PrimEx Test Beam Request for "October 2003"
Draft: September 26, 2003
Dan Dale

1 Background:

Determination of the luminosity for the PrimEx π^o lifetime experiment represents the largest contribution to the experimental uncertainty of the measurement. The various contributions to this error are shown below:

statistical	0.4%
target thickness (atoms/cm^2)	0.7%
photon flux	1.0%
π^o detector acceptance and misalignment	0.4%
background subtraction	0.2%
beam energy	0.2%
distorted form factor calculation errors	0.4%
total	1.4%

Because a tagged photon measurement of this precision has never been performed in Hall B or anywhere else (to our knowledge), it is our view that we must establish well in advance of the production data taking run that the luminosity can be determined to the required precision. The tests which we would like to perform in October 2003 will focus on the photon flux measurement.

2 Absolute calibration with total absorption counter

The absolute photon flux will be determined by placing the total absorption counter in the beam and measuring

$$R_{absolute} = \frac{N^{TAC}_{\gamma \cdot e_i}}{N_{e_i}} \tag{1}$$

Under the assumption that this ratio is the same at the low rates of the calibration run as at the higher rates of the production data taking, one can then determine the cross section from the tagged yield of π^o's detected in the HYCAL:

$$\text{TaggedYield} = \frac{d\sigma}{d\Omega} \times t \times \Delta\Omega \times N_e(experiment) \times \frac{N_\gamma^{tagged}(calibration)}{N_e(calibration)}, \quad (2)$$

where t is the target thickness, and $\Delta\Omega$ is the solid angle of the pion detector. In the calibration run, the total absorption counter rate is limited, and, therefore, the tagging efficiency must be measured at a rate which is reduced by several orders of magnitude as compared to the data taking run. As such, any rate dependence in the tagging efficiency must be considered.

3 Relative calibration with pair spectrometer

The use of the total absorption counter to calibrate the number of photons per tagging electron will provide an absolute calibration of the photon flux incident on the π^o production target. However, these measurements will be performed at intervals throughout the data taking, and will by necessity be performed at an electron beam current which is two orders of magnitude less than the production data taking runs. Consequently, we have constructed a pair production luminosity monitor which will measure the relative tagged photon flux over a range of intensities, and will operate continuously throughout the data taking runs.

The pair spectrometer will use the physics target as a converter, and will make use of the 15 kgauss-meter dipole magnet placed just downstream of it. The electrons and positrons are detected on either side of the beam in a series of plastic scintillator telescopes.

With the pair spectrometer, we can measure the relative tagging ratio:

$$R_{relative} = \frac{N^{ps}_{e^+e^-\cdot e_i}}{N_{e_i}} \quad (3)$$

where $\frac{N^{ps}_{e^+e^-\cdot e_i}}{N_{e_i}}$ is the number of pair production events in coincidence with a given tagging counter. While this is a relative number, its normalization can be fixed with the TAC, and it has the advantage of the possibility of measurement over all relevant currents, *i.e.* the high currents of the production data taking and the low currents at which the absolute tagging ratios are measured with the TAC.

4 Goals

The key goals we wish to accomplish are:

I. Determine whether the relative tagging efficiency, as measured by the pair spectrometer is rate independent at the 1% level over the ranges of photon fluxes spanning those of the TAC runs to those of the production data taking runs. This includes runs with two different pair production target thicknesses.

II. Commission the TAC, and determine the absolute tagging ratios over the largest range of currents possible and ensure they are independent of rate.

III. Determine the tagging ratios as measured with the TAC with and without a $4cm \times 4cm$ collimator in front of it. This will mock up the geometry of the HYCAL and ensure that placing the TAC behind the HYCAL will not decrease the measured tagging ratios and thereby introduce systematic errors.

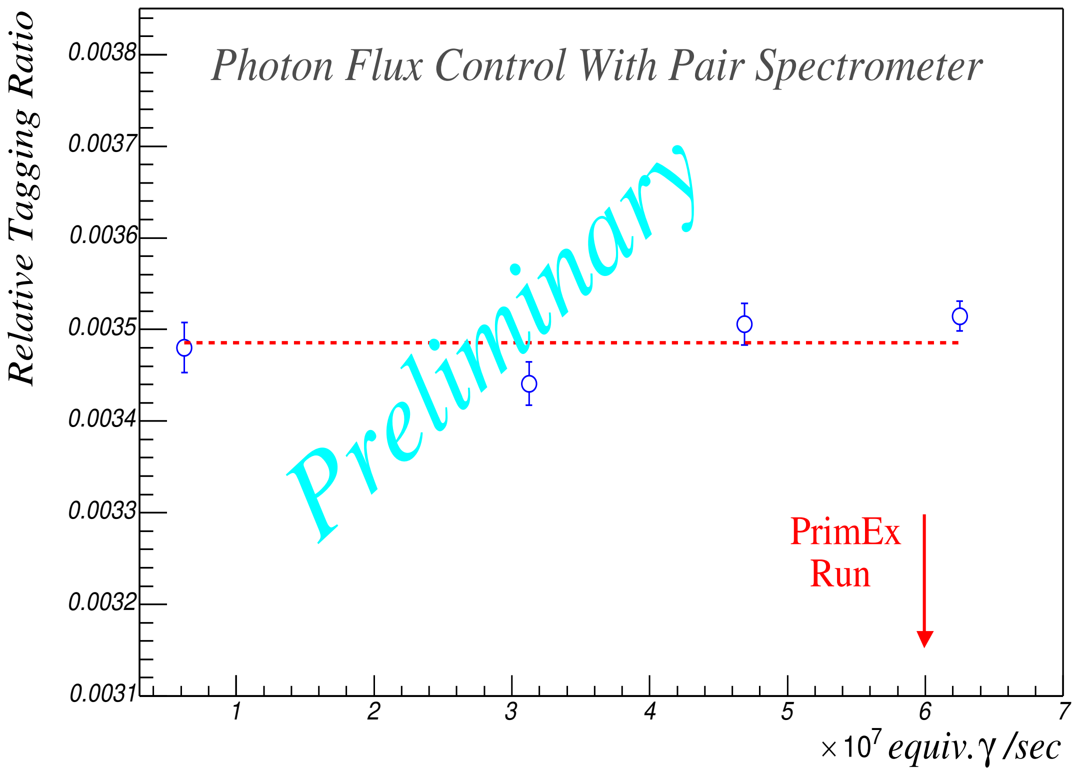
IV. Test clock trigger method for electron counting.

V. Commission a new online beam profile monitor.

VI. Implement ADC's for pair spectrometer detectors to study rate dependence of pulse heights.

5 Rate dependence of relative tagging efficiency

In August 2003, we were able to get a little over one shift of beamtime to study this issue. In this run, we measured the relative tagging efficiencies from 10 $nAmps$ to 100$nAmps$ with the pair spectrometer. Some runs were performed at lower currents, however beamtime precluded us from getting enough statistics at these very low currents to determine the relative tagging efficiencies at the 1% level. The results are shown below:



As can be seen from the plot, the relative tagging ratio is constant over the range measured. However, these measurements do not span the full range of currents relevant for the *PrimEx* run. In particular the total absorption counter runs will be performed at currents which are approximately a factor of fifty lower than the lowest current point. As such, in order to demonstrate that we can control the photon flux at the sub-one percent level, it is crucial that these low currents points be measured.

6 Commissioning the Total Absorption Counter

The *PrimEx* Collaboration has constructed a new total absorption counter for use in our experiment as well as for general use by the Hall B photon physics program. It is a $20 \times 20 \times 40cm^3$ single lead glass block (SF5, L=$17X_o$). It has a single 5" PMT (Hamamatsu R1250, rise time ~2.5ns), and is instrumented with an ADC and a TDC.

We wish to commission this detector by measuring absolute tagging efficiencies over the largest possible range of incident photon fluxes.

7 TAC measurement tests with collimator

The goal of these tests is to ascertain whether or not, in the *PrimEx* run, the total absorption counter can be placed downstream of the HYCAL. The central issue here is that the HYCAL has a $4cm \times 4cm$ central hole. Placing the TAC downstream of the HYCAL will effectively collimate the photon beam. We wish to test whether or not this is a problem by measuring absolute tagging ratios with and without a collimator in front of the TAC. This collimator will simulate the effect of the central hole in HYCAL.

8 Basic Engineering Requirement for Oct. 2003 Luminosity Tests

The following items are absolutely necessary:

- Tagger with new electronics installed and commissioned.
- PrimEx harp (along with standard electron beamline BPM's and BCM's).
- PrimEx target ladder installed. 1% and 5% X_o targets.
- PrimEx (photon) exit vacuum window installed on pair spectrometer dipole.
- Pair spectrometer detectors realigned and surveyed.
- Total Absorption Counter mounted on movable table approximately 8 meters downstream of PrimEx target.

- Removable collimator to be placed in front of TAC.
- Scintillating fiber detector (online beam monitor) mounted on same movable table.

Desirable:

- He bag from August 2002 run.

9 Prerun tasks to be performed by collaboration

- Hook up clock trigger – Dave
- Move P.S. ADC's from forward carriage to TAGE crate, cable up, set up to read – Dave, Dan
- Test TAC (look at cosmics) – Mahbub, Dan
- Remake He bag – (Dave Kashy's group), Dan
- Put in photon HARP – Dan
- Move pair spectrometer detectors, survey them, improve mounting – Dan
- Identify TAC, online monitor stand – Phil
- Check pair spectrometer HV cabling – Mahbub, Dan
- Target – Eric and Dave L.
  install 1% and 5% targets
  reproducibility tests
  install on beamline
- Additional P.S – Liping, Dan
- Design/build TAC collimator – Phil, Dan
- Prerun checkout of online monitor – Liping, Phil
- Arrange protocol for 30 Hz beam modulations
- Motion control TAC/online monitor – Mark, Abdellah
- P.S. dipole: install NMR, degaussing procedure – Abdellah
- Tagger Hall probe – Dan D., Dan S.
- Beamdump light – Mark
- TAC DAQ system – Dave
- Plateau software – Eugene

10 Rates

Pair spectrometer rates are calculated as follows. The data acquisition event rate limit is taken to be 2 kHz. In these multi-hit TDC's which we are using, each event corresponds to looking at a $32\mu sec$ sample in time. So, as long as the MOR rate is above 2 kHz, we record:

$$2 \times 10^3/sec \times 3.2 \times 10^{-5} sec = 6.4\%$$

of the events. Furthermore, the efficiency of the pair spectrometer in tagging a photon is taken to be 0.35%. Below is for a 5% X_o pair production target, radiator B. We require 1% statistics for each of 20 T counters in the tagger. The absolute maximum flux on the TAC corresponds to 1 nAmp electron beam current with radiator B.

Beam current	MOR rate(Hz)	P.S. rate (physics)	P.S. rate (recorded events)	time to run
100nAmps	10^7	35kHz	2240 Hz	2 minutes
50nAmps	5.0×10^6	17.5kHz	1120 Hz	3 minutes
10 nAmps	10^6	3.5kHz	224 Hz	16 minutes
5 nAmps	5.0×10^5	1.75kHz	112 Hz	0.5 hours
1nAmp	10^5	0.35kHz	22.4 Hz	2.6 hours
0.5nAmps	0.5×10^5	0.175kHz	11.2 Hz	5.0 hours

This corresponds to about 9 hours without overhead. We would also like to perform analogous pair spectrometer rate tests for a thinner (1% X_o) pair converter from 10 to 100 nAmps. This should take 4 hours. In addition we would need to plateau the tagger (3 hours), perform dipole scan of pair spectrometer dipole to optimize field (2 hours). TAC collimator tests are expected to take four hours. Rate tests of pair spectrometer detectors – 3 hours. Online monitor tests can mostly be done parasitically.

This comes to about 25 hours without overhead.