Monitoring Production Target Thickness*

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Abstract

Pion and muon production targets at the Clinton P. Anderson Meson Physics Facility consist of rotating graphite wheels. The previous target thickness monitoring procedure scanned the target across a reduced intensity beam to determine beam center. The fractional loss in current across the centered target gave a measure of target thickness. This procedure, however, required interruption of beam delivery to experiments and frequently indicated a different fractional loss than at normal beam currents. The new monitoring procedure compares integrated upstream and downstream toroid current-monitor readings. The current monitors are read once per minute and the integral of readings are logged once per eight-hour shift. Changes in the upstream to downstream fractional difference provide a nonintrusive continuous measurement of target thickness under normal operational conditions. Target scans are now done only when new targets are installed or when unexplained changes in the current monitor data are observed.

I. INTRODUCTION

The Clinton P. Anderson Meson Physics Facility (LAMPF) provides a high power beam of up to 1 mA of 800 MeV protons to Experimental Area A production targets. Pions, muons, and neutrinos are provided to secondary channels for six or more concurrent experiments. The pion and muon production targets consist of rotating ATJ graphite wheels 3- to 4-cm thick. Figure 1 shows a sketch of the production target at the A2 location.

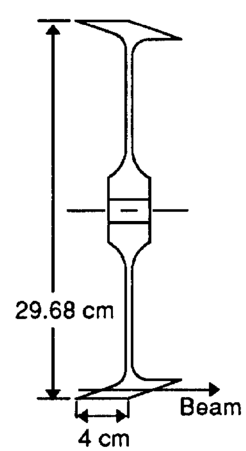

Figure 1. A cross section of the A2 production target. The beam passes through the 4-cm-thick rim. The nonrectangular shape of the rim optimizes production of muons and pions relative to the secondary channel acceptance.

During recent operating periods at LAMPF, a vacuum leak in the A2 target box has caused abnormally rapid erosion in the thickness of the A2 target. The erosion produces pits going completely through the thin edges of the target, which in one case reduced the effective target thickness by 50%. Large segments have broken off when the erosion was allowed to continue too long. Target replacement makes beam unavailable to experiments for up to three days to allow short-lived activation to die down, removal of the old target, installation of a new target, vacuum pump down and retuning the beam.

Attempts to fix the vacuum leak have been unsuccessful and a complete replacement of the target box is planned. Until this replacement is performed, however, it is necessary to optimize running conditions for experiments. Erosion of the A2 target reduces pion and muon fluxes to the two experiments running off the A2 target. Raising beam current to compensate for reduced target thickness increases the rate of erosion and forces a three-day beam off period for six or more experiments while the target is replaced. Thermal fluctuations in the A2 target box change the vacuum leak and therefore erosion rates, making it difficult to pick a single optimal operating current. The optimal strategy would be to continuously monitor the target, adjusting beam current for maximal secondary particle production for experiments while delaying the need for target replacement until scheduled maintenance periods when the beam would be off for other reasons.

II. Original Monitoring Procedure

The original procedure for monitoring target thickness made use of a Hardware Transmission Monitor [1] (HWTM), which compared the outputs of toroidal current monitors upstream and downstream of the target. The HWTM compares the difference between the current monitors to an Expected Loss set with a potentiometer on the module; the difference between the measured and expected losses is the Loss Deviation. For the A2 target, the full 4-cm thickness corresponds to an Expected Loss of approximately 12%. Variation in the Loss Deviation could indicate

- missteering of the beam, causing part of it to miss the rim of the target;
- change in beam spot size also causing part of it to miss the rim of the target;
- shift in target position with respect to the beam; or
- change in target thickness.

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The first two possibilities could be checked by observing the beam with wire scanners and harps without making beam unavailable to experiments. Target position shifts have been observed, due either to malfunction of the target positioning mechanism or thermal expansion of the 24-foot-long steel arm that supports the target. The original procedure checked all four possibilities:

1) Using wire scanners and harps, steer beam upstream and downstream of the target to within 0.1 mm of centerline. Also check spot sizes.
2) Reduce beam current to 70 μA to reduce thermal stresses on the target in the next step. This makes the beam unsuitable for most experiments.
3) Scan the target by driving it across the beam, recording the change in beam loss as a function of target position. Figure 2 is a plot of such a scan.
4) Center the target on the beam.
5) Reset HWTM Expected Loss potentiometer to give zero Loss Deviation.
6) Raise beam current back to normal levels (200-800 μA for 1992 running).

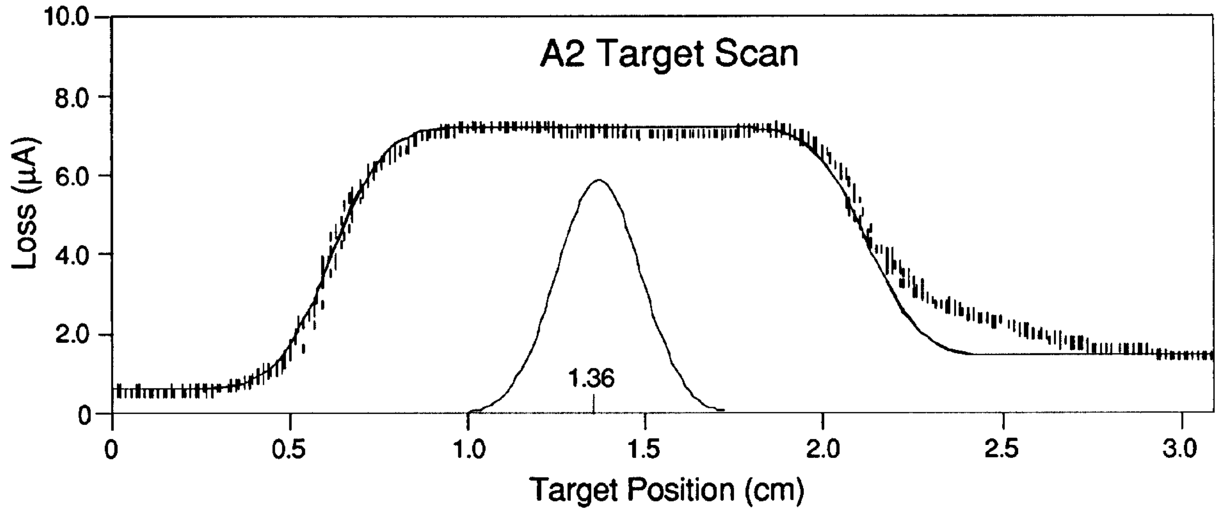

Figure 2. Result of an A2 target scan. Short vertical lines indicate the reproducibility of the data. The solid line is a fit to the data based on a Gaussian beam profile convoluted with the shape of the target. The Gaussian resulting from the fit is shown at the position which centers the target on beam. The centering position (1.36 cm) is used in step 4 of the scanning procedure. The target-shape model does not include the material in the radius between the rim and central web of the target; this causes the large deviation of the fit from the data near 2.4 cm.

The HWTM Expected Loss setting is the measure of target thickness from this procedure. The procedure has several undesirable features:

- Beam is unavailable to experiments for up to half an hour.
- Scanning the target causes stresses in the target drive and rotation mechanisms. Failure of these mechanisms could require up to three days of beam downtime to repair.
- Scanning the target even at low currents exposes the target to thermal stresses as the beam crosses the inner and outer edges of the rim. Such stresses could prematurely fracture an eroded target.
- The HWTM Loss Deviation changes significantly when the beam current is raised to normal levels. (This may be due to a change in the ratio of electrons to protons passing through the current monitors. Electrons are produced by beam halos intercepting nearby beam collimators.) This change makes it difficult to interpret the meaning of later changes in the Loss Deviation.
- To minimize loss of beam time for experiments, this procedure was done no more often than weekly. The infrequent measurements made accurate extrapolation of target lifetime difficult.

III. New Procedure

The new procedure also makes use of the upstream and downstream toroidal current monitors, but samples the data continuously and does not make beam unsuitable for experiments. The current monitors are sampled by computer once per minute, summed and recorded periodically. Plotting the fractional difference in upstream and downstream currents versus integrated current delivered to the target then gives an indication of target thickness. During 1992, the fractional loss was calculated daily. Figure 3 shows a plot of data for the A2 target taken with this procedure for the LAMPF 1992 operating period. Data were also taken for the 3-cm target at the A1 location; better vacuum at A1 resulted in no detectable erosion of the A1 target.

The new procedure was implemented near the end of the lifetime of the first A2 target used during 1992. Earlier data for the first target were extracted from archival records. Because of the continuous nature of this procedure, confidence in the state of the target was much higher and extrapolations of thickness were considered more trustworthy. Thus the second target was allowed to erode much further than the first before replacement. Target scans were done

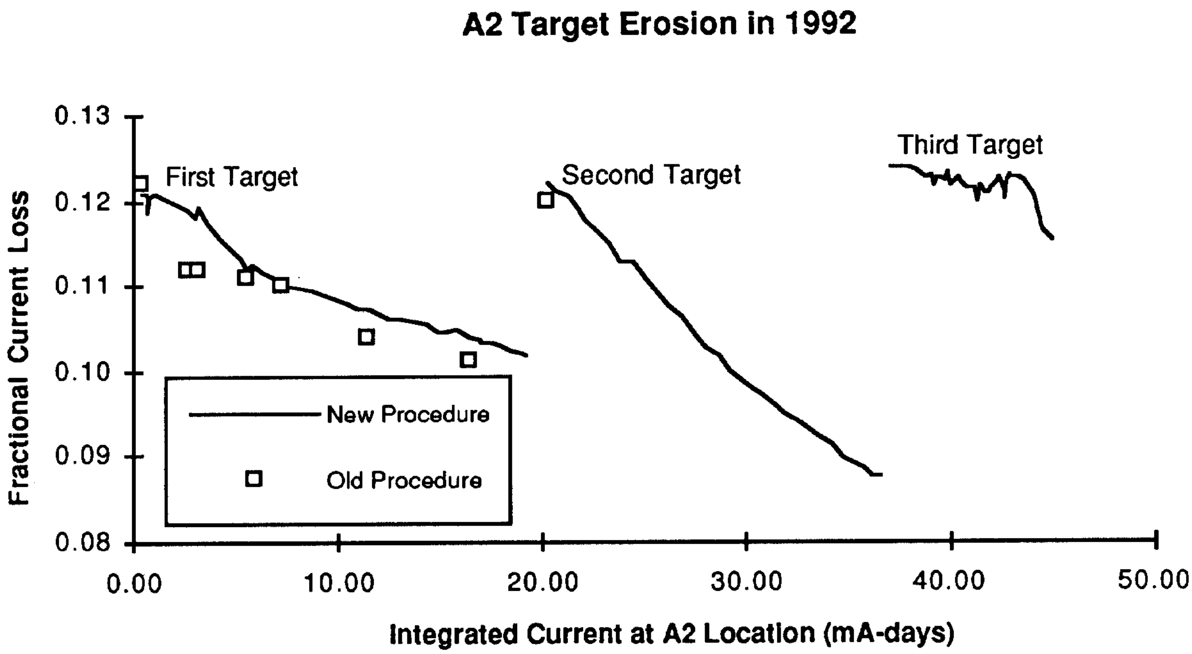

Figure 3. The fractional current loss across the A2 target as measured by the new procedure plotted against integrated current on target. The fractional loss is a measure of target thickness. Also shown is the fractional loss measured by the old procedure. Three different targets were used during 1992 running. The low rate of erosion of the third target was due to low beam currents (200 μA) run during this time period.

only when new targets were installed. Plans were to perform scans if unexplained changes in the losses were observed to check for lurches in target position; however, no significant deviations from gradual erosion were observed and no intermediate scans were done.

Based on these data it was possible to correlate target erosion with beam current and A2 vacuum pressure. It was found that at currents below 500 μA, target erosion was small at all pressures observed. Below pressures of 0.2 microns, target erosion was also very slow for currents up to 700 μA. However, for pressures above 0.2 microns, the erosion rate increased rapidly for beam currents above 500 μA.

IV. Conclusions

Use of the new procedure provided greater confidence on the status of the A2 target and permitted better scheduling of beam currents. Significant amounts of beam time were saved by avoiding the lengthy target scan procedure. Continuous monitoring of erosion also allowed correlation of with beam current and vacuum pressure.

Future uses of this technique may include recording current-monitor data as often as minute-by-minute to better understand short term fluctuations in the losses. Use of ion chambers located near the production targets will be investigated to see if data from them can be used as a cross check on the current monitor data. In addition it may be possible to use pairs of current monitors upstream and downstream of beamline collimators to better monitor beam losses during beamline tuning.

V. REFERENCES

[1] A. Browman, "LAMPF Hardware Beam Transmission Monitor Systems," *IEEE Trans. Nucl. Sci.* NS-28, N0. 3, 2237 (1981).