ROTATING WEDGE CYCLOTRON BEAM DEGRADER

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Abstract

A rotating wedge beam degrader provides rapid, continuously variable beams over wide energy ranges with good stability down to intensities as low as 100 particles per second. Used in conjunction with the energy analyzing magnets and beam switching magnet, this system has provided extremely clean beams for calibration of energy resolution and absolute energy response in detectors in the direct beam, as well as for study of other detector properties.

1. Introduction

The purpose of the rotating wedge beam degrader is to provide both extremely rapid and relatively simple continuous beam energy changes over very wide ranges of energy. Energy reduction is obtained by rotating an aluminum wedge into the beam; two analyzing magnets provide energy analysis and absolute energy calibration, and a final switching magnet cleans up the resultant beam. Following is a description of the degrader system and a brief summary of some of the experiments in which it has been used.

2. Degrader System

The degrader is an aluminum wedge bent into a circle of about three inch diameter, mounted on a cylindrical water-cooled copper base, which rotates across the beam as can be seen in the photographs of Figures 1 and 2. The particular wedge chosen, has thickness (17 mm.) sufficient to stop 170 MeV alpha particles and 85 MeV deuterons (maximum energies of cyclotron for these particles), or to degrade 100 MeV protons to 65 MeV and 65 MeV protons to zero; the degrader can also be entirely withdrawn, as it intercepts less than 180° arc about the center of rotation.

The beam emerges from the cyclotron and is focused at the object slit of the analyzing magnet system; immediately following this slit the degrader is inserted. A set of divergence slits, placed sixty inches from the object slits limits the beam divergence to about one milliradian in each direction. Two 90°, 60 inch radius double focusing analyzing

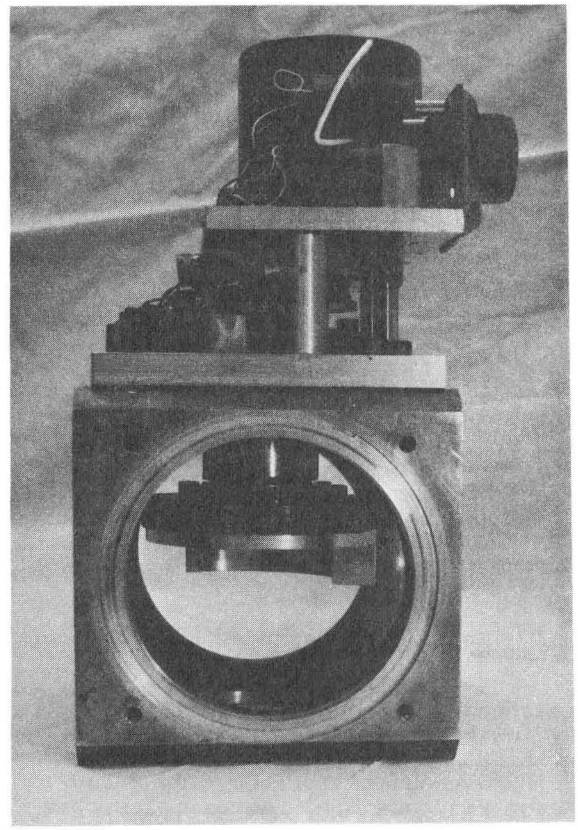

Figure 1. Horizontal view of degrader mounted in vacuum box with drive mechanism and limit switches above. Beam goes from right to left through geometrical center of box.

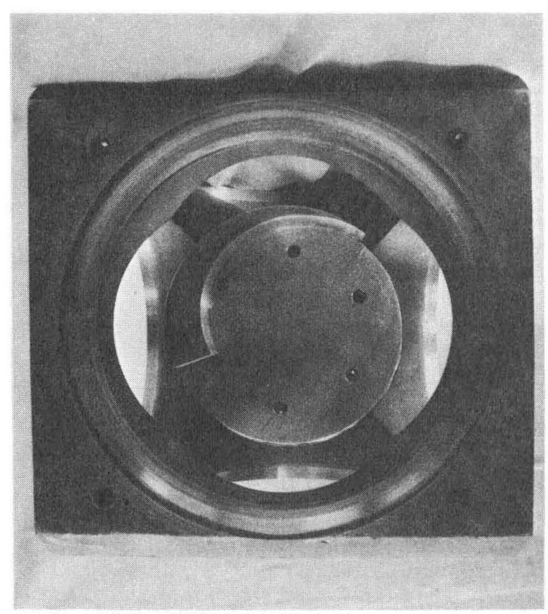

Figure 2. Vertical view of degrader.

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magnets[1,2] provide a vertical beam translation of 25 feet, and yield energy resolution of approximately 0.01% per millimeter of analyzing slit width and an absolute energy calibration within ± 0.03%.

Immediately following the energy analyzing slits a steering magnet bends the beam by 22°; a 50 foot free drift space to the test chamber allows the final beam to expand to a diameter of about 2 centimeters at the position of the detector under test. A by-product of the long drift space is virtually total cleanup of slit-scattered and other spurious beams; careful measurements have yielded no observable impurities in the beam at the test chamber. Use of the detectors in the direct beam removes effects of target thickness, kinematics, and scattering tail, and thus facilitates detailed, careful determination of detector properties.

3. Summary of Degrader Experiments

The rotating wedge beam degrader was developed for the NASA-Goddard cosmic ray physics group under the direction of Dr. F. McDonald and Dr. B. Teegarden.[3,4] This group has calibrated timing and energy response of detector telescopes consisting of up to four solid-state Si(Li) detectors; several such detector telescopes were mounted in each package carried into outer space by the Pioneer 10 and 11, HELIOS, and Mariner spacecraft.

A group from the University of Kiel, Germany, under the direction of Dr. R. Müller-Mellon, Dr. H. Kunow, and Dr. H. Witte,[5] has also calibrated detector telescopes similar to those of the NASA-Goddard group. Whereas the NASA group is studying primarily low-energy cosmic ray particles, the Kiel group is looking also at particles of energy in excess of one GeV using Cerenkov counters following the usual solid state detector telescope.

The University of Iowa group represented by Dr. J. Van Allen and Dr. D. Baker[6] has calibrated detector telescopes of non-solid state detectors in balloon packages for study of radiation in the upper atmosphere.

A Los Alamos Meson Factory users group, represented by Dr. B. Preedom of the University of South Carolina[7] is studying (π,p) reaction cross sections to high accuracy (less than one percent). This group used the low energy proton beams to experimentally determine the reaction tail for the protons in plastic scintillator; results showed the tail to be significantly lower than previously calculated.

Finally, the University of Maryland detector development group has used the degrader facility to study the properties of commercially available Si(Li) detectors as well as thick Ge(Li) detectors manufactured and packaged in our detector laboratory.

4. Experimental Results

An energy change in the degrader system as described, including setting the degrader, two analyzing magnets and the switching magnet, can be accomplished in less than five minutes. One obvious limitation of this system is that for large energy degradations the resultant maximum available beam intensity is reduced by outscattering in the degrader. This has not been a serious problem in any experiments performed thus far; stable, uniform beams of 10^2 - 10^4 particles per second have been available even with 90% energy degradations.

Results of studies verify the extremely clean quality of the beam; best results in energy resolution are somewhat less than 0.08% for 100 MeV protons, 140 MeV alphas, and 80 MeV deuterons, with less than about 0.04% of this in the beam or otherwise unaccounted for. Further improvement to our detectors and detector systems, as well as additional study and improvement of the degrader system is now underway.

Acknowledgments

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References

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