<u>Pointing offsets – v 0.1 –</u>

B. Giebels, Stanford Linear Accelerator Center, 10 April 2001

A method to estimate correction factors for observed source rates is discussed and the associated error due to pointing errors that one should associate to those estimated rates are given for every *epoch*[1] where stable source raster scans were available.

With the "good unroll model" (GUM) pointing solution recently incorporated in dat2fits we have an estimate of how far off-axis the source is. Since the collimator response is angle-dependent, a source seen at an angle $\theta \neq 0$ will be attenuated by a factor $f(\theta)$ [2]. We have ground measurements that provides us $f(\theta)$ and an associated function exists. We assume here a polar dependency only of the angular collimator response.

Anytime a lightcurve is made, the measured rate in cts/s has to be corrected by a factor of $1/f(\theta)$. I will not discuss here the Yoke obscuration correction, but the effect exists and has been quantified in a function in *USALIB*.

Now the question is: what is the error that we have to associate to the reconstructed rate due to pointing fluctuations within an epoch? The idea is to look at raster scans of stable sources and use the spread of the angular-dependent counting rate when one accumulates multiple raster scans. The comparison of this spread with the statistical Poisson fluctuations yields an estimation of the error we make in assigning the $1/f(\theta)$ correction. The shape of this distribution should reflect the angular collimator response and this is fitted. The obtained fit value is then used to set the mean value of the counting rate at a given angle θ. The square root of that value is then computed for every bin to obtain the Poisson noise. This noise, plus the spread of the background, are then subtracted from the distribution spread. The remaining spread is then normalized to the max counting rate derived from the fit, so that it gives an error that will be a fraction (expressed in %) of the reconstructed counting rate *for any source* of that epoch.

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[1] as defined in http://xweb.nrl.navy.mil/usa/calibration/PointingEpochs.html

[2] Note that also $f(\theta = 0)$ is not actually equal to 1.

1.1 Used data

The Yaw rasters (YR) and Drift rasters (DR) for the Crab and Cas A were scanned in the database. Observations with Yaw angles less than 30° were not used in order to avoid an additional attenuation effect due to the collimator that start at angles less than -32°. The FITS files were generated using dat2fits with background cuts (low electron and particle veto rates) using picktelemII. The data are then extracted in a C program that uses the cfitsiopp class, and analyzed using ROOT v2.25.

It turns out that Crab data for epochs 6, 7 and 8 are available with these constraints, and a few Cas A data for epochs 3 and 4. I am willing to analyze data for other epochs if a stable enough source exists in the database. These 5 epochs together represent 321 days of observation or about 60% of the available data.

1.2 Fitting method

The best method would be to fit a 2-dimensional collimator model on the data but multiple epochs are scarce of raster scans. I used a 1-dimensional method that uses the measured *housekeeping* counting rate R as a function of the estimated offset angle to the source θ. I then use the collimator model $f(\theta)$ (included in *USALIB*) that gives the attenuation as a function of the offset to the source.

The first degree of freedom p_1 is a scaling factor to that model, since the collimator response is approximately 1 at θ = 0 in the model, and R in our case. It can be seen as a vertical scaling factor.

The second degree p_2 is a constant background term that should be equal to the rate R at angles $\theta > 1.6$ deg. The final model thus looks like

$$p_1 f(\theta) + p_2$$

and the chisquare is minimized with the raster data.

1.3 Pointing error and absolute rate error

The idea is to use an estimator of the spread of the rate = f (angle) distribution when one cumulates several observations in one curve. We have to deconvolve for the background fluctuations and the statistical photon rate fluctuations before we can assign the spread to be due to fluctuations in the pointing.

Since we are going to use the offset θ to build corrected lightcurves (dividing the measured rate by $f(\theta)$), we want to know the error we will have to associate to that correction. Several raster observations are combined together and the obtained curve of counting rate versus estimated angle to the source is then used with the fit described earlier.

Once the fitting is done, the background fluctuations ΔB for the ensemble of observations within an epoch is estimated. The fit of the collimator model gives the best estimation of the rate of the source as a function of the angle, and I use that rate to estimate the statistical fluctuation term σ_R on the dispersion of the curve. The scatter of the curve subtracted for background fluctuations and statistical fluctuations then gives us the size of the error we are making.

Fig 1.1 shows the accumulation for epoch 8 Crab rasters. Every dot is the house-keeping layer 1 counting rate for a second of observations. The characteristic triangular shape of the collimator is visible. Fig 1.2 is the binned data (crosses) that is used for the collimator fit (line), for both a Crab raster epoch and a Cas A raster epoch.

In Fig 1.3 is shown the vertical spread of every bin of 0.04° as a function of the angle. The background spread ΔB is visible at angles larger than 1.6°, and the signal spread at angles less than 1.2°. The histogram of ΔB is in Fig 1.4, and its mean value is subtracted linearly from the σS part of the signal. The statistical fluctuation is taken as being $\sqrt{p_1 f(\theta)}$ and is also subtracted linearly from σS.

Then the σS are normalized dividing by p_1, and the histogram of the new σS gives thus an indication of the fraction of the observed rate that sould be taken as error (Fig 1.5). In this particular case the mean value is 0.16, **meaning that for epoch 8 the error on the flux is 16% (full width) of the reconstructed rate.**

1.4 Results for the epochs

The next table summarizes the analysis done for epochs 3,4 and 6,7,8, the only ones so far where useful raster scans have been found with Cas A and the Crab. Note the few files used for Cas A where the counting rate is so low that the background stability requirement was a tough selection criterion.

epoch	σS (%)	Source	# of obs
1			
2			
3	6	Cas A	2
4	11	Cas A	2
5			
6	21	Crab	14
7	10	Crab	6
8	16	Crab	11
9			
10			
11			
12			

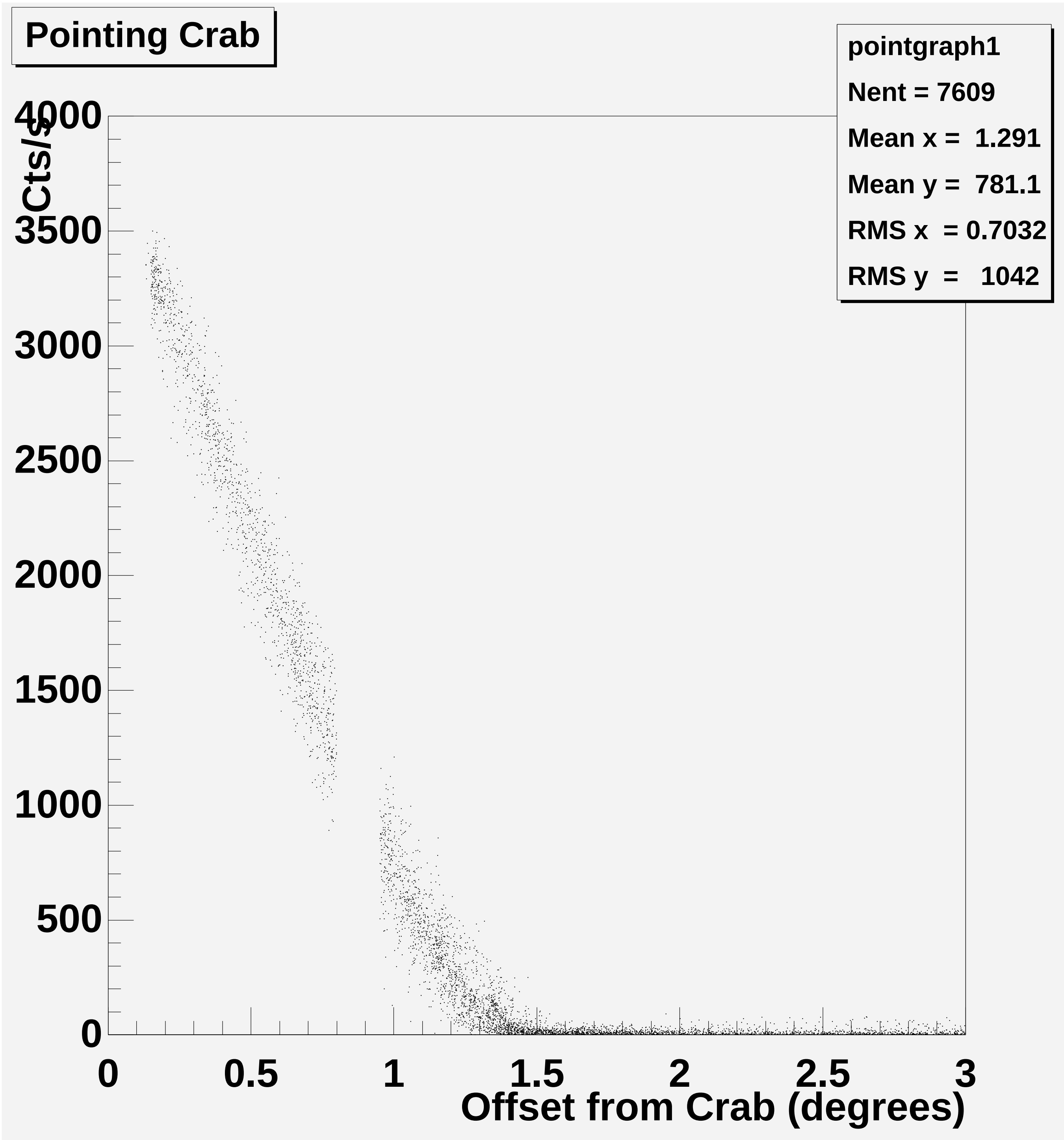

Figure 1.1: Counting rate as a function of the offset to the Crab for 11 raster scans in the Crab. The gap in the distribution close to $\theta = 1$ deg is due to a cut in the data.

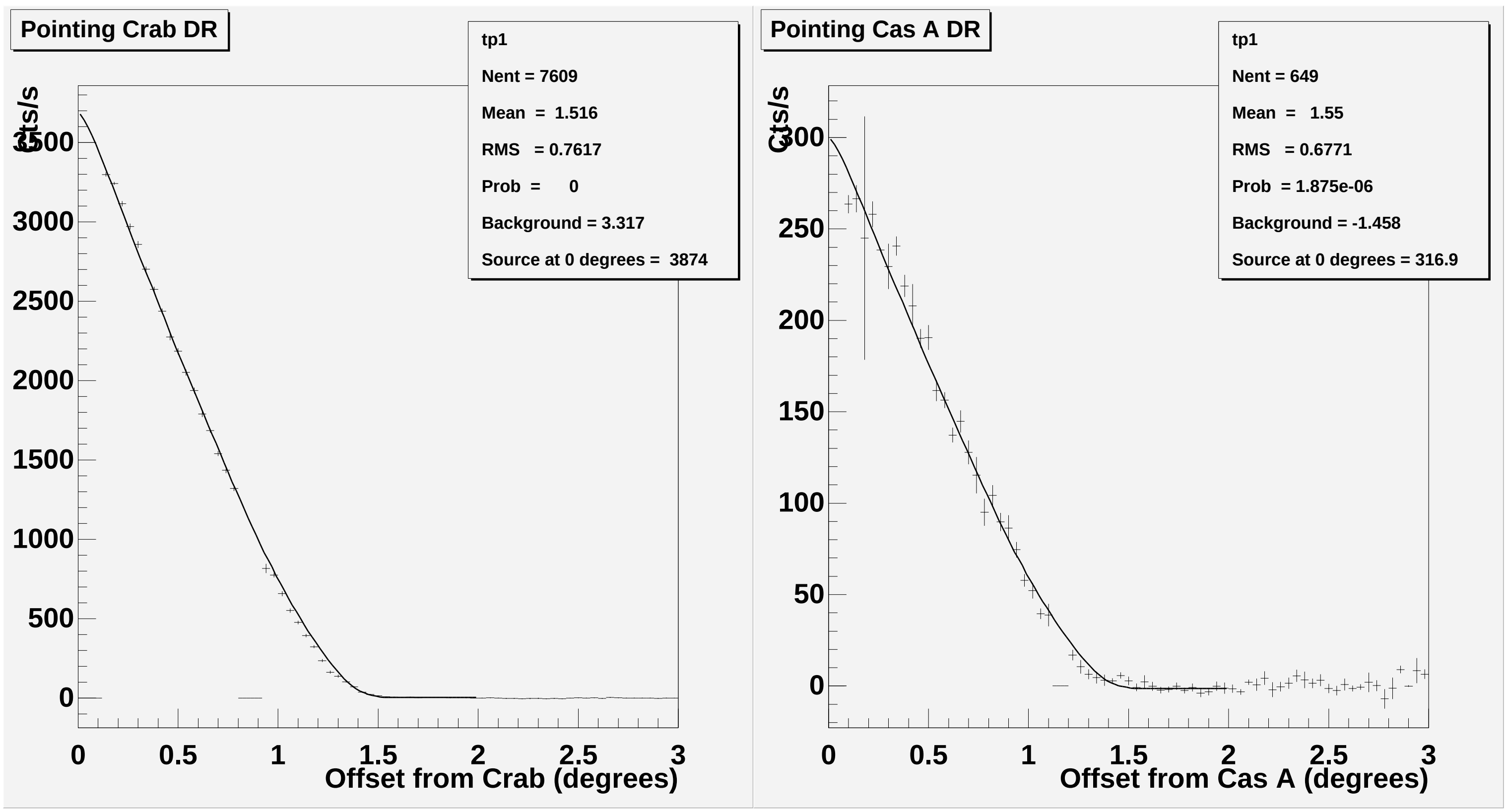

Figure 1.2: Left panel: binned data from the upper plot, with a line that indicates the result of the fit of the collimator model plus a background. Right panel: same fit for 2 Cas A raster scans from epoch 4.

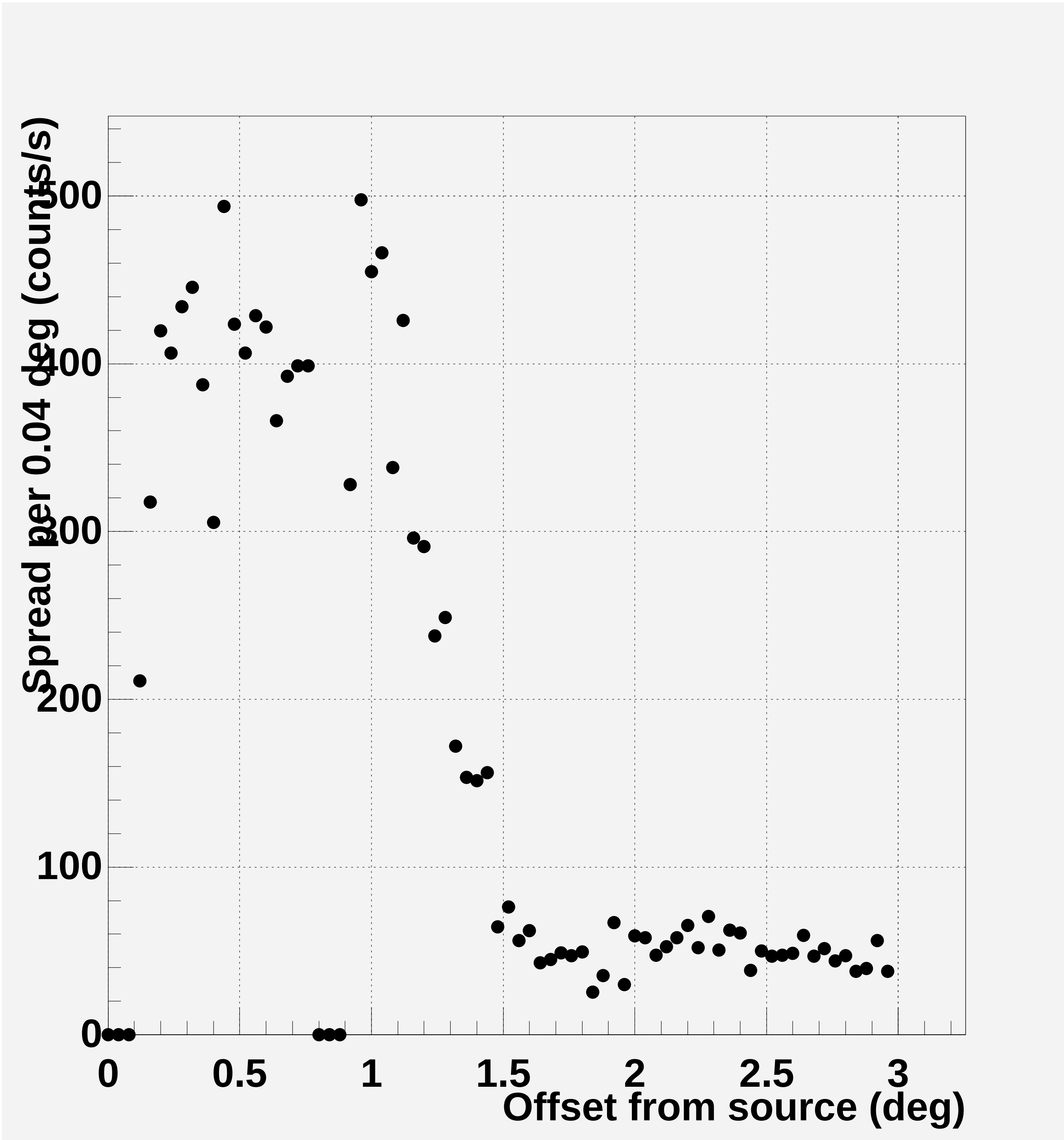

Figure 1.3: Spread of the distribution in Fig 1.1.

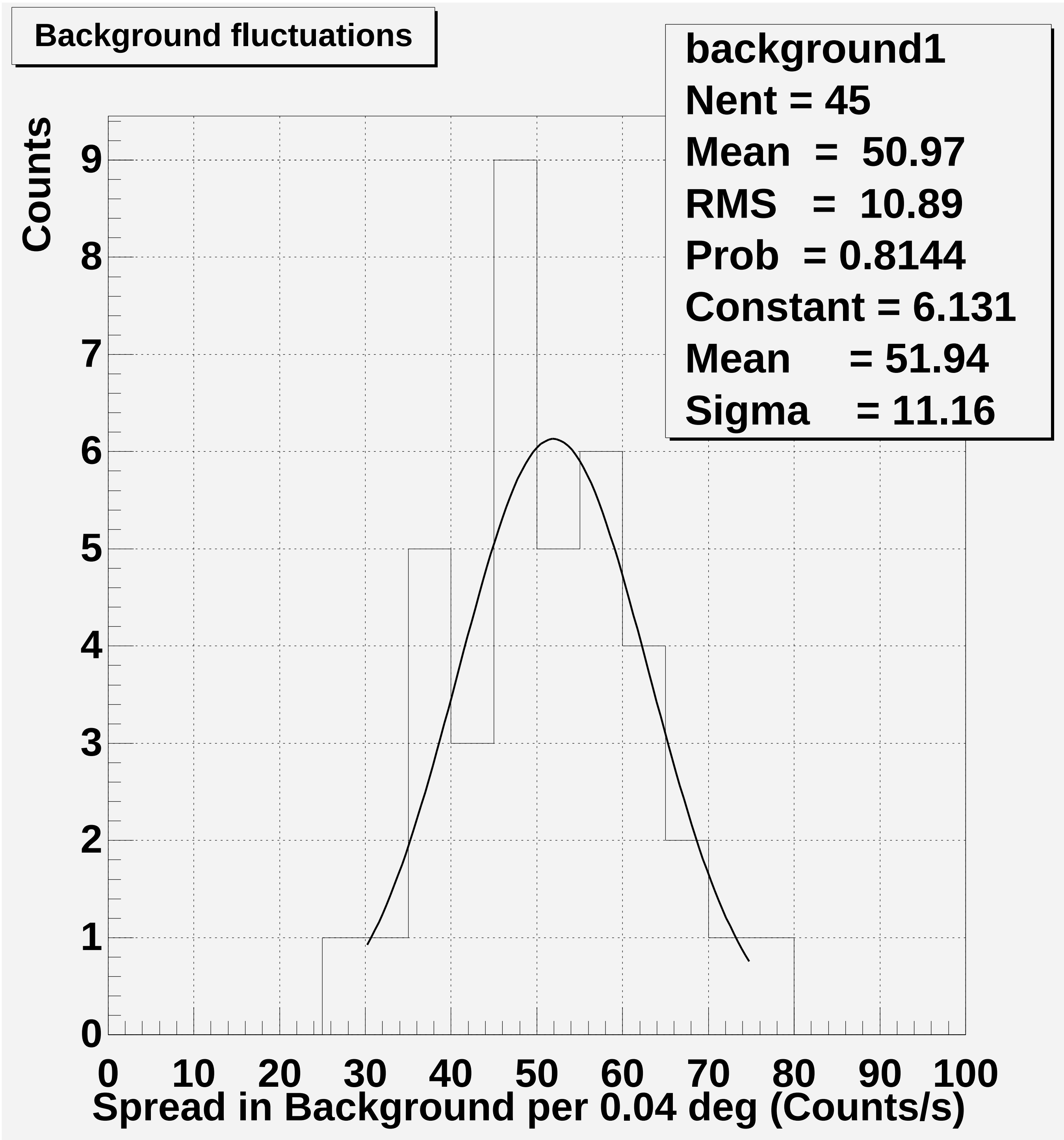

Figure 1.4: Histogram of the background spread.

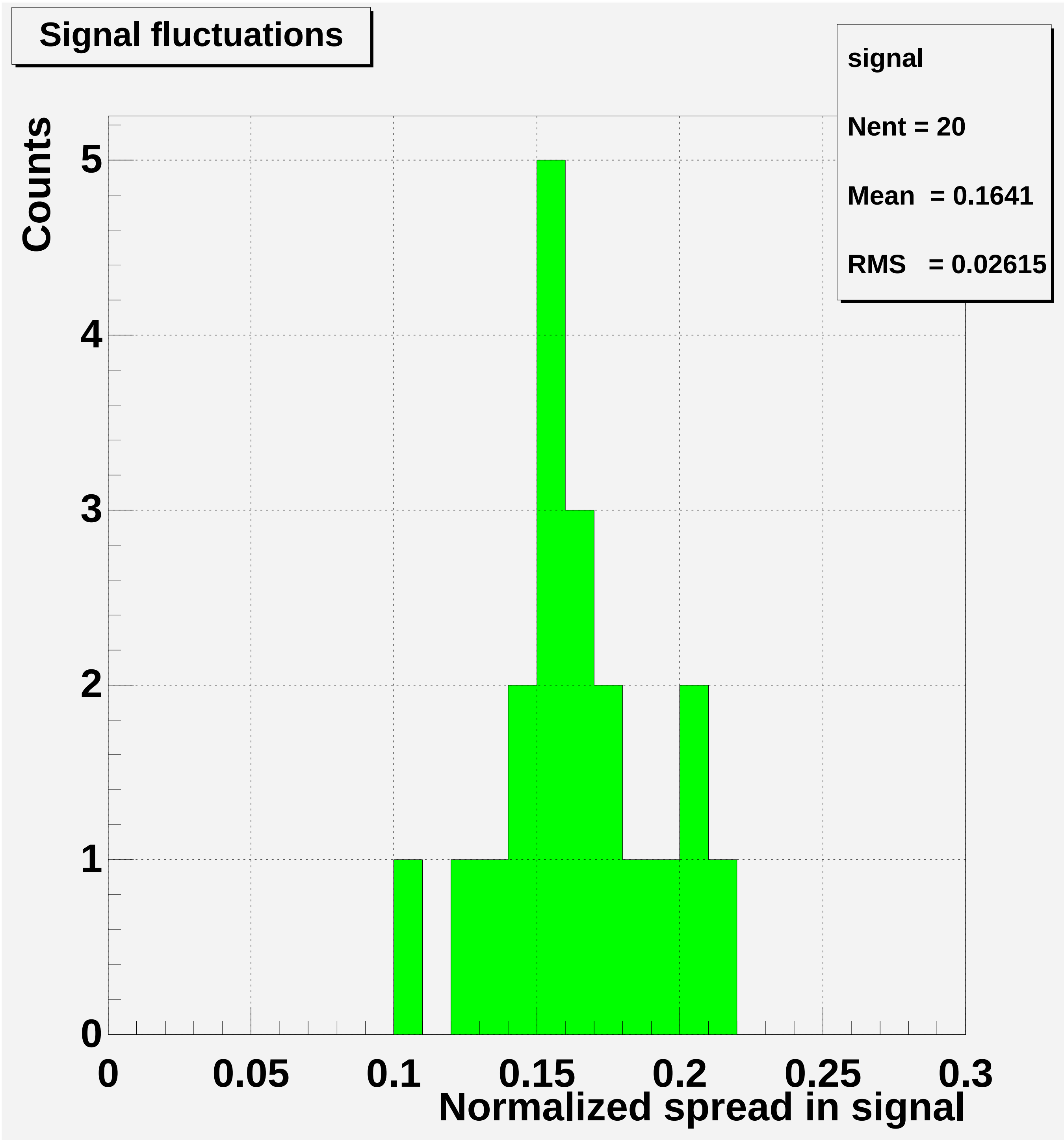

Figure 1.5: Histogram of the signal spread, subtracted for the background and the statistical noise, and normalized to the on-axis estimated rate.