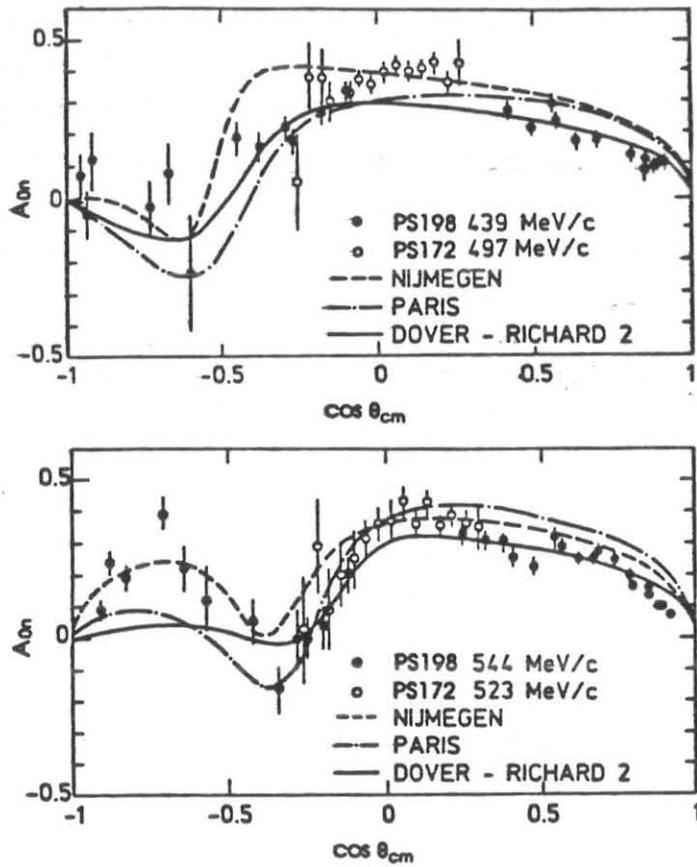


Fig. 5 - Analyzing power for $\bar{p}p$ elastic scattering at two momenta from experiments PS172 and PS198. The curves are predictions from potential models, Dover-Richard²⁶⁾, Paris³⁰⁾ and Nijmegen²⁹⁾.

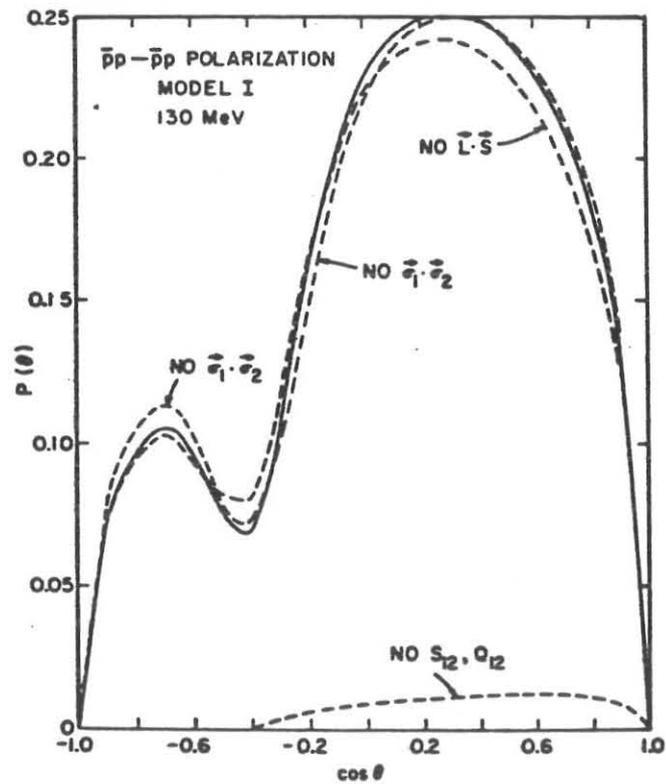
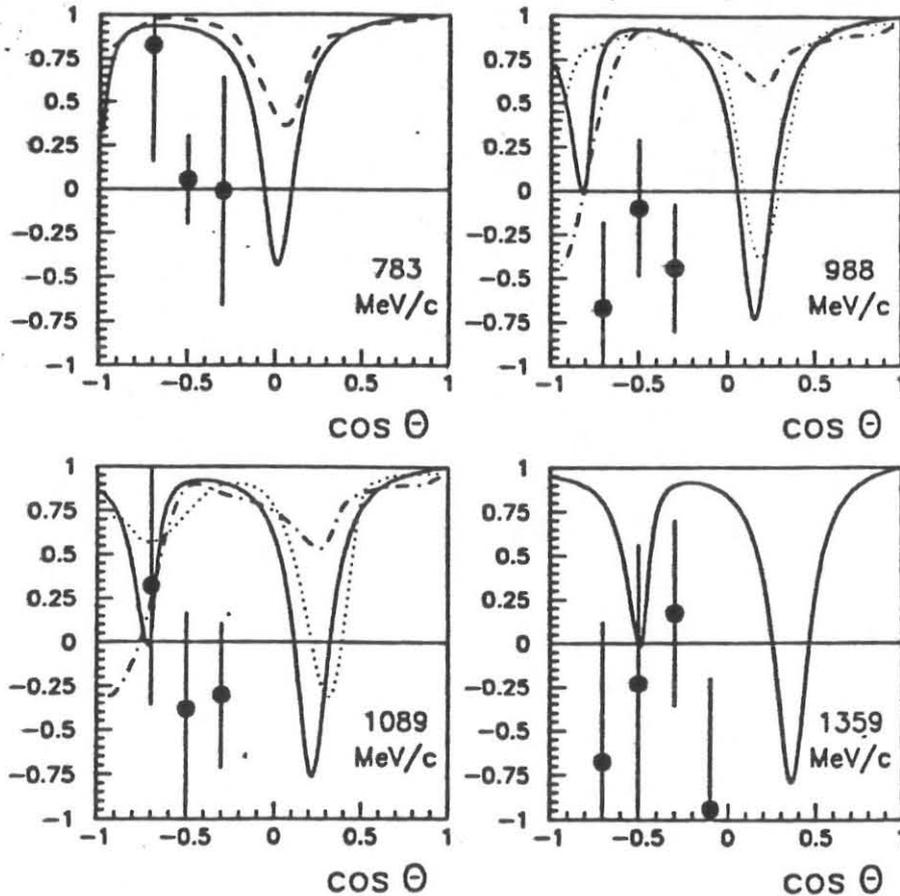


Fig. 6 - A_{0n} for $\bar{p}p \rightarrow \bar{p}p$ at 600 MeV/c as computed with the Dover-Richard model³²⁾.

By analyzing the polarization of the scattered proton with a carbon polarimeter, experiment PS172 could obtain some D_{0n0n} data in the backward hemisphere and in the higher momentum range (from 1000 to 1550 MeV/c). Some of these data²²⁾ are shown in Fig. 7: although the error bars are large, the result is interesting because it suggests either zero or negative values for D_{0n0n} (except at 1291 MeV/c), while the potential models would like this parameter to be close to 1. Data on D_{0n0n} have been collected also by experiment PS198 at 700 MeV/c, but the analysis is still in progress.



Fi. 7 - D_{0n0n} as a function of $\cos\theta_{cm}$ for four momenta. The curves are the predictions of the relativistic Dover-Richard I model (solid line)²⁶⁾, the Bonn model (dashed line)²⁵⁾, the Nijmegen model (dashed-dotted line)²⁹⁾ and the Paris model (dotted line)³⁰⁾.

6. The charge exchange channel

At variance with the elastic channel, where several measurements (even of polarization!) existed even before LEAR, the charge exchange channel was known very poorly. In particular, no measurements existed of the Analyzing Power. This situation was a consequence of the fact that this channel is more difficult to measure experimentally, due to the smallness of the cross-section, to the presence of two neutral particles in the final state and to the necessity of distinguishing the neutron from the antineutron.

The knowledge of the charge exchange channel is essential to resolve the isospin structure of the $N\bar{N}$ interaction. In contrast to the pp case, the $\bar{p}p$ system is not a pure isospin state. The amplitude for $\bar{p}p$ elastic is given by the sum of the $I=0$ and the $I=1$ amplitudes, while the $\bar{p}p \rightarrow \bar{n}n$ charge-exchange amplitude is given by the difference of the two. Clearly a complete analysis of the system requires the measurements of the two channels.

The charge-exchange reaction is expected to be a particularly sensitive channel to probe the nucleon-antinucleon force. The long range part of the interaction should be dominated by pion exchange, a well known "classical" term in any boson exchange potential model, and the fact that $I=1$ only is exchanged in the t -channel reduces the number of relevant exchanges. This well known exchange term can thus be used to probe the annihilation potential, at least to distances (~ 0.8 fm) where absorption becomes dominant, and determine possibly its spin and isospin dependence.

Experiment PS199 has measured the analyzing power in the charge-exchange reaction at eight \bar{p} beam momenta, ranging from 600 to 1300 MeV/c, in steps of 100 MeV/c, and the spin parameter D_{0n0n} at two momenta 600 and 900 MeV/c, using a solid polarized target; the measurements of the differential cross-section can be obtained from the same data. I will not mention the measurement of D_{0n0n} which is the subject of a contributed talk³³), and will concentrate on the measurement of A_{0n} .

To fully exploit the polarized target both the n and the \bar{n} produced in the reaction, are detected, and the events on the polarized free hydrogen of the target are identified using time of flight, coplanarity and angular correlation information. Also, a complete n/\bar{n} separation is achieved, to unambiguously determine the scattering angle.

The layout of the experiment is shown in Fig. 8. NC_1 , NC_2 and NC_3 are the neutron detectors, (scintillator counter hodoscopes), and ANC_1 and ANC_2 are the \bar{n} detectors, modular structure made up of limited streamer tubes (LST) planes, scintillator counter hodoscopes and iron slabs³⁴). The dashed line indicates the \bar{p} beam direction. The target sits in the nose of 1 m long cryostat (shown in the figure, together with the polarized target magnet (PTM)) and to reach the target the beam travels along its axis. For background evaluation and calibration purposes also a dummy target (DT) and a liquid hydrogen target (LHT) were used.

A rather complete description of the experimental apparatus can be found in the literature²⁴), and will not repeated here. I will just point at the main characteristics of the experiment, which are

- high target polarization ($\sim 80\%$);
- quick polarization reversal ($\sim 1\frac{1}{2}$ hour);
- high rate capability: the LEAR beam was used to its full intensity ($2 \times 10^6 \bar{p}$'s/sec);
- complete n/\bar{n} separation: the probability of misidentifying a neutron as an antineutron was measured to be less than 10^{-4} ;
- absolute measurement of efficiency of both NC and ANC detectors: the special

- configuration of Fig. 8 allowed the use of the associated particle method for calibration purposes;
- while taking data for A_{0n} , one could collect simultaneously \bar{n} -double scattering events, i.e. events in which the \bar{n} scattered on the H nuclei of the NC counters. As explained in Ref. 33, these data could allow the measurement of K , the spin transfer parameter of the reaction.

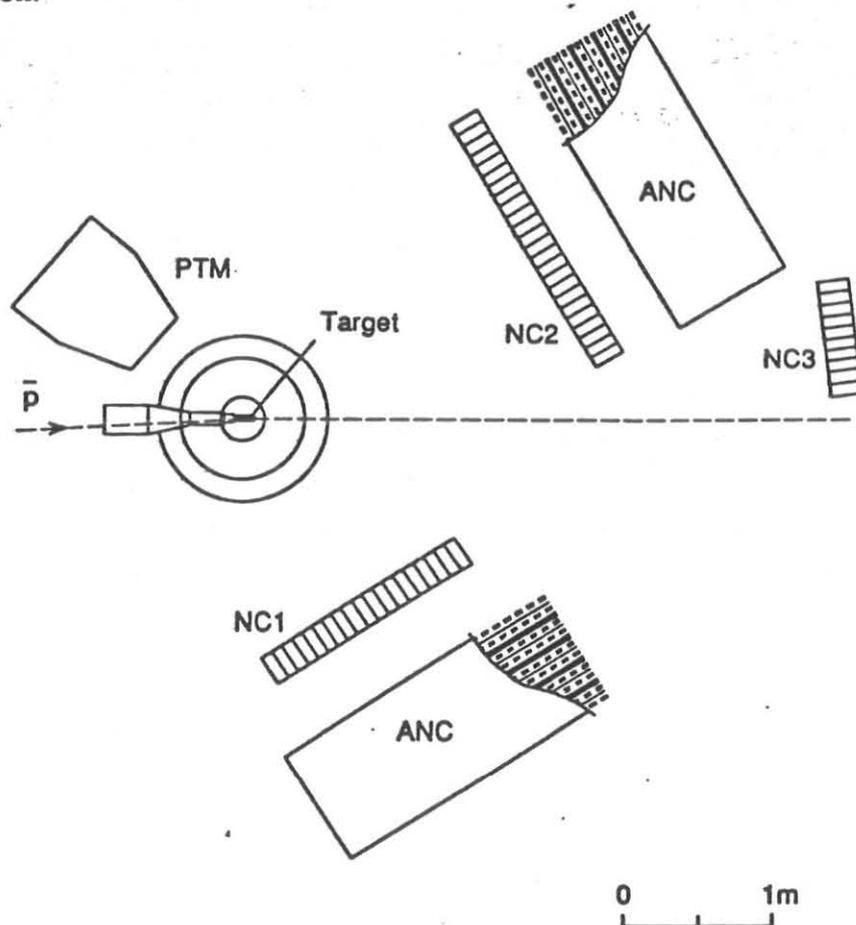


Fig. 8 - Schematic layout of experiment PS199: NC labels the neutron counter hodoscope, ANC the antineutron detectors.

The charge exchange events on free hydrogen have been selected requiring an \bar{n} candidate in one of the ANC and a neutron candidate in the corresponding NC counter, and applying 2σ cuts in coplanarity, angular correlation, and n and \bar{n} time-of-flight. The residual background is estimated using the DT data.

Fig. 9 shows the measured analysing power at 656 MeV/c, the mean \bar{p} momentum in the PT when the beam was 700 MeV/c. The results are already published²⁴⁾, and exhibit a remarkable angular dependence, reaching quite large positive values both in the forward and in the backward regions. Also shown in Fig. 9 are the predictions of some potential models: apart from the model of Ref. 27, the agreement between data and models predictions is not too good, and I will comment on this point in the next paragraph.

Asymmetry

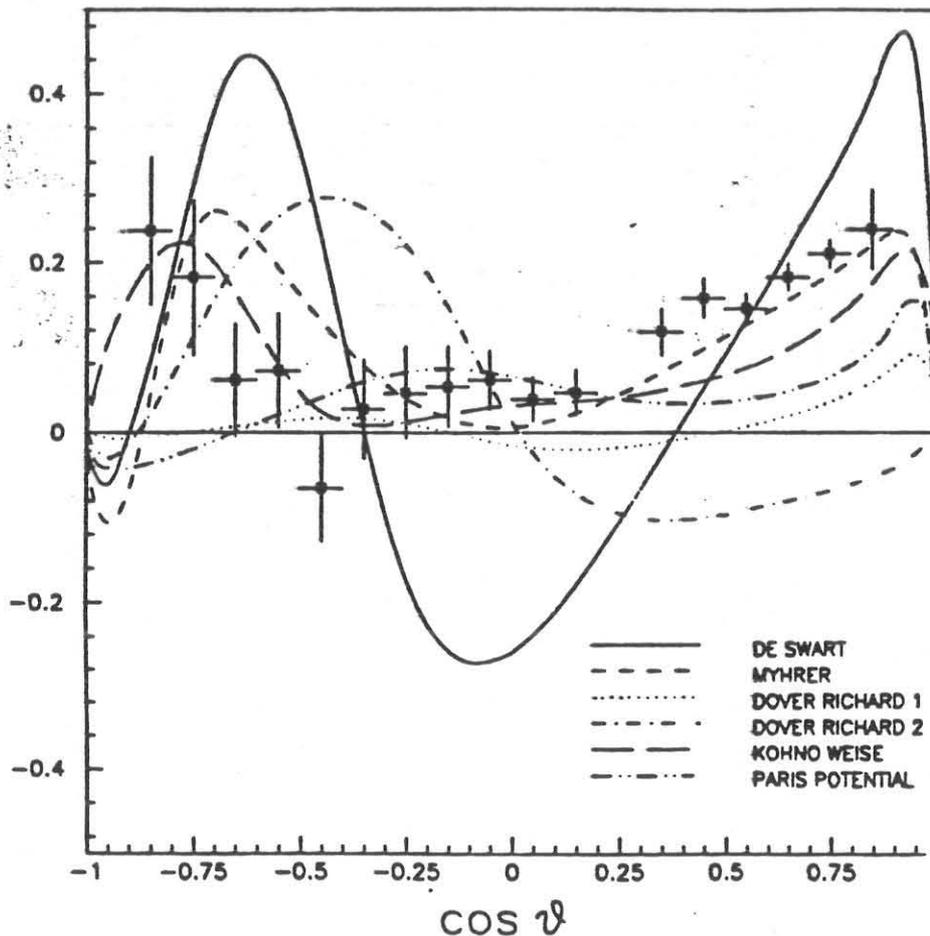


Fig. 9 - Analyzing power for $\bar{p}p \rightarrow \bar{n}n$ at 656 MeV/c, as measured by experiment PS199, compared with potential model calculations.

Fig. 10 shows new results obtained in the low-momentum range³⁵). The mean beam momentum in the target is 546, 767 and 875; for comparison also shown in the figure are the old A_{0n} data obtained at 656 MeV/c. The new results are still preliminary, but the analysis is almost finished, and the final numbers will not differ significantly from those in the figure. The main feature of the new data is again the large positive value of the Analyzing Power in the forward hemisphere. At 546 MeV/c the polarization is larger than at 656, and it decreases with increasing incident momentum, but rather slowly; at 875 it is still larger than 0.10. The data at 546 MeV/c look very similar to those at 656, but the error bars are considerably smaller, due the larger cross-section and to some improvements introduced in the experiment in the later runs. In particular, they confirm with a very good statistical significance the backward peak already observed at 656 MeV/c.

Also shown in Fig. 10 are the predictions of the model of Ref. 27. While this model, which treats annihilation simply as absorption by a black disc, was in good agreement with the data at 656 MeV/c, there is a clear discrepancy with the higher momentum data.

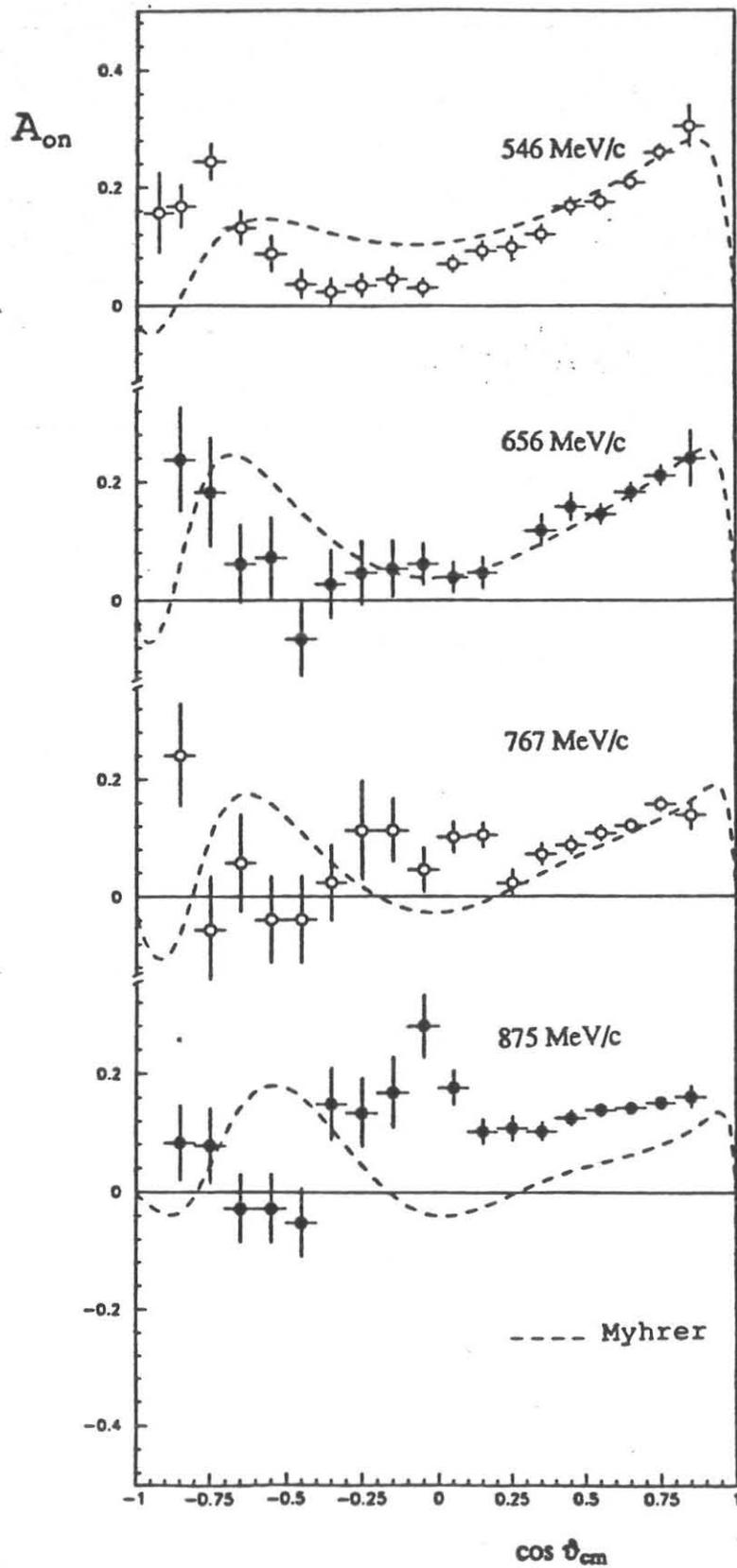


Fig. 10 - Preliminary results³⁵⁾ for the analyzing power of $pp \rightarrow \bar{n}n$, measured at 546, 767 and 875 MeV/c, by experiment PS199, plus the already published results at 656 MeV/c. The dashed curve is the prediction of the model from Ref. 27.

7. Theoretical models revisited

In so far I have compared the data with calculations performed using models which have been put forward several years ago, and notably when accurate measurements of spin observables did not exist. I think it is fair to say that those models give a good account of the bulk features of the interaction, which are rather well understood. Following the original suggestions³⁶⁾ and the later work of Shapiro³⁷⁾, all the unusual phenomena observed, i.e. the P-wave enhancement in $\bar{p}p$ elastic and $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$, the very large annihilation width of the $\bar{p}p$ atomic 2p-state, the very rapid growth of the ratio ρ between the real and the imaginary part of the forward $\bar{p}p$ elastic scattering amplitude, and maybe also the recently found A_x state, are all manifestations of the same $\bar{N}N$ nuclear force, which is expected to be strongly attractive, and where coherence among the various meson exchanges play a fundamental role.

In this respect also the large polarization signal in the $\bar{p}p$ elastic channel in the forward hemisphere can probably be understood, as discussed in paragraph 5, even though a richer model is needed to reproduce all the structures of the data. On the other hand, the physical origin of the polarization signal observed in the $\bar{p}p \rightarrow \bar{n}n$ channel remains a mystery. First of all, as already stressed in Ref. 4), it is somewhat of a surprise that the various predictions differ so much among themselves also in the forward hemisphere, where π -exchange is expected to dominate (see Fig. 9). A possible explanation could come from the fact that, to first order in Born approximation, π -exchange does not contribute to A_{0n} . Polarization is contributed by an $\vec{L} \cdot \vec{S}$ term, which could be generated by a π -exchange only by iteration. Alternatively, a spin-orbit term can be generated to first order by a vector exchange (f.i. ρ). Also, the annihilation potential could contain an $\vec{L} \cdot \vec{S}$ term, but so far it does not seem easy to draw a definite conclusion. In any case, the charge-exchange amplitude is the difference of two large amplitudes, so it is sensitive to small details of the interaction.

Since the time of the Stockholm Conference an effort has been made to understand the new data. The Paris group has undertaken a new fit to the $\bar{N}N$ data base to redetermine the core parameters³⁸⁾. In their model annihilation is inspired by the assumption that it proceeds principally via two mesons channels, and is parametrized as

$$W_{\bar{N}N}^{\text{ann}} = \left[g_c(1 + f_c T_L) + g_{ss}(1 + f_{ss} T_L) \bar{\sigma}_1 \cdot \bar{\sigma}_2 + g_T S_{12} + \frac{g_{LS}}{4m^2} \vec{L} \cdot \vec{S} \frac{1}{r} \frac{d}{dr} \right] \frac{K_0(2mr)}{r}$$

where T_L is the \bar{p} kinetic energy in the laboratory system, K_0 the modified Bessel function, g 's and f 's are the core parameters, and the spin terms have the usual meaning. The MEP is taken to

be the G-parity transform of the PARIS potential for $r \geq 0.9\text{fm}$, and a phenomenological real potential at shorter distances, defined by 6 parameters in each isospin state. All in all, the model contains 24 parameters, twelve for the absorption core and twelve for the phenomenological real potential for $r < 0.9\text{ fm}$. The long-range MEP parameters have been kept fixed in the fit.

The result of the fit is a new set of values for the core parameters, which turn out to differ slightly from the original values of Ref. 30, and a much better agreement between model calculation and data. As an example, Fig. 11 shows the old and the new calculations for the differential cross-section of $\bar{p}p \rightarrow \bar{n}n$ at $490\text{ MeV}/c$: in the forward direction the new fit is much closer to the data.

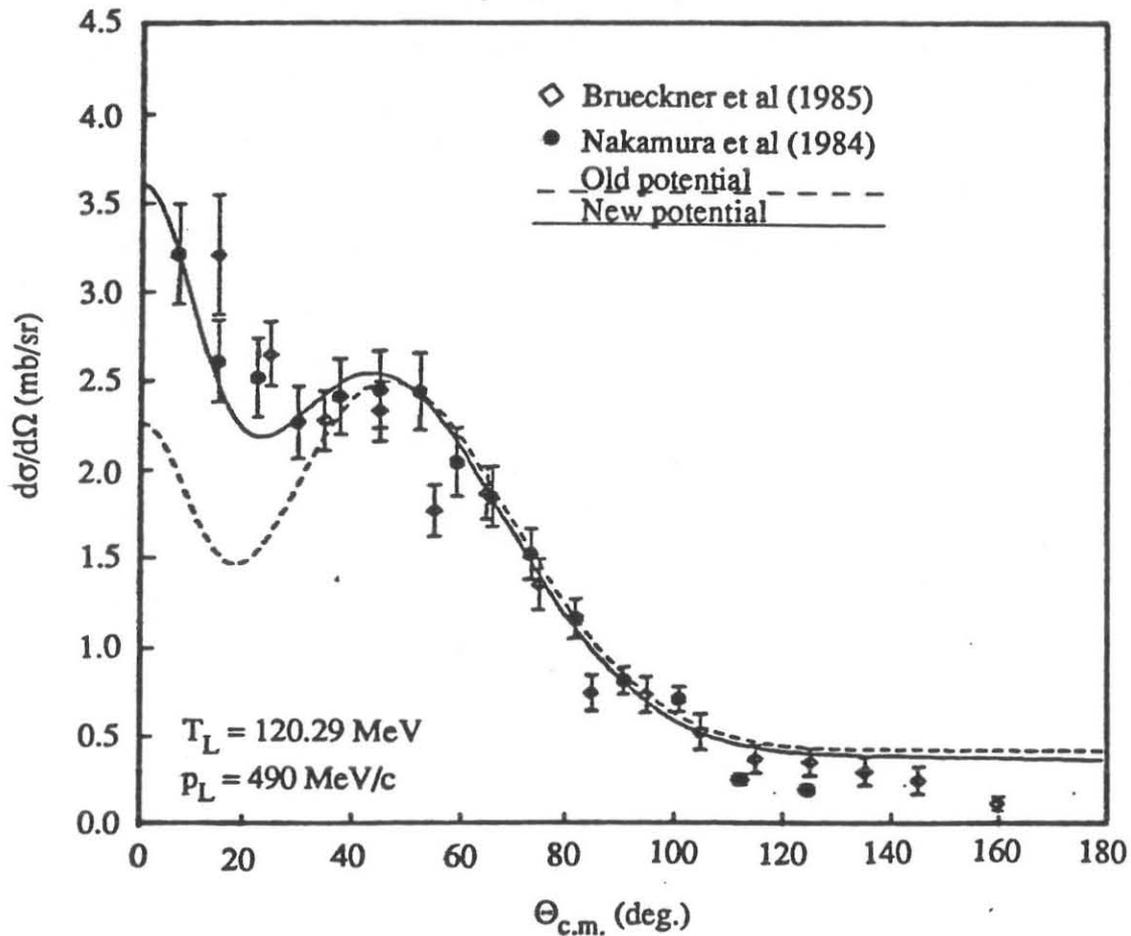


Fig. 11 - Comparison between the $\bar{p}p \rightarrow \bar{n}n$ differential cross-section measured at KEK (Ref. 39) and by Experiment PS173 at LEAR and the Paris model calculations. The dashed line calculation uses the old core parameters, the full line is a recent result after readjustment of the short range part of the potential.

Still, there are pieces of data which cannot be reproduced by the model, notably the charge-exchange differential cross-section data at the very low momentum, and the analyzing power data from experiment PS199, and work on the model is still going on.

A more general approach is the one followed by the Nijmegen group, which fits to the $N\bar{N}$ data set both the parameters of the annihilation potential and the coupling constants of the meson-exchange potential. Their calculation uses a coupled-channel formalism and electromagnetic effects are taken into account to order α in the potential. The meson-exchange potential is derived by G-transformation from the 1978 Nijmegen one-boson-exchange potential. The annihilation potential is derived from three two-meson annihilation channels for each isospin: transition potentials of Gaussian type are used in each channel, and consist of central, spin-spin, spin-orbit and tensor forces.

The quality of the fit is very good, as can be seen in Fig. 12 from Ref. 40). In this case also the Analyzing Power for $\bar{p}p$ charge exchange is fitted correctly, supporting the argument that to understand the $N\bar{N}$ data sophisticated models are needed, with many free parameters. I cannot say whether this approach is correct or not. I can only add that the coupling constants (and even the meson masses, when they are treated as free parameters) turn out to be very close to their numerical values, known from the NN data. Very close, but not identical, and the quality of the fit deteriorates if they are locked to their usual values⁴⁰). If this result will be confirmed it is an indication that the $N\bar{N}$ data will provide not only information on the annihilation mechanism, but will allow also to improve our knowledge of the long-range meson-exchange potential.

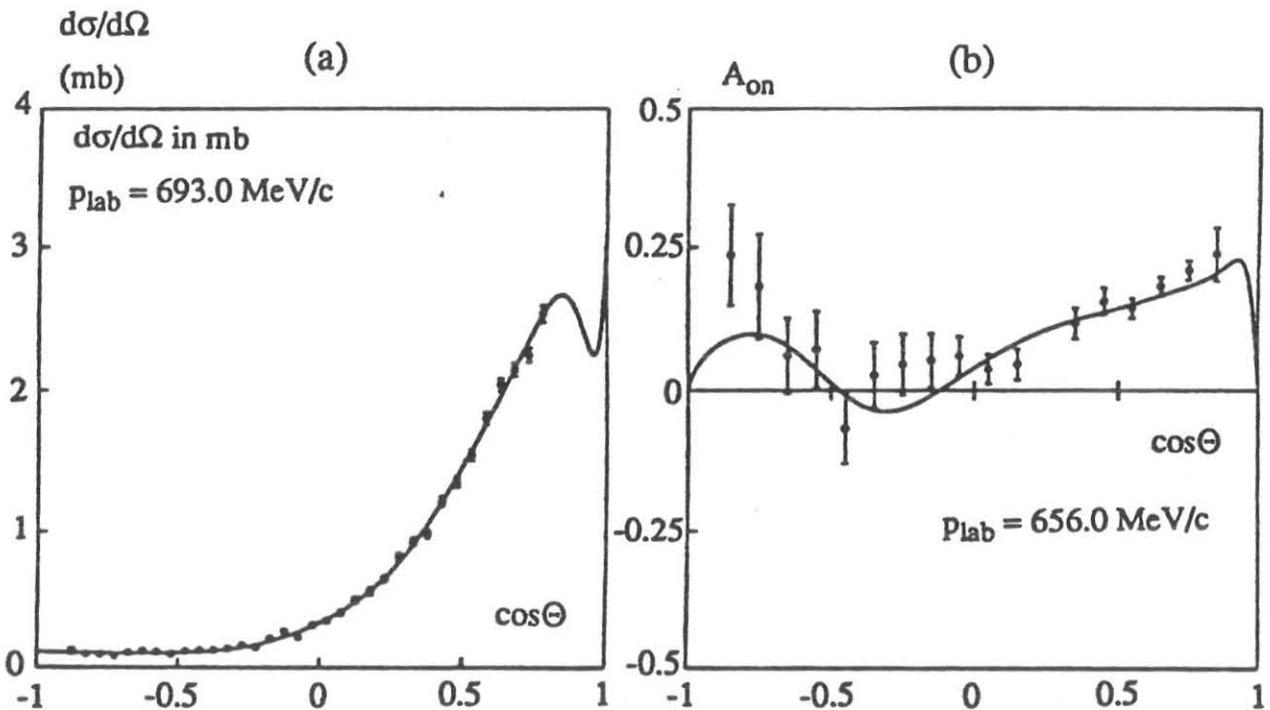


Fig. 12 - Comparison between the $\bar{p}p \rightarrow \bar{n}n$ differential cross-section (a) and analyzing power (b) measured by experiment PS199 and the most recent Nijmegen model calculation⁴⁰).

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