

Findings

The scientific effort during FY2002 at the Indiana University Cyclotron Facility can be grouped into four major areas:

- This was the last (partial) year of Cooler operations. The remaining time was divided among several experimental efforts, each of which made excellent use of the time to gather data on their highest priority scientific goals. The experiments included measurements of double-spin polarization observables for d+p breakup as part of an investigation of three-body force effects, the first observation of the isospin-forbidden $d+d \rightarrow {}^4\text{He}+\pi^0$ reaction at two energies just above threshold, a measurement of the spin correlation parameters for $p+d \rightarrow t+\pi^0$, and the first investigation of deuteron spin flip and depolarization characteristics in a storage ring.
- The year began with running the first polarized colliding beams after acceleration in RHIC. Results were presented on forward π^0 production and azimuthal asymmetries in the STAR detector. During the year, construction was completed on 1/3 of the endcap calorimeter for STAR, and that portion of the detector has now been successfully installed on the STAR endcap at RHIC.
- New results were presented from NIST on the coherent scattering length in n+p and n+d scattering and data taking was finished on the measurement of the neutron lifetime. Work proceeded on the preparation of experiments to measure the weak coupling through the parity-violating asymmetry in n+p radiative capture and neutron spin rotation in superfluid ${}^4\text{He}$. New limits were set on the precision of neutron polarization measurements using passage through ${}^3\text{He}$ gas.
- The mini-BooNE detector was commissioned at Fermilab and data taking began on neutrons produced with the Booster ring.

The work in these areas is summarized below and described in more detail by a series of individual group reports that make up the rest of this Findings section.

During this past year, considerable progress was made on the analysis of data taken earlier on the Cooler ring. The results from the elastic scattering of polarized protons on polarized deuterons is nearly complete. There is data on 15 of the 17 possible observables taken at 135 and 200 MeV incident proton energy. Preliminary calculations (not shown in the detailed report) in which various three-body forces are included in Faddeev calculations based on modern two-body potentials show mixed results. Depending on the observable, agreement may improve, grow worse, or stay nearly the same when various three-body forces are included. This points to the need for a more systematic approach. A collaboration with theorists has formed for the purpose of developing a more general framework for the calculations within which it will be possible to vary the contributions of each term to match the data.

Analysis also proceeded on the measurements of n+p backward elastic scattering cross section. A comparison with part of the data shows good agreement with calculations based on the Nijmegen potential. This potential has a lower strength coupling between the pion and nucleon than was reported a number of years ago based on precise back-angle measurements from Uppsala.

A new effort was started to measure the spin correlation parameters, and in particular the longitudinal analyzing power A_z , for the breakup of beam deuterons on a proton target. Data was taken at 270 MeV, an energy where there is elastic d+p data against which the magnitude of the deuteron polarization of the Cooler ring can be calibrated. There are general arguments why A_z might be sensitive to three-body effects, even though present Faddeev calculations indicate only a small sensitivity. Data were taken during February and May of 2002 with the PINTEX detectors in their forward position to maximize the phase space covered.

At the beginning of FY2002, there was an extended period of Cooler access to allow for the change of the T-region target box (following the last tagger run) and to stack the Pb-glass arrays for the charge symmetry breaking experiment to search for the $d+d \rightarrow {}^4\text{He}+\pi^0$ reaction just above threshold. In January, there was a commissioning run using the isospin-allowed $p+d \rightarrow {}^3\text{He}+\pi^0$ to generate a large number of π^0 events. This was successful, and procedures were developed to keep the gain of the Pb-glass array calibrated using cosmic rays passing through the detector stacks. Following the switch to deuteron beam running, two commissioning runs were made to develop the detector systems used to monitor the luminosity and show that the results were internally consistent. In June and July, there were two long production runs, one at 228.5 MeV and the second at 231.8 MeV. After analysis work involving correction to the time of flight measurements, spectra with clear π^0 peaks were seen in the data for both energies with a missing mass resolution less than 1 MeV. Spectra from the run were shown to the CSB theory collaboration which met at IUCF August 24 to discuss progress on the calculation of the CSB cross section.

Members of the PINTEX collaboration also worked on the measurement of the spin correlation coefficients $\Delta\sigma_L$ and $\Delta\sigma_T$ for the $p+d \rightarrow t+\pi^0$ reaction at 250 and 275 MeV. Such measurements help to assign strength to different partial waves in the pion production process. For this experiment, small scattering angles were needed, so the detector system was moved downstream using special mechanical extensions to the target box.

When the fiscal year began, the Indiana members of the STAR collaboration were involved with production running at Brookhaven National Lab. In December and January, the switch was made to polarized proton beams, and transverse polarization was circulating until the end of the running cycle. Problems with the motor-generator unit for the AGS made ramp times longer and the proton polarization lower than had been experienced for a number of years. Nevertheless, the Collider-Accelerator Division demonstrated, using the newly installed p+C CNI polarimeters, that it was possible to inject and ramp polarized beam to 100 GeV. Without a calibration of the polarimeters at the upper energy, only a limit is known on the possible depolarization.

For this running period, the prototype calorimeter and three arrays of Pb-glass detectors were installed in one forward direction from the STAR interaction point. This system...

A separate analysis was made for single and double spin asymmetries in leading charged particles observed at mid-rapidity in the STAR detector. A sensitivity level of 10^{-3} was achieved for particles above a momentum of 0.2 GeV/c. All of the asymmetries were consistent with zero, itself an important check of the procedures used to normalize and treat the measurements. This is consistent with theoretical expectations for charged pion fluxes. It should be stressed that these small asymmetries were measured simultaneously with the non-vanishing asymmetries associated with forward π^0 production.

Concurrent with the polarized beam running at STAR, Indiana-supported efforts were underway to verify the polarization produced by the OPPIS polarized source by using the

precision analyzing powers for p+d elastic scattering calibrated earlier with the cyclotron beams at IUCF.

Progress was also made during the year on plans for a calibration of the proton beam polarization at RHIC. This project will make use of an atomic beam target of known polarization and p+p elastic scattering in the Coulomb-nuclear interference region to transfer this information to the circulating RHIC beams.

A very large effort has been made during this year to bring the production lines for scintillator megatiles and lead radiators into operation and complete one half of the endcap calorimeter in time for installation at Brookhaven during the summer shutdown. This has involved supporting work at a number of other collaborating institutions, including Michigan State, Texas A&M, Kent State, and Berkeley, as well as Brookhaven. Particularly noteworthy has been the effort in collaboration with Argonne National Lab to construct and test the scintillator strip shower maximum detector. Details of the construction project are contained in the Contributions section to this Annual Report. Here it is important to note that despite some difficulties throughout the system, in particular with the mounting of the lead radiators, IUCF was successful in shipping the detector to Brookhaven within the required time window and mounting it in place on the STAR pole tip. Four 30° scintillator sectors have been installed and final fiber connections to the photomultiplier tube boxes are being made. It is expected that this system will be ready for commissioning and operation during the heavy-ion running period that is planned to begin in late December or early January, 2003. Production of the remaining megatiles, lead radiators, shower maximum modules, and supporting hardware will continue through the winter to be ready for installation in the summer of 2003.

Results from the neutron interferometer at the National Institute of Standards and Technology on the coherent scattering lengths for n+p and n+d scattering have become available. These new measurements agree with and help to reduce the world average values for these scattering lengths. These measurements can act as constraints, much like the properties of the deuteron, on two- and three-body calculations. In the three-body case, agreement is only obtained with the most modern potentials, including three-body force effects.

Efforts to reduce the error in the lifetime of the neutron are still underway. The primary measurements have been completed; what remains are absolute neutron flux measurements. A value with an error well below 1% will be useful as a constraint on the unitarity of the CKM matrix in the Standard Model. A similar test of the CKM matrix is offered by the measurement of the decay parameters of the neutron. The limitations now on the precision of these measurements come from a poor knowledge of the neutron polarization before decay. Work is continuing to improve this with better knowledge of the polarization of the ^3He gas that polarizes the neutrons as they pass through.

Values of the weak pion coupling to the nucleon are being investigated through the measurement of the parity-violating asymmetry in n+p radiative capture. When completed, this will represent the first isolation of the neutral weak current between quarks. IUCF is involved with the construction of the liquid hydrogen target and hardware for mounting the CsI detectors. Another experiment involving parity violation will look for the spin rotation created by the weak interaction as polarized neutrons pass through superfluid ^4He . Indiana is responsible for the design of the ^4He cryostat.

This has been an important startup year for the mini-BooNE experiment at Fermilab. The main detector was completed and filled with oil. This fall, the first neutrinos were observed from the Booster end station (although beam fluxes remain low). This experiment will look for the

appearance of electron neutrinos through mixing in $\nu_\mu \rightarrow \nu_e$ following muon neutrino production from the secondary pion beam. The large size of mini-BooNE is aimed at confirming or refuting the results of the LSND experiment from Los Alamos. IUCF is involved with project management, detector maintenance and operations, slow controls for mini-BooNE, and the testing of the mineral oil.

Work has also begun on possible detector schemes for a second detector to go on the Booster neutrino line. By observing individual neutrino tracks from neutrino-nucleon scattering, it is hoped that new information will become available on the strange quark content of the proton. Tests are underway to explore track reconstruction using either scintillator arrays or digital photography.