PROGRESS ON THE EXPERIMENTAL SEARCH FOR CHARGE SYMMETRY BREAKING (CSB) IN n-p SCATTERING

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Significant progress has been made during the past year on all aspects of the preparations for the CSB experiment,[1] although the schedule of preliminary test runs was interrupted for about six months by the polarized ion source fire. In this section we summarize the status of the equipment specifically related to the CSB experiment, and the results of some recent runs. Details concerning apparatus in the polarized neutron facility (PNF), which is now essentially complete, and n beam properties are given in the technical section of this report.

The detection arrays for CSB are now nearly complete. The four small MWPC's (active area = 37.4 x 32.5 cm) needed for the experiment, as well as two spares, are complete, as are the first x-y pair of large (83.7 x 69.8 cm) MWPC's and the associated readout electronics and software. The remaining large chambers are currently being constructed. Improved grounding on both the chambers themselves and on the commercial LeCroy (PCOS II) circuit boards has eliminated earlier problems with faulty firing of the discriminators for many wires. The wedge-shaped plastic start scintillators for the left and right detector arms and the first of the two 96-cell liquid scintillation neutron detectors have been built and successfully tested. Construction of the second neutron detector is under way. Figure 1 depicts an early stage in the assembly of the trapezoidal, highly polished aluminum "honeycomb" structure which subdivides the large neutron detectors into optically isolated cells. All of the phototube bases and nearly all of the special processing electronics for the neutron detectors are built; significant work remains to be done only on the front-end microprocessor hardware and software to read out the bit patterns, timing, and energy information for the neutron detectors and transfer all of the data from CAMAC to the computer. The phototube bases designed and constructed at Hope College incorporate constant-fraction discrimination circuits as well as voltage divider chains. In cosmic ray tests we have achieved ~600 ps timing resolution between pairs of cells, which will be useful in distinguishing the first among possible multiple fires of the neutron detectors in the CSB experiment. The results of ongoing tests for the light output and long-term stability of the laser-fiber optics light-pulsing diagnostic system for the ~200 phototubes are encouraging. All of the necessary signal cables have been strung from the PNF cave to the CSB hut, allowing the electronics setup for our most recent runs, and for all future runs, to be carried out in the hut. The "C" Harris computer will shortly be moved downstairs to a location just outside the CSB hut, providing us with a complete local data acquisition system.

In a run in December 1982 we made use of a large fraction of the CSB detection arrays, including one complete arm (wedge-shaped plastic scintillator, small

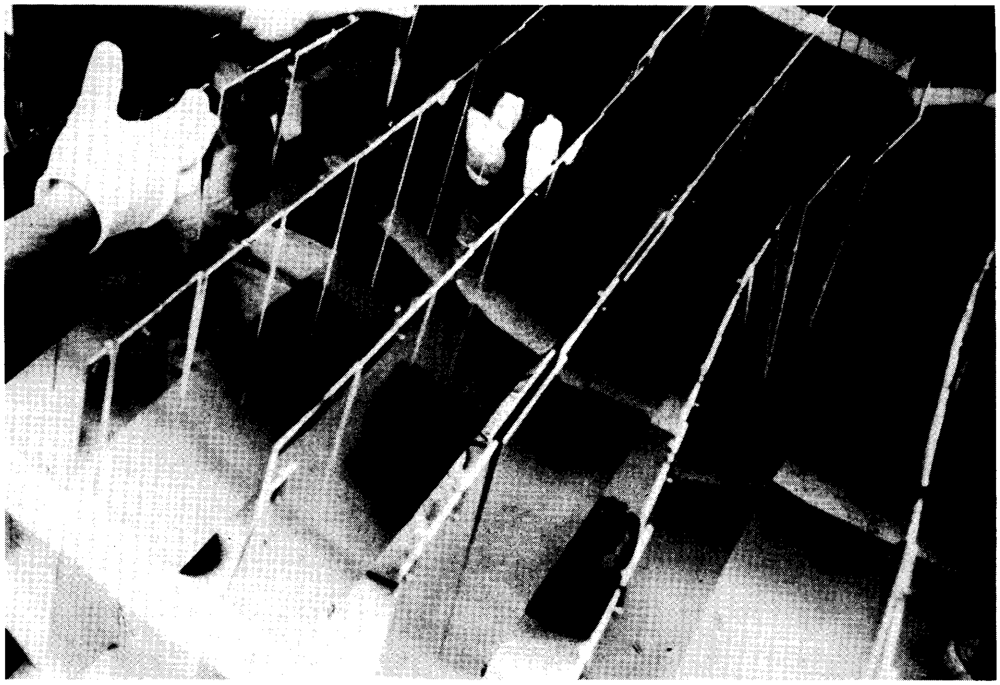

Figure 1. An early stage during assembly of the honeycomb structure which subdivides the large liquid scintillation detector into optically isolated tapered subcells. The structure comprises intersecting horizontal and vertical walls of .040"-thick highly polished aluminum.

x-y MWPC's, large x-y MWPC's and large liquid scintillation detector, although we processed signals from only one 16-cell block of the latter detector). In conjunction with the wedge-shaped scintillator and small x-y MWPC's on the second arm, we measured charged-particle coincidences induced by a secondary polarized proton beam ($E_p \simeq 190$ MeV) in the PNF (from a ^{7}Li production target). The run served as a successful in-beam test of the large MWPC's and of the associated readout hardware and software. We also tested transform software allowing ray-tracing of the charged-particle trajectory for the complete detector arm, consistency checks between position information from the MWPC's and the multicelled liquid scintillator, determination of the point of origin of the scattering event on the extended target, and accurate extraction of the opening angles (θ_{open} and ϕ_{open}) for the detected particle pair. We were able, in addition, to demonstrate the usefulness of two independent schemes for providing absolute angle calibrations for the detectors with use of the secondary proton beam. The first scheme involves measurement of the zero-crossing angle for the free p-p scattering analyzing power, constrained by the indistinguishability of the two protons to occur at $\theta_{lab} = 43.64°$ ($\theta_{c.m.} = 90.0°$). The second scheme involves a kinematic crossing for free p-d scattering, wherein the coincident protons and deuterons emerge at precisely the same laboratory angle ($\theta_{lab} = 51.12°$). The data obtained in a short p-d scattering run with a 400 mg/cm^2 CD$_2$ target are shown in Fig. 2. Both the p-p and p-d crossings are contained within the angular range spanned by the CSB detectors, and together with optical alignment of the detectors, they should adequately constrain the angle calibration for each individual position-sensitive component of the detector arrays.

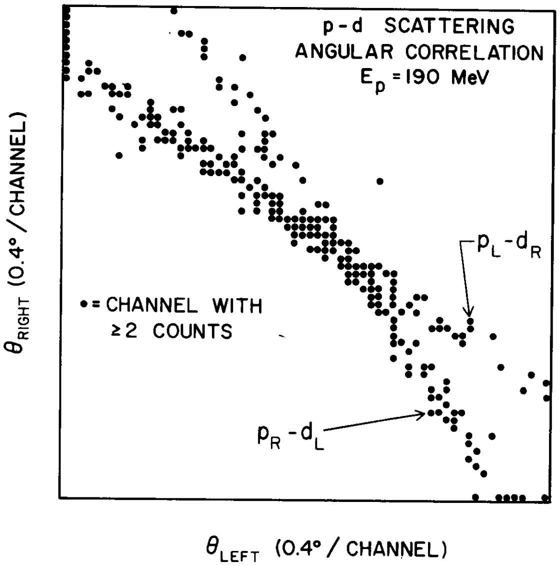

Figure 2. Illustration of the p-d scattering kinematic crossing used as one method for absolute angle calibration of the MWPC's. The intersecting kinematic loci correspond to (1) events (p_L-d_R) where the proton is detected in the left arm and the recoil deuteron on the right, and (2) events (p_R-d_L) with the deuteron on the left and the proton on the right. Each channel in the spectrum corresponds to 0.4° for both θ_{left} and θ_{right}. The crossing must occur at $\theta_{left}=\theta_{right}=51.12°$.

The opening-angle resolution obtained in the December run for free p-p scattering events initiated in a 1/4"-thick plastic scintillator target (of thickness comparable to that to be used for the yttrium ethyl sulfate polarized proton target[2] in the CSB experiment) was $\Delta\theta_{open}$ (FWHM)≃1.7°, $\Delta\phi_{open}$ (FWHM)≃4.2°. The dominant contribution to the resolution limit was from multiple scattering of the emerging protons in the plastic target. Slightly worse multiple scattering of the emerging proton in the CSB setup, coupled with the intrinsically poorer angle resolution of the neutron detector in comparison with the MWPC's, are expected to yield an n-p opening angle resolution perhaps 25-50% worse than above. As already suggested by measurements of p-p angular correlations resulting from proton bombardment of a CH_2 target, made in Fall of 1981 with a single MWPC pair on one arm and the prototype liquid scintillator on the other, the expected resolution for n-p detection should be sufficient to discriminate against quasi-free (n,np) events initiated on contaminant nuclei in the CSB target. In particular, Fig. 3 illustrates that quasi-free (p,2p) events from the CH_2 target were reduced to a tolerable background level (corresponding to ~0.5% CSB background under the free n-p scattering peak in the θ_{open} spectrum) by making reasonable cuts appropriate to free scattering on other parameters (most notably on the difference in flight times between the two detected nucleons and on their coplanarity ϕ_{open}). Sufficiently accurate

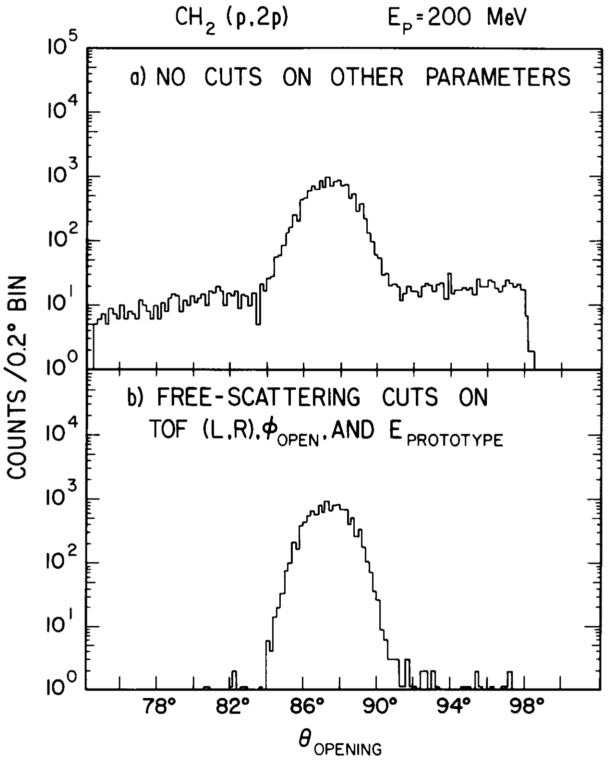

Figure 3. Opening-angle spectra for p-p coincidences from a CH_2 target, illustrating the level of quasi-free scattering background under the free scattering peak obtainable with (a) no cuts on other parameters, and (b) cuts appropriate to free scattering on the time-of-flight of both detected nucleons, on their coplanarity, and on the energy deposition of one of the protons in the liquid scintillator. The angle measurements for this data were made with one small x-y MWPC pair on one arm and the prototype liquid scintillation detector on the other.

subtraction (to ~±0.05%) of the quasi-free background in the CSB experiment will then be possible with the aid of (p,pn) measurements for the same target and (n,np) measurements on hydrogen-free targets of otherwise similar constitution.

The preparations for and analysis of results from the recent test runs have led to a considerable evolution in the data acquisition (RAQUEL) software for handling CSB-specific CAMAC interrupts, and for transforming the incoming raw signals into derived parameters most useful for on-line checks of the operation of all hardware. During the next several months we will implement a further major improvement to RAQUEL, to allow for multiple sub-groups of signal sources, each of variable word length, within an event. This modification will facilitate handling of multiple-hit data from the MWPC's and multi-celled liquid scintillators, while minimizing consumption of event tape and overhead in the interrupt-handling and on-line sorting software.

There are three major pieces of hardware needed for the final CSB setup on which significant further development work remains to be done. The "spin refrigerator" target[2] has now been polarized at the University of Wisconsin. At a target rotation speed of 20 Hz and temperature of 0.6°K, and for a polarizing field = 1.0 T, the measured polarization was ~25%, smaller than expected on the basis of previous results[2] for this type of target. It is hoped that increases in the target rotation speed, the polarizing field intensity (to 1.1-1.2 T), and the Yb-ion doping concentration in the samples will allow attainment of polarizations in excess of 60%. Detailed design and implementation of the front-end microprocessor hardware and software for readout of the liquid scintillator detectors and CAMAC event buffering should take place over the next several months. Finally, we are presently designing the rotatable arms and associated alignment fixtures which will support the detector arrays in their ultimate configuration. It is our hope to begin detailed studies of systematic errors with the complete CSB apparatus during the summer of 1983 and to initiate production runs toward the end of the year.

1) S.E. Vigdor et al., IUCF Technical and Scientific Report, 1978 (p. 15), 1979 (p. 118), and 1981 (p. 52); S.E. Vigdor et al., Proc. Fifth Intl. Symp. on Polarization Phenomena in Nuclear Physics (Santa Fe, August, 1980), edited by G.G. Ohlsen et al. (AIP, New York, 1981) Vol. II, p. 1455.

2) J. Button-Shafer et al., Phys. Rev. Lett. 39, 677 (1977).