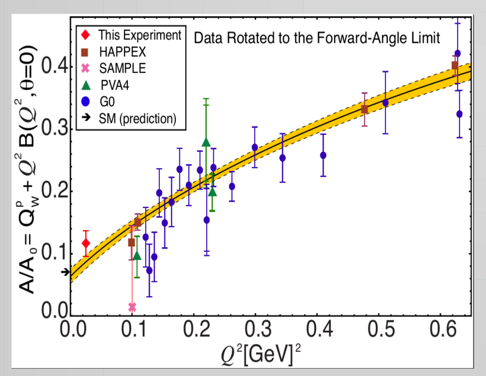
Correcting for Beamline Backgrounds in the Q_{weak} measurement

Manolis Kargiantoulakis, for the Q_{weak} Collaboration

Introduction

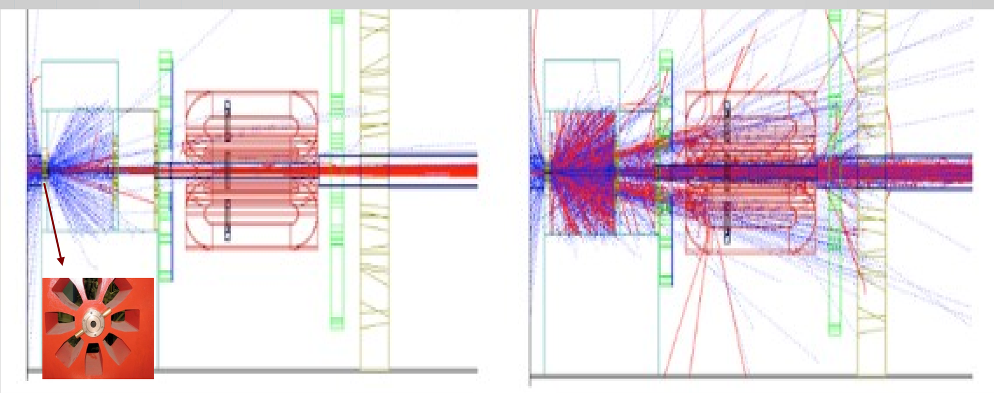
The Q_{weak} experiment completed the first determination of the weak charge of the proton through a measurement of the parity-violating asymmetry, from a preliminary analysis which utilizes 4% of the full dataset. The largest systematic uncertainty of the preliminary result came from the Beamline Background correction. The uncertainty of this correction will have to be reduced by an order of magnitude for the full Q_{weak} measurement, to reach the proposed precision that will allow access to models of Physics Beyond the Standard Model.



The first determination of the weak charge of the proton. [1]

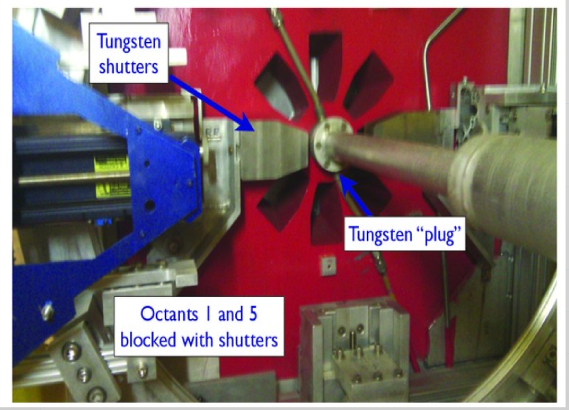
Beamline Backgrounds in Q_{weak}

Defined as backgrounds generated when electrons scatter from the beamline or the tungsten "plug", placed at the collimator immediately after the target to block electrons scattering at small angles (0.75°-4°).



Simulation of beamline backgrounds, with (left) and without (right) the tungsten plug on the upstream collimator. [2]

The W-plug dramatically decreases the beamline background but also generates secondary events. Heavy shielding and "2-bounce" strategy minimize this signal in the Main Detector.



Tungsten shutters blocking octants for a direct measurement of the beamline background component.

The "dilution" of beamline backgrounds in the Main Detector signal, measured directly in dedicated runs with blocked octants (value from preliminary result):

$$f_{BB} = 0.2\% \pm 0.1\%$$

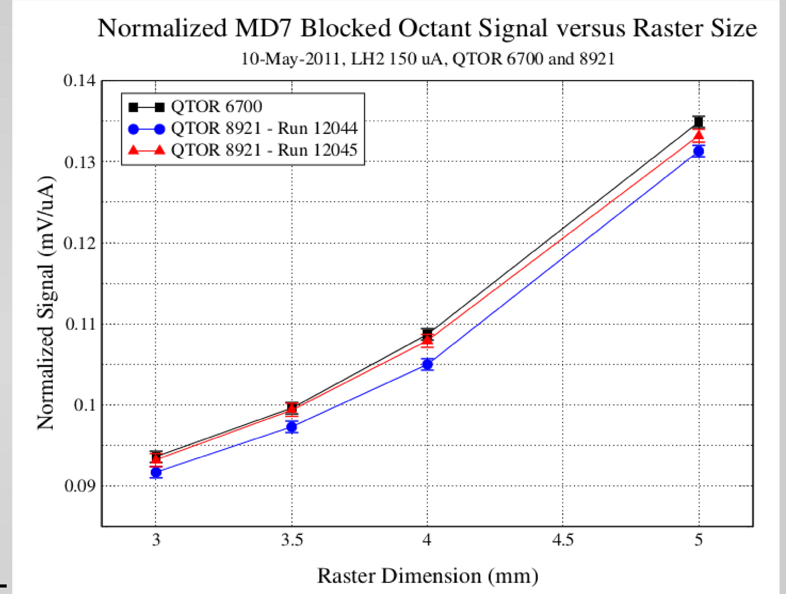
Uncertainty and fluctuations of background asymmetry

While the dilution of this background component in the Main Detector was measured very accurately in dedicated runs, this dilution as well as the size of its asymmetry were seen to vary significantly under different beam conditions. This led to the largest systematic uncertainty contribution to the measurement:

$$\Delta A_{ep}(\text{Beamline Backgrounds}) = 11 \pm 23 \text{ ppb}$$

An important indicator of the presence of beamline backgrounds was the size of beam halo, thought to be generated at the polarized source. Halo has also been suggested as a "hidden variable" of the regression analysis for the correction of helicity-correlated differences in beam parameters, to explain discrepancies between regression schemes. The Beam Asymmetries correction was the second-largest systematic uncertainty contribution to the preliminary result:

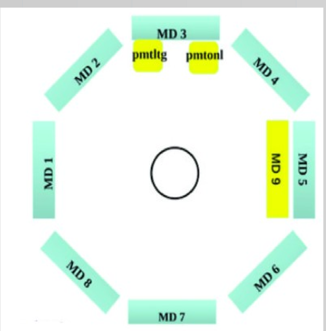
$$\Delta A_{ep}(\text{Beam Asymmetries}) = -40 \pm 11 \text{ ppb}$$



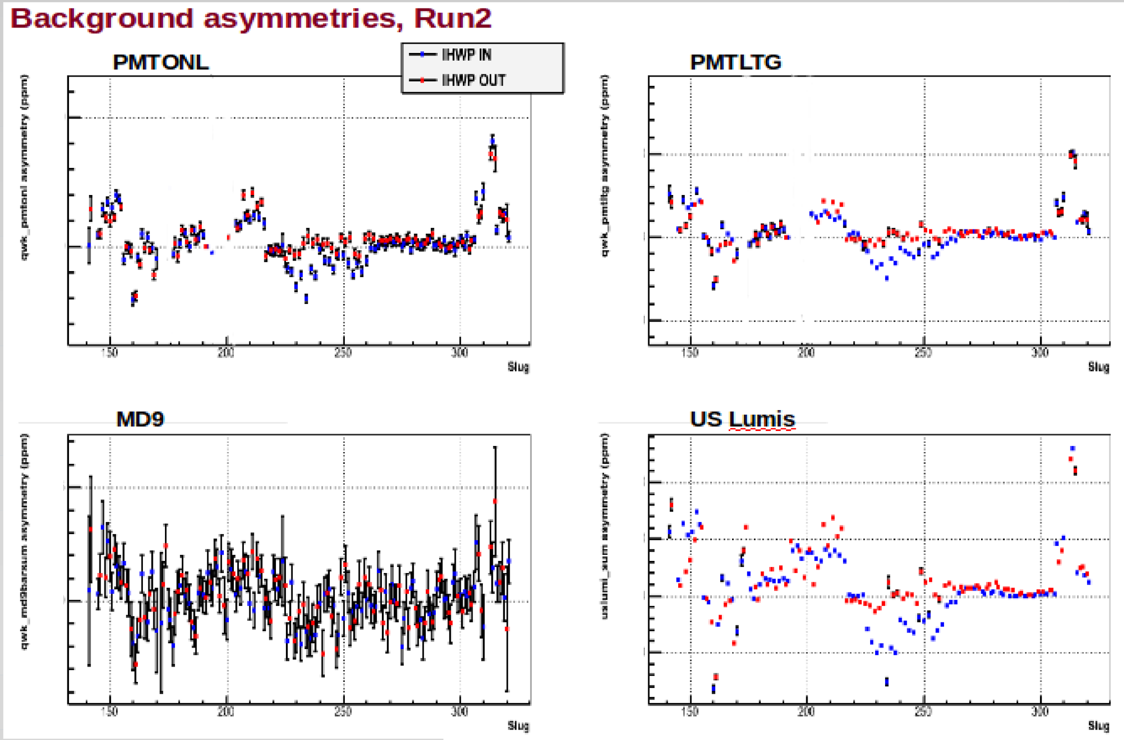
Yield of blocked octants under different raster dimensions and beam conditions. After changes in injector parameters a systematic shift was observed. [2]

Consistency among background detectors

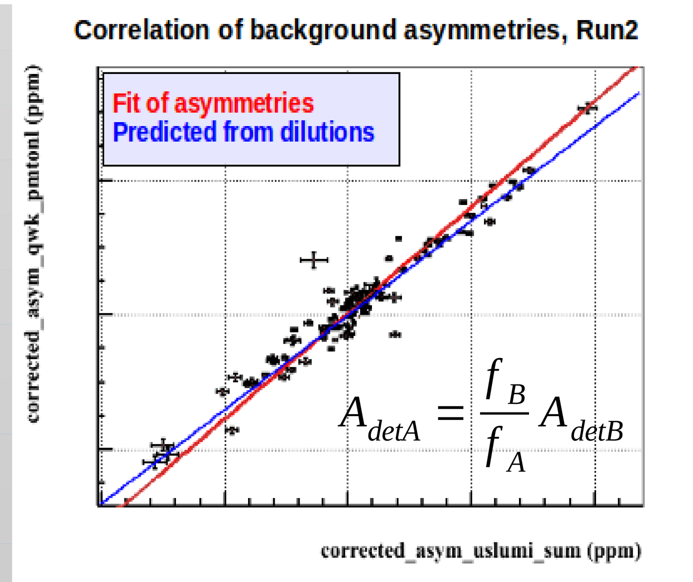
Background asymmetries were monitored continuously by detectors placed around the beamline and behind the Main Detectors in the super-elastic region, as well as the US Lumi monitors on the 2nd collimator. The asymmetries measured by background detectors were larger than 10 ppm at times, 4 orders of magnitude higher than the uncertainty budget for this correction.



Far greater asymmetries than anticipated, associated with an asymmetric beam halo. The background asymmetry magnitude and behaviour would be drastically altered after a change in the source configuration.



Dilution of the beamline component differs on each detector. The background asymmetries are seen to be very consistent among different detectors and scaling with the detector's background dilution. Dilution and asymmetry of backgrounds in each detector may vary, but consistency suggests an isotropic effect throughout the experimental environment.

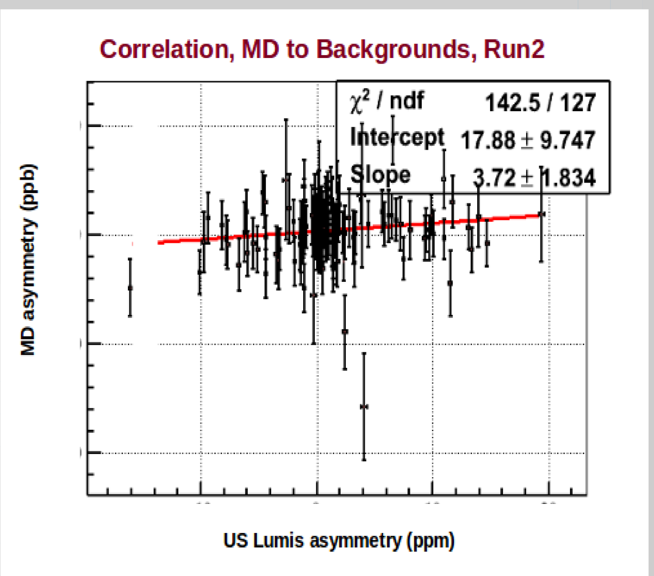


Background asymmetries from different monitors are found to be in excellent agreement and scaling with the monitor's background signal fraction, as extracted from blocked-octant runs.

Correlation to backgrounds from production data

The beamline correction can be applied through any background detector with appropriate correction factor, extracted by direct correlation to the Main Detector. Well motivated by manifest isotropy of background component.

Correlation is tiny and challenging.
Isolate systematic effect by subtracting contribution of elastic "Physics" asymmetry, sign-corrected for helicity reversals and dilution-weighted.
Choice of regression scheme and time-scale of averaging asymmetries also affects the correlation, as monitor noise averages away.



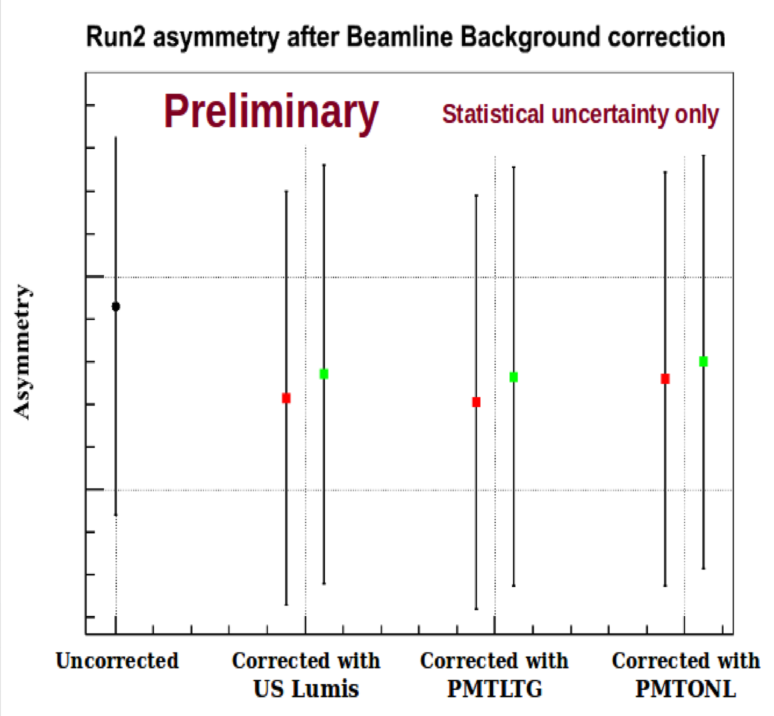
Direct correlation between Main Detector and background asymmetries.

Current status

The extracted correction factors depend on choices of regression scheme, time-scale, dilutions and weighting. The correction is then applied through the appropriate background detector.

Preliminary agreement between different methods of applying the correction is very good, in part as a consequence of successful cancellations employed by the experiment. The beamline background correction always improves the χ^2 of the measured asymmetry.

Future work:
Extract correction factors from individual periods, track changes in dilutions, fight noise that clouds the systematic effect.



Preliminary agreement between different methods of applying the Beamline Background and the Beam Asymmetries correction. Discrepancy is much smaller than statistical uncertainty.

References

[1] D. Androic et al. (Qweak Collaboration), PRL 111, 141803 (2013)
[2] K. E. Myers, Ph.D. thesis, George Washington University, 2012,