Executive summary for "EDM Polarimeter Data Base for Protons"

For Lab. use

Exp. No.:	Session No.

Collaboration JEDI

Spokespersons for test beam time:

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Total number of particles and type of beam (p,d,polarization)	Energy range (MeV)	Intensity or internal reaction rate (particles per second)	
		minimum needed	maximum useful
Polarized proton	160 – 250 MeV	10^9 /fill	4×10^9 /fill
Experimental area	Safety aspects (if any)	Earliest date of installation	Total beam time (No.of shifts)
WASA Forward Detector	N/A	January, 2018	2 weeks

What equipment, floor space etc. is expected from Forschungszentrum Jülich/IKP?

WASA Forward Detector with side-mounted target ladder

Description of request (motivation, milestone(s), goals; maximum 5 pages)

Beam Time Request

EDM Polarimeter Data Base for Protons

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For the JEDI Collaboration

Abstract

Experiment E4, which covers the production of a polarimeter data base for deuterons and protons, was approved by the CBAC at its meeting in December, 2015. The deuteron portion ran successfully in the fall of 2016 and analysis of the results is underway. This beam time request asks for the remaining two weeks of running time to complete a similar survey for proton scattering from carbon using the WASA Forward Detector now installed and operating at COSY.

Introduction

The polarimeter used in a storage ring search for an electric dipole moment (EDM) must be optimized for high efficiency as well as large analyzing power. For both deuterons and protons, the best choice of target appears to be carbon placed as a block near the edge of the circulating beam. A thickness of a few centimeters produces efficiencies in the neighborhood of 1% where efficiency is understood to be the number of scattered particles detected and used in the measurements divided by the number lost from the circulating beam. At the energies likely to be used for an EDM search, forward angle elastic scattering in the range of scattering angle between 5° and roughly 20° possesses both a high cross section and a large analyzing power. Measurements of the elastic scattering channel alone [1,2] exist. But knowledge of the properties of other reaction channels as well as typical backgrounds are needed in order that Monte Carlo simulations may be realistic enough to optimize the arrangement of detectors (both calorimeters and tracking) as well as collimators and absorbers for the best polarimeter design.

After the disassembly of the WASA target and detector, the Forward Detector (operating angles between 3° and 18°) was retained. The detectors were refurbished as needed, and a new trigger and

readout system was installed. This system served well for the deuteron beam study completed in the fall of 2016. The targets were either needles of synthetic diamond or strips of polyethylene. The polyethylene was included to provide additional calibration information by scattering from a proton target.

We plan to use this system again for the proton study, measuring all outgoing charged particles from the proton bombardment of C and CH_2 targets at energies of 160, 200, 232.8, and 250 MeV. The preferred energy for the proton EDM search is 232.8 MeV. At this energy, the frozen-spin ring required for this experiment may be built from all electrostatic elements, which allows for systematic error reduction through the use of beams running simultaneously in both directions in the ring. Other energies allow for the modeling of thick polarimeter targets in which the protons slow down, or the possibility to run above or below the "magic" energy with an ExB field system to confirm any EDM observation. They are also chosen to facilitate calibration checks against analyzing powers from the literature. The beams will consist of polarized protons with either polarization state available (as well as the unpolarized state). Completion of the WASA Forward Detector setup and data acquisition at these energies should be accomplished within two weeks of operation following one week of machine development.

Examples of detector operation

The elements of the WASA Forward Detector are shown in Fig. 1.

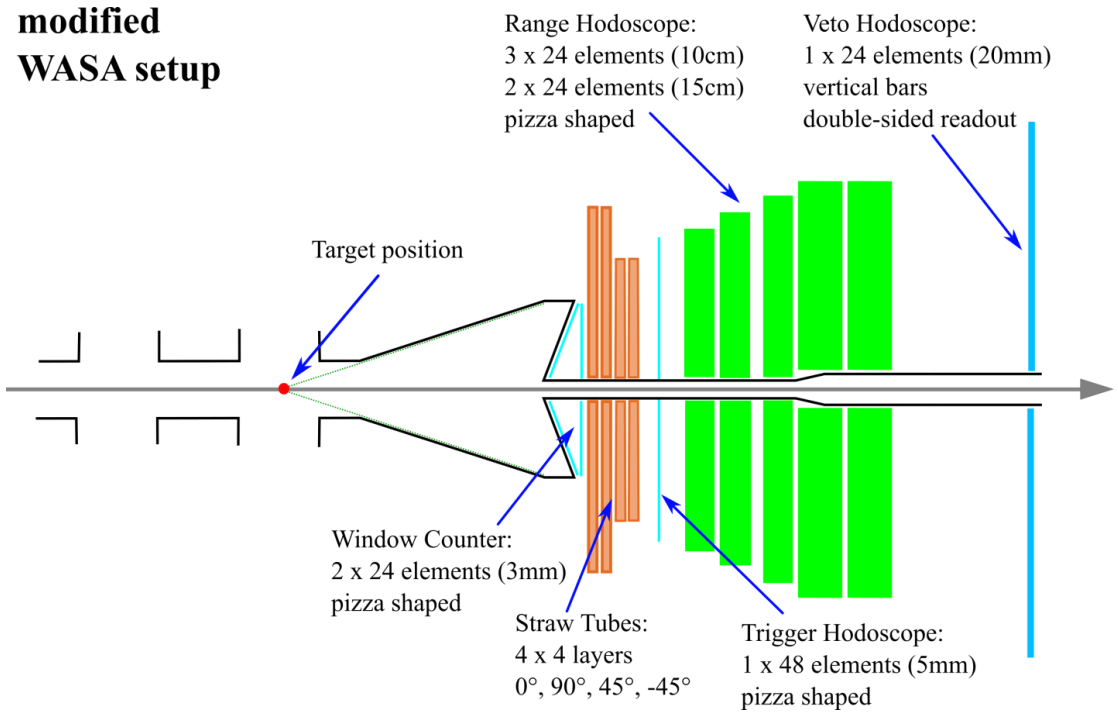

Figure 1: A cross sectional diagram of the WASA Forward Detector components.

Deuteron analysis has proceeded through the steps of calibration of all the detector components so that the signals match Monte Carlo calculations of the expected energy loss. Corrections are included for varying light collection through each detector elements, changes in the element gain over time on a run-by-run basis, and changes in the light emission strength with track energy density.

Figure 2 shows a sample of the 2-D reconstruction for adjacent pairs of scintillators.

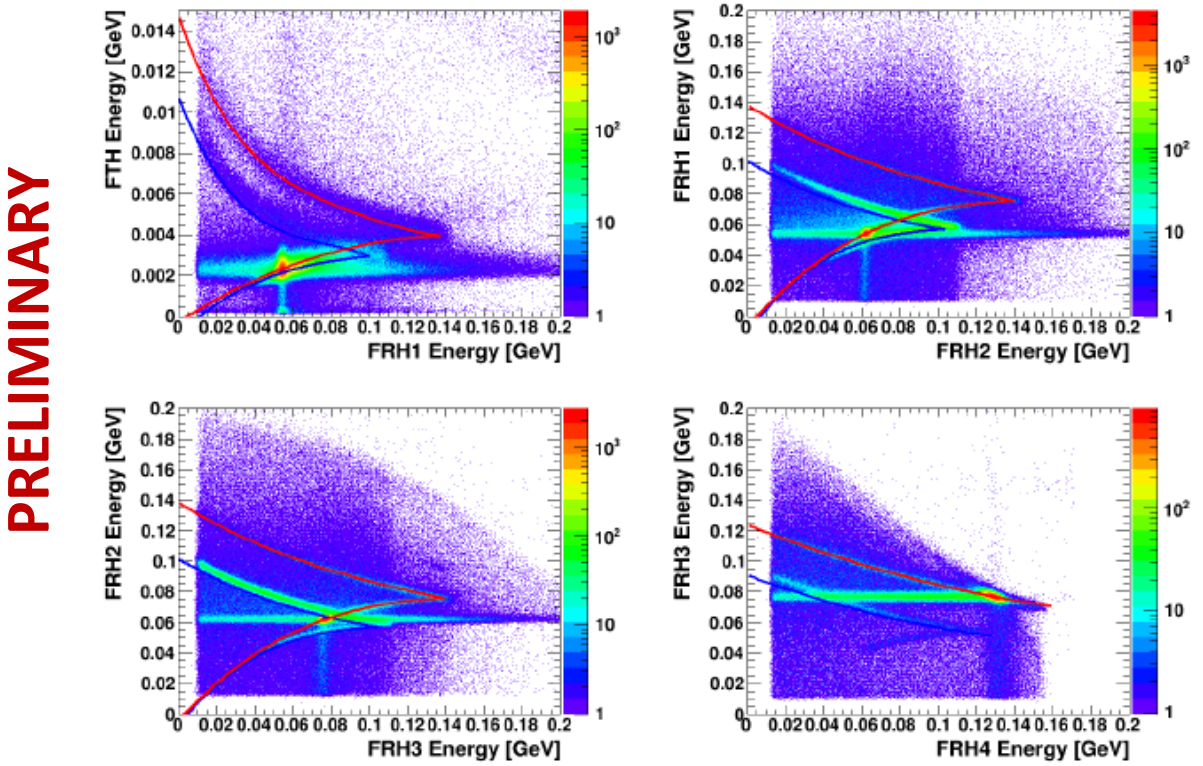

Figure 2: 2-D histograms of the tracks measured for 380 MeV deuterons in the WASA Forward Detector. Adjacent pairs of detectors are shown for the trigger hodoscope (FTH) and four of the five range hodoscopes (FRH1 through FRH4). The elastic group shows as a red feature with high rate. Red and blue lines indicate the expected loci of deuterons and protons of varying energies. Bands are clearly visible for particles the break up, scatter, or pile up with multiple hits radiating out from the elastic scattering feature.

These results are not yet fully optimized at all energies and angles, and for both protons and deuterons at the same time. We expect that this will be resolved shortly and the data put into a form that it can be used for simulations. The proton spectra expected from the new run will contain only a minor deuteron component and should be easier to handle.

Polarization Calibration

Several high-precision measurements of proton-carbon elastic scattering analyzing powers exist, and can be used to check the results from the Low Energy Polarimeter and the quality of the acceleration process through the various machine resonances. Figure 3 shows measurements from IUCF at 122, 160, and 200 MeV [1]. Figure 4 adds a measurement from TRIUMF at 250 MeV [2]. The WASA Forward Detector has coverage for the full range of azimuthal angles, so the observations of the asymmetry from the scattering of polarized protons is available for each of the polarized beam states. A reference for p+p elastic scattering based on phase shift or potential analyses is also available [3].

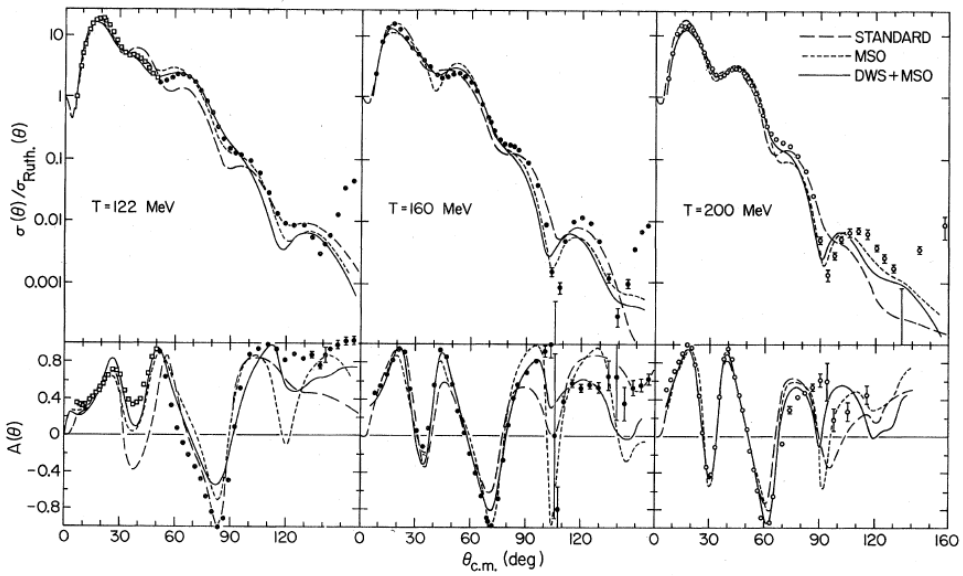

Figure 3: Measurement of the ratio of the differential cross section to the Rutherford cross section for Coulomb scattering is shown in the upper panels as a function of the center-of-mass scattering angle for proton scattering from ^{12}C. The lower panels contain measurements of the analyzing power. The curves represent optical model calculations based on different shapes for the real, central potential. The range of interest for polarimetry lies between 5° and 20°. Most of this is within the range of the WASA Forward Detector. The data were taken at IUCF [1].

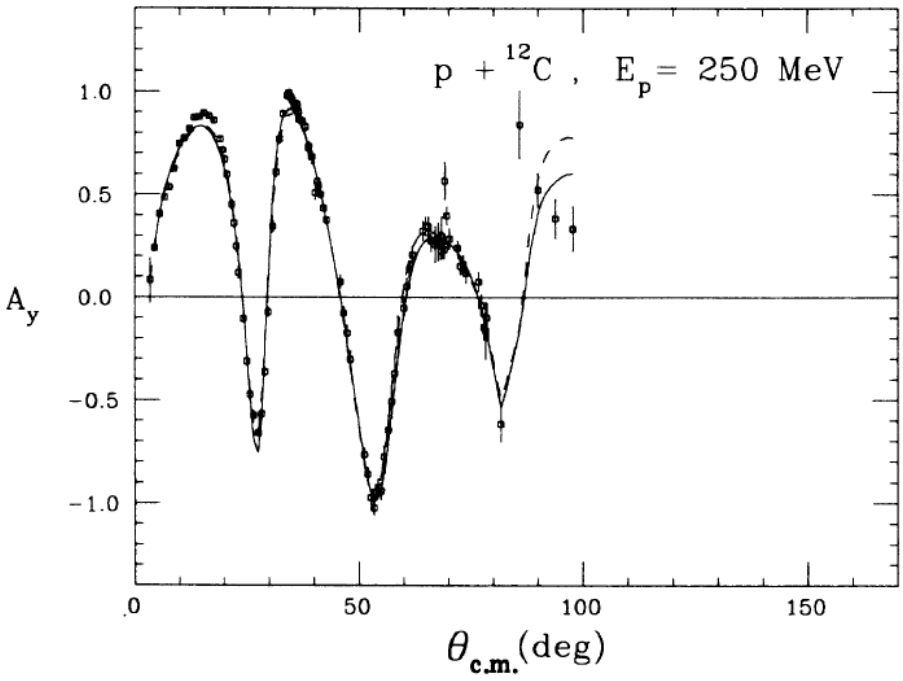

Figure 4: Measurements of the analyzing power as a function of the center-of-mass scattering angle for protons scattering from ^{12}C at 250 MeV. The curves represent a fit to the data using a relativistic optical model potential. The data were taken at TRIUMF [2].

Summary of the Request

We request two weeks (plus a week of machine development) in 2018 to measure all outgoing charged particles from the bombardment of polarized protons on carbon as a series of beam energies between 140 and 250 MeV using the WASA Forward Detector.

Some time will be needed during the setup and run to deal specifically with any machine resonances that are encountered during the acceleration process, and to optimize the choice of an online polarimeter in the COSY ring. At the lower energies of this experiment, it may be advantageous to set up a scaler trigger system based on signals from the WASA Forward Detector rather than to use EDDA in a singles scattering mode.

* Thesis student for this project.

† Institutional spokespersons.

‡ Presenter.

[1] H.O. Meyer *et al.*, Phys. Rev. C **27**, 459 (1983).

[2] H.O. Meyer *et al.*, Phys. Rev. C **37**, 544 (1988).

[3] See http://gwdac.phys.gwu.edu .