Preliminary Conclusions from Recent $Q_{\text{weak}}$ Target Density Fluctuation Studies
Mark Pitt, Virginia Tech

- Brief report on results of the $Q_{\text{weak}}$ June 2008 luminosity monitor studies of the dependence of target density fluctuation “widths” on data-taking rate for a “vigorously boiling” target

- Discussion of implications of these studies on the needed performance of a 12 GeV Moller experiment hydrogen target
Reducing the Relative Target Density Fluctuation Contribution

\[ A = \frac{N_+ - N_-}{N_+ + N_-} \]  where \( N \) = normalized detector yield

The statistical width is given by:

\[ \Gamma_{\text{stat}} = \sqrt{\Gamma_{\text{counting}}^2 + \Gamma_{\text{target}}^2} \]

For 15 Hz pairs  \( Q_{\text{weak}}: \Gamma_{\text{count}} \sim 50 \text{ ppm} \)

12 GeV Moller:  \( \Gamma_{\text{count}} \sim 9 \text{ ppm} \) (assuming 180 GHz)

The relative contribution of target density fluctuations can be reduced by going to higher data-taking rates:

\[ \Gamma_{\text{stat}} \propto f^{1/2} \]

Assume \( \Gamma_{\text{target}} \) = constant

Fractional increase above counting statistics

Assumes counting statistics width of 50 ppm at 15 Hz
15 Hz pair rate
125 Hz pair rate
500 Hz pair rate

\[ \Gamma_{\text{target}} \propto f^{0.4} \]

Assume \( \Gamma_{\text{target}} = \Gamma_{15 \text{ Hz}} \left( \frac{15 \text{ Hz}}{f} \right)^{0.4} \)

Fractional increase above counting statistics

Assumes counting statistics width of 50 ppm at 15 Hz
15 Hz pair rate
125 Hz pair rate
500 Hz pair rate
**Q\textsubscript{weak} June 2008 Luminosity Monitor Test Conditions**

- Performed parasitically to Gep in Hall C

- **Beam conditions:** currents ~ 10 - 80 \( \mu \)A, \( E = 5.7 \) GeV

- **Targets:**
  - 20 cm LH\(_2\), 2.3% \( X_0 \), 1.4 g/cm\(^2\)
  - 4.4 mm C, 2.1% \( X_0 \), 0.88 g/cm\(^2\)
    → target known to be poorly designed from “boiling” point of view

- **Detectors:**
  - \( G^0 \) luminosity monitors and \( Q\text{weak} \) prototype lumi monitor
  - quartz radiators with PMT directly attached at \( \theta \sim 0.6^\circ \)
  - bare PMTs at \( \theta \sim 0.9^\circ \)
  - quartz radiator, air lightguide, PMT in “unity” gain mode at \( \sim 0.6^\circ \)

- **DAQ:** Using TRIUMF 18 bit \( Q\text{weak} \) ADCs
  Set up to flexibly change data taking rates: 30 Hz, 250 Hz, 1000 Hz
  (pair rates: 15 Hz, 125 Hz, 500 Hz)

- **Participants:** Paul King, Greg Smith, Dave Mack, Silviu Covrig, Mark Pitt, John Leacock

→ John Leacock performed the analysis described here
Observed “Boiling” Parameters from $G^0$ Target

For the $G^0$ target (20 cm LH$_2$) some observed parameters were:

**Target Density Fluctuations:**
\[ \Gamma_{\text{targ}} \sim 238 \text{ ppm at } 40 \mu\text{A for } 7.5 \text{ Hz} \]
(ie. quartets at 30 Hz data-taking rate)

**Global Density Reduction:**
About a 1.5% reduction in target density was observed at 40 $\mu$A

Normalized Yields in June 2008 Test

After proper “beam-based” pedestal determination, luminosity monitor yields normalized to beam current were constructed:

Notes on above plots:
• Normalized yields for each target were scaled to be the same at 80 μA
• For a given lumi, the normalized yields on carbon and hydrogen were the same at 80 μA

→ Normalized yields for the solid carbon target constant to ~ 1%

→ Substantial normalized yield reduction of ~ 22% observed from low beam current to 80 μA (compare to 1.5% for G at 40 μA)
“Decomposition” of Carbon Asymmetry Widths

To extract “target boiling widths” from the hydrogen data, we first need to understand the contributions to the random width on the carbon target.

\[ A = \frac{N_+ - N_-}{N_+ + N_-} \]

where \( N \) = normalized detector yield

\[ \Gamma_A^2 = \left( \frac{A}{\sqrt{I}} \right)^2 + \left( \frac{B}{I} \right)^2 + C^2 \]

counting statistics  electronic noise  beam parameter fluctuations

Results from typical fit:
At 80 µA:
counting ~ 230 ppm
electronic ~ 98 ppm
beam ~ 300 ppm
Sensitivity to 60 Hz Noise at Higher Data-Taking Frequencies

Paul King and Bill Vulcan implemented a line phase monitor to track our detector signal’s correlation with the 60 Hz linephase at the higher data-taking frequencies (250 Hz and 1000 Hz)

- In our analysis, we regressed out the linephase noise but it was not completely successful; we have ideas for ways to improve it.

- Reminder that this needs to be dealt with: One possible way – run “line-locked” at n x 60 Hz (ie. 240 Hz) and form asymmetries in separate “timeslots” (ie. 4 timeslots) like PV experiments at MIT-Bates
Extraction of Target Density Fluctuation Widths from Hydrogen Widths for the hydrogen target have additional contribution from $\Gamma_{\text{targ}}$:

$$\Gamma_A^2 = \left( \frac{A'}{\sqrt{I}} \right)^2 + \left( \frac{B'}{I} \right)^2 + C^2 + \Gamma_{\text{targ}}^2$$

$$A' = A_C / \left( \sqrt{N_H / N_C} \right) \quad B' = B_C / \left( N_H / N_C \right)$$
Dependence of Target Boiling Width on Data-Taking Rate

Target density fluctuation widths were extracted at three data-taking rates: 30, 250, 1000 Hz (pair rates - 15, 125, 500 Hz)
Dependence of Target Boiling Width on Data-Taking Rate

At 40, 60, 80 μA the target boiling width is well-described by $\Gamma_{\text{targ}} \sim f^{-0.4}$.

We will do further analysis to try to extract usable results at 10-20 μA.
Spectrum Analyzer Results

Is the $\Gamma_{\text{targ}} \sim f^{-0.4}$ result for “vigorously boiling” targets also valid for good parity-violation targets? Compare this target (top panels) to the $G^0$ target at 56 $\mu$A.

$G^0$ target at 56 $\mu$A from March 2007
Implication of These Results for 12 GeV Moller

If the $\Gamma_{\text{targ}} \sim f^{-0.4}$ result is correct in the regime of the 12 GeV Moller target, then the right-hand plot below shows the implications:

Example: If one can tolerate up to a 1.10 fractional increase over counting statistics, then at a 500 Hz pair rate a 100 ppm (at 15 Hz pair rate) target density fluctuation could be tolerated (compare to 240 ppm at 7.5 Hz for $G^0$)
(At 500 Hz, the counting statistics width would be 52 ppm while the target density width would be 25 ppm)

Assume $\Gamma_{\text{targ}} \propto \text{constant}$

\[
\frac{\Gamma_{\text{targ}}}{\Gamma_{15\text{Hz}}} = \left(\frac{15\text{ Hz}}{f}\right)^{0.4}
\]

Assume $\Gamma_{\text{targ}} = \Gamma_{15\text{Hz}} \left(\frac{15\text{ Hz}}{f}\right)^{0.4}$

Fractional increase above counting statistics