COUNT-RATE FEEDBACK TO STABILIZE THE COOLER BEAM ON A SKIMMER TARGET

H.O. Meyer and T. Rinckel
Department of Physics, Indiana University, and
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

P.V. Pancella
Western Michigan University, Kalamazoo, Michigan 49008

The relatively weak damping provided by electron cooling limits the thickness of internal targets for which a heating-cooling equilibrium can be maintained. For a 200-MeV proton beam, for instance, internal targets should be thinner than about $10^{16}/Z^2$ atoms/cm^2, where Z is the atomic number of the target material. This rules out self-supporting solid targets.

It is, however, possible to use thick, solid targets when the so-called skimmer mode is employed. In this mode, an unsupported edge of a solid target is placed near the beam. The target is then intercepted only by beam particles that have a sufficiently large betatron amplitude. The luminosity in this mode is a function of the distance from the target edge to the beam center, and can be adjusted to the requirements of the experiment by moving the target transversely with respect to the beam. Carbon targets of this design are routinely used to measure the proton beam polarization via $^{12}C(p,p)^{12}C$ scattering.

The skimmer mode resembles slow extraction of the (hot portion of the) stored beam. The experiment usually requires that the target is placed such that a steady count rate s_0 of a predetermined value results. To this aim, the target is mounted on a fast linear motion actuator (FLIM), and the count rate of a detector in the flux of scattered particles is processed by a ratemeter. The FLIM is controlled by a PC-based interface that also reads the ratemeter output and provides a feedback loop in software.

In the ratemeter, a current that is proportional to the rate $s(t)$ at the input is used to charge a capacitor. A bleeding resistor parallel to the capacitor defines the integration time τ. The lower the count rate, the longer the integration time has to be if one wants to minimize statistical fluctuations of the output $r(t)$. The available rate information $r(t)$ lags behind the actual rate, and changes in $s(t)$ are manifest at the output only after some delay. Thus, the corrections applied to the FLIM position are therefore "out of date," resulting in large oscillations of the luminosity. This time lag of the feedback information seems to be a fundamental hurdle. Therefore, for many years large luminosity fluctuations were accepted for Cooler experiments with skimmer targets. This is illustrated in Fig. 1, which shows the skimmer performance during a run on March 16, 1992 of the CE20 experiment which used the CE01 detector as a polarimeter. The upper trace shows the beam current and the lower trace the rate in the detector (ratemeter output). The latter exhibits the large fluctuations mentioned.

Recently, we found that this difficulty can be overcome, because the functional dependence of the ratemeter output, r, on the input, s, *is known.* It is straightforward to show

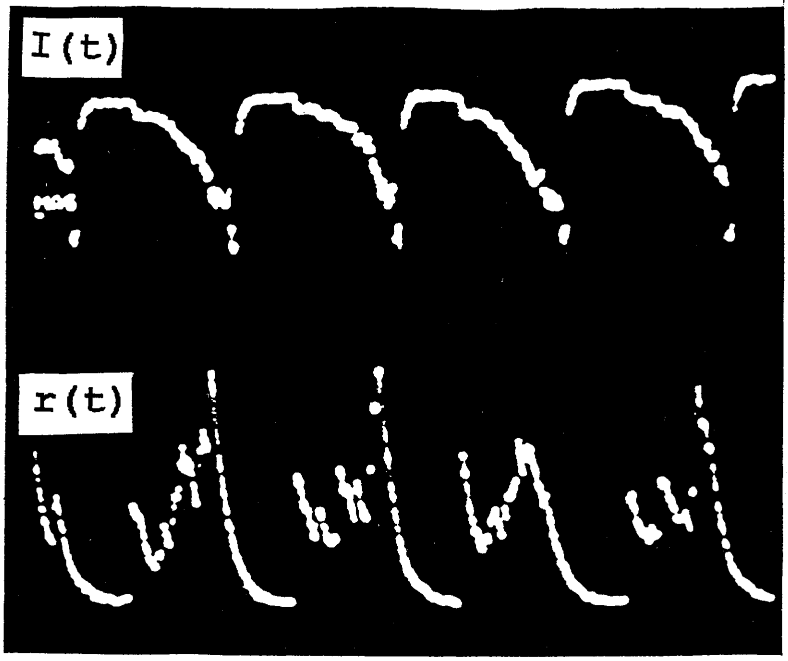

Figure 1. Old method: beam current $I(t)$ and ratemeter output $r(t)$ for four cycles. The data are from a CE20 run in March 1992. The beam energy was 108 MeV. A carbon skimmer was mounted in the A-region, and the CE01 detector was used as a polarimeter.

that the following relation holds:

$$r + \tau \frac{dr}{dt} - \alpha \cdot s = 0 \ . \tag{1}$$

Here, τ is the (known) time constant of the ratemeter, and α an (unimportant) calibration constant. The feedback code that receives the output r of the ratemeter is used to deduce the derivative dr/dt from the change of r during a short time interval. Then, the instantaneous rate s at the input is calculated according to Eq. 1. Comparing s to the desired s_0 yields an error signal that is used to adjust the position of the FLIM. The idea is simple and only a minor change to the feedback code is required. However, the improvement in being able to stabilize the luminosity is dramatic. This is illustrated in Fig. 2, which shows the skimmer performance during a CE42 run in January 1995 in which the CE01 detector was used as a polarimeter. The upperand lower traces show the ratemeter input $s(t)$ and output $r(t)$, respectively, for one cycle.

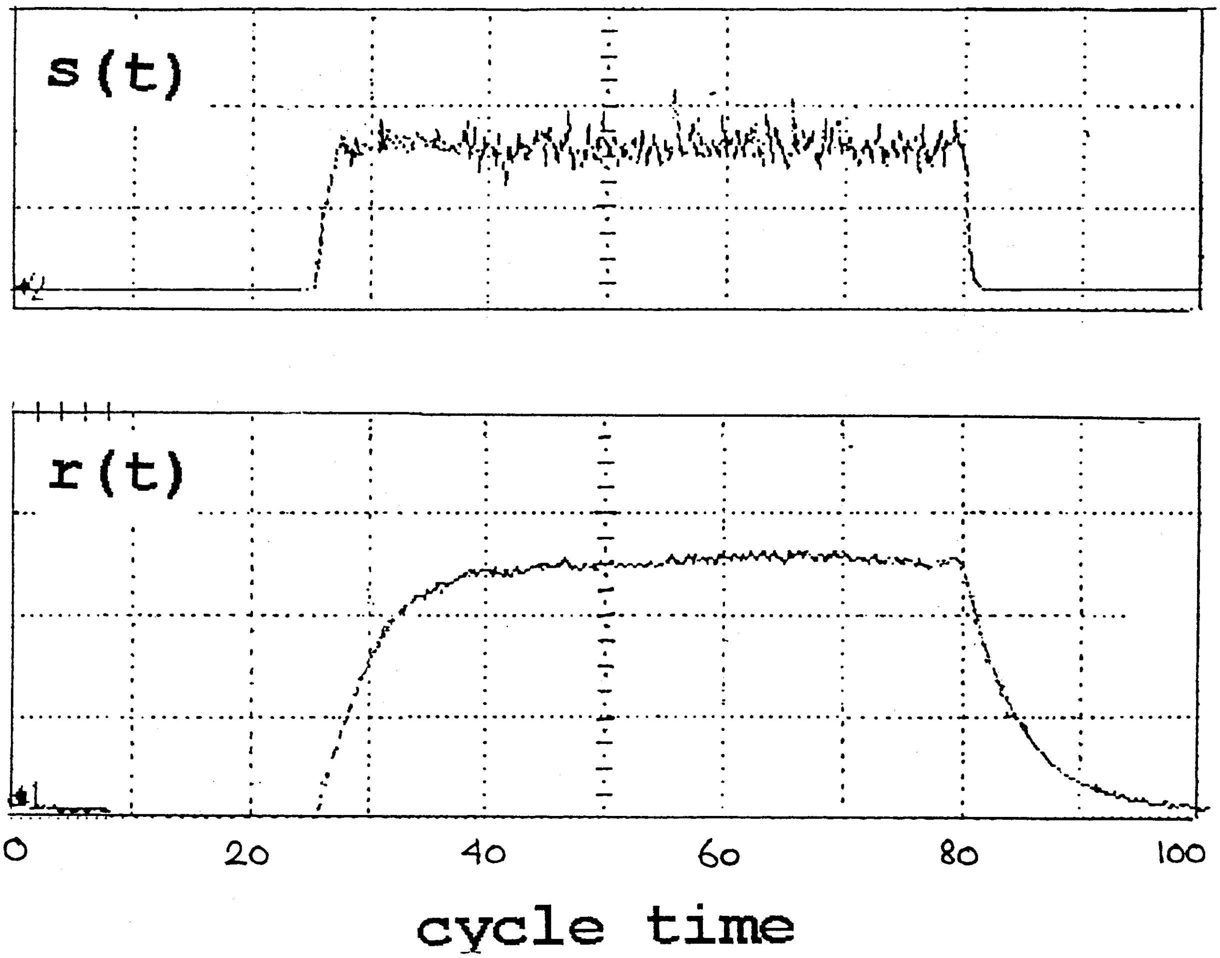

Figure 2. New method: ratemeter input $s(t)$ and output $r(t)$ for a single cycle. The data are from a CE42 run in January 1995. The beam energy was 200 MeV. A carbon skimmer was mounted in the A-region, and the CE01 detector was used as a polarimeter.