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PHYSICS I

ELECTRONICS EXPERIMENTS COMMITTEE

A FROZEN SPIN POLARIZED TARGET IN THE OMEGA SPECTROMETER : FEASIBILITY AND PHYSICS INTEREST

by

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In this note we propose to install a frozen spin polarized target in the Omega spectrometer during the P.S. shut-down at the beginning of 1975. This implies that all the running periods of Omega in 1975 will be devoted to polarized target experiments. One specific proposal (Direct Measurement of Helicity Amplitudes in $\pi^+p \to K^+\Sigma^+$ and $K^-p \to \pi^-\Sigma^+$-PH I/COM-71/7) and one letter of intent (A Study of the $\pi\pi$ and $K\pi$ Interactions above 1 GeV/c^2 using a Polarized Target - PH I/COM-73/9) have been submitted. Further proposals are being studied. Final decisions are not expected to be taken before the end of 1973 when the performances of the installed trigger systems will be known better. It is also understood that such a programme has an obvious continuation with the SPS especially if an RF separated beam is available.

This report is divided as follows :

In part 1 we recall the physical significance of polarization measurements.

In section 2 we review some of the possible experiments using the triggers already installed in Omega.

Section 3 will be devoted to the technical problems of installation.

Finally in section 4, we comment on the insertion of polarized target experiments in the long range programme of Omega.

In the appendix, we outline a possible schedule for installation.

1. PHYSICAL SIGNIFICANCE OF POLARIZATION MEASUREMENT

In this section we describe briefly some of the areas in high energy physics for which future polarization measurements will be particularly valuable. We emphasize our view that polarization can make a unique contribution to understanding, and not just serve as another constraint on parameters in models of doubtful fundamental significance. The past few years have seen some particularly beautiful results from polarization studies. They have been crucial in phase-shift analyses, for example, and have made possible a nearly model independent determination of high energy amplitudes in πN elastic scattering. It seems to us possible at this point to identify certain reactions or classes of reactions for which future polarization studies will yield great rewards. We do not advocate measurement of polarization in each of a 100 or more distinct processes; rather a small set of well-chosen investigations are most desirable.

Observable hadronic reactions necessarily involve particles with spin. The most complete measurements involve controlling simultaneously the spin states of as many particles as possible with polarized targets, good acceptance observation of decay particles, recoil polarization analysis, etc.

Although for many years spin was expected to be an inessential complication in two-body scattering amplitudes, data from polarization measurements (particularly for πN-πN) have shown, on the contrary, that spin complications are very intriguing. Quantum number exchange amplitudes with different over-all helicity flip have strikingly different features. Study of separated helicity amplitudes in processes related by line reversal, duality, SU(3), are needed to understand the systematics.

Backward scattering and $\bar{p}p$ annihilation to mesons are relevant to the study of baryon exchange. Here the additional question arises of why parity doublet baryon states are not observed. Either the couplings are zero, or the doublet states lie on a suppressed trajectory, or additional singularities put the doublet states on an unphysical sheet. Polarized target data are essential to unravel this question.

The study of the production of many particle states is best performed by a partial wave analysis at each effective mass. Particularly interesting are the diffractively produced πN, $\pi\pi N$, $\pi\pi\pi$, and $K\pi\pi$ systems and the relation between the diffractively produced states and those found in formation experiments. A polarized target gives more observables to help in analysing the effective mass partial waves, and also to allow a further study of the production mechanisms.

1.1 Polarized target measurements for forward exchange reactions

a) Amplitude determinations

To extract the moduli and relative phases of the amplitudes for a given process, data are needed with all the particle spin states controlled. For instance for πN elastic scattering the relevant R and A parameters have been measured at 6 and 16 GeV/c. Using isospin relations this enables all the $\pi N \to \pi N$ amplitudes to be extracted at 6 GeV/c. These parameters were obtained by the combined use of a polarized target and the measurement of recoil proton polarization from double scattering.

An important property of the hyperons Λ, Σ^+ and $Y^*_1(1385)$ ($\Lambda\pi$ decay) is that the observation of their decay distributions allows a complete analysis of their spin states. Thus a combination of a polarized target and measurement of all decay products will yield a complete set of observables (and hence amplitudes) for the processes

$$\begin{array}{ll} \pi N \to K\Lambda & \bar{K}N \to \pi\Lambda \\ \to K\Sigma^{+} & \to \pi\Sigma^{+} \\ \to KY^{*}_{1}(1385) & \to \pi Y^{*}_{1}(1385) \end{array}$$

Data on such line reversed pairs of reactions at the same values of s and t will also allow a direct determination of the signatured amplitudes. Corresponding measurements on the SU(3) related processes with the outgoing π replaced by η and η' are also valuable.

Similarly a complete set of measurements can be made for the 1^- vector meson production reactions

$$\pi N \to K^{*} \begin{pmatrix} \Lambda \\ \Sigma^{+} \\ Y^{*}_{1} \end{pmatrix} \qquad \bar{K}N \to \begin{pmatrix} \omega \\ \rho \\ \phi \end{pmatrix} \begin{pmatrix} \Lambda \\ \Sigma^{+} \\ Y^{*}_{1} \end{pmatrix}$$

Here the angular correlations of the hyperon and vector meson decays must be observed. Unnatural, as well as natural, parity exchange is illuminated by these reactions.

From such complete sets of measurements the structure of the helicity amplitudes can be investigated in a model independent way. We can check whether they are peripheral. The phase-energy relation for signatures amplitudes can be studied. SU(3), exchange degeneracy - quark model comparisons can be made directly for amplitudes. The quark model additivity frame can be investigated in reactions like $\pi N \to KY^{*}_{1}$.

b) Polarization measurements

Even when the recoil baryon polarization is not measured, a lot of information can be learnt from polarized target experiments. One should choose reactions with limited exchange quantum numbers and their line-reversed, duality, or SU(3) related partners. The basic "quartet" to study is

$\pi^- p \to \pi^0 n$ $\quad$ $\pi^- p \to \eta n$ $\quad$ $K^- p \to K^0 n$ $\quad$ $K^+ n \to K^0 p$

$(\pi^- p \to \eta' n)$ $\quad$ $K^0 p \to K^+ n$

The interest aroused by the $\pi^- p \to \pi^0 n$ polarization data indicates the importance of such experiments. In particular the other reactions allow the even signature exchange to be studied as well. Duality predicts zero polarization in exotic s channel reactions such as $K^+ n \to K^0 p$.

The analogous charge exchange vector meson production reactions

$\pi^- p \to \rho^0 n$ $\quad$ $\pi^- p \to \omega^0 n$ $\quad$ $K^- p \to \bar{K}^0 n$ $\quad$ $K^+ n \to K^{*0} p$

together with their non-charge exchange partners

$\pi^{\pm} p \to \rho^{\pm} p$ $\quad$ $K^{\pm} p \to K^{*\pm} p$

are of great interest. The observables here are the moments of the angular distribution of the meson decay products (e.g. $\pi^+\pi^-$ from ρ^0 decay) and a partial wave analysis is to be performed. However, for clarity we discuss only the resonant P waves. The correlations of the vector meson decay with the target polarization vector provide six additional independent observables. Indeed 10 out of the maximum of 11 independent observables can be obtained.

For example, for $\pi^- p \to \rho^0 n$, three of the four observable (P wave) $\pi^+\pi^-$ moments proportional to P_T^y (target polarization perpendicular to the reaction plane) arise from π-A_1 exchange interferences and so are an indicator of possible A_1 exchange components. The fourth observable is associated with natural parity exchange. The two observable $\pi^+\pi^-$ moments proportional to P_T^x (target polarization in the reaction plane but perpendicular to the beam) arise from interferences between unnatural (π) and natural (A_2)

parity exchange. These will be invaluable for fixing the phase of natural parity exchanges relative to π exchange. The importance of these six observables to $\pi\pi$, πK phase shift analyses is apparent. With target polarization P_T^z along the beam direction, two $\pi^+\pi^-$ moments are observable. They are equivalent to the P_T^x observables in that $\langle P_T^x \rangle^2 + \langle P_T^y \rangle^2 + \langle P_T^z \rangle^2 = 1$ while nevertheless helping to remove ambiguities and improve errors.

Also in the case of $\pi^- p \to \omega^0 n$ the number of observables per exchange is rather favourable. A study of ρ exchange in $\pi^- p \to \omega^0 n$ is just as interesting as in $\pi^- p \to \pi^0 n$ and allows a comparison of ρ exchange amplitudes of different helicity structure. Moreover, these data when studied together with ρ-ω interference effects in $\pi^- p \to \rho^0 n$ will be particularly illuminating.

Polarization effects in the non-charge exchange reactions $\pi^\pm p \to \rho^\pm p$ and $K^\pm p \to K^{*\pm} p$ are expected to be large since the natural parity exchange contributions are relatively stronger than in the charge exchange reactions.

1.2 Polarized target measurements for baryon exchange reactions

The interest of being able to perform an amplitude analysis from polarized measurements is clearly of no less interest in the backward direction than in the forward direction, and therefore it is not necessary to repeat what has been already quoted above. There are anyhow two important reasons to advocate strongly that polarization measurements be performed in the backward direction.

The first reason is that nothing is known at the present time on the backward amplitudes. No A and R measurement is yet available, and therefore any amplitude analysis so far performed is ambiguous and strongly model dependent ($\pi^- p \to \Lambda K^0$ results may be available soon).

The second reason is that the theoretical situation is even more confusing for baryon exchange than for meson exchange. And this can be very easily realized, by noticing that the very large majority of accessible reactions in the forward direction are of the type (pseudoscalar meson) + b → (pseudoscalar meson) + d, which by parity conservation implies that only one type of naturality (in fact natural parity) can be exchanged in the crossed t channel. Now, for baryon exchange not only both naturality states can be exchanged, but they must be exchanged simultaneously due to analyticity requirements. This is the famous and unresolved problem of parity doublets. It has been recently recognized that the measurement of the differential cross-section and of the polarization of an interacting baryon was sufficient to allow a complete model independent separation of parity doublet partners. For any production of a pseudoscalar meson off a polarized target, $a + p \rightarrow d+$(pseudoscalar meson) (a and d arbitrary particles), the differential cross-sections $d\sigma^{\pm}/du$ corresponding to natural or unnatural parity exchange can be computed from the simple relation

$$\frac{d\sigma^{\pm}}{du} = \frac{d\sigma}{du}\,(1 \mp P(u))$$

where $P(u)$ is the polarization parameter and $d\sigma/du$ the unpolarized cross-section.

For more complicated reactions in which the final state meson does not have spin zero, an equivalent separation can be performed through measurement of the spin states of this particle (from density matrix element measurement in the transversity frame).

It is clear that once the separation has been performed, one can play around separately for each component with SU_3 relations, isospin relations, energy dependence, dip bump structures, etc.

With this respect it is important to make available experimental data for different channels.

Particularly attractive reactions to study baryon exchange are :

1) those with much data presently available : the three $\pi N \to N\pi$ charge states and the line reversed counterparts $\bar{p}p \to \pi^{\pm}\pi^{\mp}$ $\pi^{-}p \to \Lambda^{o}K^{o}$;

2) those with restricted exchange quantum numbers : $\bar{K}N \to \Lambda\pi$ etc;

3) those with simple duality expectations because of exotic s channels ($K^{+}p \to pK^{+}$) or exotic t channels ($\pi^{-}p \to \Sigma^{-}K^{+}$, $K^{-}p \to \Sigma^{-}\pi^{+}$, $K^{-}p \to \Xi^{-}K^{+}$, $\bar{p}p \to K^{+}K^{-}$).

1.3 Polarized target measurements and diffractive production

The diffractively produced N* baryon states in processes $\pi N \to \pi N^*$, $KN \to KN^*$, $NN \to NN^*$ can be analyzed in spin-parity. This requires a detection of the decay products $N^* \to N\pi$, $N\pi\pi$, ΛK etc., with good angular acceptance. In practice, since several spin parity states contribute in a given mass region, a polarized proton target is essential to help in sorting out the states contributing in this process (which can be thought of as Pomeron + p N*). The structure of the N*(1400) bump; possible narrow high spin - high mass states; the link to phase shift analyses of π+p N* data; possible quark model states that do not couple to π+p; .... many questions arise. In such an effective mass phase shift analysis, the dissociating beam whether $\pi^{\pm}$, $K^{\pm}$, p, etc.) is not important - although higher energy where diffraction is more likely to be dominant is perhaps preferable.

In contrast, to study the interrelation of diffractive (Pomeron exchange) components with quantum number exchange components, one should study several related processes. Thus, in $K^{\pm}p \to Q^{\pm}p$, a Deck model suggests the transverse proton polarization should be as in $\pi^{\pm}p$ elastic scattering, while a resonance production approach suggests a transverse proton polarization (from duality arguments) which should be as in K p elastic scattering. An analogous test is possible using p and $\bar{p}$ instead of K ; thus pp $\rightarrow$ pN* with the N* fast in the laboratory frame would have polarization like $\pi^{\pm}p$ elastic scattering for various Deck model produced N* states, while the polarization would be like pp elastic scattering if the N* state is treated as a resonance. These predictions are very different, which is indicative of the kind of progress that can be made by studying polarization in diffraction dissociation of $\pi \rightarrow 3\pi$, $K \rightarrow K\pi\pi$, $N \rightarrow N\pi$ or $N\pi\pi$ etc.

1.4 Inclusive experiments

Polarization data in inclusive reactions also yield additional information. Polarized target data for (0^- meson) + $p\uparrow$ $\rightarrow$ (0^-meson) + x, and correlations with final Λ polarization in (0^- meson) + $p\uparrow$ $\rightarrow$ Λ+x, both give complete amplitude determinations for forward three-particle scattering. Of interest is the relationship, as the missing mass of x increases, between individual states x in their major decay modes and the smooth inclusive average of all such states.

2. REVIEW OF POSSIBLE EXPERIMENTS

In this section we review the status of the studies in progress in various groups on the possible use of the triggering equipments existing or being installed around the Omega in conjunction with a frozen spin polarized target. It is thought that the few beam periods of 1975 can be used efficiently only with triggers of known properties and performances. For each experiment a short run with carbon target will be desirable in 1974.

2.1 Recall of needed number of events

The target will likely be made of 1,2 propanediol ($C_3H_8O_2$) with a very high initial polarization ($\gtrsim$ 75 %) and a relaxation time around 100 hours *). Therefore even with an infrequent repolarization every one or two days, a mean polarization of 70% can be reached.

a) Polarization measurement

- Let us first assume that the events on free protons are cleanly separated. If ϕ is the angle between the normal to the production plane and the polarization of the target, the differential cross section is :

$$\frac{d\sigma}{d\phi} = \left(1 + P\, P_t \cos\phi\right) \frac{d\sigma}{d\phi}\Big|_{90^0}$$

where P_t is the target polarization and P the unknown polarization.

Because of the nearly 4π geometry of the Omega all the angles may be used and P may be determined by the experimental average of $\cos\phi$

$$P = \frac{2}{P_t} \langle\cos\phi\rangle$$

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*) see section 3.

with an accuracy

$$\sigma_P = \frac{1}{P_t} \sqrt{\frac{2}{N_H}}$$

(N_H number of events on hydrogen).

For P_t ~0.70, this means that 200 events give an accuracy of 13% and 2000, 4%.

- If the geometry is restricted by the trigger to a production plane approximately perpendicular to the polarization, by the usual method of counting the number N^+ and N^- of events with normal appr ximately parallel or antiparallel to the polarization, one gets

$$P = \frac{1}{P_t} \frac{N^+ - N^-}{N^+ + N^-} \qquad N^+ + N^- = N$$

with an accuracy

$$\sigma_P = \frac{1}{P_t} \sqrt{\frac{1}{N}}$$

- When the hydrogen peak cannot be separated (1C fits, multineutral) one may then use a subtraction procedure. If ρ is the proportion of events on hydrogen (determined by the comparison with a run on hydrogen and/or on carbon), the differential cross section is now

$$\frac{d\sigma}{d\phi} = \left[(1-\rho) + \rho\,(1+P\ P_t \cos\phi)\right] \left.\frac{d\sigma}{d\phi}\right|_{90^0}$$

and

$$P = \frac{2}{P_t\rho} \quad <\cos\phi>$$

with

$$\sigma_P = \frac{1}{P_t} \sqrt{\frac{P^2 P_t^{\,2}}{\rho^2}\ \sigma_\rho^{\,2} + \frac{2}{\rho N_H}}$$

where σ_ρ is the accuracy on ρ. When the polarization is small, the first term is negligible and in this method $1/\rho$ times (typically 4 times) as many hydrogen events are required as in the case where the hydrogen peak can be separated. Because of the smallness of the factor in front of σ_ρ^2 the number of events to be taken on carbon or/and on hydrogen target in order to measure ρ remains in all cases small compared to the total number of events.

Therefore for a good polarization measurement, although this depends obviously on the experiment, about 1000 hydrogen events per bin are required if the hydrogen peak can be separated and about 4000 when the subtraction method is used.

b) A and R measurement in hyperon production reactions

The approximate 4π geometry of Omega allows to record events with production plane containing the polarization vector and therefore if an hyperon is produced, to measure the A and R Wolfenstein parameters.

As explained in the proposal on "The direct measurement of helicity amplitudes in $\pi^+ p \to K^+ \Sigma^+$ and $K^- p \to \pi^- \Sigma^+$ " (CERN/D Ph II/Phys 71-2 revised) the accuracy on A and R is roughly

$$\sigma_A \approx \sigma_R \approx \frac{1}{\alpha P_t} \sqrt{\frac{6}{N_H}}$$

where α is the asymmetry parameter of the decaying hyperon (α = .65 for the lambdas, = .5 effectively for the Σ since only p decays may be used).

Typically an accuracy of 11% is obtained with 2000 hydrogen events. A maximum likelihood method taking into account the constraint $A^2 + P^2 + R^2 = 1$ may allow a gain of a factor 2 in the number of events. A meaningful measurement requires therefore a minimum of 10.000 hydrogen events.

c) Sensitivity of Omega

The proposed target is 15 cm long. The density is .8, the filling factor .7, and 1/9.5 of the nucleons are free protons. This gives approximately

$$= 5.5\ 10^{-7} \text{ hydrogen event/}\mu\text{b/incoming particle.}$$

Therefore with 4 10^5 particles per burst, the maximum sensitivity of Omega will be for a fortnight run :

	P	π^+	π^-	K^+	K^-	$\bar{P}$
Events per microbarn	5 10^4	5 10^4	1 10^5	1.3 10^3	1.1 10^3	5 10^2

This refers obviously to the case of a 100% efficient trigger and a low data taking rate. The dead time of the data acquisition system (~20 ms) will usually be the limiting factor for p, π^+ and π^- beams.

Although there is only one free proton for 9.5 nucleons, because of screening effects in carbon and oxygen, hydrogen events represent about 25% of total proton events and 15% of total events. It seems therefore important to reject neutron events : we are at present thinking of using one (or two) cylindrical multiwire proportional counter around the target to impose an even number of particles. We are also studying the possibility of recognizing the nuclear events with nuclear X rays or γ rays or detection of recoil of heavy fragments.

2.2 A and R measurement in hyperon production reactions

The proposal to measure the A and R parameter and therefore the helicity amplitudesin the reactions $\pi^+p\to K^+\Sigma^+$ and $K^-p\to\pi^-\Sigma^+$ (Proposal PH I/COM-71/7) still appears to be interesting. The only modification with respect to the submitted proposal would be to run at one energy only at the PS (~ 7 GeV/c) since the SPS together with the RF beam would allow a more efficient run at 15 GeV/c and possibly higher energies. The running time could be divided as follows: 1½ - 2 days for $\pi^+ p \to K^+\Sigma^+$, Y^{*+} (1385) giving about 15000 $K^+\Sigma^+$ useful hydrogen events and 13 days with negative beam for $K^- p \to \pi^-\Sigma^+$, Y^{*+} (1385) giving 7000 $\pi^-\Sigma^+$ hydrogen, protonic decay events. The window on the missing mass to the π^- will be opened in order to saturate the trigger. Another alternative, if the number of events obtained with K^- looks too marginal, would be to concentrate efforts on π^+ obtaining more than 100,000 events.

Let us also note that the experiment $\pi^- p \to K^0\Lambda$ as proposed in the letter of intent of Imperial College in the CERN-ETH magnet may be performed equally efficiently in Omega. However this experiment will be a nice testing ground for the target as installation costs in the CERN-ETH magnet are lower.

Finally we are presently studying (Berthon et al.) the possibility of the reactions

$$\pi^- p \to K^*\Lambda$$

$$K^- p \to \pi^0\Lambda,\ \rho\Lambda,\ \omega^0\Lambda,\ \eta\Lambda,\ A_2\Lambda,\ \phi\Lambda \text{ etc.}$$

The interest of measuring the helicity amplitudes in these reactions has already been emphasized in section 1. The incident momentum would be relatively low ($\lesssim$ 6 GeV/c) and the Omega magnetic field would be decreased to 10 kG in order to be able to enter the beam in the target and to reconstruct the π's of Λ decays (25% have less than 160 MeV/c). We are thinking of a multiplicity trigger on 2 prongs 1 V^0 using one cylindrical multiwire proportional counter around the target and some other multiwire proportional chambers at suitable places. If the cylindrical proportional chamber is very close to the target, the efficiency, according to very rough estimation, will be around 50%. In K^- induced reaction we could then reach a sensitivity of 200-300 events/μb giving 10.000 events in most of the channels mentioned above. In π^- the corresponding figure would be 500 events/μb. Clearly further studies are needed before concluding about the feasibility of the experiment. It would be a good complement to present K^- bubble chamber experiments at 4.2 and 8 GeV/c (~200 events/μb each); $K^-p \rightarrow K^*p$ reactions would be obtained simultaneously.

2.3 ππ and Kπ Scattering

A letter of intent is submitted by the Birmingham-Rutherford-Westfield College collaboration on "The Study of the ππ and Kπ Interactions above 1 GeV/c^2 using a Polarized Target" (PH I/COM-73/9). The nearly 4π acceptance of Omega allows a reliable determination of the higher order Y_l^m terms of the ππ angular distribution. A more careful separation of π exchange would be achieved and therefore the reliability of phase shifts will be improved.

The trigger would consist of the existing neutron counter mounted successively sidewise and on top of Omega, and the multiwire proportional counters around the target for selection of two prong events. Some 150000 hydrogen events could be obtained at 17 GeV/c in a $|t|$ range $0.015 < |t| < .8$ GeV^2.

The possibility of measuring $\pi^- p\uparrow \rightarrow \underset{\hookrightarrow \pi^+\pi^-\pi^0}{\omega^0} n$ is also studied.

2.4 Study of baryon exchange processes

a) Fast proton trigger (Fleury et al)

Baryon exchange processes have not yet been studied in so many details as meson exchange processes, essentially because the cross-sections are smaller and decrease faster with energy. In particular polarization measurements have only been made for $\pi^{\pm}p$ (backward) elastic scattering up to 6 GeV/c.

The fast proton trigger experiment (S117 PH I/COM-71/8) - which is planned in the Omega system for later in this year - is aimed at observing a large class of baryon exchange processes induced by pions and kaons on hydrogen in the energy region 8 - 15 GeV. Certainly, results from this experiment must be waited for, before making any clear statement on the interest and feasibility of an extension with a polarized target.

One of the open questions for the presently planned experiment on hydrogen concerns the ratio of the number of events accepted by the trigger to those corresponding to identifiable two-body reactions on hydrogen. We will require a secondary proton having a momentum equal or greater than half of the incident momentum; this large momentum band is chosen so as to open the trigger to events with the production of a forward N^* (subsequently decaying into a proton and one or two pions). In this rather loose trigger the kinematically constrained two-body reactions might correspond to less than 10% of the recorded events. On a polarized target, this figure would be decreased by at least the ratio of quasi-free over bound protons in the target and possibly by the limitation to 4C fit reactions.

The trigger should therefore be tightened and aimed at more specific reactions; in particular the accepted band of the secondary proton momentum should probably be narrower in order to select events of the type $\pi^{\pm}$ (or $K^{\pm}$) + $p \rightarrow p + X^{\pm}$ (i.e. without excitation of the baryon). Such reactions have typically cross-sections of the order of 1 μb at 10 GeV/c; each of these reactions could give about 4 x 10^4 events in 15 days if induced by pions and about 1000 events if induced by kaons, under the condition that the trigger is not flooded by fast protons of other origins.

b) Study of $\pi^- p \rightarrow \Lambda K^*$

Similarly the existing fast Λ trigger (Experiment S114 proposal PH I/COM-71/6) allows study of the $\pi^- p \rightarrow \Lambda K^0$ and $\pi^- p \rightarrow \Lambda K^*(890)$ baryon exchange reactions with some 15000 events in each channels. The different helicity amplitudes may be separated.

The very interesting reactions $K^- p \rightarrow \Lambda\pi^0$, $\Lambda\rho$ etc... (isospin ½ nucleon exchange) seem for the time being very difficult to study with an unseparated beam, but clearly will have to be studied with the SPS.

2.5 Diffraction dissociation

We are finally studying (J. Gallivan, J.K. Bienlein) the possibility of measuring on a polarized target the reactions

a) $\pi^{\pm} p\uparrow \rightarrow \pi^{\pm}\pi^{+}\pi^{-}p$ (A_1, A_3)

b) $K^{\pm} p\uparrow \rightarrow K^{\pm}\pi^{+}\pi^{-}p$ (Q, L)

c) $pp\uparrow \rightarrow p\pi^{+}\pi^{-}p$ $(N^*(1400), N^*(1700))$

$n\pi^{+}p$

$p\pi^{0}p$ (?)

The interest of reaction a) is to test whether the polarization behaves in a way similar to the elastic scattering. The study of the reactions b) and c) allows us, in principle, to distinguish Deck mechanism from resonance production. Typical beam momentum would be 10 GeV/c.

All the above processes have sizeable coherent cross sections on nuclei (~ 3 mb from C) whereas the hydrogen cross sections are $\sigma \sim 400\ \mu b$.

Two triggers may be adequate to overcome this problem:

a) Use of the proton counter (experiment S113, proposal PH I/COM-70/63): one rejects coherent events and select events in horizontal plane where information is greatest.

Numerical estimations show that for $\pi^{\pm}p \rightarrow \pi^{\pm}\pi^{+}\pi^{-}p$ for example we get 200000 $(3\pi)p$ events in 8 days with $|t'| > .1$. In a bin width $\Delta\ |t'| = .1\ \mathrm{GeV}^2$, at $|t'| = .6\ \mathrm{GeV}^2$, one gets 2000 events and the accuracy is of the order of 3%.

b) Use of a multiplicity trigger: (Multiwire proportional counters around the target). Requiring 4 prongs will cut the coherent background and allow simultaneous study of the target fragmentation region. As the reaction plane is not fixed by the trigger, the asymmetry with respect to the normal and the transversal spin direction of the polarized target can both be studied.

3. TECHNICAL FEASIBILITY

3.1 Introduction

The frozen spin technique envisages polarizing the protons in a magnetic field with the required strength and homogeneity and afterwards transfering the polarized target into a holding field which is adapted to the requirements of the scattering experiment. The polarization then decreases towards zero with a relaxation time which is strongly dependent on the holding field and on the temperature of the target.

Actually this principle is applied in a target which is under construction at the Rutherford Laboratory3). The target at Rutherford still suffers from one limitation: the holding field has still to be 30 kG in order to reach reasonable relaxation times. This is because the refrigeration technique employed does not allow one to lower the holding temperature below 0.3 K. A dilution refrigerator would remove this limitation as is shown in Figs. 1 and 2, which present some relaxation time measurements of propanediol samples2). This figure shows clearly that by lowering the holding temperature to below 0.1 K one can have a holding field as low as 10 kG and still one can guarantee a period of independence of the target which is measured in days. Proton polarization approaches 100% below 0.4 K in samples of about 1 cm^3 (Fig. 3).

3.2 Design parameters

a) Target dimensions

We are planning a target 15 cm long with a diameter of 20 mm (possibly 10 mm if required by the experiments).

b) The holding time

We define the holding time τ as one tenth of the relaxation time. Experience has shown that an experiment with a polarized target requires polarization reversal at least once every 24 h, hence a holding time of a minimum of 24 h is needed in order to keep the average polarization to 95% of the initial polarization. It is necessary, in addition, that polarization reversal should be accomplished within 2 h in order not to impair the running efficiency by more than 10%.

Summarizing, we can write down the following specifications:

Target size:	length 150 mm, diameter $\leq$ 20 mm, total volume $\leq$ 50 cm^3.
Initial polarization:	$\geq$ 75%
Holding time:	$\geq$ 24 h
Average polarization for a 24 h run:	$\geq$ 70%
Polarization reversal time:	$<$ 2 h
Holding field:	$\geq$ 10 kG

c) Technical specifications

The cooling system will have two separate stages: a pre-cooler capable of absorbing 1 W at 1.2 K,and a dilution refrigerator which is optimized for the two modes of operating the target - the polarizing stage and the holding stage.

The operation of the target will be as follows. When sufficiently high polarization has been reached, the microwave power is gradually reduced to zero, allowing the target to be cooled below 0.1 K. The inlet of ^{3}He is closed and the dilution refrigerator is used in single cycle mode during transfer to

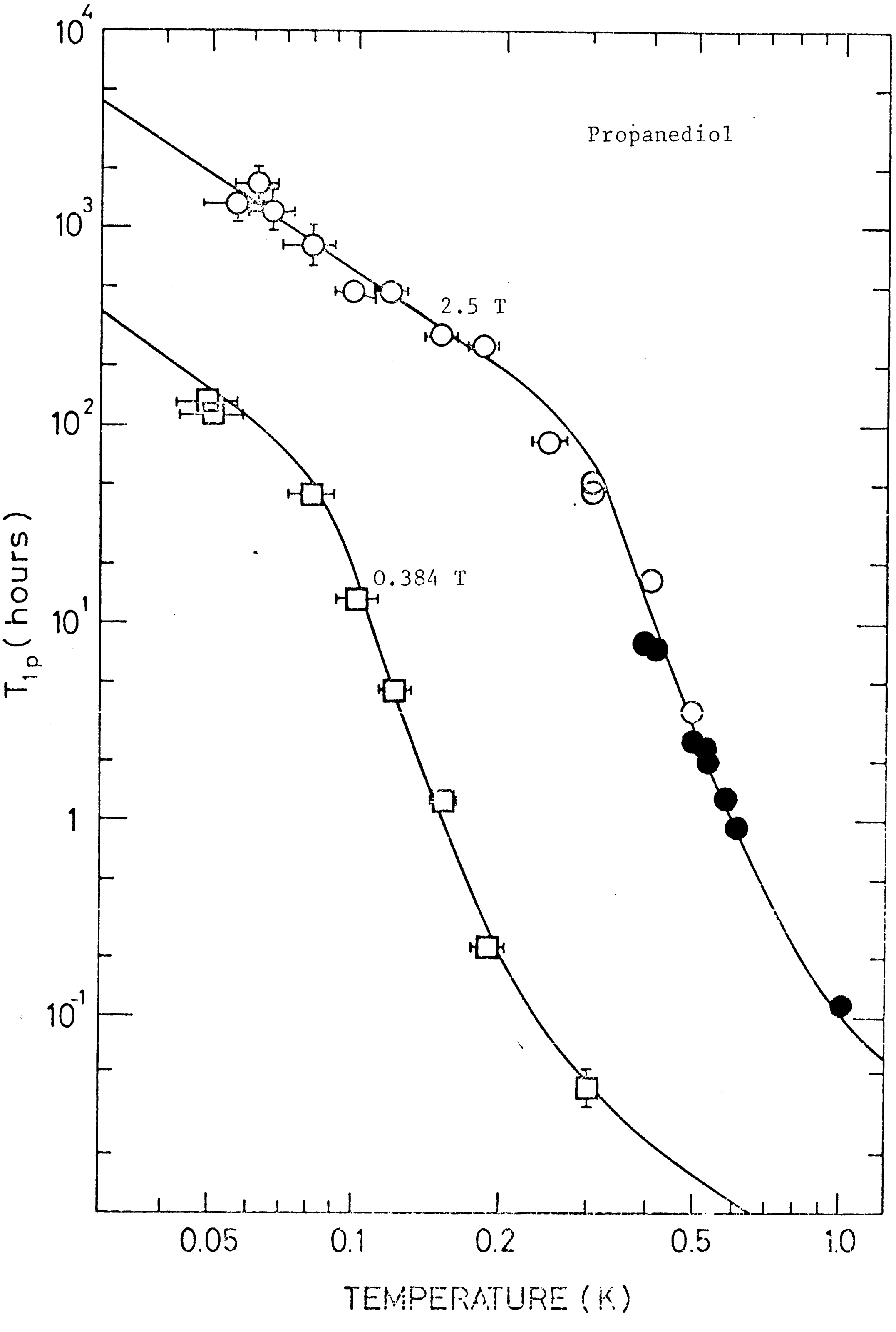
Propanediol
2.5 T
0.384 T
T_{1p} (hours)
10^4
10^3
10^2
10^1
1
10^{-1}
0.05
0.1
0.2
0.5
1.0
TEMPERATURE (K)

Fig. 1

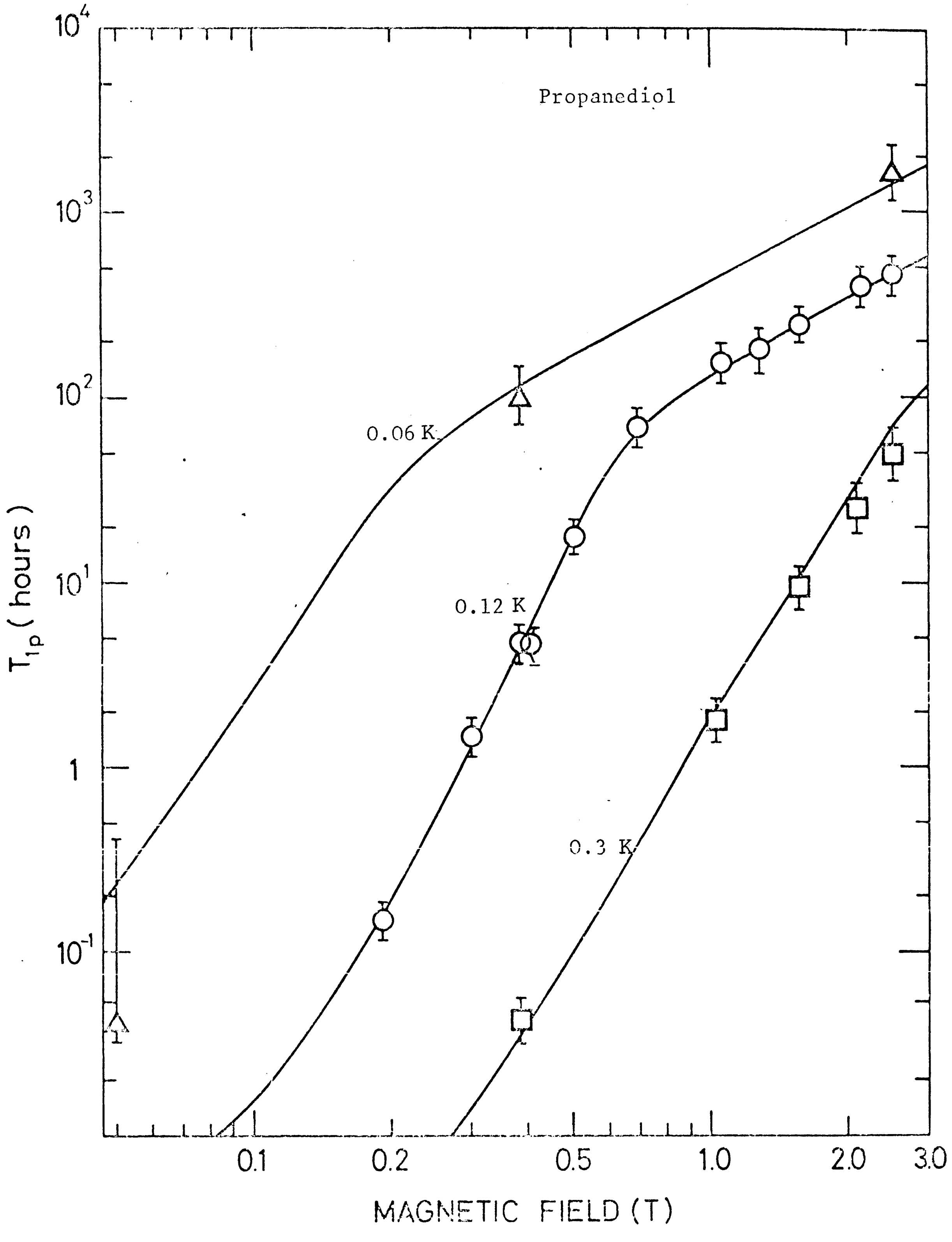
Propanediol
0.06 K
0.12 K
0.3 K
10^4
10^3
10^2
10^1
1
10^{-1}
T_{1p} (hours)
0.1
0.2
0.5
1.0
2.0
3.0
MAGNETIC FIELD (T)

Fig. 2

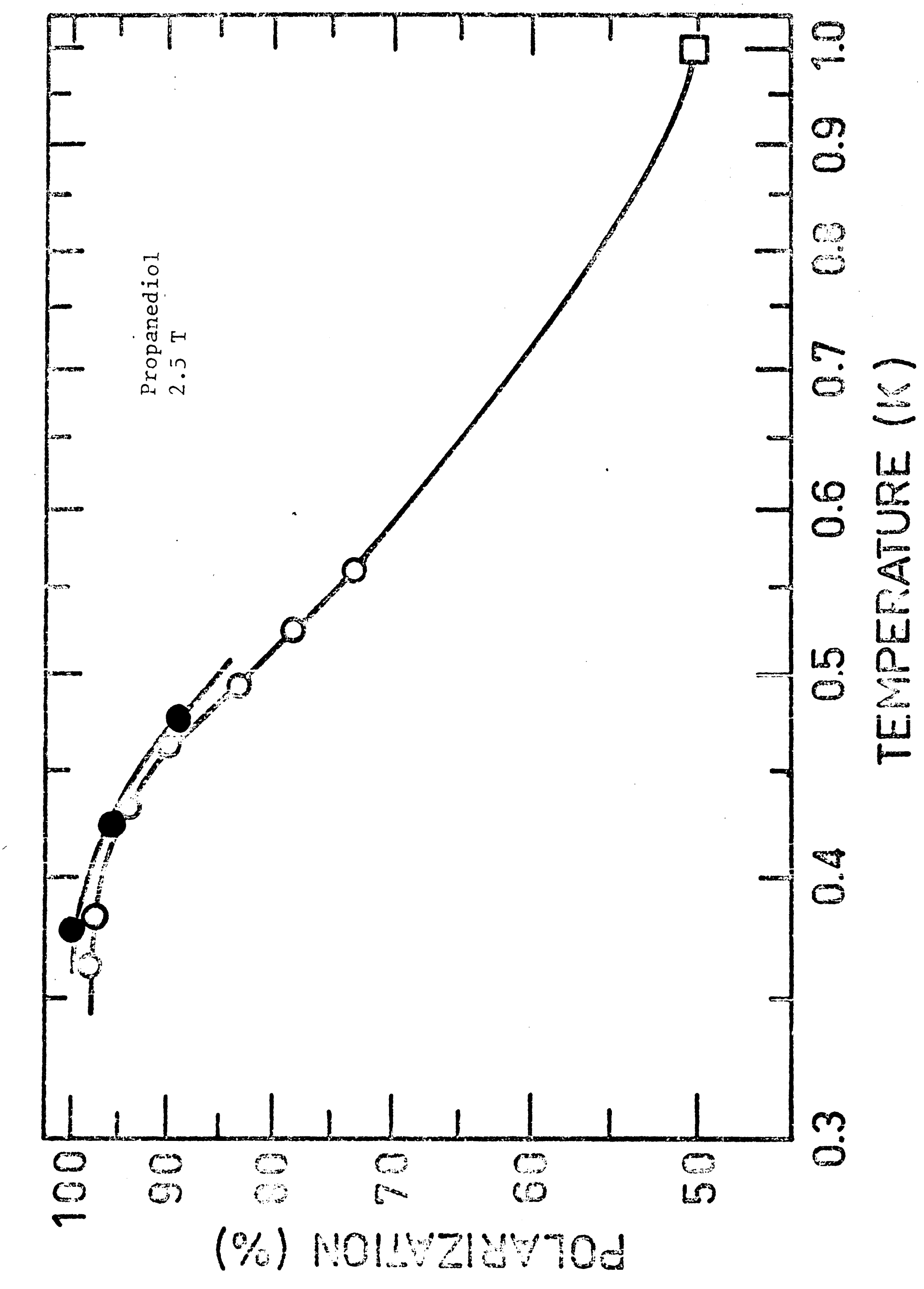
Propanediol
2.5 T
POLARIZATION (%)
100
90
80
70
60
50
TEMPERATURE (K)
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Fig. 3

the spectrometer. This allows the lowest possible temperature when moving through the low-field region. It also reduces the influence of eddy current heating in the heat exchangers; the eddy current heating is almost entirely brought to the evaporator along the dilute stream. For further reduction of eddies the heat exchangers of the dilution refrigerator are long and narrow and they are made using a minimum amount of copper. The eddy current heating of the cavity is absorbed by the evaporator causing no harm to the mixer, most of which is made of dielectric material.

The total time of movement is estimated to be about 10 min. Depending on the electron spin relaxation time in the target material, the transfer through the lowest field region can be made in nearly adiabatic conditions, thus reducing the magnetization heating of the target when going up the field gradient towards the final target position. The nuclear spins in the target become aligned along the lines of the holding field.

In the holding position the dilution refrigerator is again switched to a continuous mode of operation.

d) Target geometry

The most flexible arrangement is the one applied in the target for the $K^- p(\uparrow) \rightarrow \bar{K}_0 n$ experiment[4], in which the particle beam enters along the axis of the cryostat. This limits the momentum of the incident beam as a function of the field of Omega, as the beam has to pass a tube of diameter 4 cm and length 80 cm.

3) Polarizing field

The position most suited for installing the 25 kG field enhancement is very probably near a pillar in between the superconducting coils. It seems difficult to produce the required field with pieces of iron only and coils will then be needed. The position and the design of the magnet will not be decided upon before the field map of Omega is available. The gap will be wide enough (10 cm) in order to allow equipment such as a cylindrical multiwire proportional counter to remain around the target while repolarizing it. The system should be able to be run at half maximum field.

3.3 Omega geometry

We will probably use the standard Geometry II. Surrounding the target with a set-up of multiwire proportional chambers for Multiplicity trigger is clearly essential for most planned experiments.

REFERENCES

1) M. Borghini, in Proc. 6th Rencontre de Moriond, 1971, p. 145.

2) W. de Boer and T. Niinikoski, "Dynamic proton polarization in propanediol below 0.5 k" January 1973, submitted to Phys. Rev. Lett.

3) M. Russell, "A separated function polarized target" published in Proc. Conf. Polarized Targets, Berkeley, 1971.

4) J. Vermeulen, "A ^{3}He-cooled polarized target", published in Proc. Conf. Polarized Targets, Berkeley, 1971.

4. A POSSIBLE TIME SCALE AND ITS MEANING

A PS shutdown is clearly needed to install the polarized target. The January 1974 shutdown seems to be out of question because a) the time scale for construction would be very tight, b) the time available for technical tests would be almost inexistent, and c) the target would have to be taken out again (which takes much less time) in order to complete the hydrogen experiments.

The more realistic possibility is then the shutdown of January 1975. Enough time is available to build and test the target beforehand (CERN-ETH magnet?). To the extent that the physics programme will be based only on the standard and, by then, operational trigger systems, this option would enable us to run Omega almost continuously until the West Hall shutdown (Summer 1975), leaving the remaining months of the year to the East Hall users. About 3 experiments with data taking time of 20 days could then be planned.

The several 10^7 events taken during this well defined lapse of time should not only give useful results for several experiments, but should also allow us to assess their relevance for physics and to judge whether further polarization measurements at the SPS will be desirable, in particular in the RF separated beam with its kaon fluxes of 10^6/burst in the 10-30 GeV/c range.

If such a beam were not available, the interest of polarized target physics at the SPS should be reconsidered.

APPENDIX

Possible Schedule

1973 Summer : Decision about the R.F. beam.
Design of the repolarizing magnet.

Fall : Final decision on the installation of a frozen spin polarized target in Omega in 1975.
Proposals of experiments.

1974 Installation of the frozen spin polarized target in the CERN-ETH magnet :
Technical tests.
Possible experiment: $\pi^- p \to K^0 \Lambda$ (CERN-ICL)

Construction and test :
Repolarizing magnet, homogeneity ?
Moving platform.
Small cylindrical multiwire proportional chamber.

Test runs of provisionally approved experiments on hydrogen and carbon.

1975 During the PS shut-down, installation of the whole system.

Continuous run till the West Hall shut-down :
3 experiments with 20 days data taking time each.