# The Re-re-reconstructed Crab

Andy Smith

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## 1 Introduction

This is a short memo on the current status of the crab reconstruction effort. My hope is that the contents of this memo will wrap some outstanding issues with the crab analysis that have been holding up publication of the crab paper. Hopefully this memo will present a solution to these problems and provide the collaboration much needed documentation of the origin of all those numbers in the crab paper.

As of the March, 2003 collaboration meeting in Maryland there remains two issues holding up the crab paper: 1) The inconsistency between the PE scales of the old (Bussy generated) and the new (mine) calibrations. 2) Understanding the statistics thing.

## 2 Reconciling the Calibrations

For calibration purposes, the data collected to date have been divided into 4 epochs, each roughly a year long and separated by PMT repairs. The epochs and their corresponding optimal calibrations are listed in table 2.

The problem is that PE calibrations for the first 2 epoch seem to be inconsistent with those from the third and fourth epochs. The difference in the PE scale has been observed to be proportional to the pulse size, indicating that it is probably due to a mis-calibration of the filter wheel. Even a small systematic error in each step of the filter wheel calibration can compound to create a substantial departure over the full range of the wheel. The calibration scale shift has the disturbing effect of changing the efficiency of the $x_2 > 2.5$ cut, increasing the efficiency for data by about 33%.

The problem is resolved scaling the filter wheel calibration function by a factor proportional to the log of the amplitude of the laser signal. The scale of the correction is defined by the equation

$$factor = 0.04\% \times lnAmplitude. \tag{1}$$

This represents a 9.2% scale change at 10 PEs, and a 18.4% scaling at 100 PEs and so forth. The amplitude of the correction was selected to make the efficiency of the $x_2 > 2.5$

| Epoch | Run Numbers | JD range | Dates | Best Calibs |
|---|---|---|---|---|
| 1 | 1-2465 | 1349-1805 | June 18,1999 - Sept 16,2000 | Bussy-1999 |
| 2 | 2466-3266 | 1814-2162 | Sept 25,2000 - Sept 8,2001 | Bussy-2000 |
| 3 | 3267-4479 | 2171-2532 | Sept 17,2001 - Sept 13,2002 | calib2 v307 |
| 4 | 4480- | 2533- | Sept 20,2002 - | calib2 v406 |

Table 1: Best Calibrations by Epoch

| Cuts | $\epsilon$ | $N_S$ | $N_{B-TS}$ | $N_B \times \alpha$ | excess | Signif |
|---|---|---|---|---|---|---|
| $Nfit \geq 20$ | 1.00 | 18374036 | 18366378 | 18365694 | 8342 | 1.9 |
| $Nfit \geq 20$, $x_2 > 2.5$ | 0.115 | 2119449 | 2110528 | 2109732 | 9716 | 6.4 |
| $Nfit \geq 20$, $x_2 > 3.0$ | 0.069 | 1260692 | 1254554 | 1254007 | 6685 | 5.7 |
| $Nfit \geq 20$, $x_2 > 4.0$ | 0.025 | 457413 | 454003 | 453699 | 3714 | 5.3 |
| $Nfit \geq 20$, $x_2 > 5.0$ | 0.009 | 167589 | 166326 | 166213 | 1376 | 3.2 |

Table 2: Results of analysis of Crab data June 18,1999 to Sept 13,2002.

cut equal that of the older Bussy-2000 calibrations. Figure 1 shows the old calibrations (Bussy-2000), the new calibrations unrescaled (v306) and the new calibrations rescaled (v307).

Data from epoch 3 was reconstructed using the new calibrations and combined with the previously reconstructed data from epochs 1 and 2. The results of the analysis of the data combining all three epochs is shown in table 2.

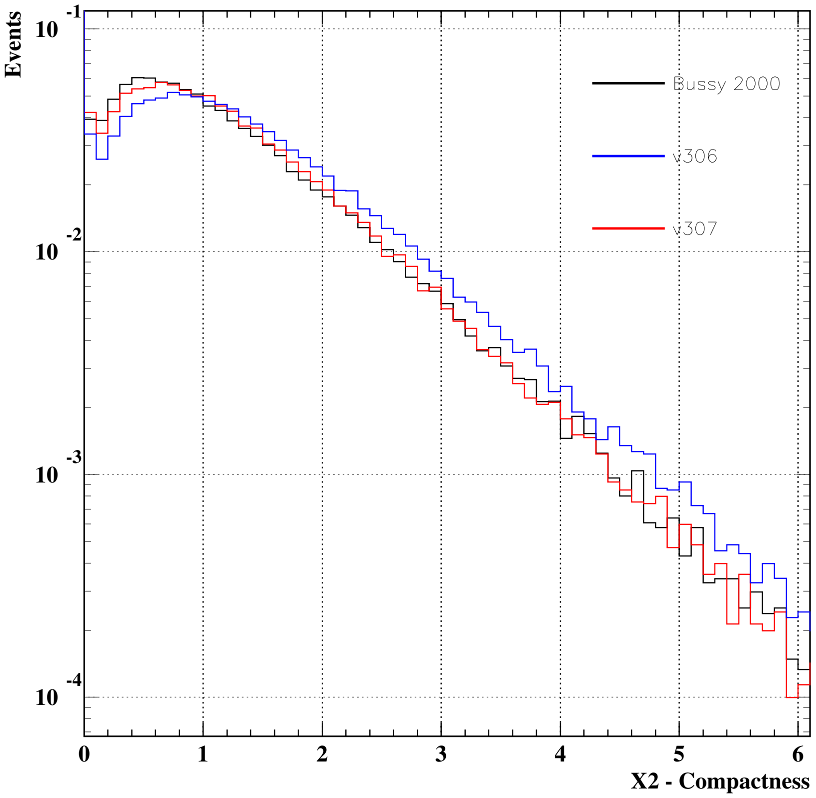


Figure 1: Compactness (X2) for new old and older calibrations.

The third and forth columns of table 2 are the number of events in the signal bin and the background calculated from direct integration time sloshing. The background integration time employed was 2 hours, however integration periods can be shorter because excessive clock error, time gaps and run completion can also signal the termination of a background

| Epoch | $N_S$ | $N_{B-TS}$ | $\epsilon_{X2>2.5}$ | Signif |
|---|---|---|---|---|
| 1 | 682809 | 680446 | 0.140 | 3.0 |
| 2 | 684297 | 681235 | 0.104 | 3.9 |
| 3 | 752343 | 748847 | 0.108 | 4.2 |

Table 3: Crab results by epoch, $Nfit \geq 20$, $x_2 > 2.5$.

integration period. In general, the actual background integration period is shorter than the 2 hour maximum integration time. The actual period is calculated to be the event weighted average time of each integration period. For this analysis, the average integration time was 6740s.

## 3 Computation of Background and Significance

The method of computing significance of and excess suggested by Li and Ma requires 3 parameters, the number of events in the signal bin ($N_S$), the number of event in a background region ($N_B$) and the ratio of the experiments exposure to the signal region and the background region ($\alpha$). For our data the number of signal events is easy to calculate, it is just the number of events passing the cuts and falling within the signal bin. The background computation is trickier. Backgrounds computed from time sloshing are NOT equal to $N_B$ because time sloshing includes events from the signal bin as candidate background events. It is important to remove the contribution of the signal bin to the background calculation before employing the method of Li and Ma. In Roman Flscher's analysis of the galactic plane he removed the events that contributed to the signal bin from his time sloshing sample while doing the time sloshing. The problem with this method is it requires the definition of the point of consideration prior to building the map. For allsky analyzes, a general purpose map making algorithm is required that can correctly estimate the significance of the excess/deficit at all points in the sky.

To remove the contribution of the signal to the background, one must realize that time-sloshing creates a background map from events falling within the same declination band, but arrived at different sidereal times as the events that contribute to the signal bin. In the case of this Crab analysis, the width of the signal bin in the RA dimension is $2.3^O$ (a $2.1^O$ bin widened to account for declination). For the average time sloshing duration, the sky rotates $28.1^O$ ($30.0^0 \times \frac{6740}{7200}$). Therefore, the background derived from time sloshing is composed on average of 2.3 parts signal bin and 25.8 parts background. One can remove the contribution of the signal bin with the simple formula

$$N_B = (\frac{28.1}{2.3} \times N_{B-TS} - N_S) \times \frac{2.3}{25.8}, \tag{2}$$

where $N_{B-TS}$ is the background derived from time sloshing. The final Li-Ma parameter $\alpha$ is simply the ratio of exposure, $\frac{2.3}{25.8}$. Using these 3 numbers the significance is calculated using equation (17) of Li and Ma's paper. All significances in this memo are calculated using this method.

## 4 The Data

The data used in this analysis contains 917.1 days of data collected between June 18,1999 (JD=51358) and Sept 13,2002 (JD=52532). This data sample spans the first three calibration epochs and runs up until the Fall 2002 PMT repairs. Data from epochs 1 and 2 were reconstructed using Bussy's "1999" and "2000" calibrations. Data from epoch 3 was reconstructed with the calibration version 307. The programed time sloshing duration is 2 hours, but the actual average duration was 6740s. Figure 2 shows the significance sky map in the vicinity of the crab. Figure 3 shows the distribution of sigmas for all points in the sky. Figure 4 shows how the excess from the crab is distributed as a function of number of air shower layer PMTs. Figure 5 shows how the excess is distributed vs $X_2$.

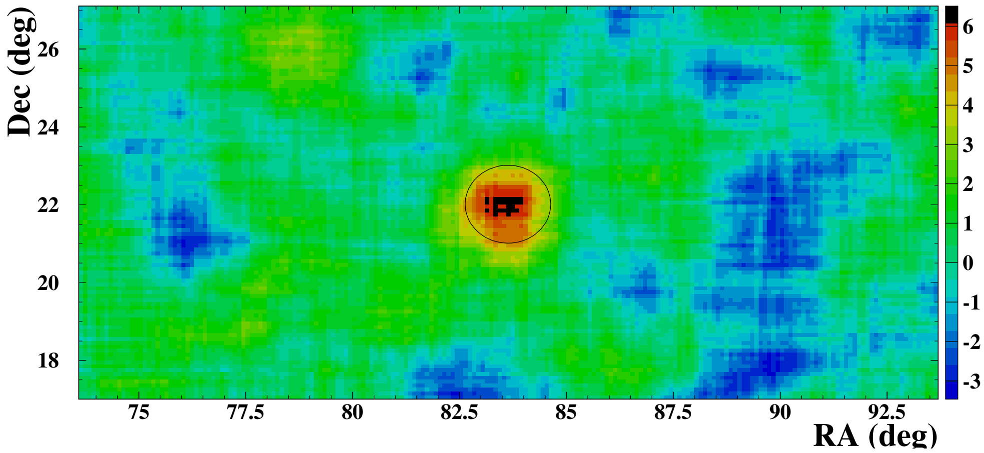


Figure 2: Significance skymap for the vicinity of the Crab.

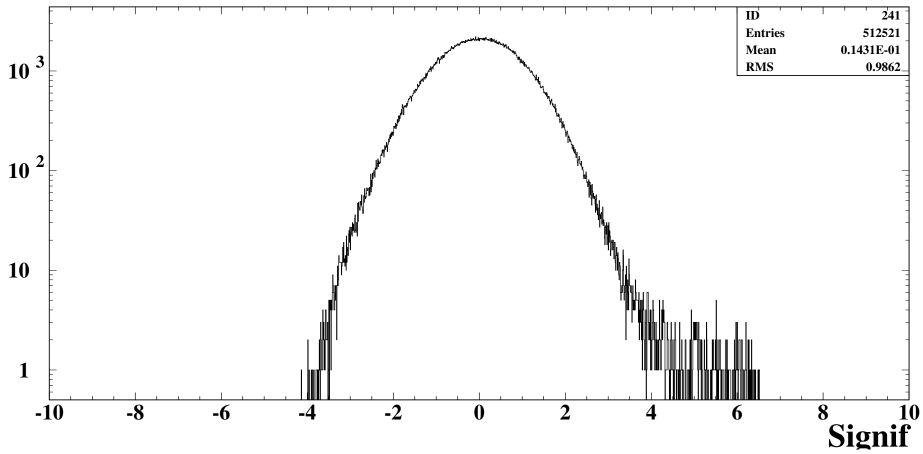


Figure 3: Significance distribution

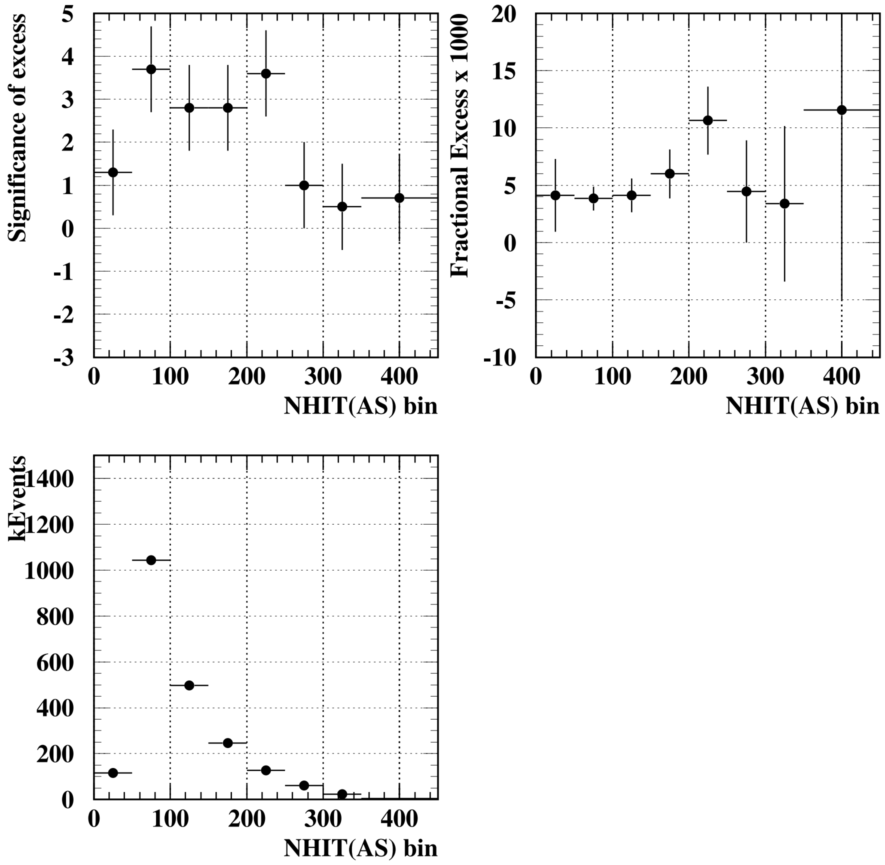


Figure 4: Crab excess ploted vs number of hit air shower layer PMTs.

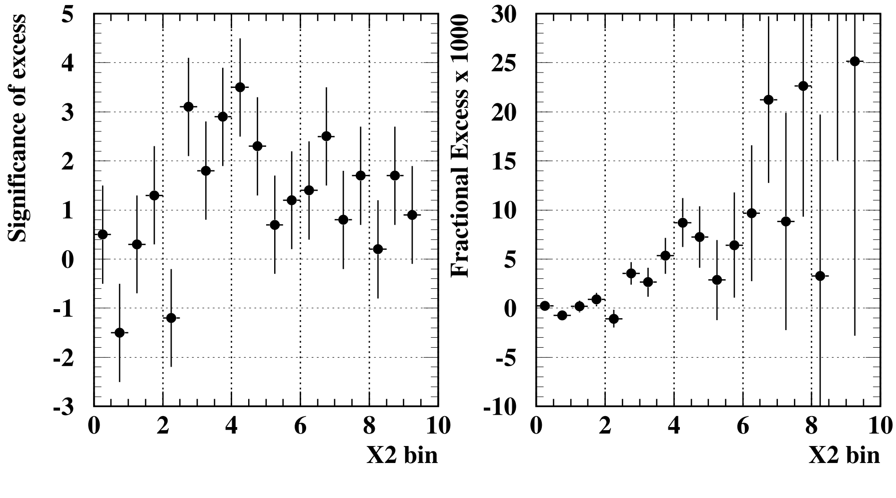


Figure 5: Crab excess ploted vs $X_2$.