Q^2 for HAPPEX-2 2005 Run

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In this report we discuss the measurements of Q^2 for the HAPPEX-Helium and HAPPEX-Hydrogen runs in 2005 summarized in Table I. The previous year's report including several details about the systematic errors and the kinematic recoil angle determination can be found online at http://hallaweb.jlab.org/experiments/HAPPEX/docs/qsq_2004.pdf.

In this report we describe the issues that were new in 2005.

I. SWEEPER MAGNET

In 2005 we used a sweeper magnet to reduce the low energy Moller flux on the sweeper magnet and reduce the heat load. This sweeper magnet introduced a kick of 5 mrad, as was verified in sieve slit runs with sweeper on and sweeper off. The central angle determination (for details see HAPLOG 829 and the 2004 report) was done for sweeper on, and takes into account the small deliberate mis-pointing of the beam coming into the target. The mis-pointing was done to equalize the Q^2 of the two HRS.

II. SENSITIVITY TO MATRIX ELEMENTS

This year we made a new study of the systematics errors due to the reconstruction matrix elements. See also the 2004 Q^2 report referenced in the introduction for a discussion of some of the issues. Last year the Z-dependence of the matrix elements gave a 0.5% error in Q^2 because an optimization that involved the foils at extreme locations $Z = \pm 12$cm failed to converge. This year the optimization of one database for all Z foils succeeded by adding new terms in the tensor. We believe the error in Q^2 arising from Z-dependence is now $\leq 0.1\%$.

To understand the possible instability of the matrix elements near the edge of the acceptance, a study was performed in which the last column of sieve holes at smallest angle (nearest the beam) were omitted when constraining the horizontal angle, which is approximately the scattering angle. The difference in Q^2 between this database and the normal database was 0.2% which is negligible. Another calculation was performed with the same aim, in which we deliberately shifted the horizontal angle by 1.5 mrad for those data with angles smaller than the last column of sieve holes. The idea is that perhaps those angles are not well constrained by the fit procedure, although there is no evidence for that since the distribution of angles looks like the approximately rectangular acceptance and extends 6 mrad beyond the last column. The calculation led to a 0.8% shift in Q^2 (HAPLOG 894), which gives an indication of the maximum for the systematics due to matrix element errors at the edge of acceptance. We will assign no error for this effect.

TABLE I: **ADC Weighted Q^2 for 2005 HAPPEX Runs**

	Helium Run	Hydrogen Run
L-arm Q^2 $(\mathrm{GeV})^2$	0.07829 ± 0.0007 (0.9 %)	0.1107 ± 0.0011 (1.0 %)
R-arm Q^2 $(\mathrm{GeV})^2$	0.07625 ± 0.0007 (0.9 %)	0.1070 ± 0.0011 (1.0 %)

The error in the database at $Z = 0$ was evaluated the same way as last year (see 2004 report), by correcting the residual shifts in angles at the sieve slit and observing a shift in Q^2 of 0.3%. The angles from the database have been used for the final Q^2 analysis.

III. RATE DEPENDENCE AND TIME DRIFTS

In 2005 we had 8 measurements of Q^2 during ^{4}He and 8 measurements with both arms during Hydrogen; in addition we had 7 L-HRS measurements in one day for Hydrogen; it was a rate scan done when the R-HRS dipole was down. The rate scan results are plotted in figure 1. In this plot it's important to note that the Helium data have a cut on the track multiplicity ($N_{\rm trk} == 1$) while the Hydrogen data do not; however, all final results use this cut. The Helium data exhibit a rate dependence even with this cut, but for hydrogen the rate dependence disappears. The difference is that in helium, high rate data mixes the nearby quasielastic peak into the elastic, but hydrogen sees a much weaker radiative tail. For Helium we used only data with rates $\leq$100 kHz and assign a systematic error for Q^2 of 0.3% based on the slope in fig 1, while for hydrogen we used all data (max rate 277 kHz) and have an error 0.1%.

We also observed drifts in Q^2 during the run, see figure 2. The RMS in these values are about 0.6% and have an unknown origin (though we speculate on this in the next paragraph). Based on these findings we assign a systematic error of 0.6% to "time drifts", and it becomes our largest source of error.

Numerically, the drifts are attributable primarily to shifts in the distributions of horizontal angle. Note, the HRS magnet readings were stable at the $\leq 10^{-3}$ level, so unless the magnet readbacks were wrong and drifting the magnet fields cannot explain the Q^2 drifts. The beam energy was also quite stable at the few MeV level. It may be that this "time drift" is due to drifts in the beam position at the ~ 0.8 mm level. However, this is not certain because the Q^2 measured on the two HRS do not have a clear correlation indicative of beam position movement. Because of pileup in the VDCs we knew the high rates at this low Q^2 would be a problem entering the 2005 run, and therefore we tried to keep the beam current as low as possible ($\sim 0.5\mu$A) to keep the rate $\leq$300 kHz. Unfortunately, at beam currents below 0.5μA the EPICS readback of beam position goes below the noise floor and reads zero. We usually tried to verify that the beam didn't move by checking at higher beam current before and after a Q^2 run, but there may have been problems with reproducibility at the few hundred micron level sufficient to explain the drifts.

IV. ADC WEIGHTING SYSTEMATICS

As usual we apply ADC weighting:

$$Q^2 = \frac{(\Sigma\, Q_i^2\, W_i)}{(\Sigma\, W_i)} \qquad (1)$$

where W_i is a weight factor for event i and Q_i^2 is the corresponding measurement. For the helium run, the W_i were the detector ADC values minus their pedestal. For the hydrogen run with two detectors it was necessary to adjust for their relative gains. Let $g2$ be the gain of the second detector relative to the first. Then we have $W_i = (g2 \times {\rm ADC}_1 + {\rm ADC}_2)_i$ where ${\rm ADC}_k$ is the ADC value minus pedestal for detector k.

For the Helium data the weighting is accurate and the systematic for Q^2 is 0.1%, but for the hydrogen 2005 run we had a problem that the gains were too low and also quite mismatched between detector segments. For example the seperation between peak and pedestal on one of the detectors was only 256 ADC channels. We have determined the sensitivity to the parameters used in weighting and found a 0.5% systematic error in Q^2 for hydrogen. The lesson learned is that the gains should be kept reasonably high on the two detectors.

TABLE II: **INPUTS to** Q^2 **(2005)**

^{4}He HAPPEX	
Beam Energy	2.7503 GeV
$E- < x\frac{dE}{dx} >$	
L-arm Angle	6.06°
L-arm Momentum	2.7361 GeV
R-arm Angle	6.12°
R-arm Momentum	2.7346
Hydrogen HAPPEX	
Beam Energy	3.176 GeV
$E- < x\frac{dE}{dx} >$	
L-arm Angle	6.043°
L-arm Momentum	3.1234 GeV
R-arm Angle	6.106°
R-arm Momentum	3.1126

TABLE III: **SYSTEMATIC ERRORS in** Q^2 **(2005)**

Error Source	Error (in source units)	Percent Error in Q^2
Scattering Angle	0.01 degrees	0.4 %
HRS Momentum Scale	5 MeV	0.2 %
Beam Energy	3 MeV	0.1 %
Drifts in Time		0.6 %
Matrix Elements:		
At Z = 0		0.3 %
Z dependence		0.1 %
ADC Weighting		
Helium		0.1 % (He)
Hydrogen		0.5 % (H)
Pileup (Rate Effect)		
Helium		0.3 % (He)
Hydrogen		0.1 % (H)
Total Systematic Error		
Helium		0.9 % (He)
Hydrogen		1.0 % (H)
Statistical Error		≤0.1 %
TOTAL ERROR		
Helium		0.9 % (He)
Hydrogen		1.0 % (H)

V. SUMMARY

The Q^2 results are summarized in table I. The inputs are shown in table II and the error budget in table III. The Q^2 has been weighted by ADCs. Typical non-ADC-weighted spectra are shown in figures 3 and 4.

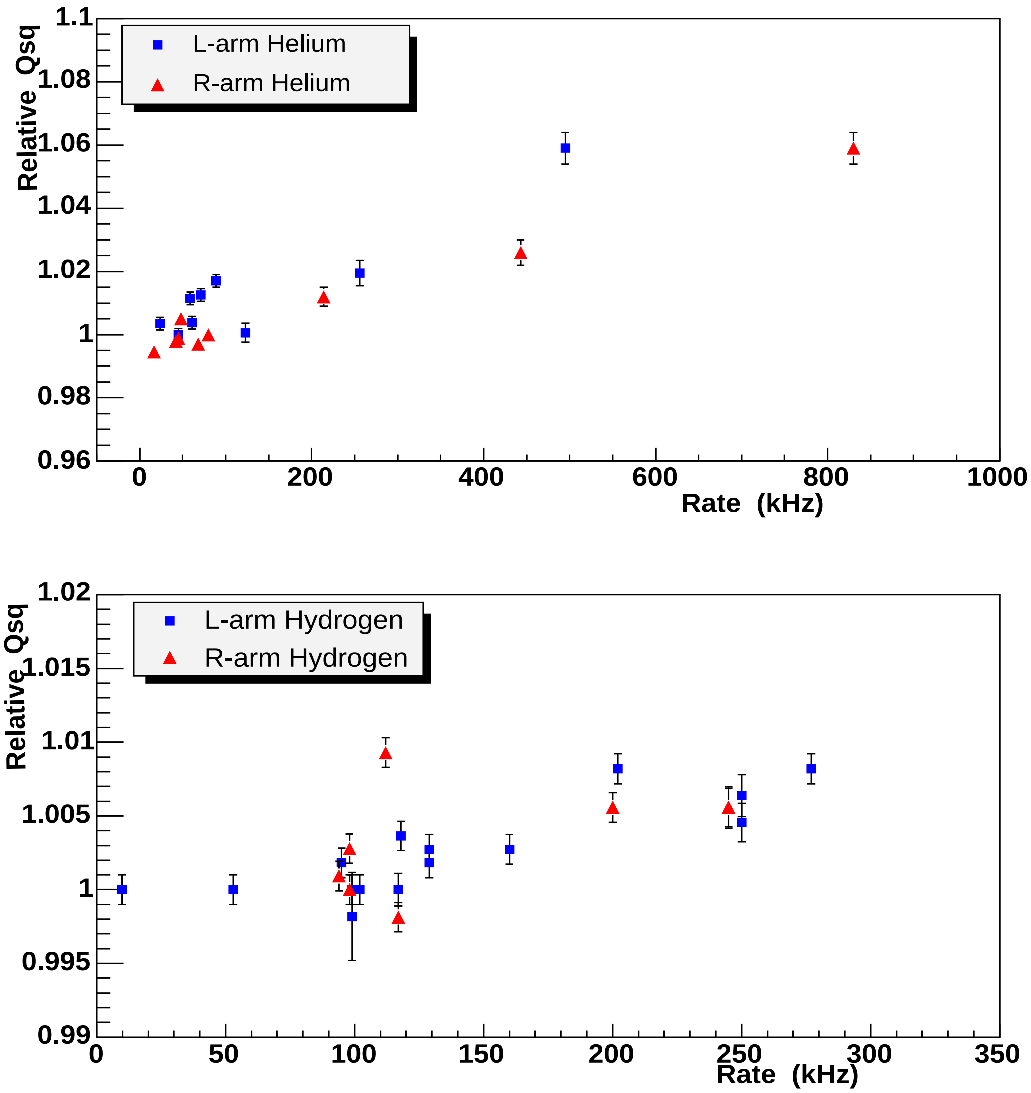

FIG. 1: Effect of rate on Q^2 (relative units). Distortions for ^{4}He occur in spite of the cut that demanded only one good track because of the quasielastic peak, and we used data only below 100 kHz. The Hydrogen result shown in this plot did not require a 1-track cut, although it was done for the final result in fig 2. In contrast to ^{4}He, the 1-track cut makes the Hydrogen result constant, and all data are used. See text for why.

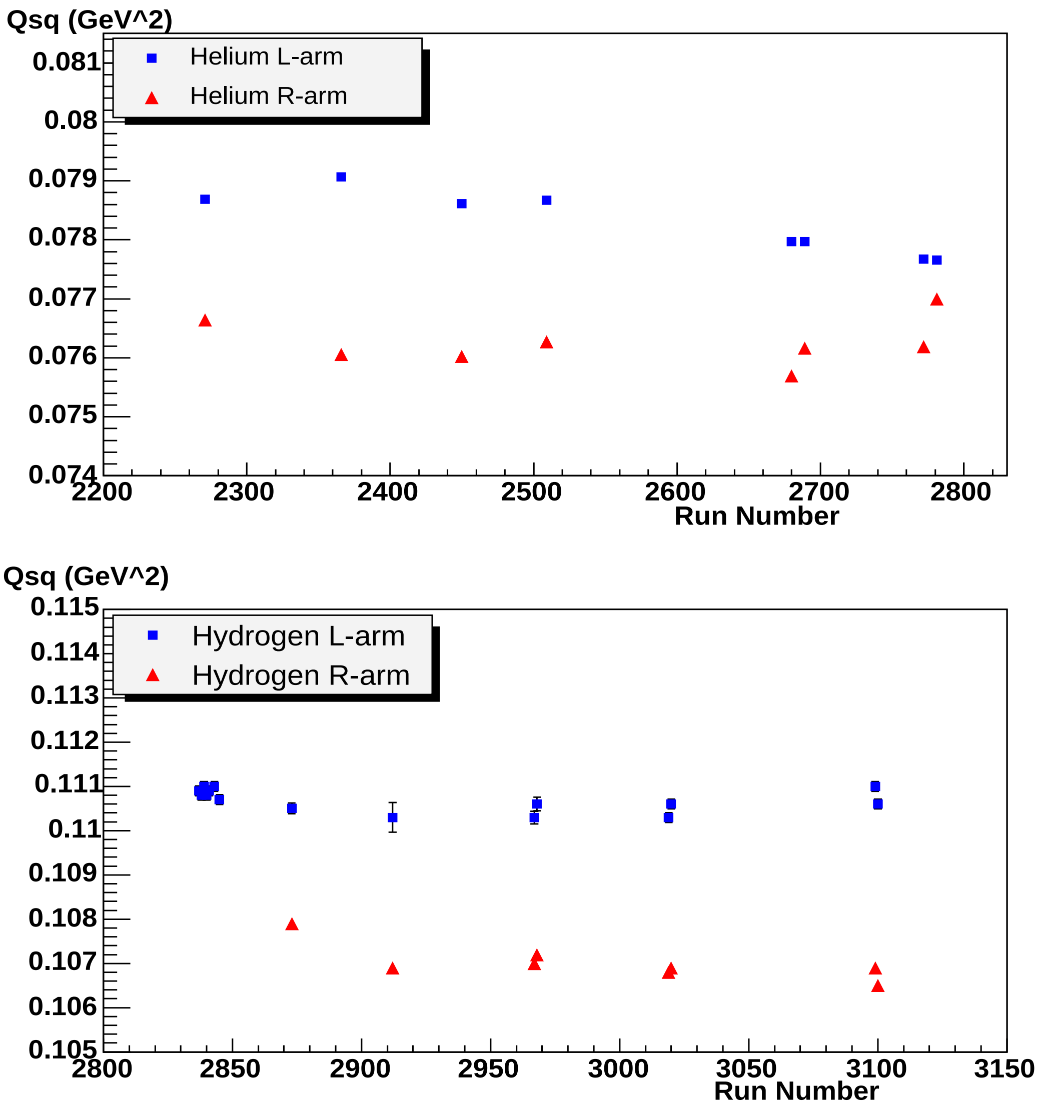

FIG. 2: Q^2 versus run number during HAPPEX 2005 for ^{4}He (top) and Hydrogen (bottom). These have been ADC weighted. Standard cuts are: 1) One track; 2) Track deposits energy in HAPPEX detector; 3) Track within collimator acceptance.

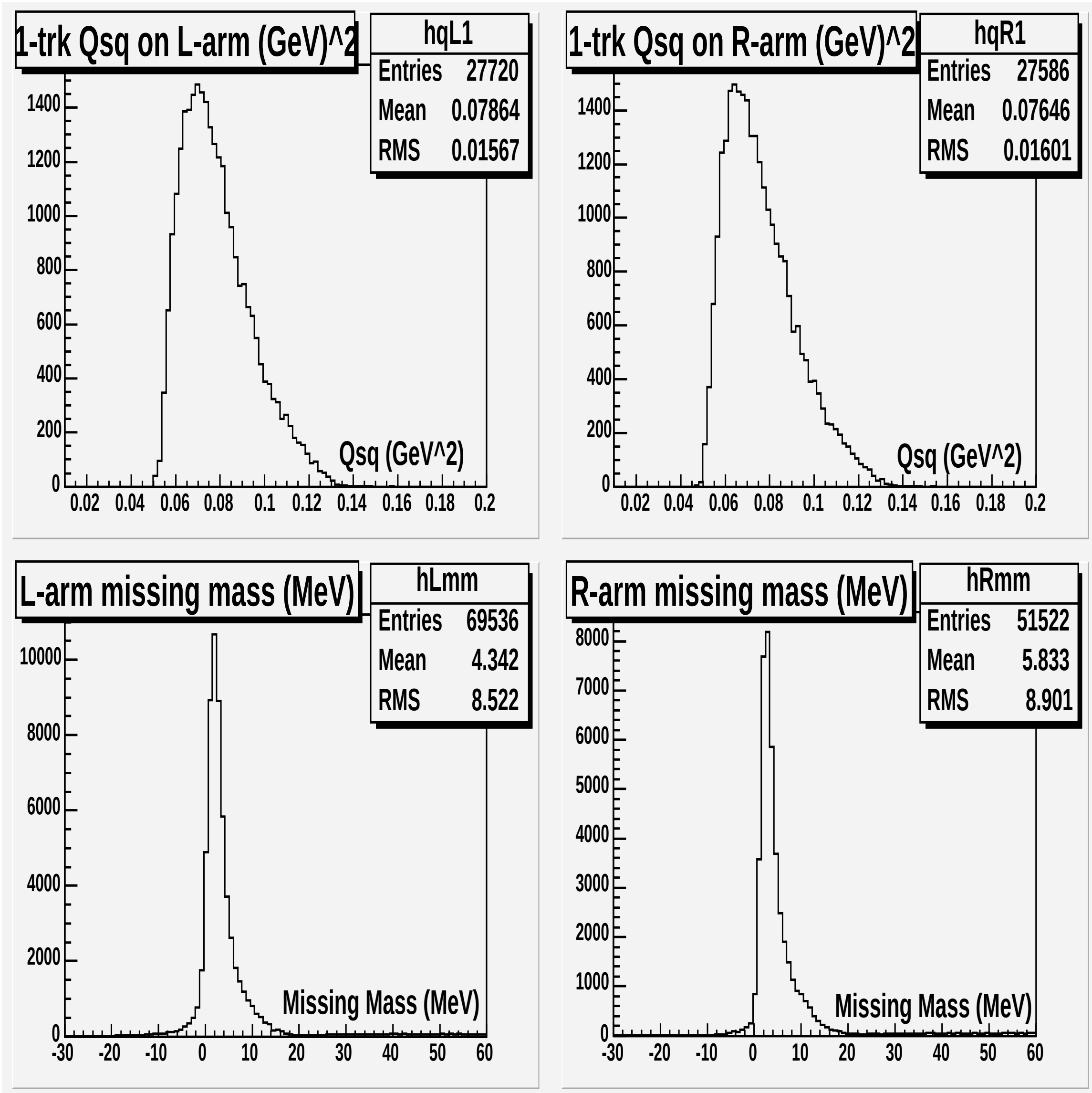

FIG. 3: Typical Helium Q^2 on Left and Right HRS (top row) and missing mass (bottom row). Not weighted by ADC. The missing mass peaks a few MeV from zero, consistent with our systematics – also for Hydrogen.

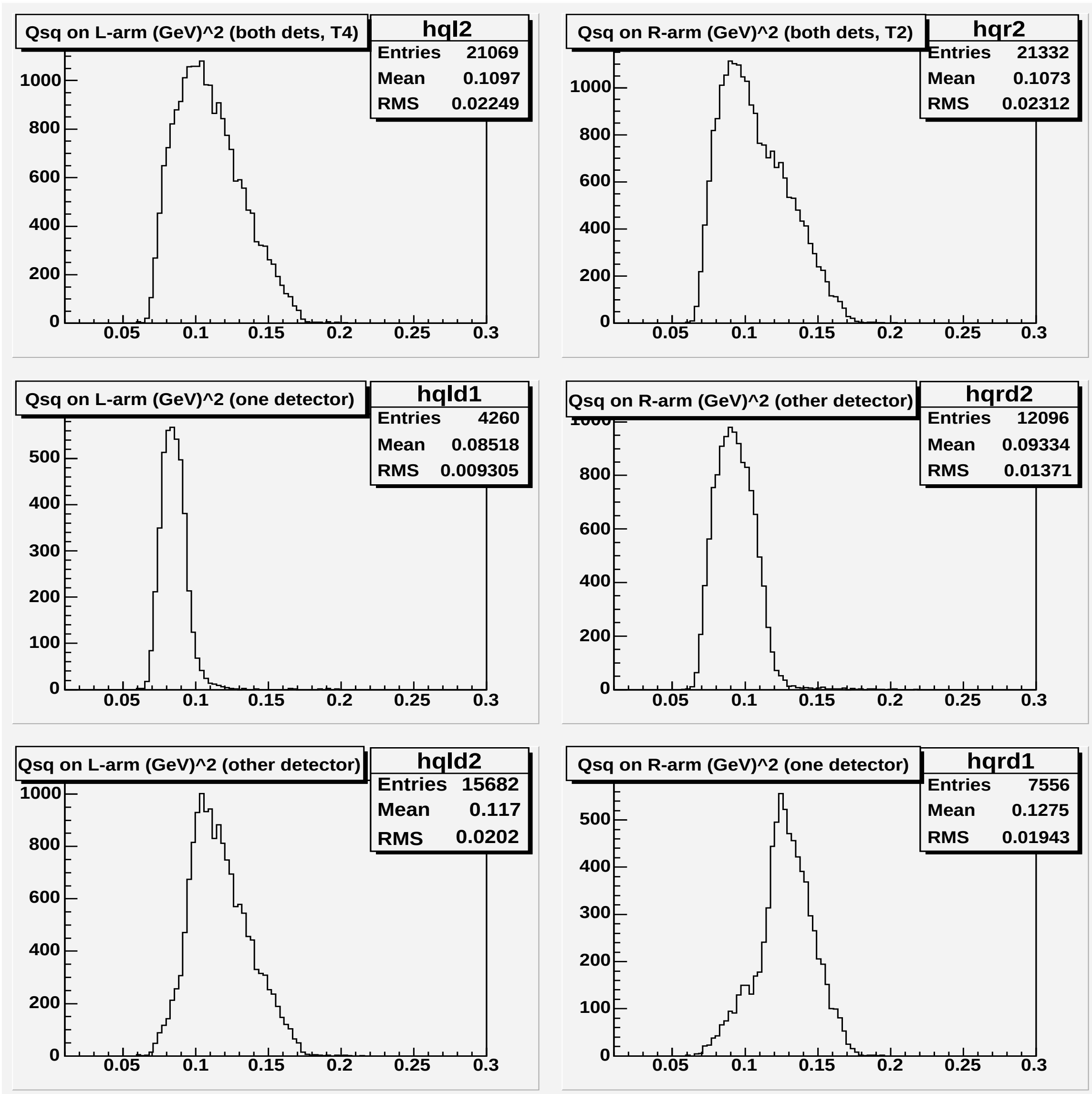

FIG. 4: Typical Hydrogen Q^2 on Left and Right HRS (top row) and also seperately for each detector segment (bottom four plots). Not weighted by ADC.