QWeak Main Detector

Scott MacEwan
University of Manitoba

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UNIVERSITY OF MANITOBA

Jefferson Lab

OUTLINE

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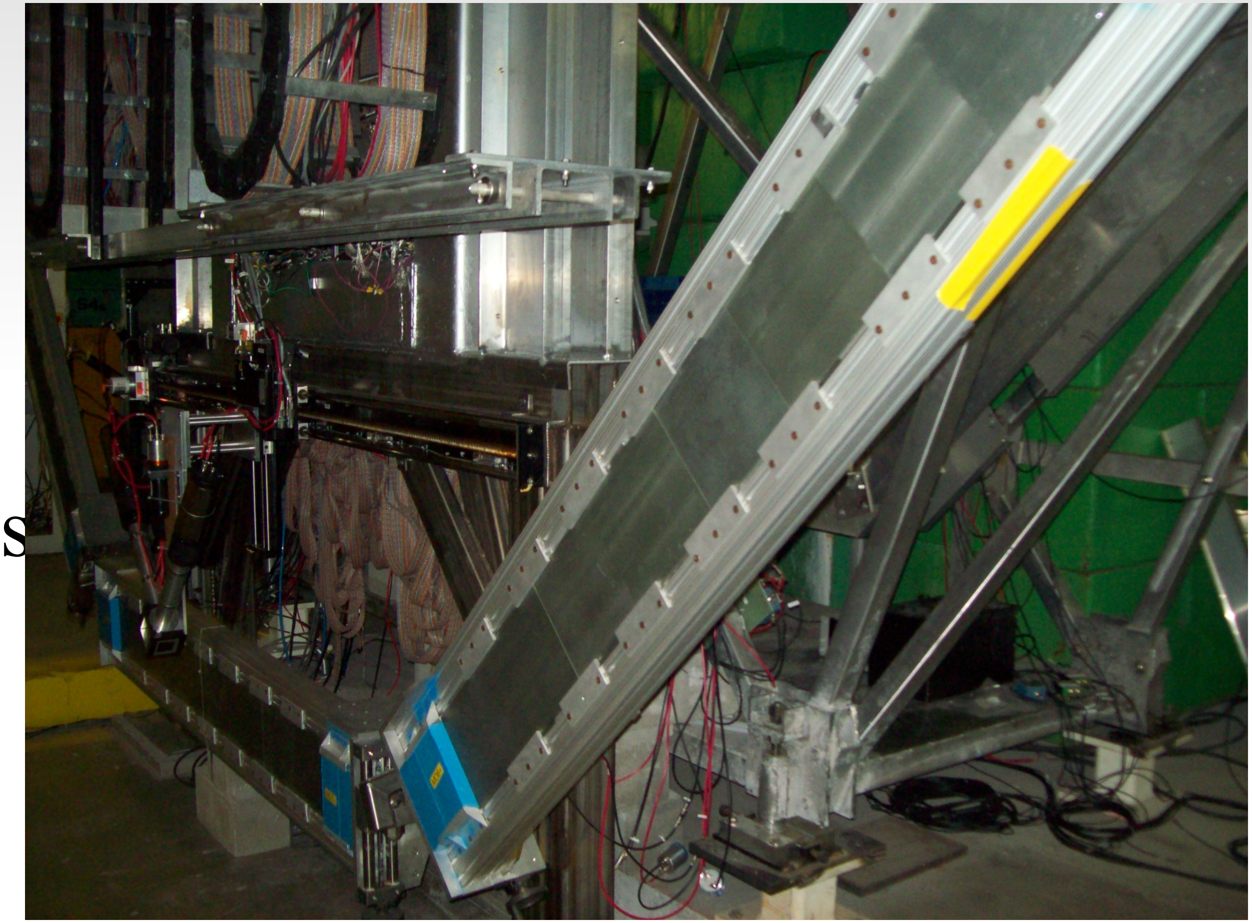
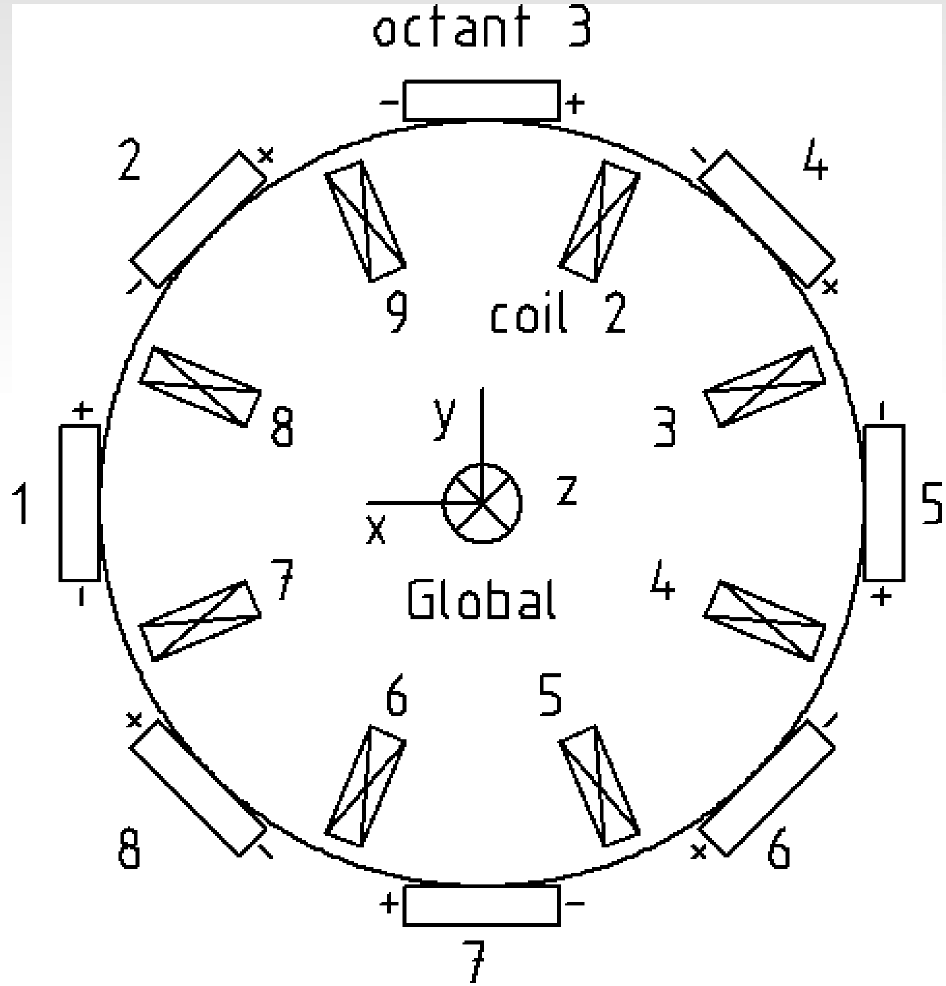


INTRODUCTION

The QWeak Main Detector

- Eight 2 m long quartz Cerenkov detectors
- 2 5” PMT's per bar
    - Low gain Current Mode bases
    - High gain Event Mode bases
- Pre-radiating lead tiles on each bar



INTRODUCTION

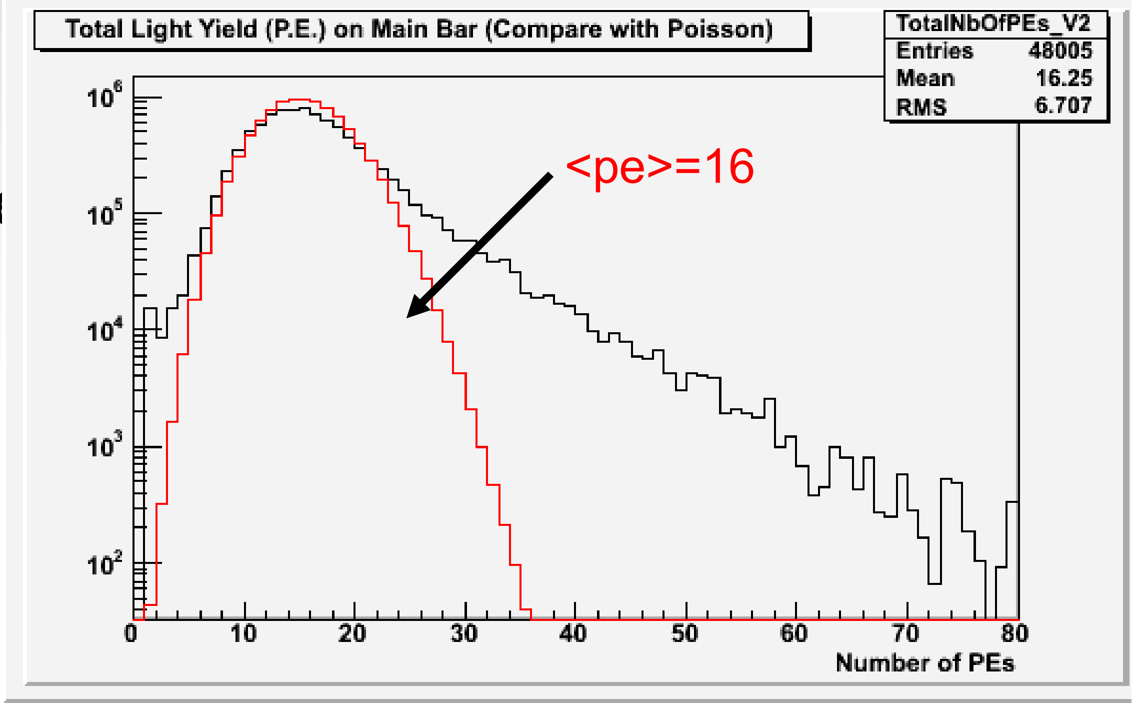
Current vs Event Mode:

- Current/Integrating/Parity Mode
  - Parity data acquisition
- Event/Tracking/Counting Mode
  - Q^2 determination
  - Projection of electrons from tracking regions
  - Determination of elastic scattering rate
- Configuration changes take ~1.5 hours including tests!

EVENT MODE

Pulse Height Distributions

<u>Monte Carlo Results:</u>



- Simulations from the summe done in GEANT4 in order to estimate the pulse height distributions for bare bars.

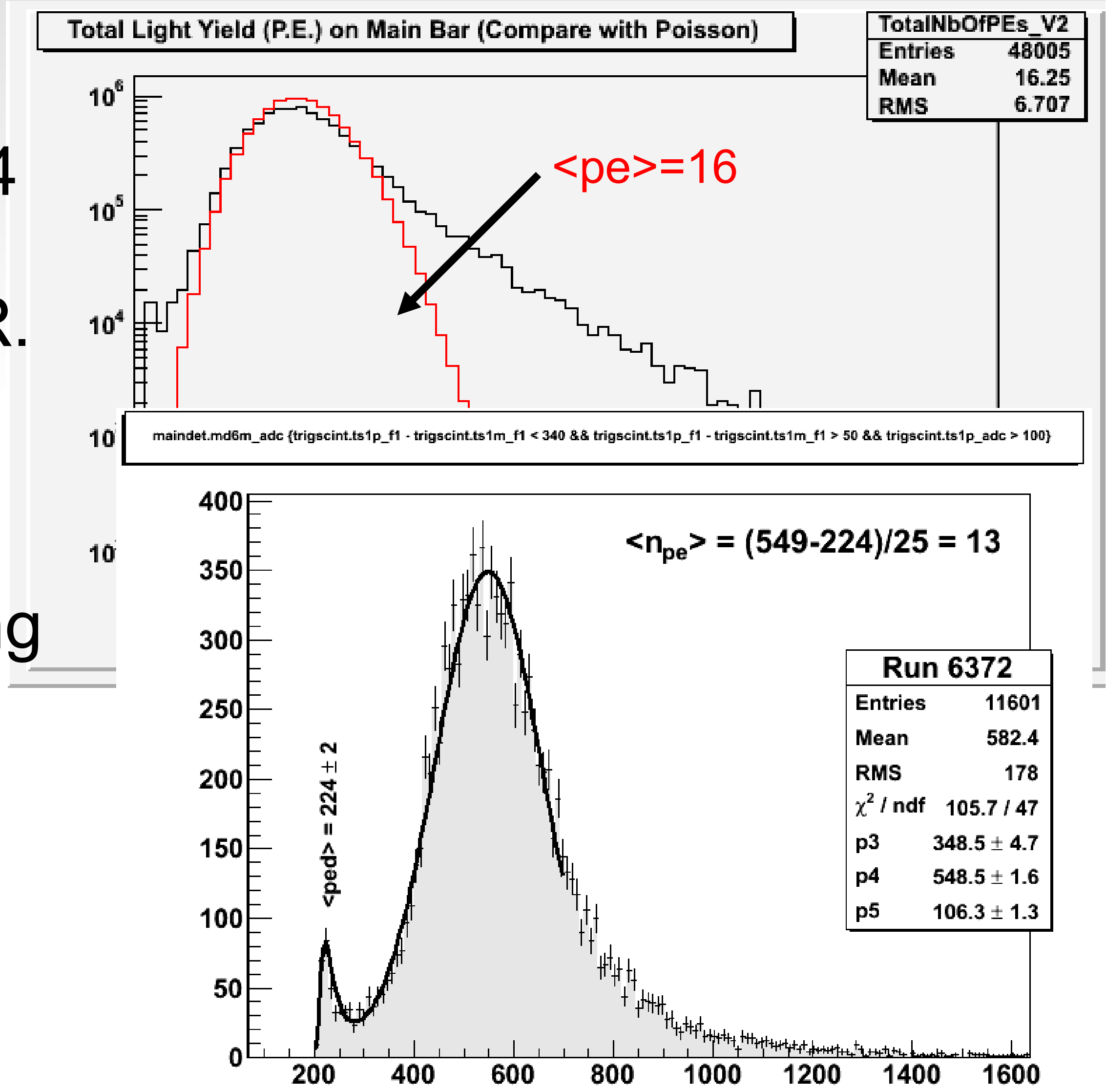
- Peiqing Wang determined that each incident scattered electron should produce <pe>=16.

EVENT MODE

Monte Carlo Results:

Pulse Height Distributions

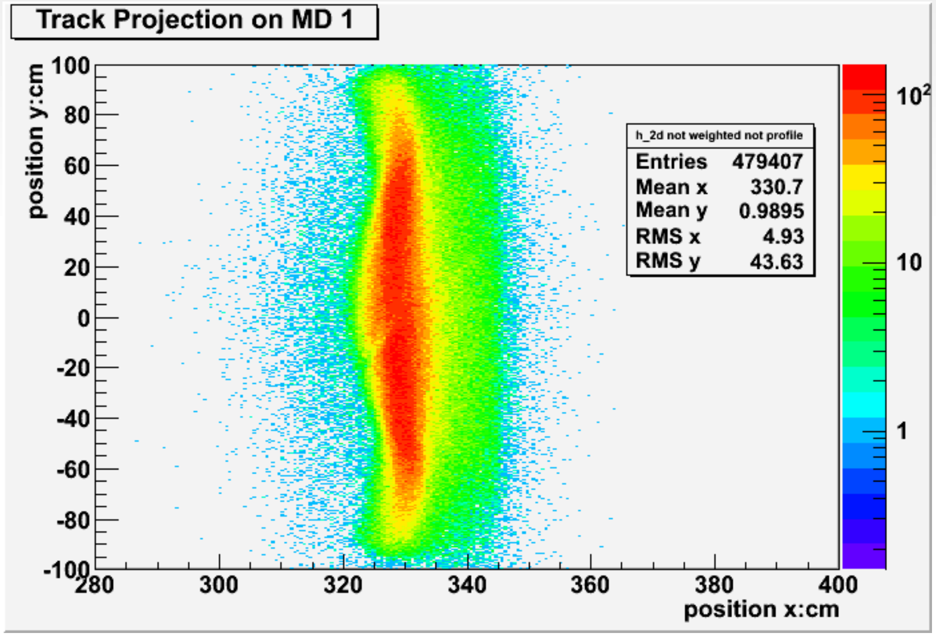
- M. Gericke found <pe>=12-14 using a photoelectron-to-ADC channels calibration done by R. Mahurin.
- For pre-radiated bars, similar analysis showed that showering increased <pe> by a factor of ~6 dependent on the bar.
- Analysis of **recent** tracking mode data is currently underway!



EVENT MODE

Region III Projections

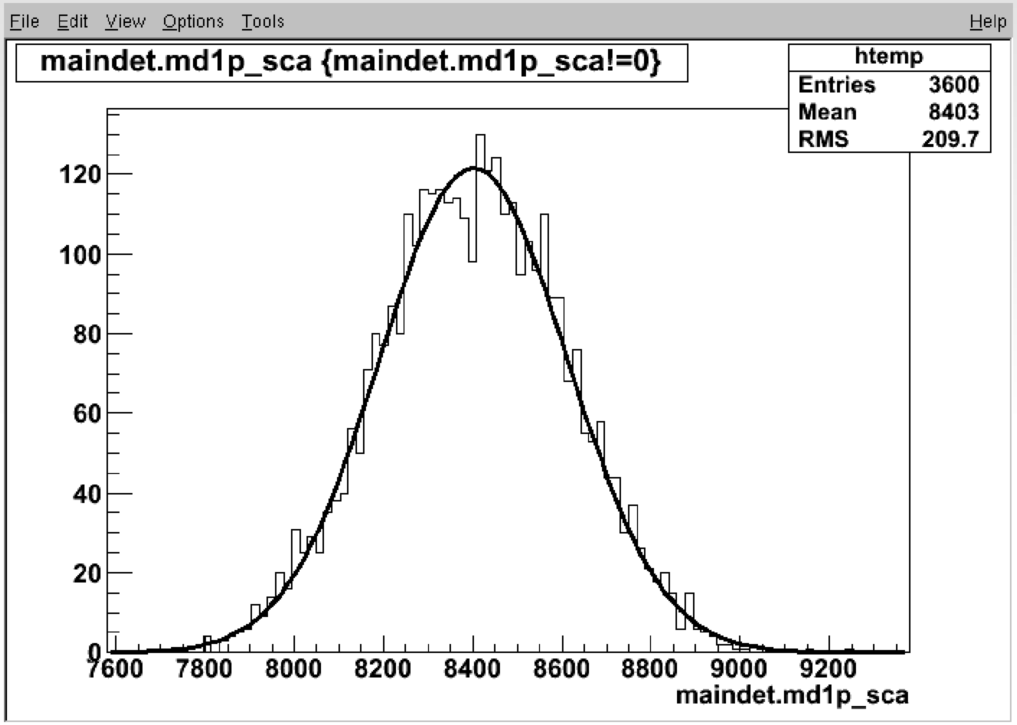
- Region III capable of providing projections onto MD plane.
- Currently operating at 95% efficiency.
- Figure is for pre-radiated bar.
- Allows us to map detector response.



EVENT MODE

Rate Determination

- Event mode data allows us to determine actual rates in bars.
- Have been using simulated rates thus far.
- Analysis is taking place to determine correct scaling from nA tracking data to uA parity data.



CURRENT MODE

Counting Statistics

Counting Statistics Floor:

$$N = 800MHz \times \frac{150\mu A}{180\mu A} \times 8 * 0.004s = 2.13 \times 10^7$$

$$\Gamma = \frac{1}{\sqrt{N}} = 216ppm$$

Winter running showed MD widths of ~290ppm. D. Armstrong accounts for this excess noise in Elog 124 by citing:

- Detector Resolution (10% broadening)
- Settling time after helicity flip (7%)
- BPM noise (~105ppm added in quadrature)

https://qweak.jlab.org/elog/Analysis+%26+Simulation/124

CURRENT MODE

Noise Levels

Battery Tests:

- MD ADC tests in July: ~4ppm asymmetry width
- BCM ADC tests Nov. 25, 2010: ~1.3ppm asymmetry width

Electronic noise in these ADC's is much smaller than the expected asymmetry full luminosity main detector width.

CURRENT MODE

Noise Levels

<u>Real MD Data:</u>

- Yields calculated by normalizing MD signals to beam current. Use these to calculate asymmetries for each tube.

$$A = \frac{Y_+ - Y_-}{Y_+ + Y_-}$$

- "Combination" detector asymmetries are built from summing yields, with *static (!)* scaling factors based on individual tube yields and asymmetry widths

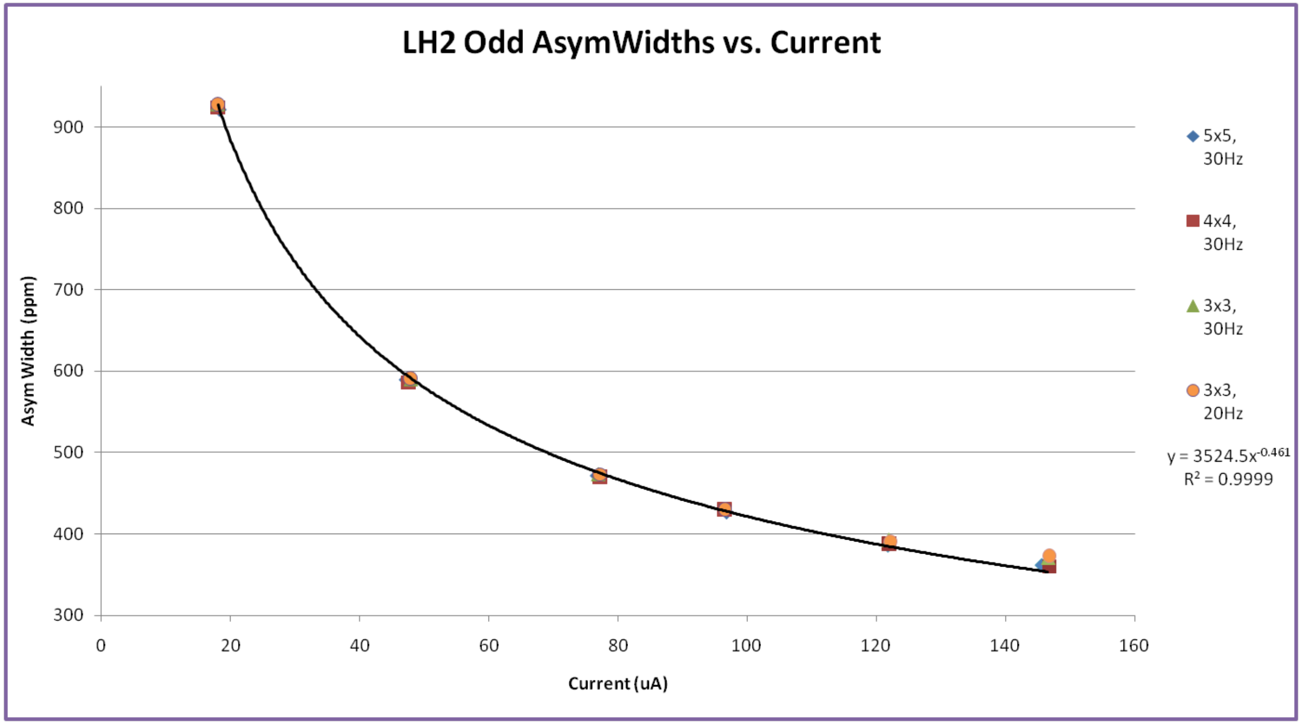
- Found ~1.2 times counting statistics in the fall, before numerous shielding improvements. New data coming in as we speak.

CURRENT MODE

Asymmetry Widths vs Current

- Took **a lot** of diagnostic data in the fall, including a few sets of target boiling studies. These were also useful in studying detector response to varying current.

- Observed behavior very close to the expected 1/sqrt(I) dependence of the MD asymmetry widths.

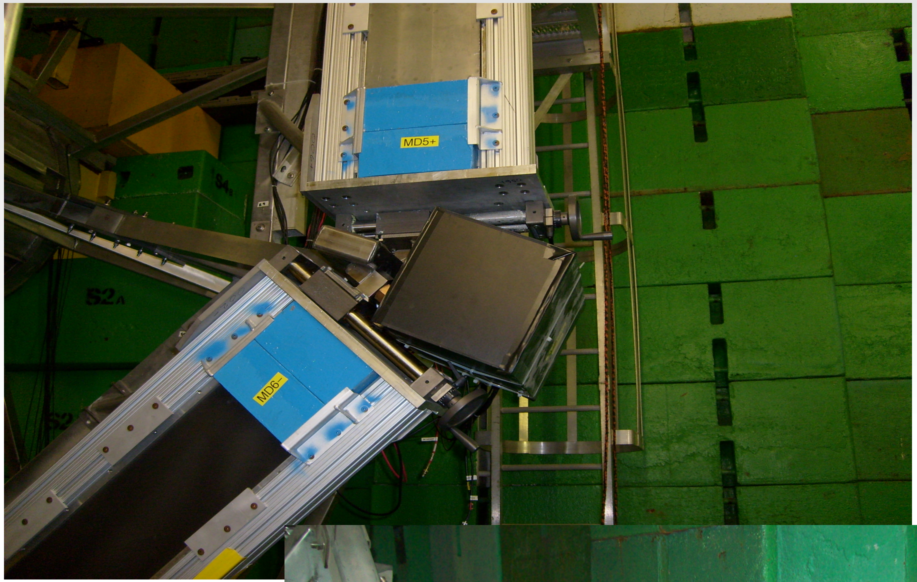


*plot developed using only odd bars

BACKGROUND STUDIES

Background Detectors

- PMT
- PMT + 18 cm light guide
- PMT + light guide + LED
- MD 9



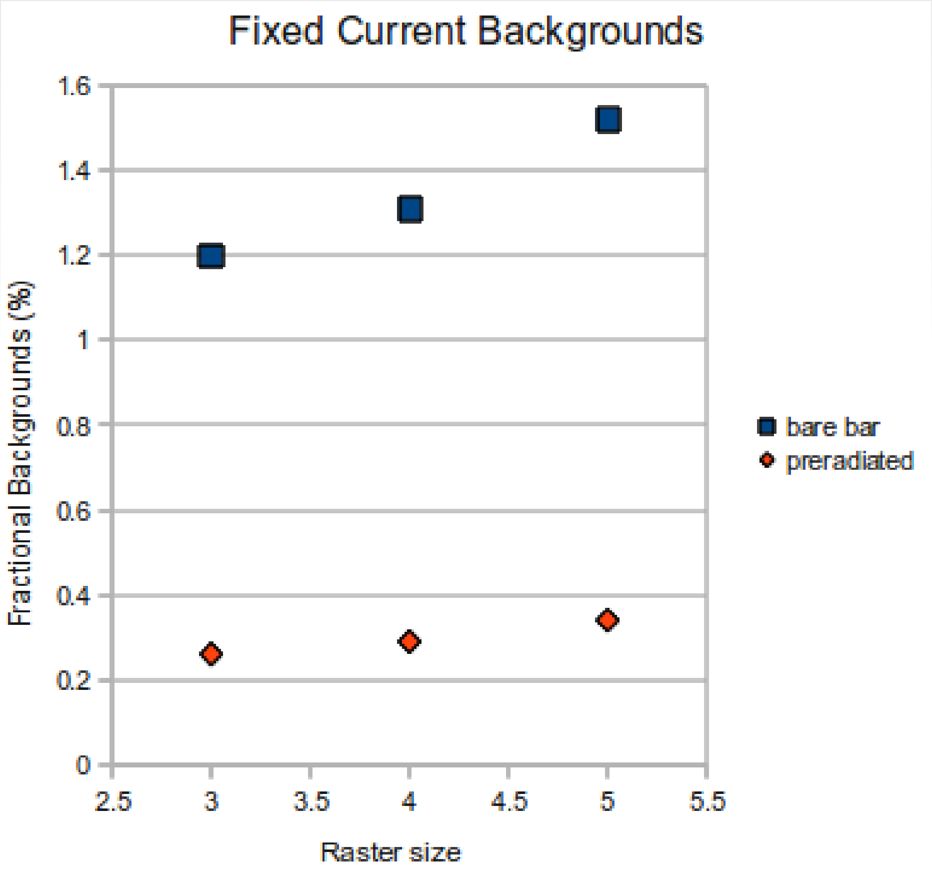
BACKGROUND STUDIES

Background Detectors

From Buddhini's log 202571:

$$\mathrm{FracBkgd} = c \times \frac{Y_{bkgd}}{Y_{md}}$$

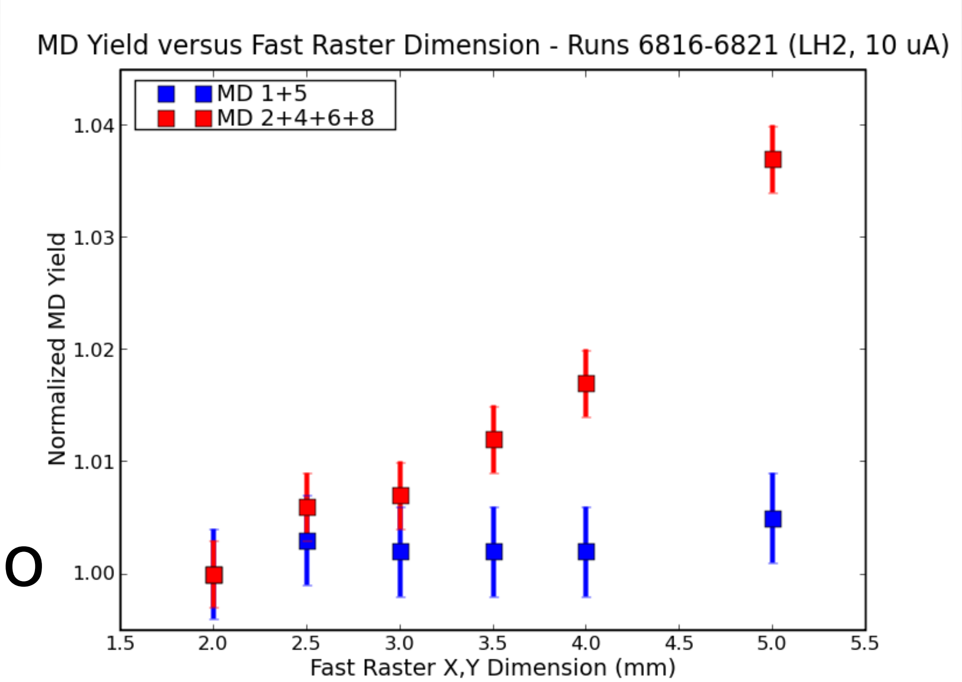
- c = scaling constant for gain mismatch
- Pmtonl saw negligible background
- Pmtltg saw 1-2% background in bare bars. Scales to O(20%) for full bar. O(5%) for pre-radiated bars.
- Plot is for pmtltg



BACKGROUND STUDIES

Raster Dependence

- Have determined, after many “raster scans,” that Fast Raster size is a critical variable.
- MD yields varying strongly with increased fr size.
- Attributed to scraping of the raster on the W-plug.
- Pre-radiators decrease, but do not eliminate the effect.
- 3x3 – 3.5x3.5 mm^2 raster sizes appear to be optimal



BACKGROUND STUDIES

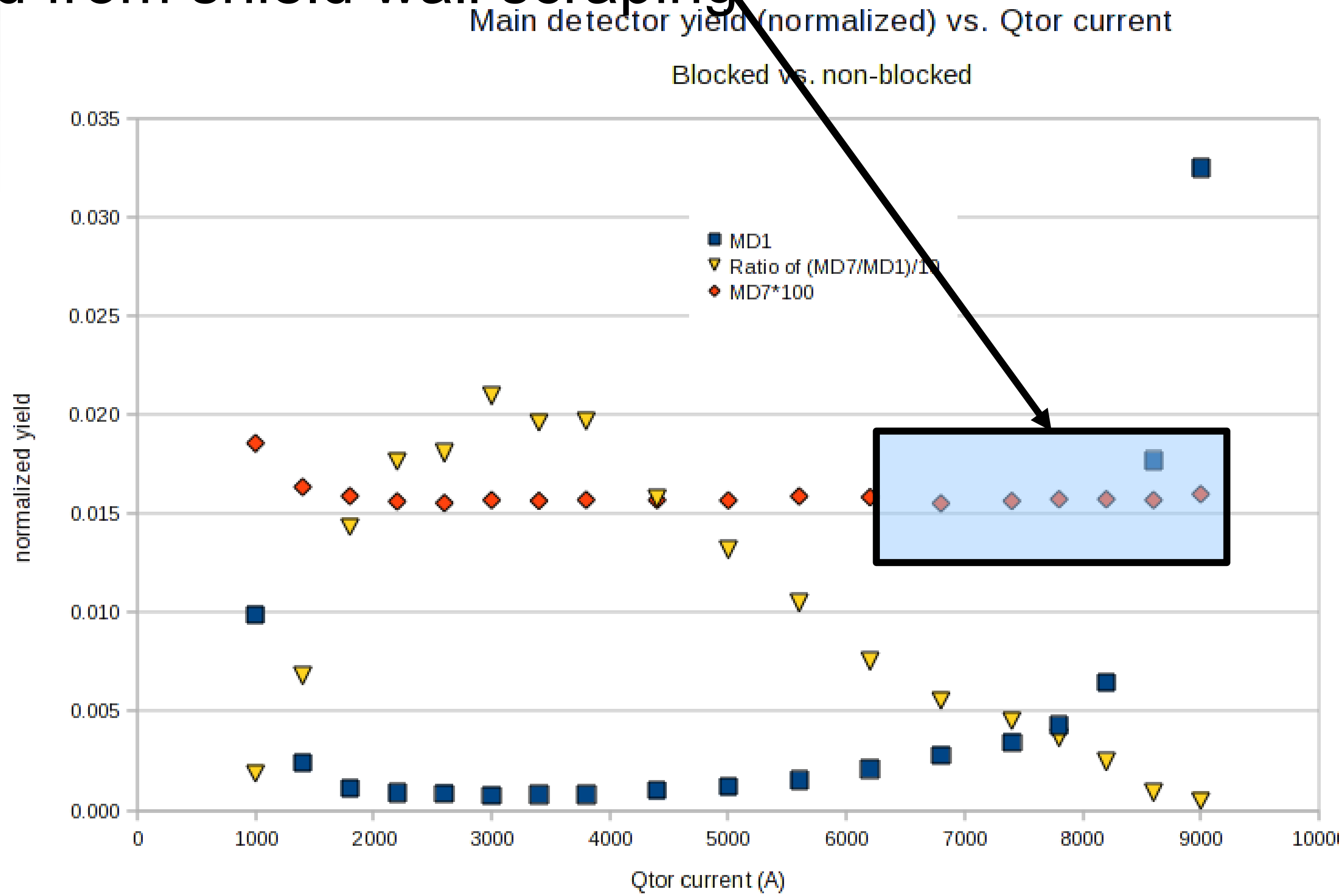
QTor Scans

- Nominal QTor current = 8921 A.
- Completed current scan ranging from ~1000 to 9000 A.
- Octant 7 in Region II blocked.
    - This blocks only stuff downstream of Region II, **does not** eliminate backgrounds induced from scraping off of the W-plug.

BACKGROUND STUDIES

QTor Scans

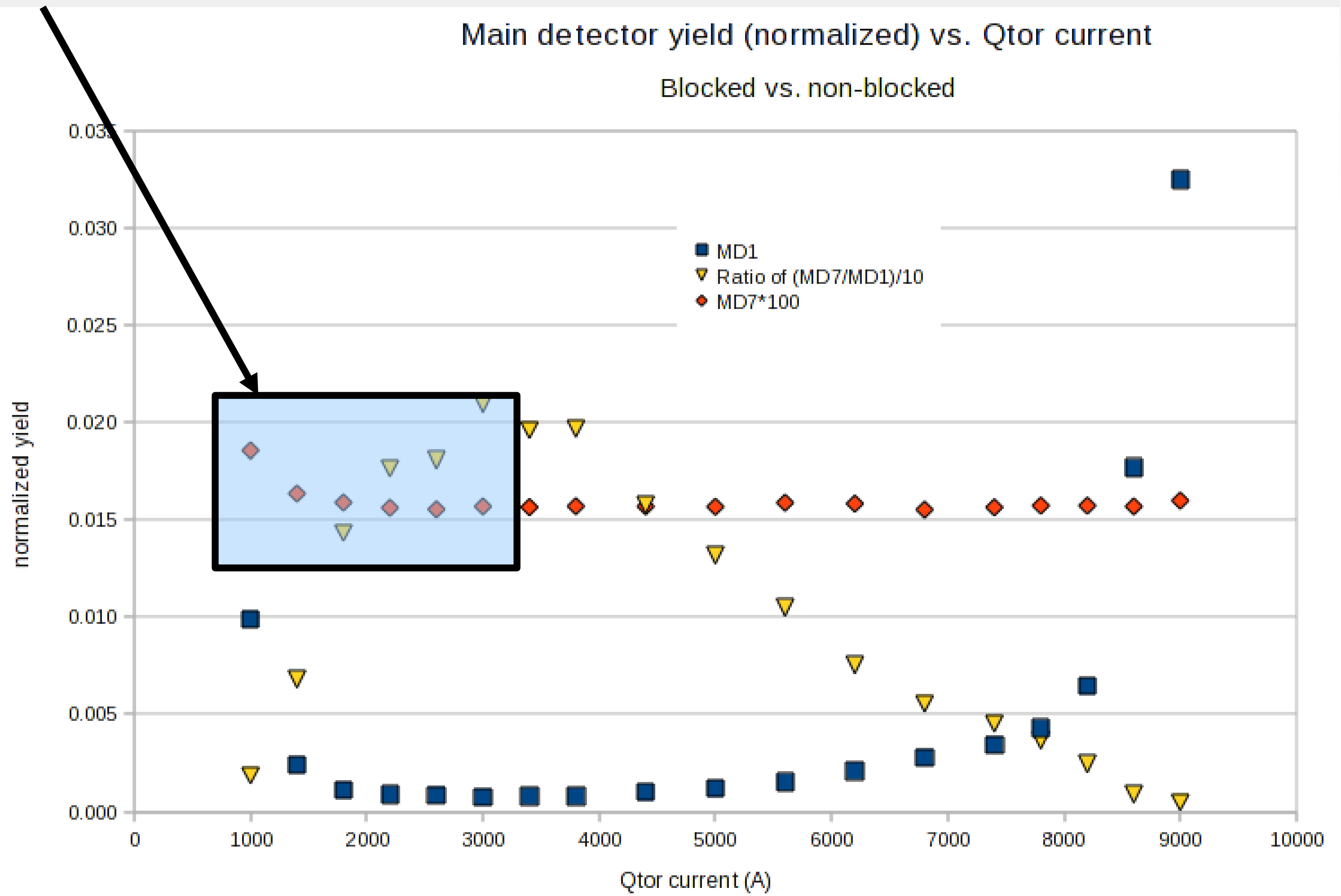
- As we lower QTor from nominal current:
  - No background from adjacent octants
  - No background from shield wall scraping



BACKGROUND STUDIES

QTor Scans

- Signal increases when Moller fountain is sprayed onto the quartz bars.



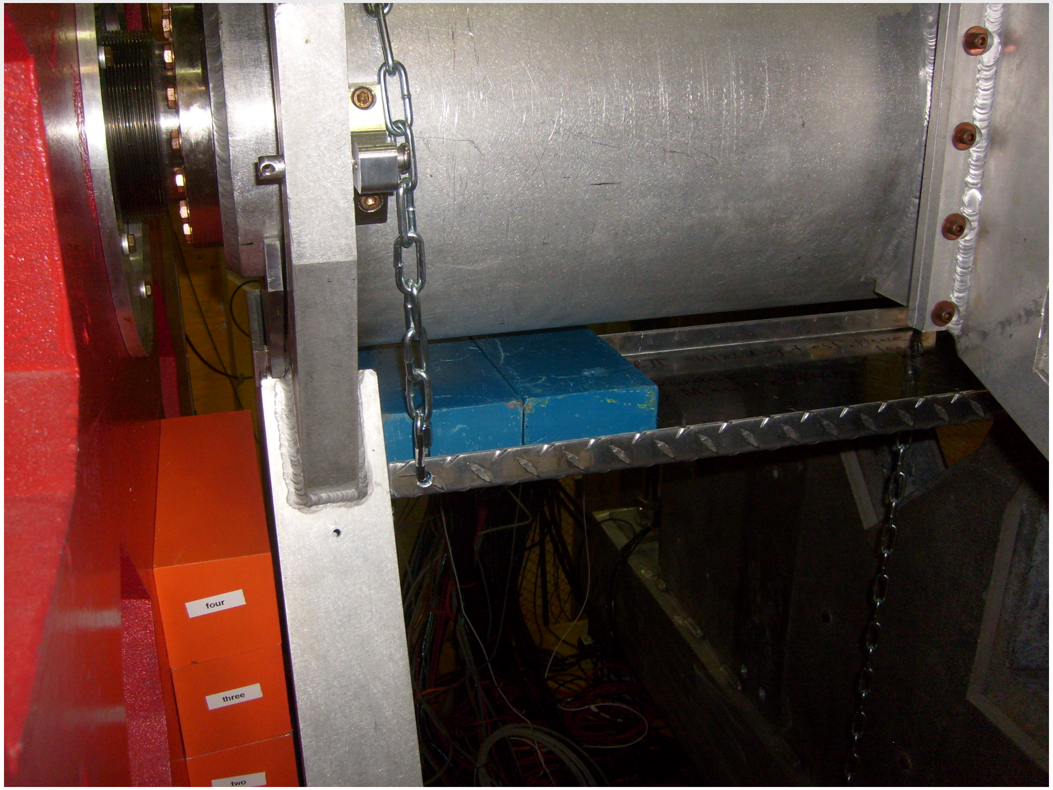
BACKGROUND STUDIES

Region 2 Shielding Studies

- Plugged octant 7 in Region II to study backgrounds from Pb collar, just upstream of the rotator.

- Since oct7 was plugged, all signals would correspond to backgrounds and not primary scattered electrons.

- Different configurations of Pb brick were studied to determine how to properly shield detectors from this background source.

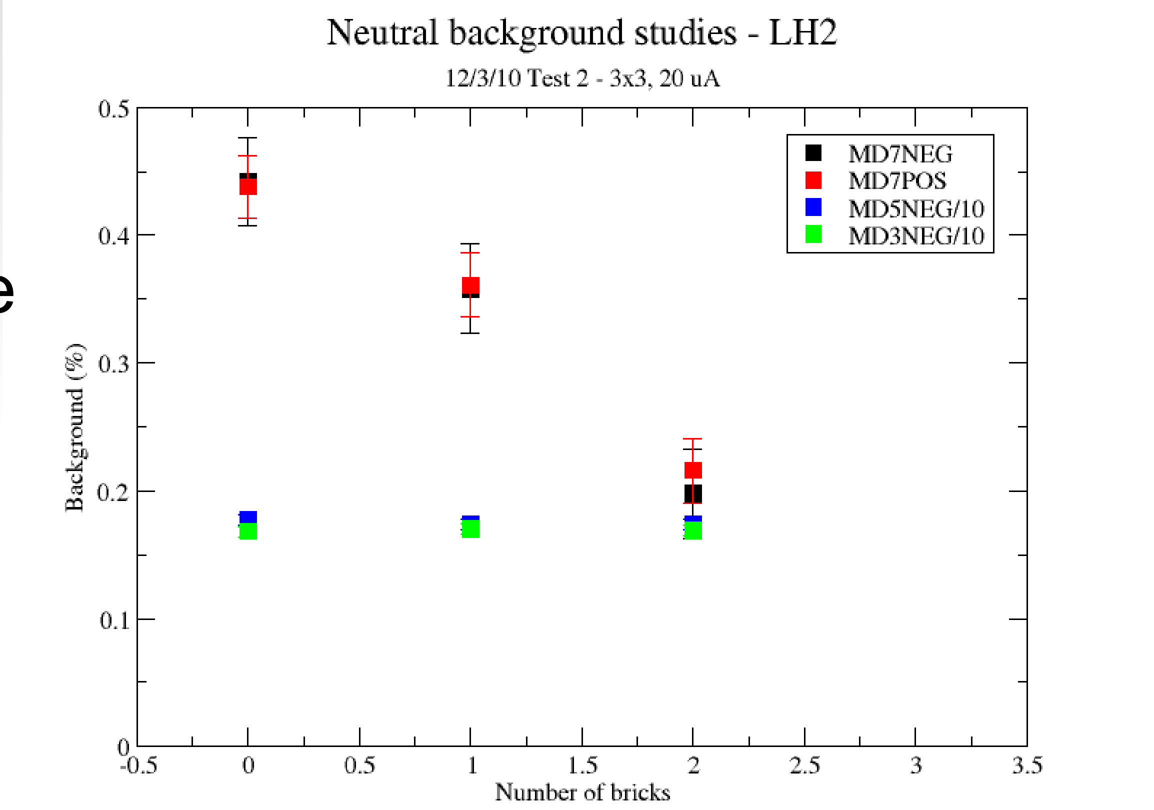


BACKGROUND STUDIES

Region 2 Shielding Studies

- Took data with LH2 *and* upstream Al targets.

- Addition of bricks was able to bring LH2 background levels down by ~56%...

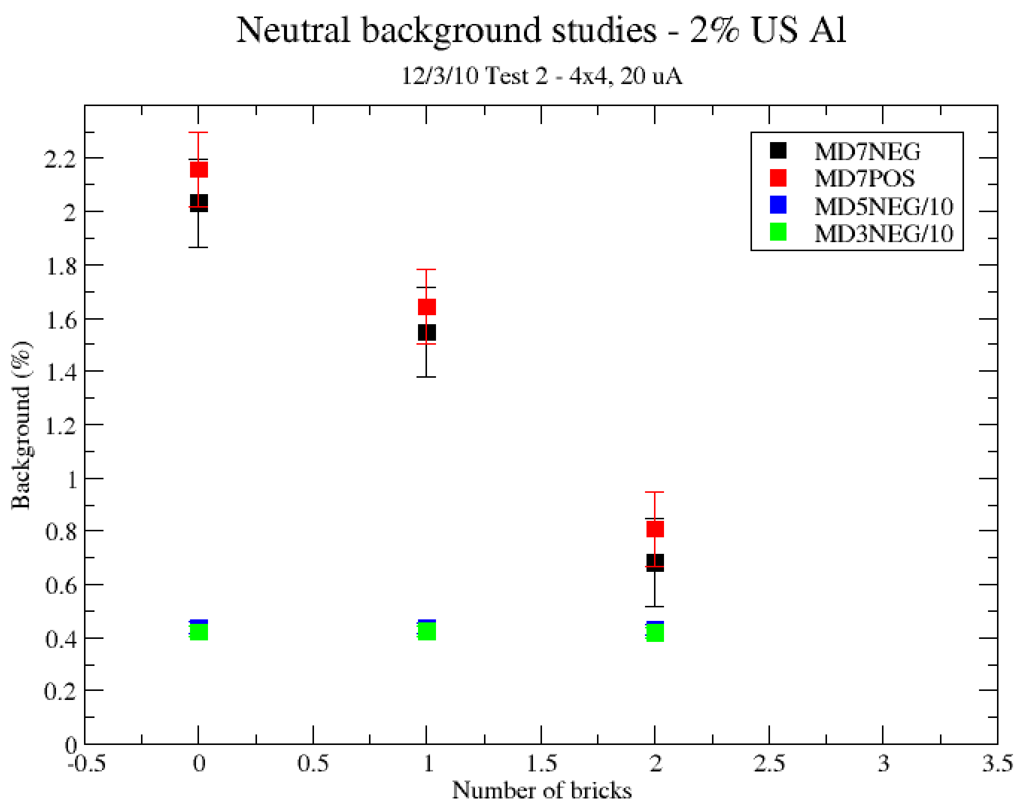


BACKGROUND STUDIES

Region 2 Shielding Studies

- Took data with LH2 *and* upstream Al targets.

- Addition of bricks was able to bring LH2 background levels down by ~56%... and US Al target backgrounds down by 75%!



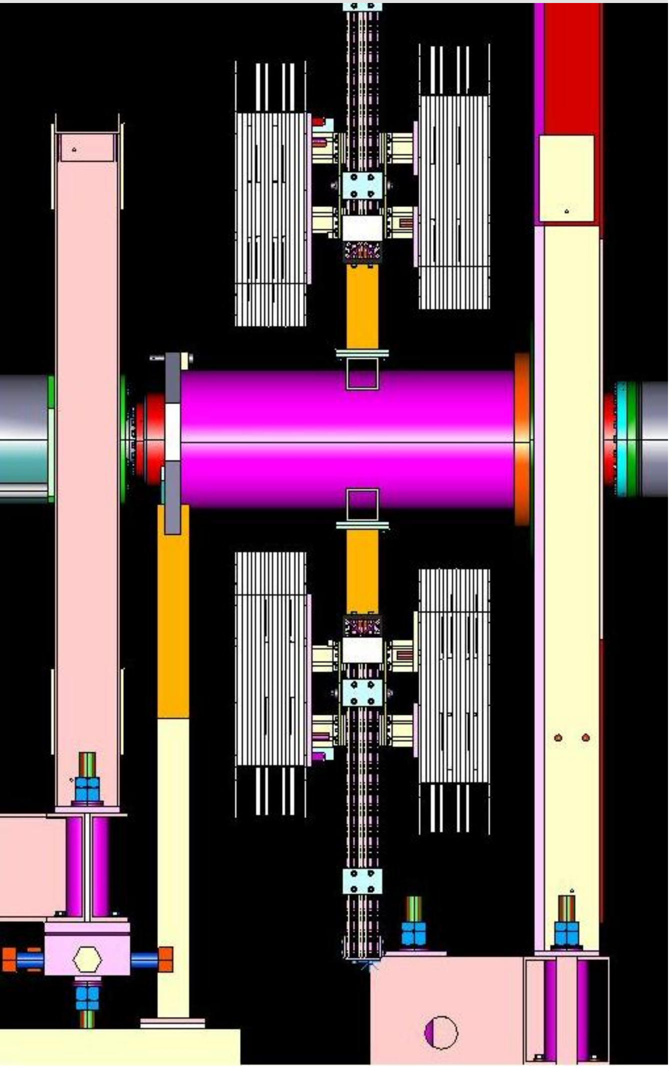
Caveat:

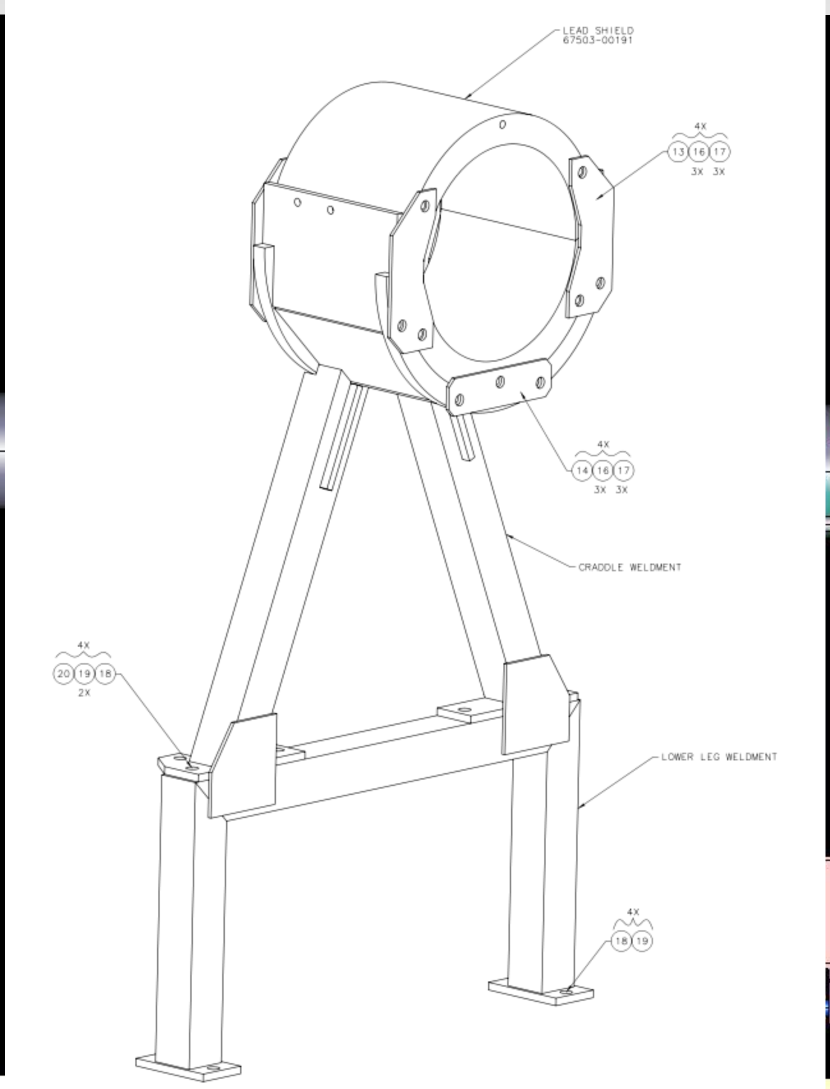
- These are *neutral* backgrounds only, with QTor off.

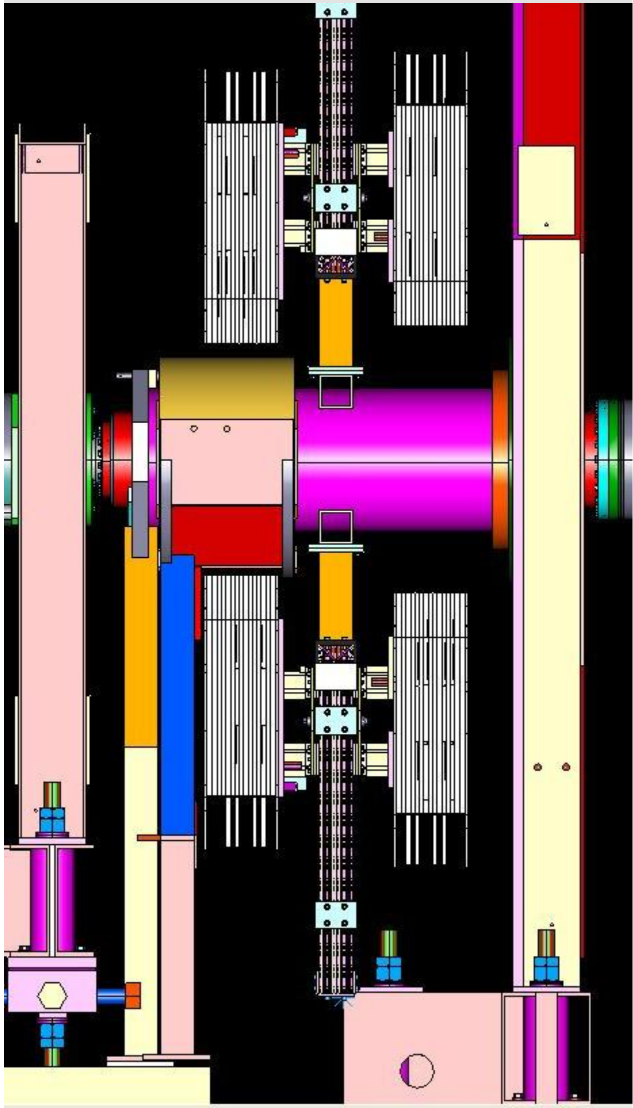
Full report available at https://qweak.jlab.org/elog/Analysis+%26+Simulation/145

BACKGROUND STUDIES

Region 2 Shielding Studies







SUMMARY

- Numerous shielding changes have taken place since our initial evaluation of background levels in the fall.

- Both configurations have had their hardware chains thoroughly shaken down and are in a stable state ready for a long period of production running.

- Event mode data has been taken and put to use in calculating pulse height distributions.

- Current mode excess noise levels have been improving steadily as we make changes. Fresh results to be available soon.

ONGOING AND FUTURE WORK

- Calculation of normalized track rate from event mode data.

- Use rate and pulse height distributions from event mode data to calculate expected signals and compare to those observed.

- Study gain drifts to determine how long scaling factors for combinationPMT's are accurate. How to calculate in real-time?

- ...

SUPPLEMENTALS

CURRENT MODE

Expected Anode Current

$$I_a = R \times \langle pe \rangle \times e^- \times G$$

Using scaled simulated rates and average light yield for pre-radiated bars: $I \sim 1.6\mu A$

Assuming 2MOhm impedance in hardware gives signal levels of 3 – 4.5 V.
Recent data shows 5.5 – 6 V...still need to carefully determine values for rates, gain, and <pe>!

Asymmetry Calculations

How were we calculating asymmetries for BARS as opposed to individual PMT's?

Method 1:

$$A_{bar} = \frac{A_L + A_R}{2}$$

$$= \frac{1}{2}\left(\frac{N_{L+} - N_{L-}}{N_{L+} + N_{L-}} + \frac{N_{R+} - N_{R-}}{N_{R+} + N_{R-}}\right)$$

Where N_{L+} is the yield for the left PMT for helicity state +

Asymmetry Calculations

Method 2:

$$A_{bar} = \frac{(N_{L+} + N_{R+}) - (N_{L-} + N_{R-})}{(N_{L+} + N_{R+}) + (N_{L-} + N_{R-})}$$

Making “CombinationPMT” constructs like this is as easy as defining what tubes you want to combine in a the appropriate mapfile. The analyzer already has some of these implemented, including one CombinedPMT that corresponds to all 16 PMT's.

Combination Scaling Factors

Our current method of combining PMT's does NOT take into account gain mismatching.

Relative scaling factors of tubes that go into a "CombinationPMT" detector were calculated based on December 8th, 140 uA data.

$$C = \frac{1}{Y} \times \frac{1}{A^2}$$

Ideally we will want this to happen on a real-time basis: updating the scaling factors as the yields change. For now, the static values are better than nothing.

% Bkgd at "Zero Signal" QTor Currents

- Determined during RII-blocked QTor scan.
- Calculated by taking the minimum yields observed (at I = 3000 A) and dividing by yields at nominal QTor current (I = 8921 A).

- Pre-radiated bar : ~3%
- Bare bar : ~15%