

## CE46: SKIMMER TARGETS FOR THE COOLER

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Most nuclear physics experiments in the Cooler to date have used gaseous targets, either as supersonic jets or in storage cells. Because of the stringent limit on target thickness, targets in the solid phase are more problematic in the Cooler. The methods studied so far for introducing ultra-thin solid targets to the Cooler beam are oscillating micro-ribbons,<sup>1</sup> and gas-entrained jets of micro-particles.<sup>2</sup> Solid targets have also been used as beam skimmers in the Cooler at various times, but until now there was very little quantitative data on how useful they might be as actual targets for nuclear physics. A recent experiment (CE46) set out to study skimmer targets for the first time in some detail. Our purpose was to explore the average luminosity as a function of a few operating parameters, and to compare that luminosity with an internal target that is already well understood, a nitrogen gas cell.

A skimmer target consists of a small solid target mounted on an arm that can be moved perpendicular to the beam in vacuum under computer control. When the detectors and beam are ready, the target is moved into contact with the edge of the beam. With sufficient beam current, a desired event rate can be established while the target intercepts only part of the beam. Once established, this rate can be kept constant by moving the target closer to the beam center, even though the beam current starts to decrease as soon as the target overlaps the beam. For the same physical target thickness, the event rate can be adjusted over a wide range. At some point in the cycle, however, there is no longer enough beam remaining to maintain the desired event rate. (This happens when the target edge is near the center of the beam.) At that time, the target is withdrawn, the Cooler refilled and the cycle is repeated. The heart of the skimmer target system is the so-called "FLIM" linear motor capable of fast, precise motion, and the software to implement the appropriate feedback between event rate and position.<sup>3</sup>

The three solid target configurations mentioned above each have advantages and disadvantages for particular applications. The microparticle targets tested at IUCF require some amount of gas thickness that may be considered a contamination. Since particle size must be uniform for optimum performance, the choice of target materials is limited. A skimmer target can be made from virtually any room-temperature solid that is compatible with a high vacuum, and so can share the advantages that micro-ribbons have in the way of small energy loss and multiple scattering, and the detectibility of recoil nuclei. The skimmer method has an advantage over the oscillating micro-ribbon configuration in

its duty factor. As tested so far, the ribbons oscillate at a frequency near 30 Hz, giving the correct time-averaged thickness by being out of the beam most of the time, providing events in pulses with an instantaneous rate about 100 times the average rate. Although the skimmer mode does not sample all of the beam phase space equally, it is relatively easy to keep the event rate near an optimum during the data-taking part of the cycle, and to have a duty factor that is very close to unity. However, the skimmer mode probably does not involve an equilibrium between target heating and electron cooling, which may result in an efficiency penalty due to increased scattering out of the beam elsewhere in the ring. The main purpose of CE46 was to test whether this penalty in efficiency would outweigh the other advantages under actual experimental conditions. This was accomplished by measuring the cycle-averaged "luminosity" with different targets and running parameters (see below).

CE46 ran in the "A" region of the Cooler over a period of nine days in the summer of 1994, using the detector stack for CE35.<sup>4</sup> Average luminosity was measured by counting events from elastic proton scattering. We used unpolarized proton beams, strip-injected at 45 MeV, then ramped to 200 or 300 MeV. Typical stored beam current was around 200  $\mu\text{A}$  after ramping, limited by dead time at the higher event rates tested. A storage cell target filled with nitrogen gas of a known thickness was measured for comparison. During the run, the skimmer system was very reliable and relatively easy to use. For most targets it was possible to achieve stable operation at event rates which varied by a factor of 25 from lowest to highest. Besides the event rate, we also explored different target physical thicknesses (most targets were carbon) and various nuclear masses (up to lead). Varying amounts of RF noise were used to change the transverse distribution of the beam, to see how this would affect the performance of the rate feedback circuit, and a few runs were made without electron cooling to determine what role cooling plays in skimmer operation. Table 1 summarizes the data taken.

The data are currently being analyzed to determine an absolute average luminosity for every run. Although there is a trivial scaling expected with the stored beam current, precise knowledge of the beam current is not required for determining the luminosity. (It would not be very useful anyway, since a varying and unknown fraction of the beam is intercepted by the target.) Luminosity can be determined very accurately for the carbon runs because data were taken with both pure carbon and polystyrene targets where the ratio of carbon to hydrogen nuclei is known to be 1:1. Although the energy resolution of the detector stack was coarse (about 6 MeV), peaks from carbon and proton elastic scattering were sufficiently separated in the energy of the detected proton ( $\theta_{\text{lab}} = 15^\circ$ ) to distinguish scattering from the two nuclei (see Figure 1). Therefore, luminosity on any of the pure carbon targets can be measured as accurately as our knowledge of the proton-proton elastic scattering cross sections in this energy range (about  $\pm 5\%$ ). Absolute calibration of luminosity from the heavier nuclei will be limited by the accuracy of previous cross section measurements in the literature.

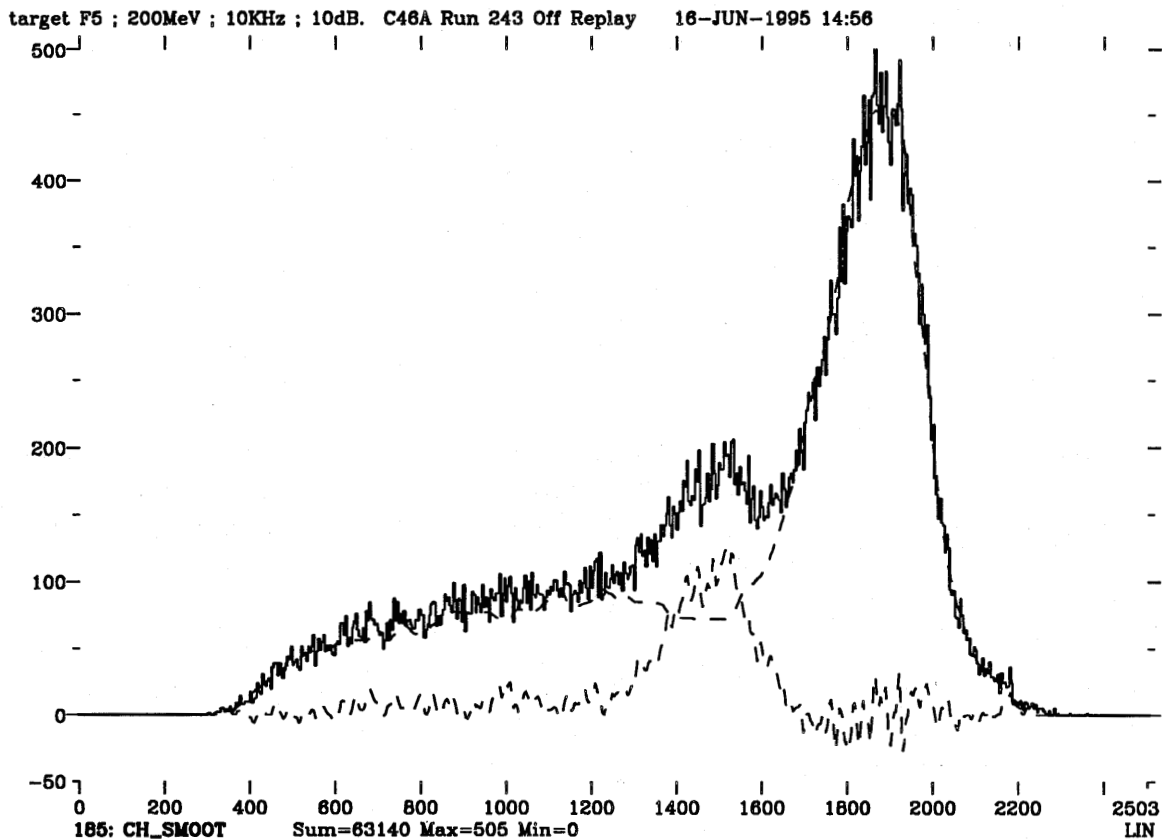
Preliminary results indicate that when normalized to the same stored beam intensity (200  $\mu\text{A}$  at 200 MeV) the cycle-averaged luminosity for a typical carbon skimmer was equal to or greater than that for the nitrogen gas cell operated near its optimum thickness<sup>5</sup> (the measured average luminosity was between 4 and  $7 \times 10^{28} \text{ s}^{-1} \text{ cm}^{-2}$ ). Since the CE46 run,

target	proton beam energy:	
	200 MeV	300 MeV
N <sub>2</sub> gas cell (5 thicknesses)	11, no noise	none
CH foils:		
160 $\mu\text{g}/\text{cm}^2$	20, 6	none
1.2 $\text{mg}/\text{cm}^2$	23, 5	6, 1
Carbon ribbons or fibers, linear density: (nuclei/cm)		
$1.8 \times 10^{14}$	12, 3	
$1.5 \times 10^{15}$	2, 2	5, 2
$2.3 \times 10^{15}$	6, 4	
$7.2 \times 10^{15}$	19, 7	
$1.2 \times 10^{16}$	1, 1	
$3.0 \times 10^{16}$	3, 2	
Carbon foils or slabs, areal density ( $\mu\text{g}/\text{cm}^2$ ) or thickness:		
6	1, no noise	6, 2
25	5, 2	
77		3, 1
190		4, 2
3000	5, 4	8, 3
1.03 mm	3, 2	1, 1
Other materials, foils between 200 and 500 $\mu\text{g}/\text{cm}^2$ :		
Aluminum	8, 3	2, 1
Scandium	1, 1	2, 1
Nickel	6, 3	1, 1
Zirconium	4, 2	3, 3
Lead	7, 2	3, 1

**TABLE 1** The first number in each position is the total number of data runs for that target and beam energy, the second is the number of different RF noise settings used. Most of the targets were tested with at least 4 different event rates in the region of maximum luminosity.

further improvements have been made in the feedback software that give a much more constant event rate, (see contribution by H. O. Meyer in this report) and two additional FLIM units have been constructed and tested.

1. B. v. Przewoski, *et al.*, Nucl. Instrum. & Methods **A328**, 435 (1993); H. R. Koch, *et al.*, Nucl. Instrum. & Methods **A271**, 375 (1988).
2. H. O. Meyer, A. Berdoz, H. Rohdjess, J. Doskow, and F. Sperisen; Nucl. Instrum. & Methods **A295**, 53 (1990).
3. P. V. Pancella, *et al.*, IUCF Sci. and Tech. Rep. May 1989 - April 1990, p. 125.



*Figure 1.* Luminosity calibration using pp elastic scattering. These energy spectra were taken at 200-MeV beam energy, where the combination of aluminum degrader and thick scintillator stopped all scattered protons. The upper histogram is the sum of several runs on the polystyrene CH reference target. The heavy solid curve is an accumulation of several runs on pure carbon targets, smoothed and scaled to match the large peak of the CH data. The lower curve is the result of subtracting the pure carbon from the CH spectrum, showing a peak from proton-proton elastic scattering at the expected energy.

4. M. A. Ross, *et al.*, IUCF Sci. and Tech. Rep. May 1992 - April 1993, p. 161.
5. R. E. Pollock, *et al.*, Nucl. Instrum. & Methods **A330**, 380 (1993).