# Luminosity Monitor for E 89-044

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## 1. Objective

We seek a detector that will be sensitive to target density fluctuations by local heating due to the high-currents electron beams of 50-100 μA. The device should determine the luminosity of the beam - target gas combination at the 1-2 % level.

## 2. Concept Solutions

Two possibilities were considered, a detector at forward angles, or a large-angle detector at >90°.

### A Forward Angle Detector

*Advantages*

- High count rates → precision

*Disadvantages*

- The luminosity monitor will see the target cell windows. The background contribution of particles produced in the windows can be minimized by using a magnetic spectrometer to measure, *e.g.*, the $^3$He elastic cross section. This method is used at Mainz (Akio Hotta, Report, May 1999) .
- One would need to design such a spectrometer so that it did not interfere with the electron and proton spectrometers.

*Conclusions*

The realization of a forward-angle magnetic spectrometer to measure luminosity represents a considerable engineering project that would significantly impact current Hall A productivity. It would also be expensive. Given present constraints, it is not an option.

### B Large Angle Detector

*Advantages*

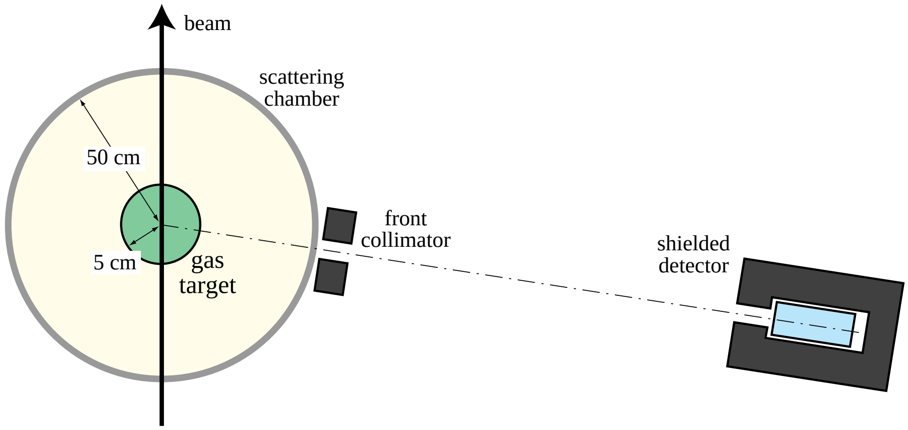
- Situated near 90°, the monitor can be readily made blind to particles produced in the target cell windows.
- It is more practical to design the monitor so that it does not interfere with the electron and proton spectrometers.

*Disadvantages*

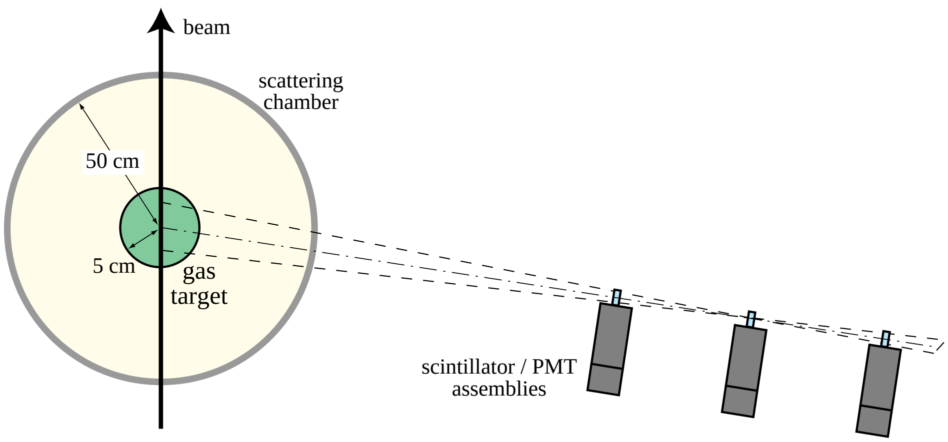
- Event rates at large angles are necessarily smaller.

***Two options for a large-angle luminosity monitor were investigated:***

(*i*) A single counter that would observe all particles produced in the target gas, as indicated below. A Čerenkov detector is advantageous for the reasons that its directional properties and intrinsic threshold can assist in background rejection. Particles produced in the target cell windows can be prevented from reaching the detector by means of a simple collimator, located just outside the scattering chamber. Although the count rate in such a detector would be high, operational experience in Hall A suggests that such a detector would be excessively sensitive to small variations in Hall backgrounds due to changes in the beam steering and other properties. For this reason, we reject this option.




(*ii*) A coincidence telescope consisting of three scintillators or Čerenkov detectors, as shown in the second diagram. The cross sectional size of the detectors is determined by the need to resolve individual particles, and the detector spacing is set to give an angular acceptance that excludes the target cell windows. No front collimator is needed in this design.

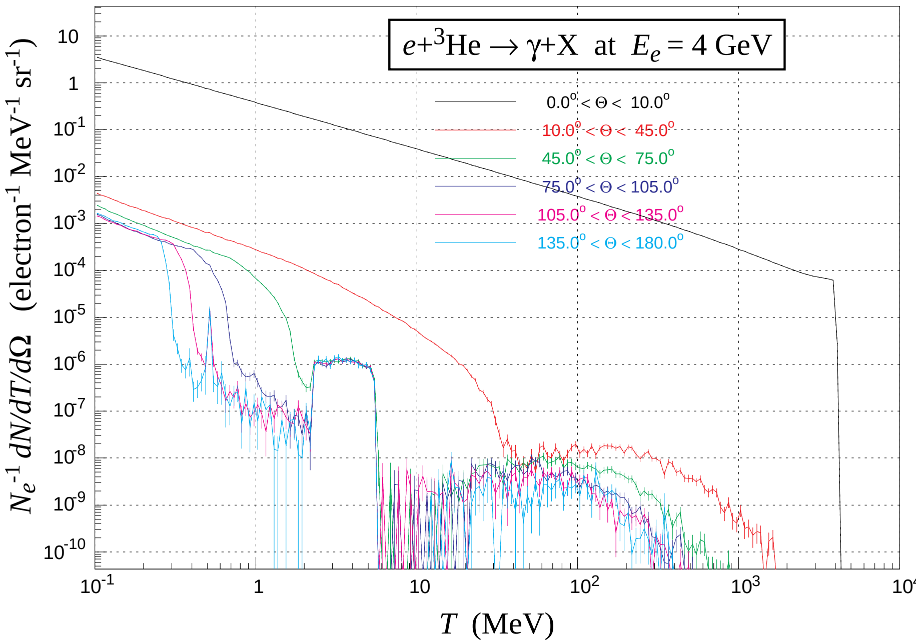



Scaling from rates previously observed in third-arm scintillators mounted in Hall A, we estimate that scintillators of size 1×1 $cm^2$ would satisfy the need to resolve individual particles without pile-up. A scintillator thickness of 0.5 cm provides adequate sensitivity to minimum-ionizing particles. The angular acceptance requirement is satisfied by three detectors 37.5 cm apart, with the first scintillator mounted 150 cm from the target. Relative to the target, the solid angle acceptance of such an arrangement is about 30 μsr. Installed at an angle near 120°, such a telescope would not interfere with either the proton or electron spectrometers. The alignment of the telescope would be established by the use of a red diode laser, mounted on the telescope, which is pointed towards the center of the target cell.

In order to assess the statistical precision of such a telescope for determining luminosity, we utilized the extensive results of production rate calculations made for us by Pavel Degtiarenko. The following conditions were assumed:

| | | |
|---|---|---|
| Produced particles | = | $e$, $\gamma$, $p$, $n$, $\pi^+$, $\pi^-$ |
| $^3$He target thickness | = | 900 mg/$cm^2$ |
| Beam current | = | 100 μA |
| Beam energy | = | 1.345 GeV and 4.00 GeV |
| Angular distributions of produced particles | = | 0–180° |
| Detector solid angle | = | 50 μsr |

Production distributions were calculated as a function of kinetic energy and scattering angle. One example is shown below. The complete set of calculations may be found at http://www.jlab.org/~pavel/he3_lum_monitor/. In order to assess the likely count rates for each of the different particle types, we considered the production rates, ranges, and multiple scattering angles, as well as the mean flight lengths for the unstable pions. Our findings are as follows:




**Electrons**

Although electrons having kinetic energies $T \leq 10$ MeV are copiously produced, they experience large multiple scattering angles ($\theta_{rms} \geq 7^o$) in 0.5 cm of scintillator. The multiple scattering diminishes significantly for larger kinetic energies- at T = 50 MeV it is 1.4°, but unfortunately, production rates drop preciptiously.

⇒ Electron production is not useful.

**Photons**

Photons are produced with large rates, but for these a telescope consisting of thin scintillators is an inappropriate detector.

⇒ Photons are not a candidate.

**Neutrons**

The detection efficiency of thin scintillators for uncharged neutrons is too small.

⇒ Neutrons are not a candidate.

**Protons**

Protons with $T \leq$ 50 MeV are not useful due to their short range in scintillator of < 2 cm. For protons with T > 100 MeV the range increases beyond 7 cm, and the rms multiple scattering angle in 0.5 cm of scintillator is < 0.32°.

⇒ Protons with $T > 100$ MeV merit further consideration.

**Pions**

Pions produced with $T \approx 50$ MeV have a range in scintillator of about 9 cm, a rms multiple scattering angle in an 0.5 cm thick scintillator of ≈ 0.8°, and a mean flight length of 5.3 m. While detectable with reasonable efficiency, things improve for 100 MeV pions: The range is > 25 cm, multiple scattering angle ≈ 0.44°, and the mean flight length 6.3 m.

⇒ $T$ > 100 MeV pions will be efficiently detected in a scintillator telescope.

**3. Estimated Precision**

According to the foregoing, we consider Degtiarenko's predictions for the likely counting rates of $T$ > 100 MeV protons and pions in a scintillator telescope.

$E_e$ = 1.345 GeV, θ = 120°, $T$ > 100 MeV

| | |
|---|---|
| $\pi^+$ | $1.2\times10^3$ Hz |
| $\pi^-$ | $1.0\times10^3$ Hz |
| $p$ | $3\times10^2$ Hz |
| ***Total*** | $\mathbf{2.5\times10^3}$ Hz |

$E_e$ = 4.000 GeV, θ = 120°, $T$ > 100 MeV

| | |
|---|---|
| $\pi^+$ | $2\times10^3$ Hz |
| $\pi^-$ | $2\times10^3$ Hz |
| $p$ | $3\times10^2$ Hz |
| ***Total*** | $\mathbf{4.3\times10^3}$ Hz |

In practice, for the following reasons the actual counting rate will likely be smaller by about one order-of-magnitude:

- The detector telescope we propose has a solid angle of 30 μsr rather than 50 μsr assumed by Degtiarenko.
- In order to avoid the background production in the target cell windows, the telescope is designed to see only the central 5 cm of the target gas.
- The monitor is not just to be used for beam currents of approximately 100 μA, but it should also give useful results at lower beam currents.
- Detection inefficiencies and pion decay-in-flight have not been considered.

Accordingly, we estimate that such the signal rate in such a detector would be about 300 Hz. At this rate it would take about 30 s to give a 1% measurement of the luminosity. Of course, this accuracy is just statistical, and, furthermore, the device is only capable of making a relative measurement.

The detector would need to be shielded. Bad beam tunes can gererate large backgrounds, and, even with a triple-coincidence requirement, the accidental background rate could be significant in the absence of shielding.

**4. Conclusions**

This study suggests that a triple-coincidence scintillator telescope could give a useful relative measurement of the luminosity in a time interval of the order of 1 minute. Would this satisfy the E89-044 collaboration?

Such a telescope would be relatively simple and inexpensive to construct. The UMass group would take responsibility for this. Support from DAQ experts would be needed to interface the results of the telescope with the rest of the E89-044 data stream.