The Moon, as Seen Through Outriggers
Progress Report

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(**Please note that this is a progress report. There is still much more to do.**)

As a continuation of trying to understanding how much the outriggers (and bottom layer) help us improve Milagro's angular resolution, I have re-reconstructed a small raw moon data set (~ 3 months) using the outriggers. Hopefully this analysis will be independent of using the Crab and other techniques, but will likely have different if not more difficult complications such as protons versus photons and the earth's magnetic field.

My goals for this analysis are to:

1. Quantify any improvement in angular resolution we get using the outriggers.
2. Help decide which calibration version to use, one with zenith align build into the calibrations or not.
3. Determine angular resolution versus nfit?
4. Side goal: Can one make an energy cut on our data to look at high energy events?

Please recall from my last memo on outrigger reconstruction (on UCSC Milagro memo page 11/12/03) that I have modified our offline code and shower timing parameterizations to incorporate outrigger (and muon layer) hits into our shower fits. This included determining calibrations parameters for the outriggers, and an overall time offset between the pond and outriggers. I also determined new 2-dimensional parameterizations for curvature and sampling corrections. Also recall that I used two different calibrations sets; one based on calibration version 406 (latest at that time, without zenith-align corrections build-in) and one based on version 408 (which I call here 409). So 406 has no zenith aligned corrections and version 409 does have zenith align corrections. Both have outrigger calibrations.

Graciously, Gus and Xianwu gave me access to 24 Moon tapes with raw data, spanning the time from March 8, 2003 to June 13, 2003 (mjd 2707-2804, runs 4855-5004). I have reconstructed the events in this data set using the following methods:

1. Use version 406 with outriggers (**note: if outriggers were used so was the bottom layer**).
2. Use version 409 with outriggers

3. Use version 406 without outriggers (and without bottom layer)
4. Use version 409 without outriggers.

I also will show plots of moon shadows from online REC events.

The technique I used to present the moon shadow was a standard 2-D sigma map of source-background significances of overlapping bins with a 1.2° radius on a 0.1° x 0.1° grid. The background was estimated by time sloshing 10 times over the 10° wide dec strip. The sink area of the shadow was not removed of compensated for in the background estimate. This effect should be roughly

$$\frac{A_{moon}}{A_{strip}} = \frac{\pi(0.25)^2}{90(10)} = 0.00022$$

, that is the background should be raised by 1.00022.

First I wanted to decide which calibration version was the best to use, with or without zenith-align built in. So the idea was to reconstruct with version 406 and 409 and look for offsets of the moon shadow. However, the moon shadow should be offset and we don't know exactly where since we don't know the energies of individual events very well. To get around this, I used Gaurang's energy estimator (see his 3/14/00 on memo webpage). I used an E > 10 TeV cut and no energy cut. With this 10 TeV cut, the standard MC (version 3.2) says about 75% of the events will be above 10 TeV. Figure 1 shows the significance maps near the moon for events reconstructed with methods 1 and 2 above, and with a 10 TeV cut. One can clearly see that the shadow using calibration version 409 (with "built-in" zenith align) is better centered that the 406 version. Qualitatively one can also see that the width in RA is roughly the same as the width in DEC, hopefully indicating little magnetic field deflection.

Next I wanted to compare angular reconstruction with and without outriggers. I did this using calibration version 409 and with the 10 TeV cut. Figure 2 show's the "no-outrigger" shadow (no outrigger also means no bottom layer). Comparing this to the shadow in the bottom of Figure 1 at least qualitatively indicates an improvement.

For completeness I also show in Figure 3 the moon shadow obtained from online REC files with no-zenith align for the same run range as the raw data I used. Both online and no-outrigger shadows have some amount of the shadow at lower declinations that the moon. Since the moon is always in the southern part of the sky, this seems to indicate that we are systematically getting too large a value of theta (tilting away from the pond?).

Finally, instead of using a 10 TeV cut on Gaurang's energy estimator, I did a nfit cut. Other's have used a nFit cut of 100. Here I use 200 since using the outriggers and bottom layer increases the average nFit by a factor of about 2. Figure 4 shows the moon shadow for reconstructions using calibration versions 406 and 409, with outriggers. Again the shadow using 406 is shifted down and to the left compared to the 409 version. You can also see that for version 409 the “RA” width is larger than the “DEC” width, indicating that there is still some magnetic deflection. Also the “RA” width of 409 in Figure 4 (nFit>200) is wider that of 409 in Figure 1 (E>10 TeV). Figure 5 shows the shadow with nFit>200 from online data.

As I stated earlier, this is a progress report. I still want to quantify this analysis by doing 2-D fits to this data. I also want to apply Bob and Allen's rotations so as to look at the shadow's width perpendicular to the magnetic deflection direction.

Please email me comments/suggestions on ways to improve this analysis.

Thanks, Tony...

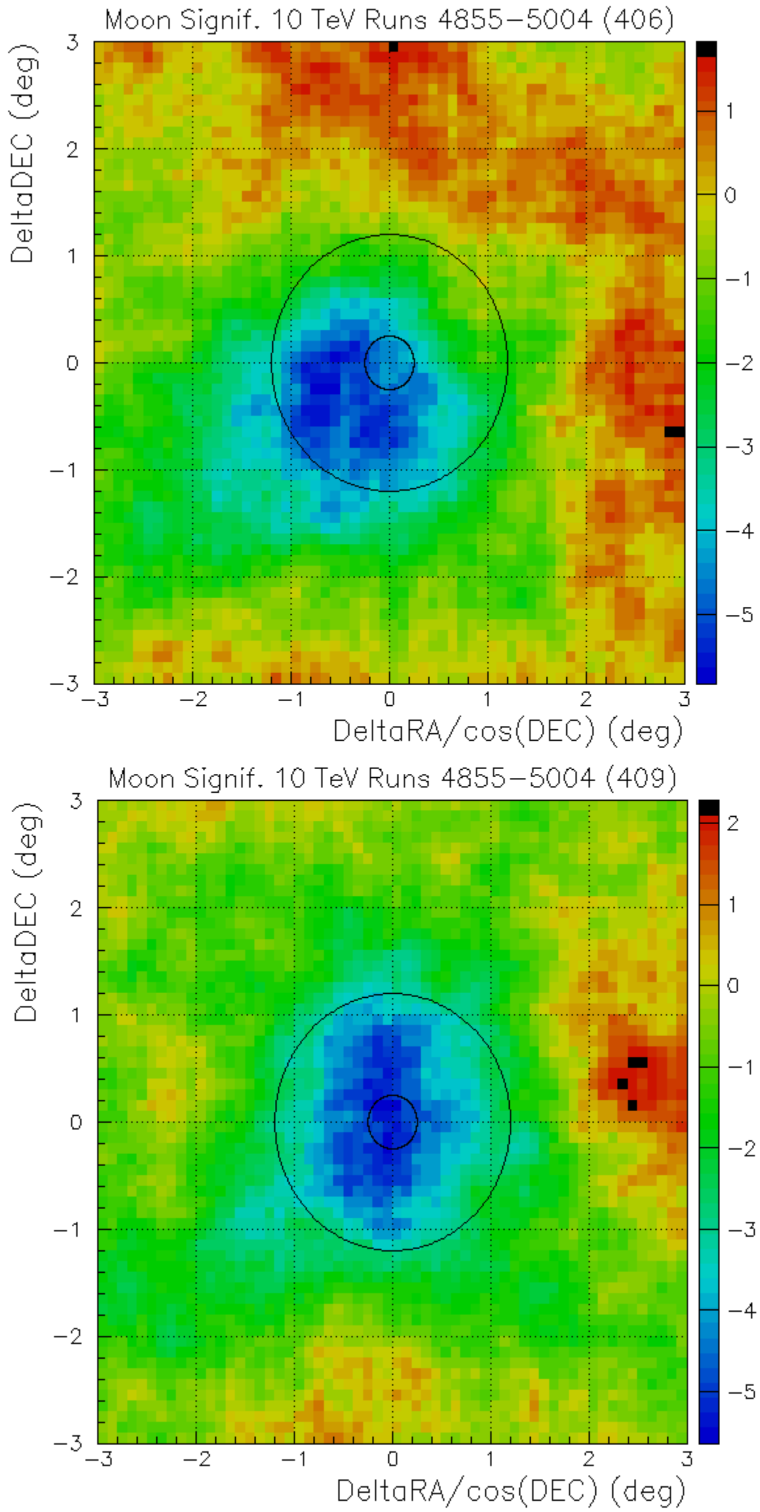

Figure 1: Moon Shadows for E > 10 TeV, Outriggers in fit and cal. Versions 406 & 409

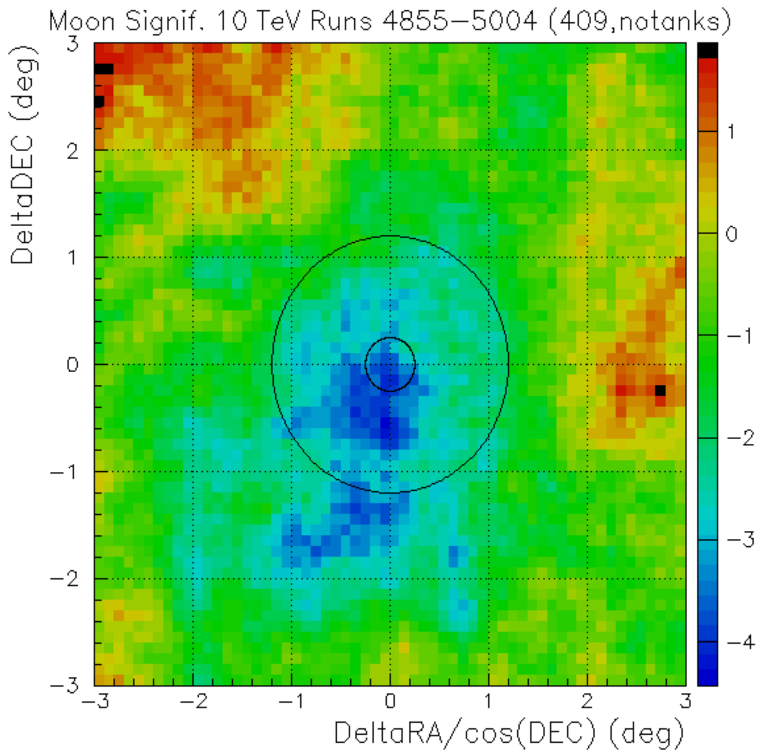

Figure 2: Moon Shadow, angular reconstruction without outriggers, but with calibration version 409.

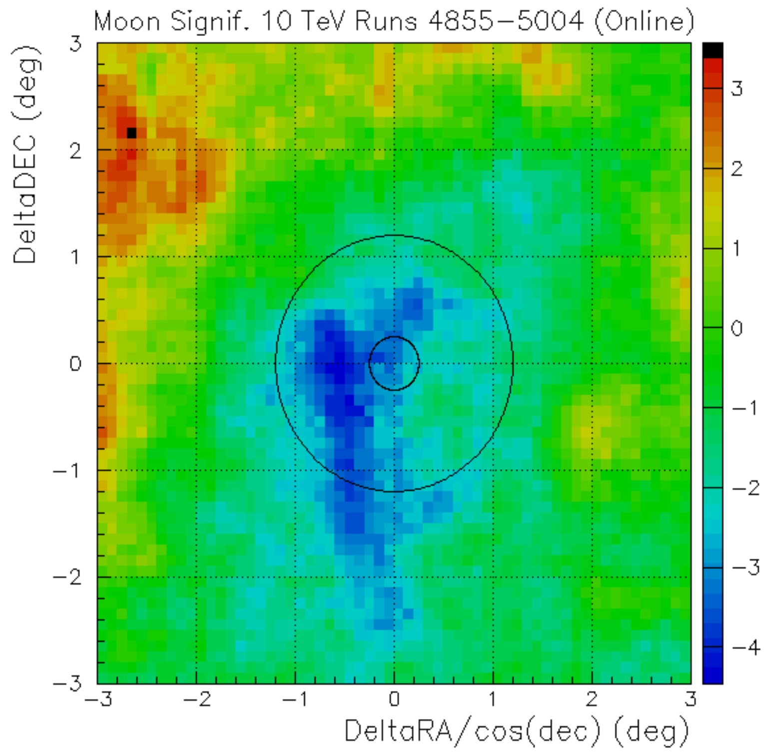

Figure 3: Moon shadows from online REC files without zenith alignment corrections.

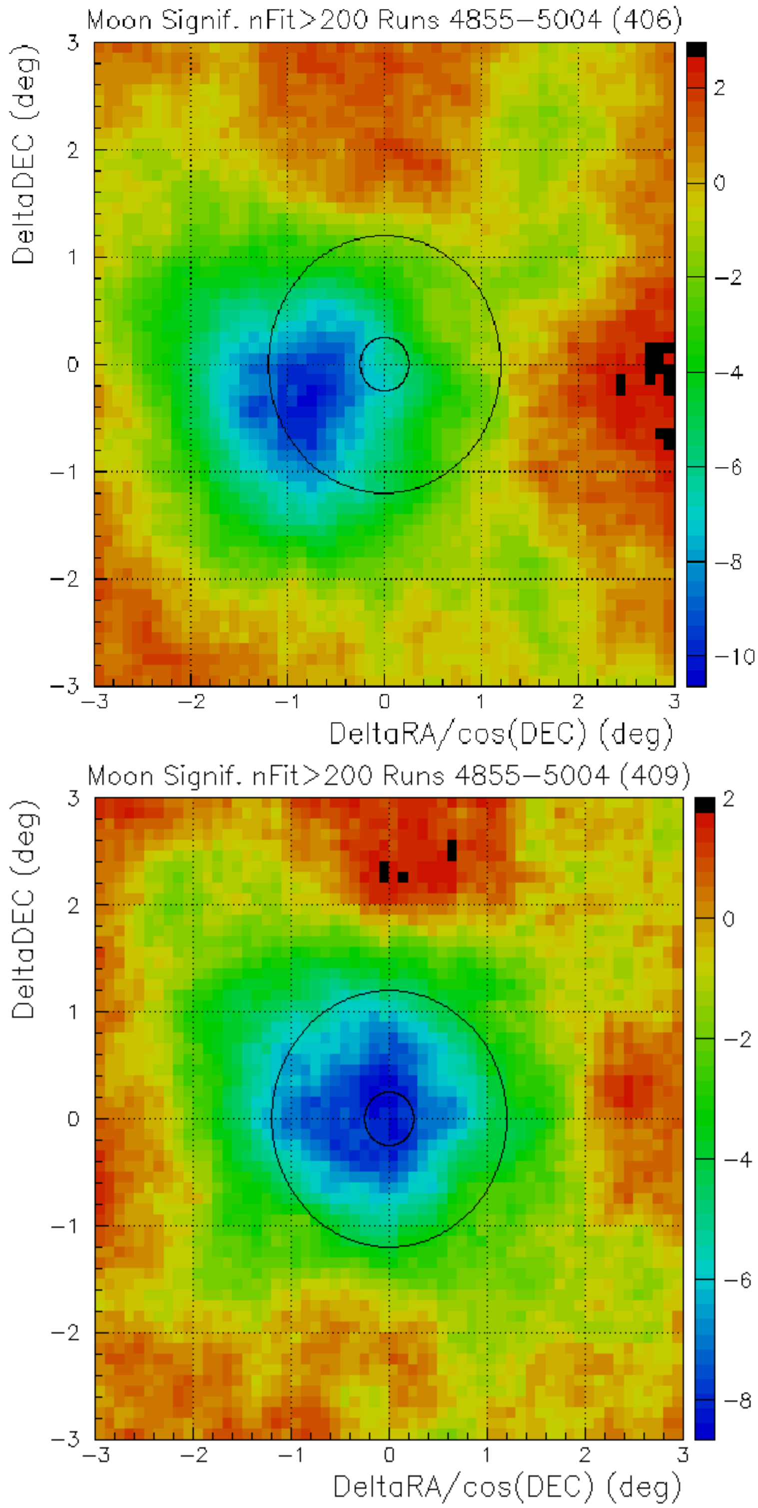

Figure 4: Moon Shadows for versions 406 (top) and 409 (bottom) with nFig > 200.

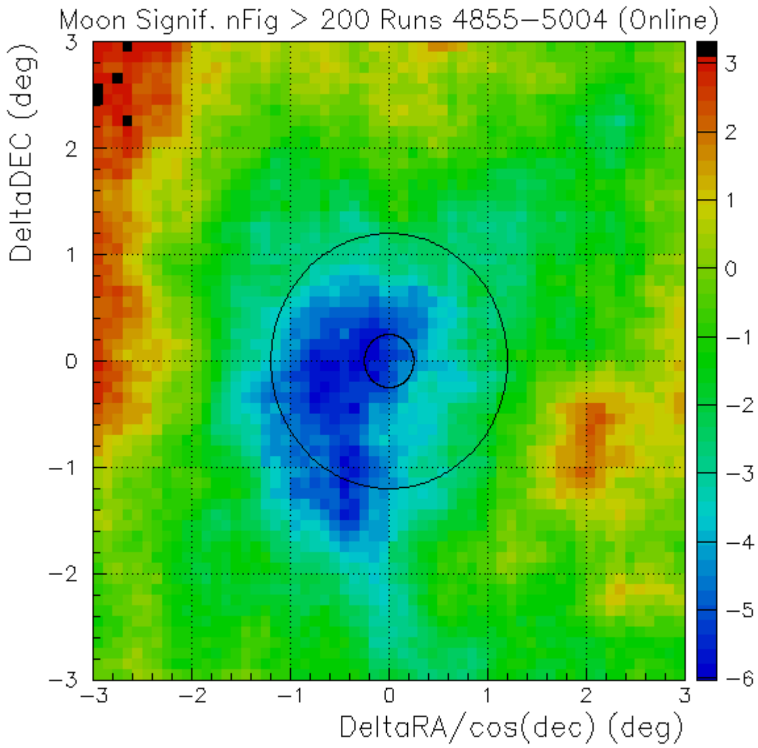

Figure 5: Moon Shadow from online rec files with nFit>200.