SPIN STUDIES WITH A POLARIZED JET TARGET IN LEAR

Y.Onel[1] and A.Penzo[2]

Geneva, 28 March 1986

Abstract: It is very unlikely that many of the problems addressed at LEAR concerning the NN interaction mechanisms and the new spectroscopy, will provide a clear answer without polarization measurements. Ideally these should be performed both polarized beam and target to map out in detail the spin structure of the NN system and/or allow spin−parity determination of new states.

[1] DPNC, University of Geneva, Geneva, Switzerland
[2] INFN and University of Trieste, Italy

THE POLARIZED JET

INTRODUCTION

It is very unlikely that many of the problems addressed at LEAR concerning the NN interaction mechanisms and the new spectroscopy, will provide a clear answer without polarization measurements. Ideally these should be performed both with target and beam polarized[1] to map out in detailed the spin structure of the NN system and/or allow spin–parity determination of new states. The polarized jet target is an essential ingredient for systematic polarization studies, as it would overcome the intrinsic limitations of a standard polarized target operated in external beams and also will relieve the pressure for time–sharing (because it could in principle operate in parallel with other users) and could easily match with a flexible multi–purpose detector with large acceptance.

POLARIZED JET TARGET (PJT)

The use of an internal polarized hydrogen jet target (PJT) in the LEAR ring has definite advantages compared with a conventional solid state polarized proton target(PPT) used in an extracted beam environment. This is apparent from the following table.

	PPT	PHJ
Density (g/cm^3)	.92	2.10^{-12}
Bound(unpol)nucl. /Free(pol) H	7	0
L_{rad} (g/cm^2)	45	61.3
Polarization P_T	75%	>90%
Holding field B(Gauss)	25.10^3	10
Polarization reversal time(min)	20	0
Operating temp. (K^0)	0.5	–

Therefore, the PPT is already less favorable than a liquid hydrogen target due to the large background arising from non-hydrogenous nuclei in the target material. This unpolarized background is particularly important in precise resonance studies at low energies and requires extensive background measurements with a "dummy" target. Also the strong holding field required by a conventional PPT restricts the experimental acceptance for charged particles. The PJT has all the advantages of an unpolarized internal jet target (essentially perfect transparency, localized interaction point and high efficiency in using the anti-protons from the AA) and the following advantages, specific for polarization studies, over a conventional PPT-extracted beam set-up.

- Higher polarization
- Pure hydrogen (no need of substraction of unpolarized compounds)
- Polarization can be reversed very rapidly (100 Hz) and can be oriented in any chosen direction with essentially no limination in the acceptance with respect to the PPT.
- Immunity to radiation damage (although the limit of 10^{14} m.i.particles/cm^2 for PPT might not to be considered a limitation for the available anti-proton intensities)

These advantages are for most of the experiments sufficient to balance the lower density of the polarized jet, which should be however quite satisfactory even for low rate processes: with 10^{10} p circulating in LEAR, a polarized jet with 10^{12} polarized p/cm^2 would produce 5.10^3 strong $\bar{p}p$ interactions/sec at 500 MeV/c. The figure of merit of PJT with respect to PPT can be estimated in comparing the parameters affecting the statistical accuracy of a polarization measurement and efficiency in using the anti-protons:

	PPT(3cm)	PHJ
Target proton/cm^2	2.10^{23}	10^{12}
Beam $\bar{p}$/sec	5.10^5 (*)	$1.5.10^{16}$ (**)
Geometrical acceptance	0.15	0.40
Dummy + pol. reversal/data taking	30%	0
Integrated $\bar{p}$/day	4.10^{10}	5.10^9

*) Spill time in LEAR is assumed 1 hr, with 2.10^9 stored $\bar{p}$. Also limited by apparatus and acquisition system rates.

**) One filling of LEAR/day with 5.10^9 $\bar{p}$

Therefore the running time necessary to achieve the same precision for the measurement of asymmetry with the PJT is the same as with a PPT (not taking into account the additional error from background events affecting PPT) but the total number of $\bar{p}$/day is 10 times less. In view of the smaller luminosity of the PJT with respect to the unpolarized jet an appropriate strategy would be to run with PJT specifically in the energy range where significant structures have been identified in broader energy scans with the unpolarized jet. However the reduced density of PJT is not a limitation at energies below 200 MeV/c, where also the unpolarized jet density must be decreased; at energies higher than 700 MeV/c additional cooling of the stored beam might not be necessary. Therefore the PJT seems particulary suited both for parallel running with the SPS collider and in parasitic mode with slow anti−proton extraction.

PHYSICS WITH PJT

Obviously an ideal situation would be to dispose of polarized $\bar{p}$ circulationg in LEAR in conjuction with PJT, as in this case a complete spin dependent description of the $\bar{N}-N$ interaction would be possible, thus allowing the determination of the amplitudes for elastic scattering and charge exchange. In this case the meson exchange potentials for $N-\bar{N}$ could be understood and compared to the $N-N$ system.

Leaving for the moment the study of elastic and charge exchange reactions to the near future possibility of obtaining polarized $\bar{p}$ beam in LEAR, a lot can be achieved already with the PJT alone in the study of annihilation processes. Here the major problem is to disentangle the relative importance of quark diagrams and conventional meson−baryon intermediate states[2]. Furthermore in the former case it is relevant to understand the role of quark rearrangement and $q\bar{q}$ annihilation both in disconnected diagrams and with gluonic intermediate states[3] (Fig.1); in both cases the presence of new flavour pairs would be additional tag of these latter processes. The indications from hadron spectroscopy that spin effects are important and mainly governed by a spin−spin short range interaction, characteristic of vector gluon exchange,and that the spin orbit term is negligible. These notions could be studied by investigating the relative roles of $q\bar{q}$ exchange versus annihilation mechanisms.

There is an experimental evidence that a large negative polarization is found for many reactions where Λ are produced and this extends to other hyperon inclusive production over an energy interval of few orders of magnitude. This effect demands an explanation that being simultaneously general and simple must be related directly with the spin dynamics in the creation process of the ss pair and the recombination process leading to the final state hadrons. In $\bar{p}p \rightarrow \bar{Y}Y$ polarization studies one can therefore observe selectively the $s\bar{s}$ pair creation and the dynamics of both the strange and anti−strange valence quarks in the final states. The hyperon−antihyperon channels with their simple two−body kinematics play the role of model reactions for ambitious polarization studies. Correlation parameters are obtainable and with a polarized target three spin measurements are possible with good statistics.

Treshold phenomena could be studied in an optimal way owing to the high resoluion due the jet target. The relatively high interaction rate allows the study of channels with branching ratios far below 10^{-4}./

Niskanen's[4] calculations for the reaction $p\bar{p} \rightarrow \Lambda\bar{\Lambda}$ in a $K+K^*$ exchange coupled−channel model reproduces the cross section data satisfactorily considering that no parameter has been fitted, and gives net predictions for the polarization. Also in this case, quark diagrams involving ss pair creation can be considered and the spin correlation for the final hyperons is a sensitive probe of the exchanged quantum numbers in the s− and t− channel. Recently an internal fusion[5] diagram with one gluon exchange has been proposed as the dominant mechanism for $\bar{p}p \rightarrow \bar{Y}Y$ production, predicting cross sections in fair agreement with data. Although a careful consideration is required for the possibility of meson exchange $K+K^*$ may be sufficient to describe this reaction, before any other conclusion on possible quark contribution, on the other hand,there is an experimental evidence that a large negative polarization is found for many reactions where Λ^0 are produced ($\gamma p \rightarrow K\Lambda$, $\pi^- p \rightarrow \Lambda K$, $K^- p \rightarrow \Lambda \phi$), as well as an impressive systematics hyperon polarization in inclusive production

The measurement of the polarization asymmetry in the study of the $\bar{p}p$ annihilation dynamics and the search for new exotic states is likely to complete the cross−section measurements in a decisive way, allowing in many cases the determination of the quantum numbers of these new states and the amplitude structure of the relevant processes. From this point of view annihilation channels into two spinless mesons $\pi\pi$, KK, $\eta\eta$, $\eta\pi$ have definite advantages as compared with $\bar{p}p$ elastic scattering, these advantages are:

− absence of diffractive background

− only 2 amplitudes contribute

− definite s−channel quantum numbers

Also in $\bar{p}p$ annihilation into meson pairs, the competing mechanism of quark interchange and annihilation could be distinguished. A comparision of the channel $\pi^+\pi^-$ and K^+K^- should give a discrimination of the relative importance of the two diagrams, including polarization effects that should manifest as a result of the underlying spin correlations in quark−antiquark pair creation as suggested above; assuming that u−quark from a polarized proton carries its spin, it should combine preferencially with the anti−quark of the created pair in antiparallel configuration to form the final meson. Measurements of charged channels $\pi^+\pi^-$ and K^+K^- with the PJT would follow up and refine the polarization studies of PS172[5], in particular studying the state observed at KEK at 1935 MeV and the ξ at 2232 MeV reported by the Mark III group. Data on the two body annihilation channels could also distinguish between competing processes of quark interchange, $q\bar{q}$ annihilation and pair creation. A study of polarization properties in K_sK_s and $Y\bar{Y}$ final states would extend the scope of PS185. Allowing the measurements of spin correlations in the latter case when the hyperon polarization can be analyzed in addition to the target polarization asymmetry, s−channel one gluon−exchange could imply simple helicity correlations. The specific properties of the jet target (localized interaction region, no absorption etc.) make this facility very suitable for the measurement of final states containing neutral particles(π^0,η^0,ω^0) with γ's as decay products. In association with an adequate electromagnetic calorimeter the apparatus would be capable of measuring $pp \to \pi^0\pi^0$, $\eta\eta$, $\eta\pi^0$, which gives access to $T^G = 0^+, 0^+, 1^-$ s−channel states with a simple 2−amplitude structure. Other quasi two body final states decaying into vector mesons (ρ,ω,ϕ), although having a more complicated amplitude structure, have partial cross−sections that are larger than the true two−body channels and cover a larger variety of s−channel quantum numbers: this is an important feature both for baryonium studies and for searches of glueballs and hybrids.

As a first step to achieve this goal of complete spin studies in LEAR, there is a new proposal by JETSET group[6] which uses an internal molecular hydrogen jet or an internal polarized hydrogen jet target. They have proposed an advanced detector with large acceptance and complete information on charged and neutral tracks in its final implementation; however, the immediate interest is to study of $\phi\phi$ and K_SK_S production, on both unpolarized and polarized hydrogen targets in the momentum range 600 − 1900 MeV/c. They intend to measure the differential cross section and polarization P at different energies. The measurement of P will have two interesting aspects:

i) As stressed by S.Cooper[7], the exclusive reaction and the two spin directions allow partial wave analysis of the $\phi\phi$ mass plot, and $\bar{p}p \to \phi\phi$ is simpler than $\pi^-p \to \phi\phi n$ (BNL experiment). The polarization parameter P will provide additional constraints on the partial wave analysis.

ii) The polarization will allow to sudy the correlation of the spin directions in the initial and final states, in a process involving purely gluonic intermediate states. The specific nature of the spin−spin short range interaction characteristic of vector gluon coupling to $q\bar{q}$ pairs, involves a correlation in the helicity of the qq both in the initial and final states.

The channel $\bar{p}p \rightarrow K_S K_S$ represents 25% of $K^0 K^0$ events. The series of quantum numbers accessible both $\bar{p}p$ and $K_S K_S$ are $J^{PC} = 0^{++}, 2^{++}, 4^{++}$... in a pure isospin system I = 1. The initial $\bar{p}p$ spin state is also constrained to have spin equal to one. It is foreseen to measure $d\sigma/d\Omega$ and P at the same momeenta as the K^+K^- annihilation measurements done by PS172. That will allow a simultaneous amplitude analysis from the two isospin coupled channels. (whereas the $K_S K_S$ is a pure isospin I = 1 system, the K^+K^+ is a mixture of I = 0 and I = 1)

Concerning spin amplitudes, scattering in these channels can be expressed in terms of two amplitudes F^{++}, F^{+-} which refer to helicity non−flip and helicity flip parts, as $\bar{p}p \rightarrow \pi^+\pi^-$ annihilation. The differential cross section and polarization are then defined as :

$d\sigma/d\Omega = |F^{++}|^2 + |F^{+-}|^2$

$P = 2\mathrm{Im}\,\{(F^{++})(F^{+-})\}/\{|F^{++}|^2 + |F^{+-}|^2\}$ These measurements combined with the PS172 data could provide significant insight into the annihilation mechanism of $\bar{p}p \rightarrow KK$.

CONCLUSIONS

By using atomic polarized jet target and flexible multipurpose detector, there is a very good opportunity for a systematic study of the various annihilation channels accesible in $\bar{p}p$ interaction and hence improve our understanding on the spin structure of the $\overline{N}N$ system. The polarization observables also play a very important role in a decisive way, allowing in many cases the determination of the quantum numbers if any possible exotic state is located.

ACKNOWLEDGEMENTS

We want to thank our colleagues of JETSET collaboration for extensive discussions.

REFERENCES

/1/ Y.Onel, A.Penzo, R.Rossmanith, paper submitted to Workshop on Low Energy Antiproton Facility, Fermilab, April, 1986.

/2/ Physics with Antiprotons at LEAR in the ACOL Era, Workshop, Tignes, 1985, J.A.Niskanen, p.193; A.M.Green, p.185.

/3/ A.Penzo, Rapporteur talk at VI Int. Symp. on Polarization Phenomena in Nuclear Physics, Osaka, Japon, 1985.

/4/ H.Gerz and S.Tatur, Phys. Rev. D30 (1984) 63.

/5/ Y.Onel, Review talk, Proc. of Topical Seminar on Few and Many Quark Systems, San Miniato, 1985.

/6/ JETSET Proposal, G.Bassompierre et al, CERN/PSCC 86 – 24.

/7/ S.Cooper, SLAC – PUB – 3819, 1985.

$\bar{P}P \longrightarrow$ MESON ANNIHILATION

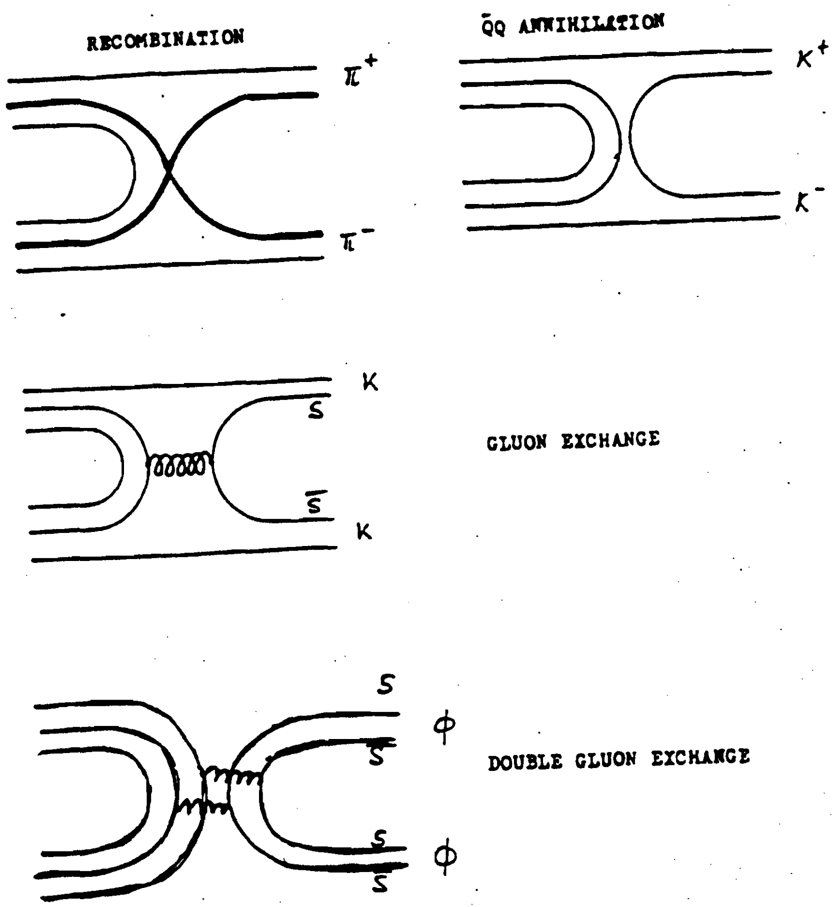


Fig. 1

$\bar{P}P \longrightarrow \bar{Y}Y$ QUARK DIAGRAMS

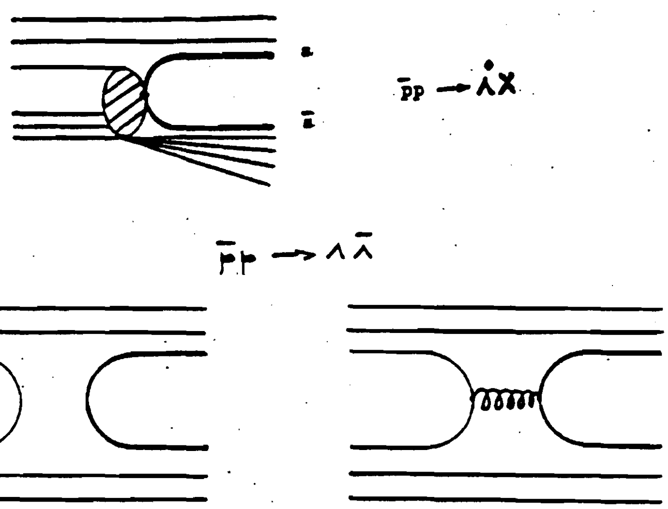
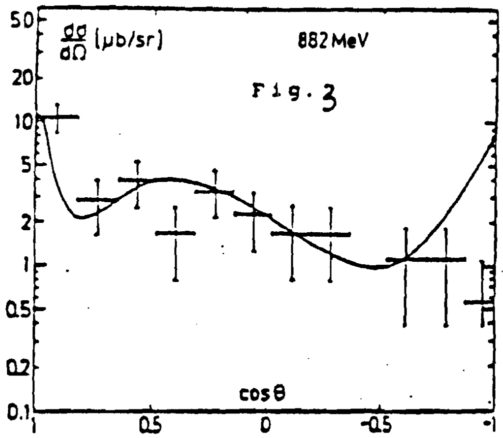


Fig. 2

$q\bar{q} \longrightarrow$ gluon fusion



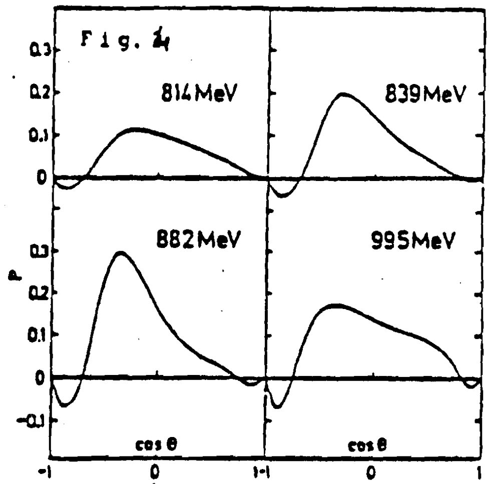


Fig. 3 The differential cross section at the laboratory energy 882 MeV. The data from Jayet et al[4].

Fig. 4 The polarization of $\bar{\Lambda}$(or Λ) for four laboratory energies including the ones of the LEAR experiment[1].