Moon Shadow

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Topics

1. **Effect of Zenith Alignment on Moon Shadow**
   The shift is in the right direction.
2. **MC Proton Energy and Zenith Angle Distributions**
   Many very-low-energy protons trigger. Distribution is log-normal at high Nfits.
3. **Simulation of Magnetic Deflections**
   Using proton MC energy spectra, the deficit is spread out over 5-10 degree radius.

1. Zenith Alignment.
   The effect of Andy's 'Zenith Alignment' on the moon shadow was studied with two years of moon shadow data (Sept 00 - Sept 02). The deficit is fit with Paw to a 2-D Gaussian deficit, with position X, Y, standard deviation σ and fractional deficit. The background distribution was a fit to a linear + polynomial function, excluding the shadow (cut of 2.5 degrees.)

   The shadow is not truly Gaussian, but for studying shifts of the shadow center, this is a reasonable approximation.

   With no "Zenith Alignment" (nods) the results for $N_{fit} > 25$ and $N_{fit} > 100$ are shown in Figures 1 and 2.

   On the maps the X axis is $\alpha - \alpha_{moon}$. Defining the **co-latitude** θ by $\theta = 90° - \delta$, the Y axis is $\theta - \theta_{moon}$.

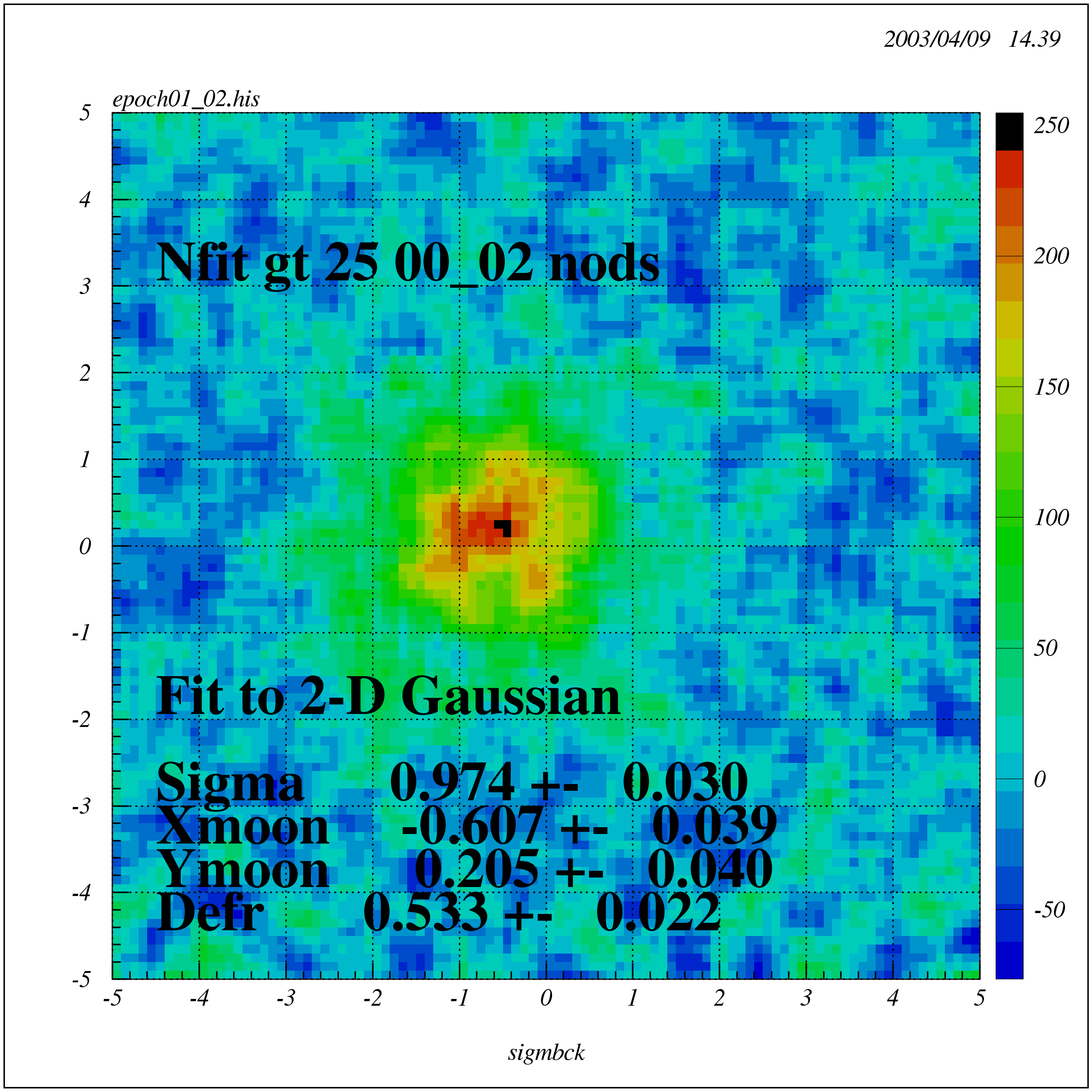

Figure 1: Map for $N_{fit} > 25$. $X\ axis\ is\ (\alpha - \alpha_{moon})$, $Y\ axis\ is\ \theta - \theta_{moon}$

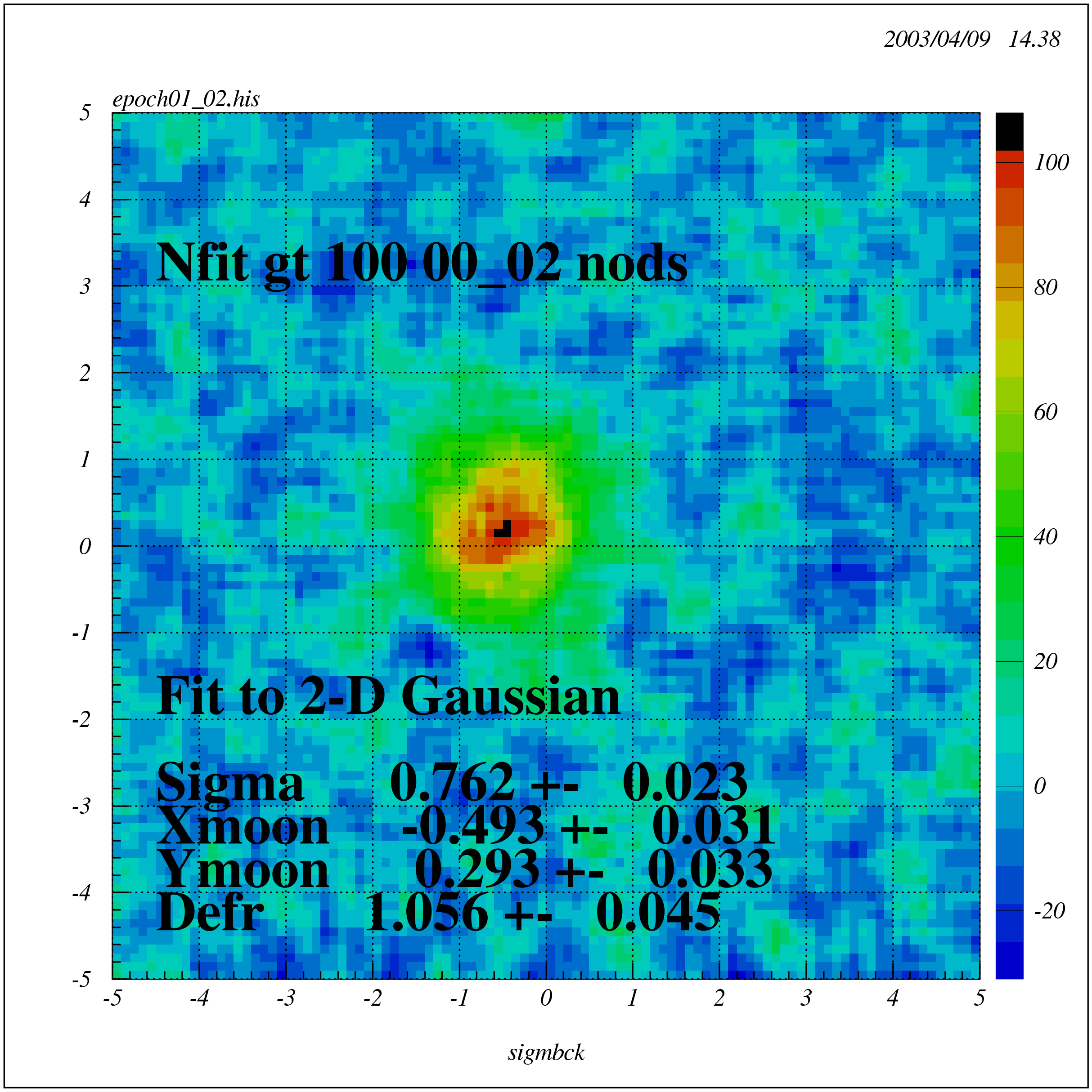

Figure 2: Map for $N_{fit} > 100$. $X\ axis\ is\ (\alpha - \alpha_{moon})$, $Y\ axis\ is\ \theta - \theta_{moon}$

With "Zenith Alignment" (wds) the results are

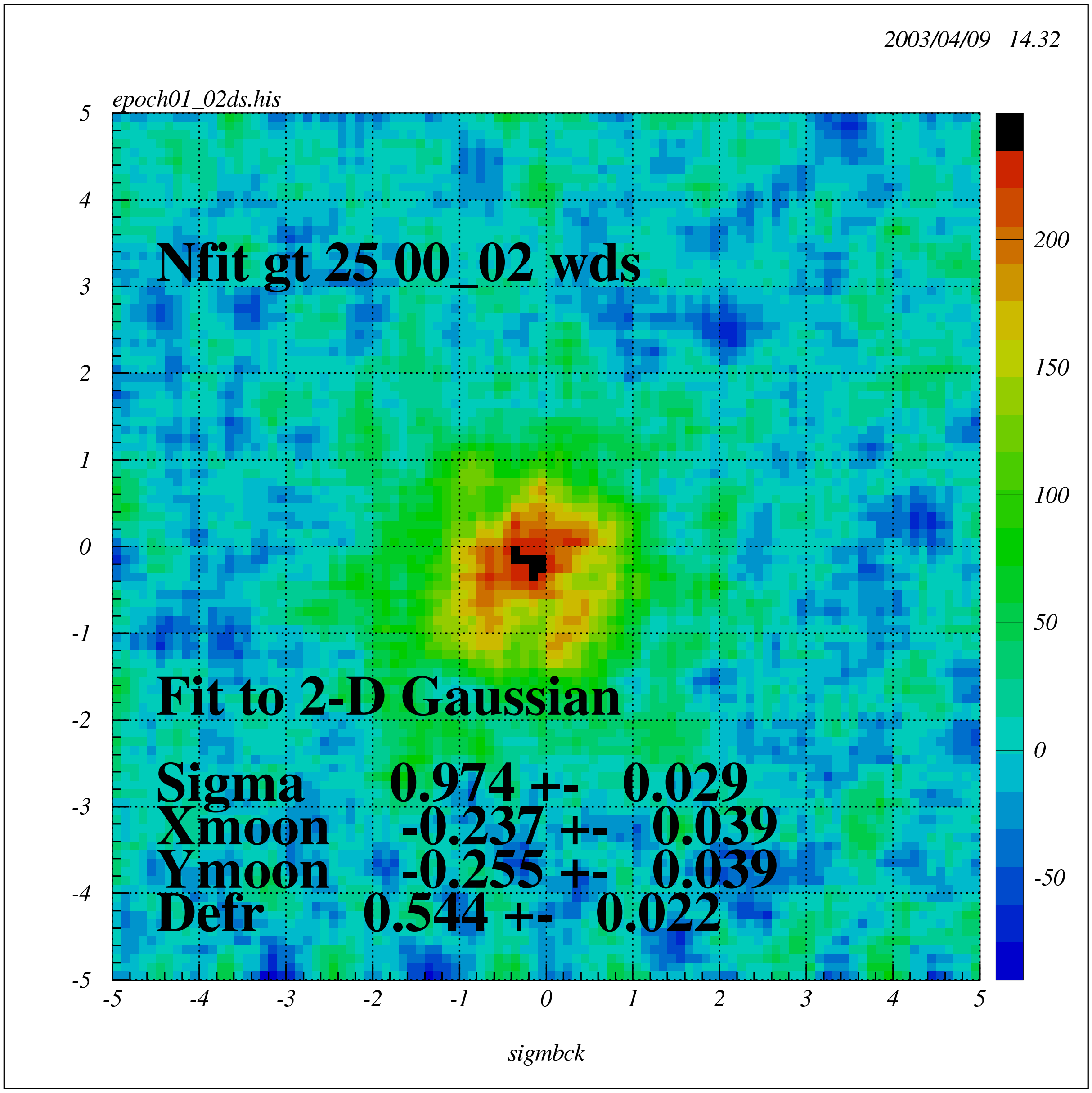

Figure 3: Map for $N_{fit} > 25$. $X\ axis\ is\ (\alpha - \alpha_{moon})$, $Y\ axis\ is\ \theta - \theta_{moon}$

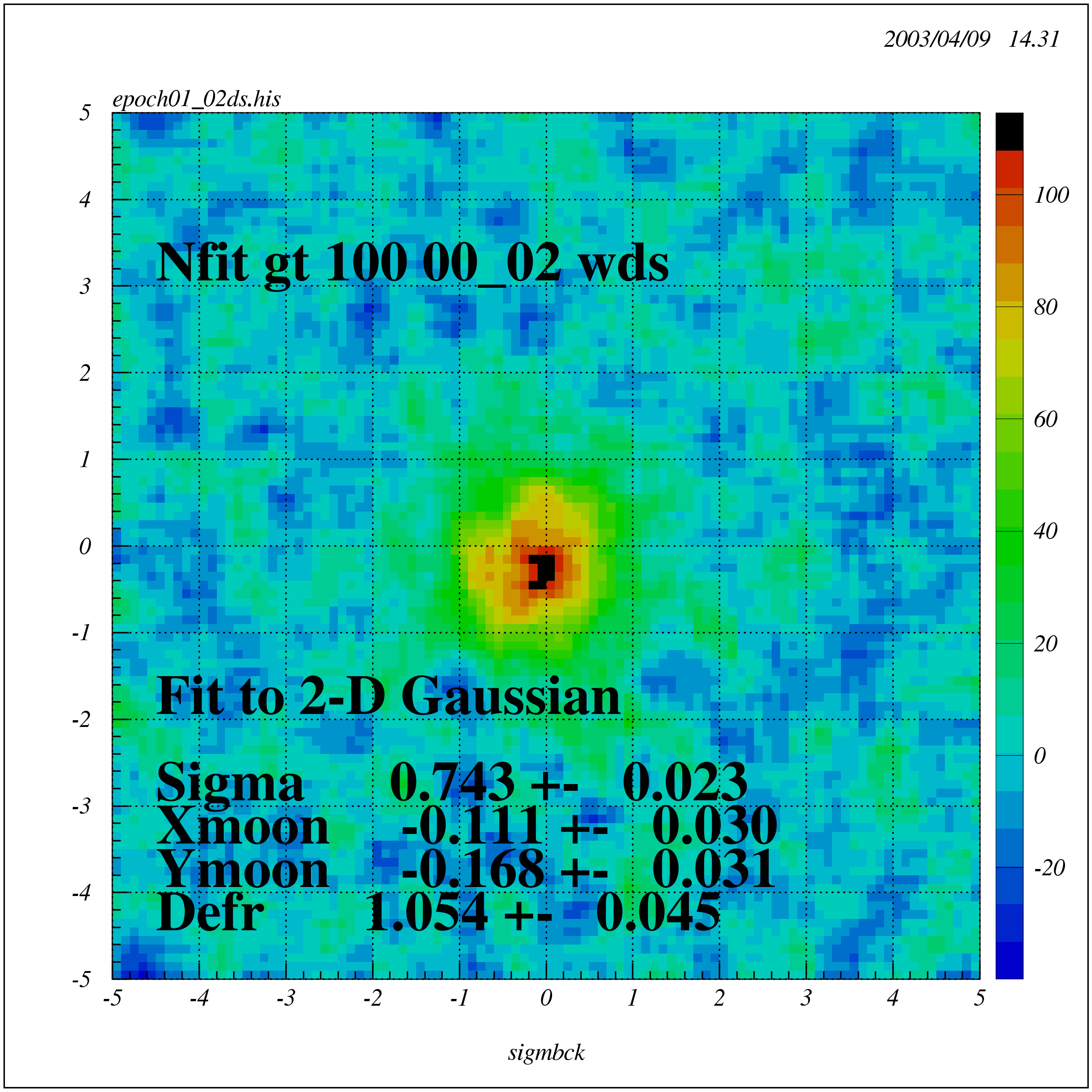

Figure 4: Map for $N_{fit} > 100$. $X\ axis\ is\ (\alpha - \alpha_{moon})$, $Y\ axis\ is\ \theta - \theta_{moon}$

The zenith alignment has shifted the shadow center. As we will argue below, the new position in $-\delta$ closer to that predicted by the sign of the magnetic deflection.

Why is this? The deflection in the direction of co-latitude, $\theta = 90 - \delta$ is shown in the following figure for the (non-physical) case in which the magnetic pole and the geographic pole coincide. In this case, it is evident that when the particle comes in along the meridian, its θ-deflection will be zero. So the deflection distribution should be symmetric about zero, and should have zero average.

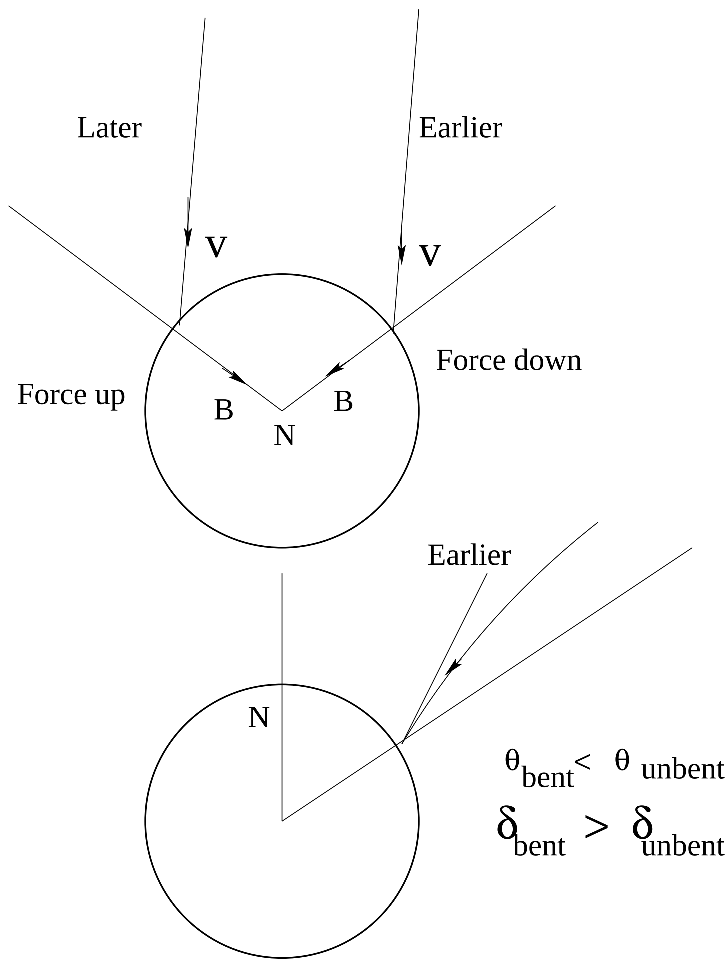

Figure 5: The θ-component of the magnetic deflection. Magnetic and geographic poles are the same.

The actual case is shown in Figure 6.

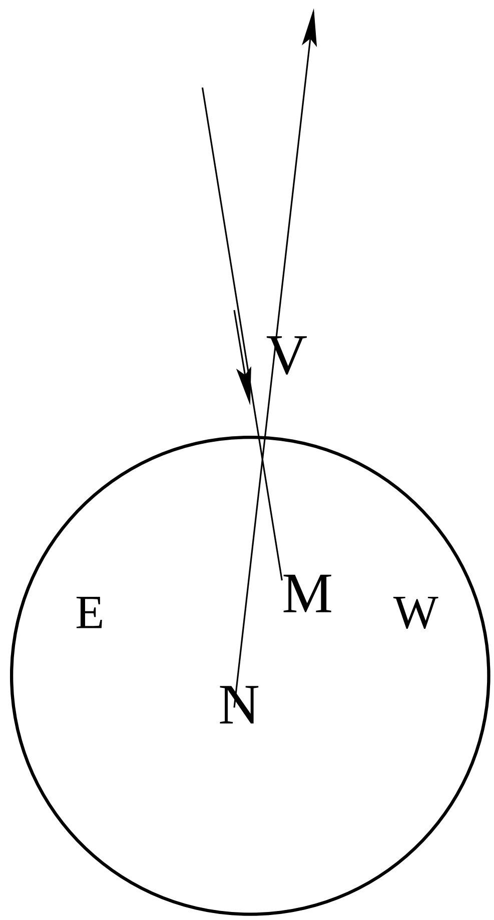

Figure 6: The θ-component of the magnetic deflection. Magnetic and geographic poles are the different.

When the difference between geographic and magnetic poles is considered, it becomes evident that the time of zero θ-deflection is **later** for the actual magnetic pole position. This is illustrated by a calculation of the magnetic deflection vs. time for a particular day, shown in Figure 7.

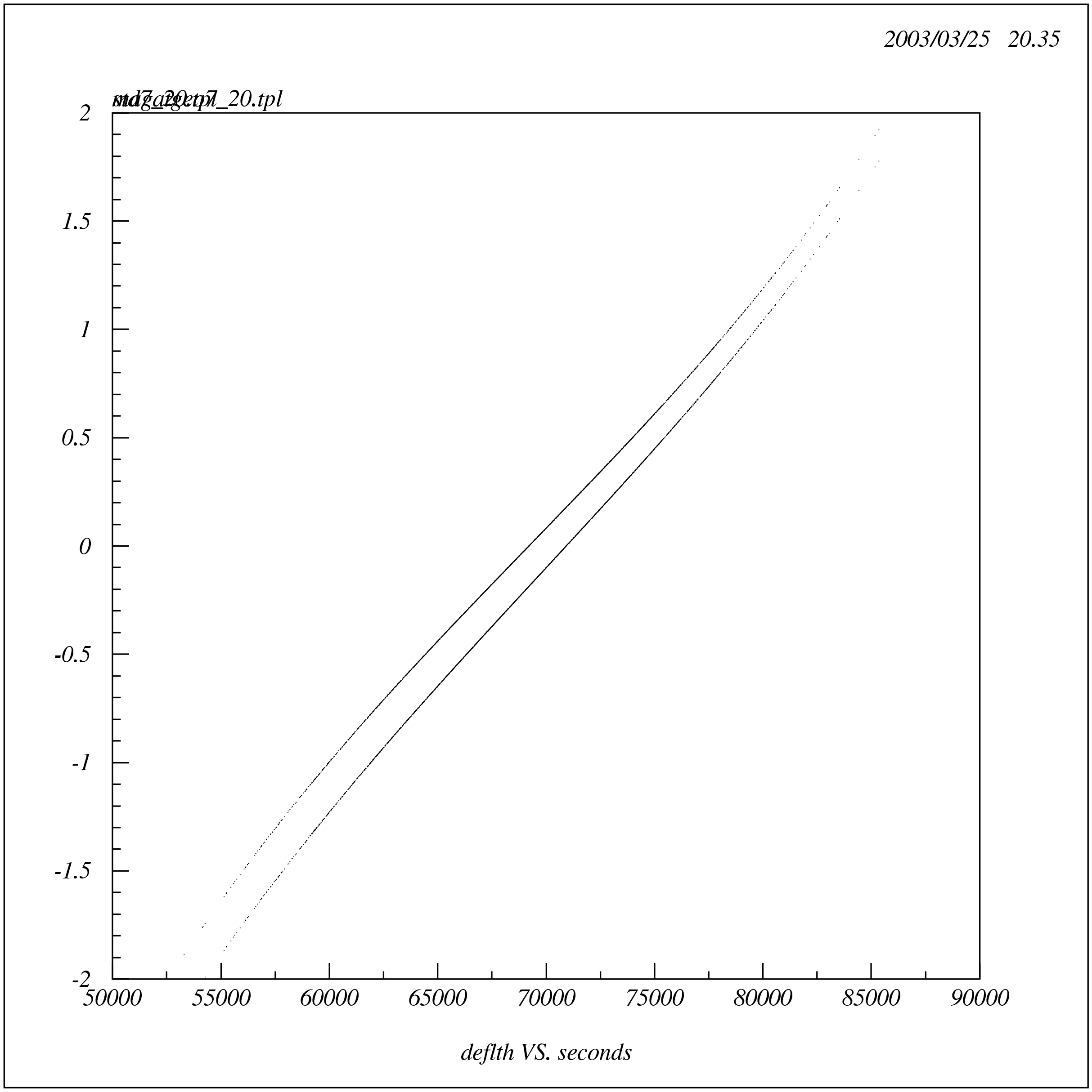

Figure 7: The θ-component of the magnetic deflection vs. time on a particular day. The left-shifted curve is for the case in which the magnetic and geographic poles are the same. The right-shifted curve is for the actual situation.

Taking deflections over a period of a month, as is shown in Figure 8, we see that the mean θ-deflection is slightly negative ($-.19^\circ$) for the actual case. **So the downward shift produced by zenith alignment puts the moon center where it should be.**

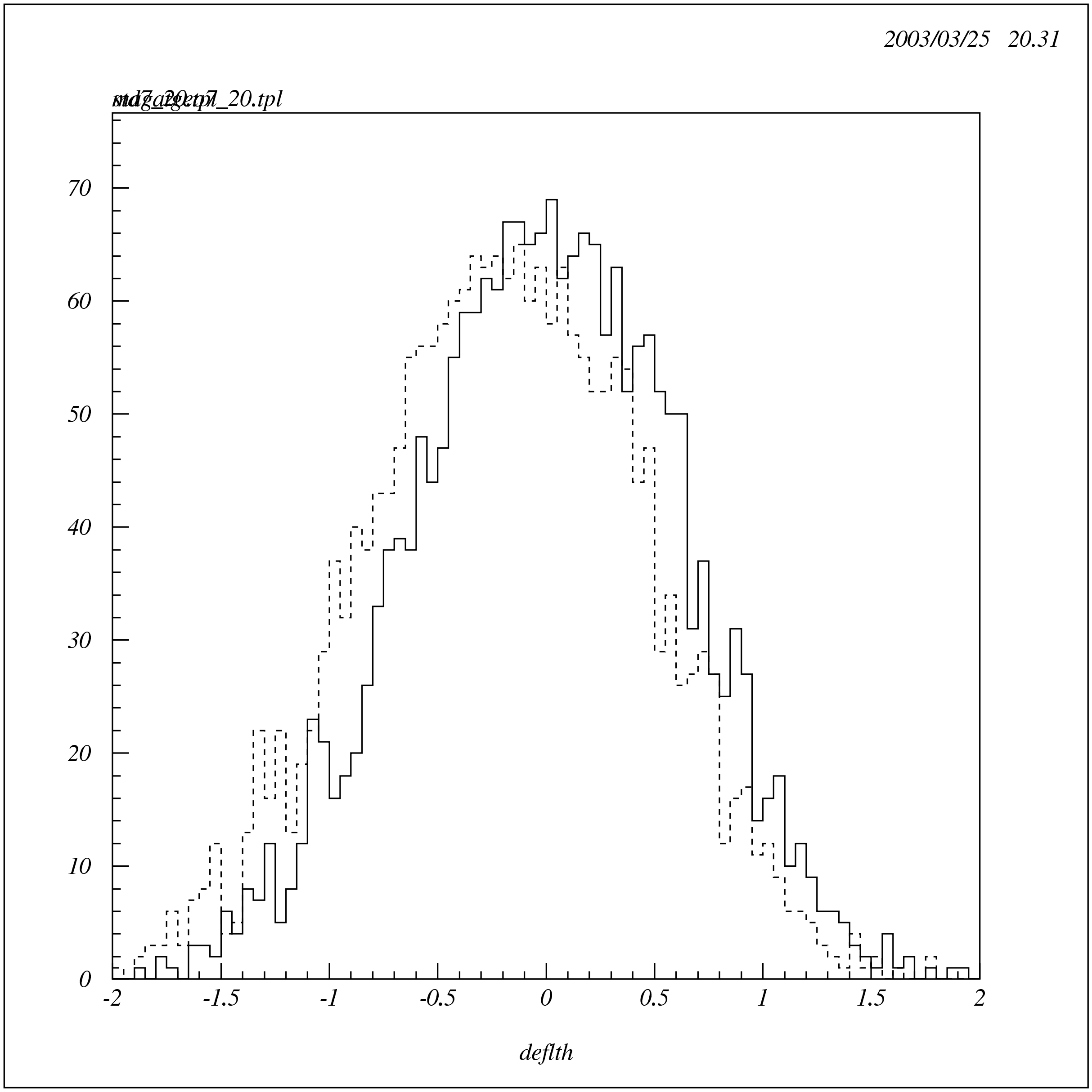

Figure 8: The distribution of the θ-component of the magnetic deflection over a month.

2. Proton Monte Carlo.
   The threshold for Julie and Stephan's proton Monte Carlo has been lowered to 30 GeV. Here are some figures which show the triggered energy distribution on a log(E) scale. It is evident that the distribution looks log-normal, but at an Nfit minimum of 100.

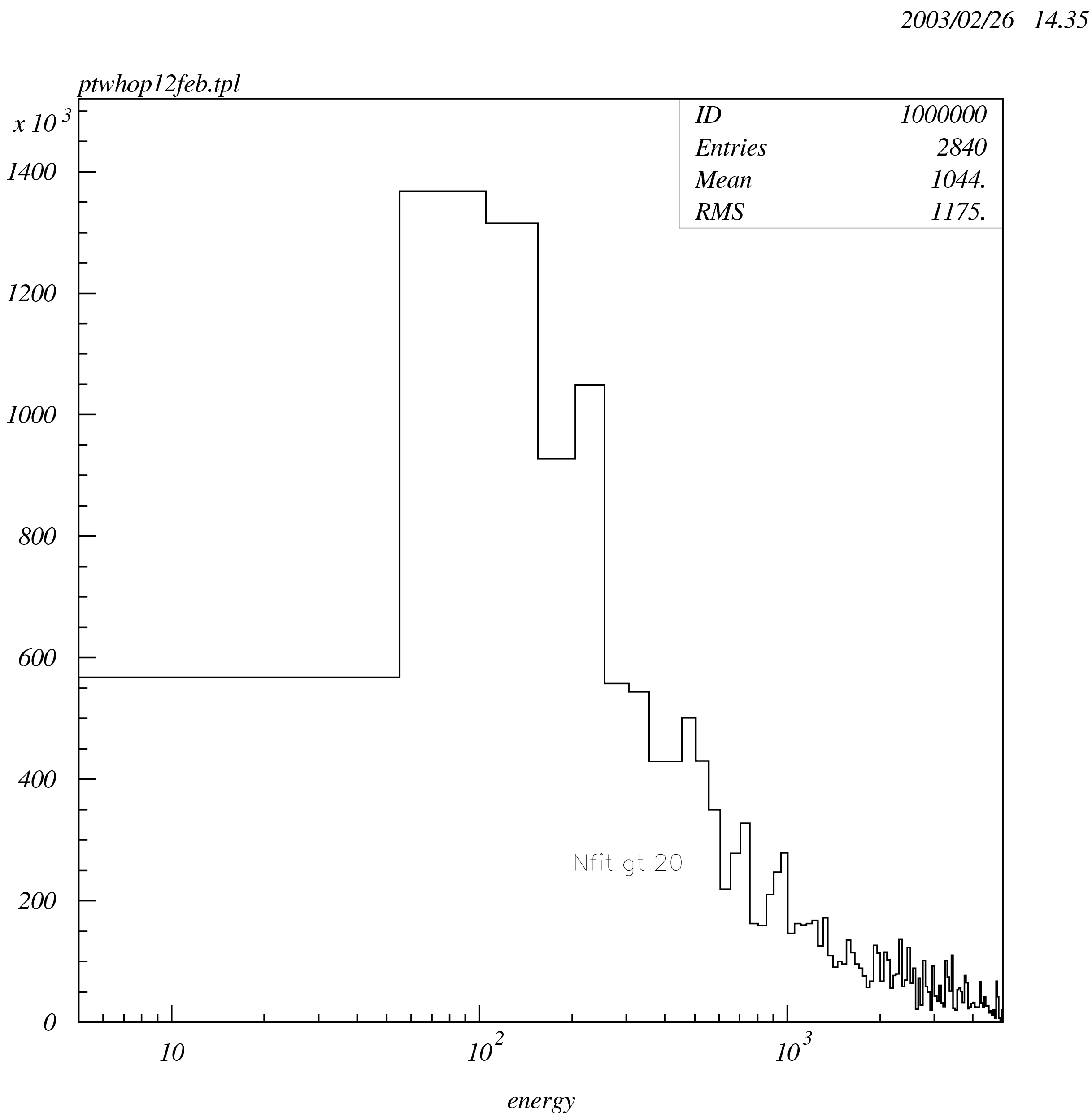

Figure 9: The distribution of triggered energy with $N_{fit} > 20$

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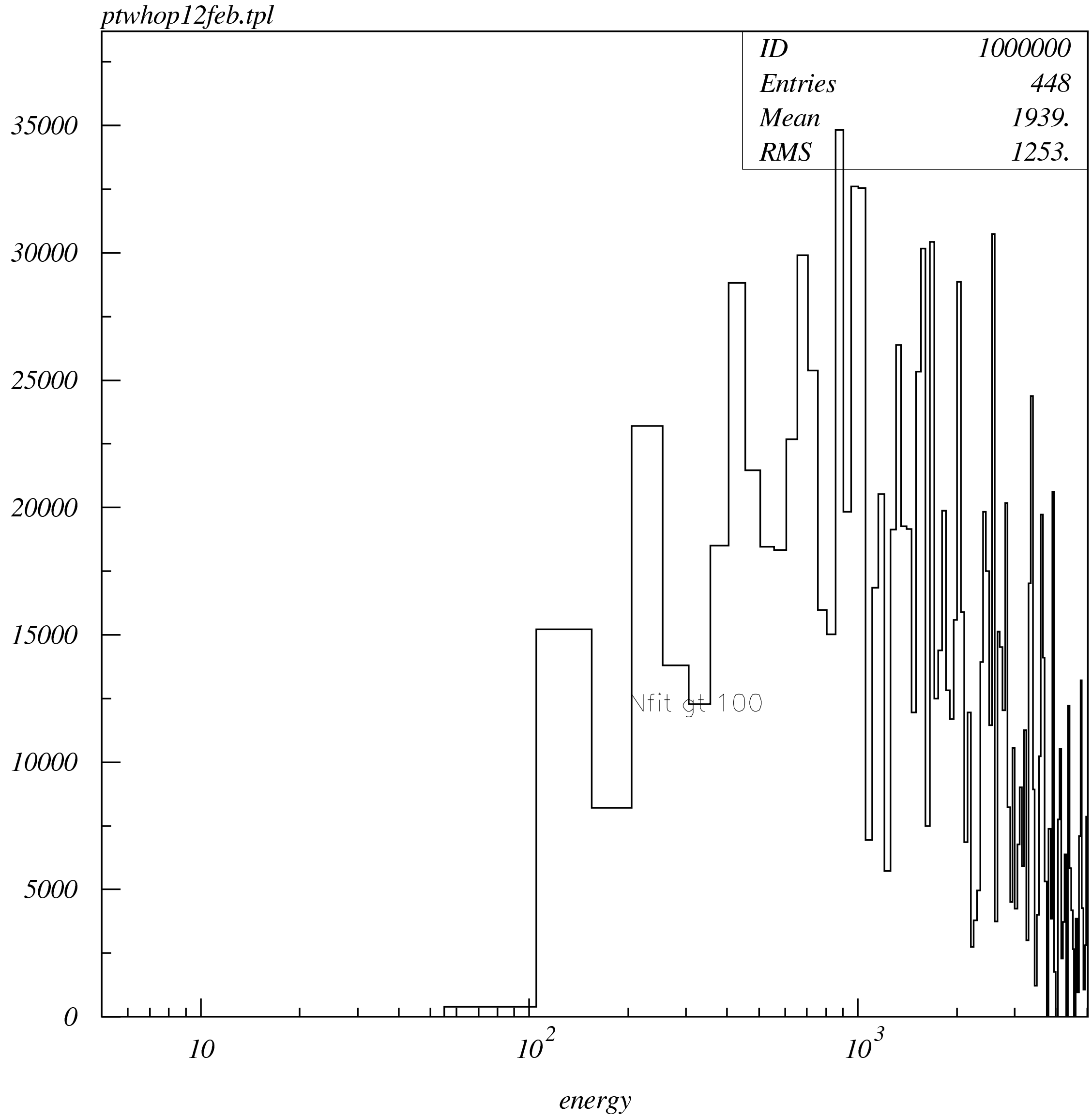

Figure 10: The distribution of triggered energy with $N_{fit} > 100$

3. Simulation of Magnetic Deflections.

(a) No angular resolution.
(b) Throw undeflected events on $\pm 20 \times \pm$ degree square. Moon shadow at center.
(c) Already generated: 30 days of magnetic deflections of a $1 - TeV$ proton, with zenith angle biasing. Choose one of these deflections.
(d) Already obtained: a histogram of 1/E from triggered Monte Carlo protons (Emin $>$ 50 GeV,Nhit$>$ 55) with specified Nfit.
(e) Multiply chosen deflection by chosen 1/E.

The resulting deflections in the θ and α directions are shown in the next two figures for $N_{fit} > 25$. Notice how **large** are the deflections.

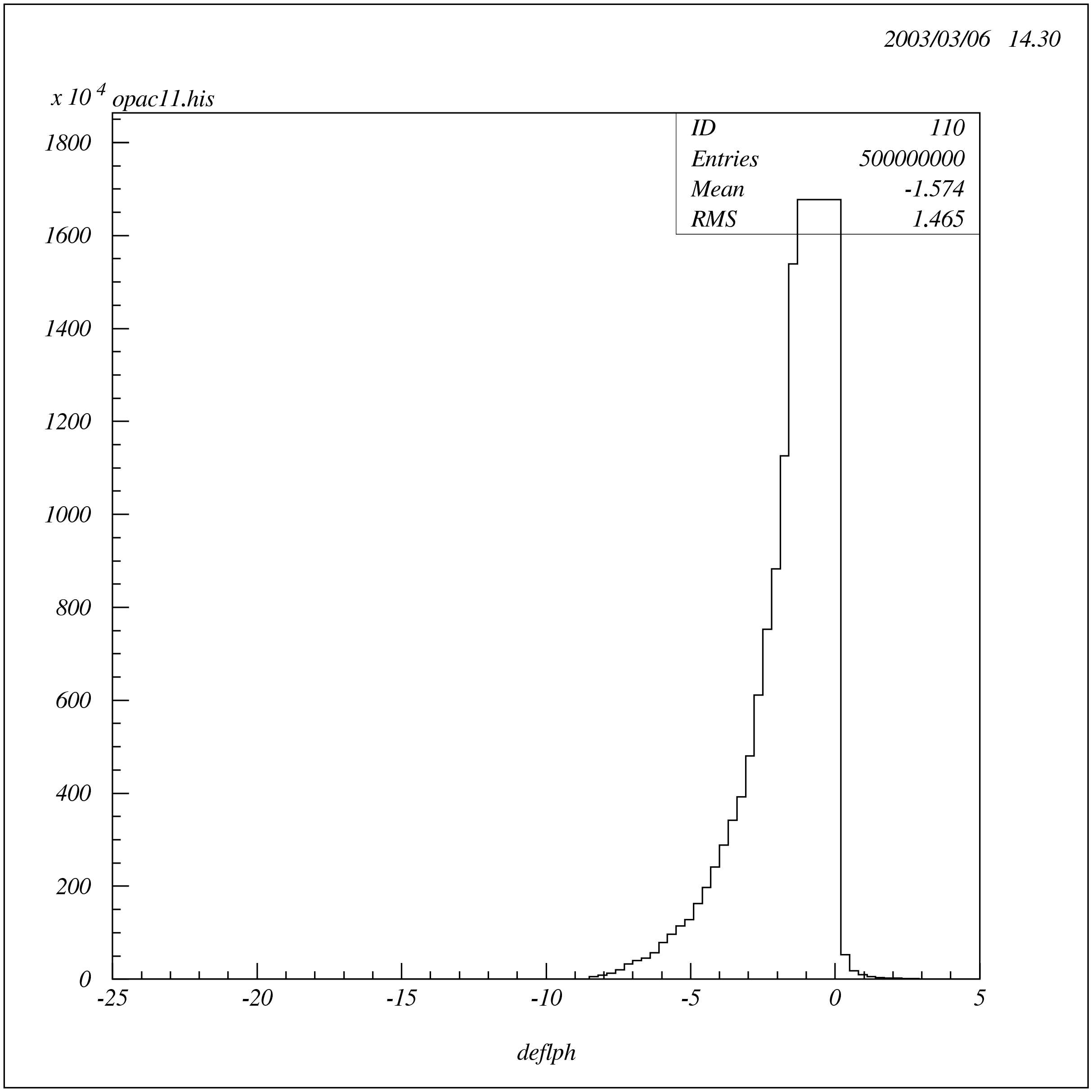

Figure 11: The distribution of the magnetic deflection in the α -direction, for $N_{fit} > 25$.

A map of the deflections, again for perfect angular resolution, is in Figure 13. The deficit is estimated by fitting to the background for $r > 2.5°$, and subtracting it from the map. Even with this large r_{max} a noticable amount of the deficit is at larger radii, giving about 88% of the true deficit.

(The next step is to include the angular resolution as a function of N_{fit}.)

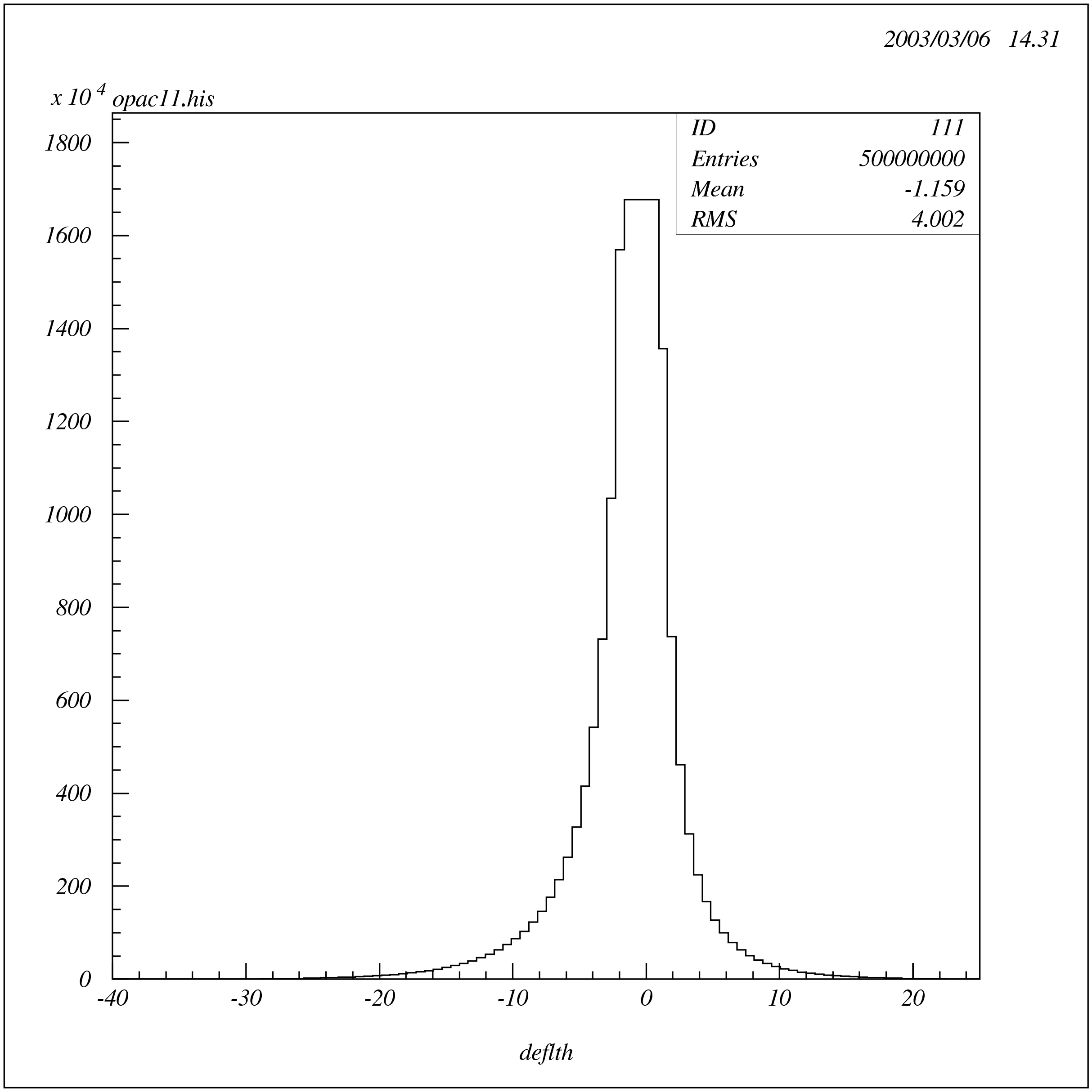

Figure 12: The distribution of the magnetic deflection in the θ -direction, for $N_{fit} > 25$.

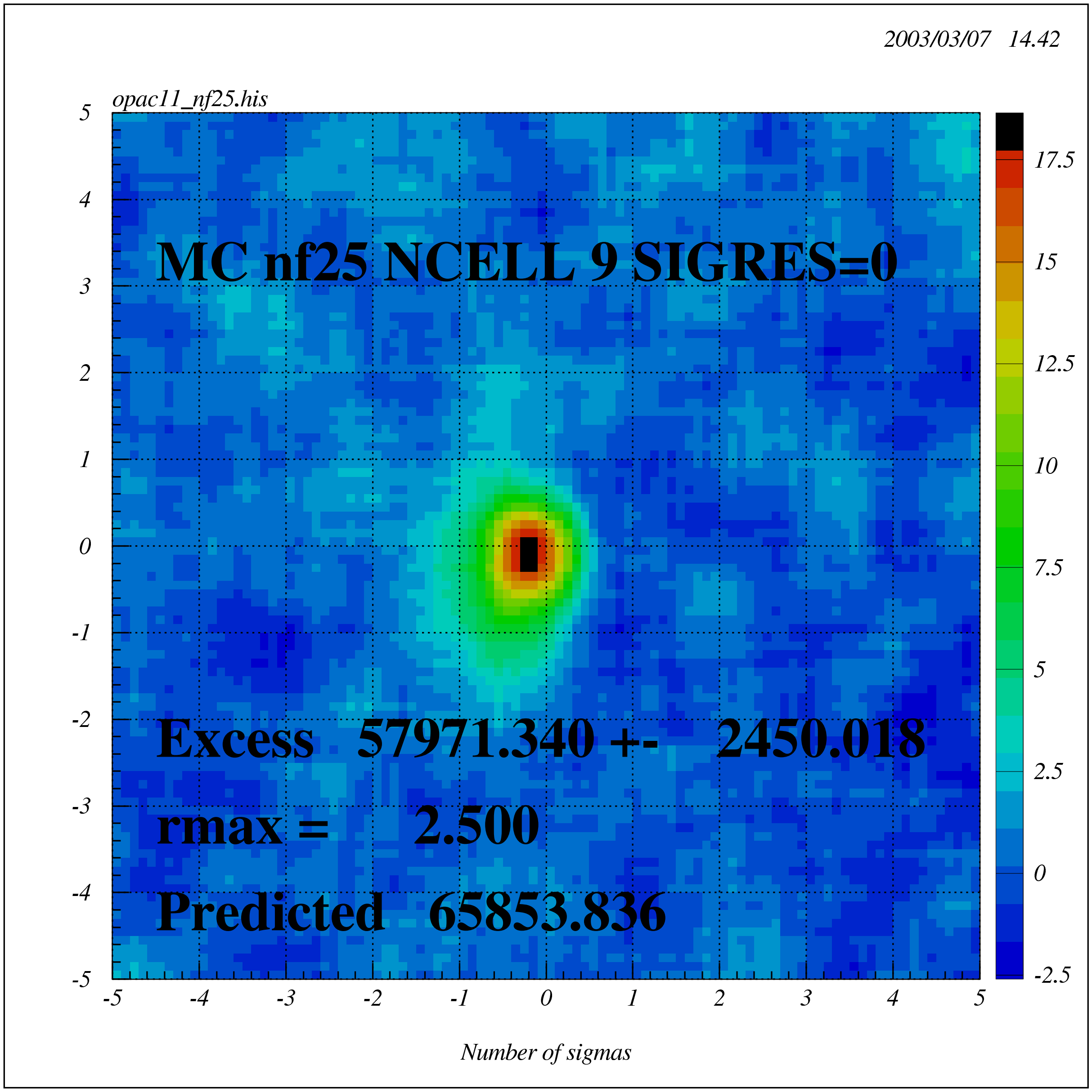

Figure 13: Moon shadow map for magnetic deflections only, for $N_{fit} > 25$.