MAGIC-TDAS 08-02
080527 / Vincenzo Vitale

# Data Analysis of H 1722+119 (Cycle III)

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**Abstract**

Data taken on H 1722+119 during MAGIC Cycle III were analyzed. The applied analysis provided a 50 hours sensitivity of 1.5% of Crab above 240GeV and better than 5% between 130 and 240GeV. No $\gamma$ ray signal was found from the source. The event excesses for both bands (between 130 and 240GeV and above 240GeV ) have significance compatible with statistical fluctuations. Upper limits ($2\sigma$) to the $\gamma$ ray flux from H 1722+119 could be set:

- $\Phi_\gamma$(130GeV<E<240GeV)< 3.4% Crab Units;
- $\Phi_\gamma$(E>240GeV)< 1.0% Crab Units.

Also a night-by-night analysis did not provide significant excess. Sub-samples taken when the source had higher optical activity (such as 2007 data) provide slightly larger excess rate than those taken during low optical activity. This suggests that future observations of the source could be carried out when the optical flux of the source is at least larger than the 2007 flux (2.7 mJy).

## 1 Data Description

The observation of H 1722+119 was proposed for the third MAGIC observation cycle (see proposal HBL1722+119, Persic et al.). The required exposure amounted to 35h hours of dark time. A first campaign of observation of 1ES 1722+119 was performed with MAGIC during 2007. The source was observed in March, August and September. The 2007 exposure was 12 hours. A second campaign was done in March-April 2008.

In table 1 and 2 are reported days, exposures, mean Zenith Angle (ZA) and event rate of data, which were used for this study. The observations were carried out in wobble mode: +000 and +180 pointings were performed.

The MAGIC optical psf was not stable during 2007. In table 3 periods and optical psf values, relevant for 1ES 1722+119, are listed.

## 2 Data Quality

Not optimal observational conditions and telescope performances may degrade the quality of the data. The *Data Quality* selection is aimed to reject data affected by major problems.

A first part of Data Quality selection consists of a monitoring of parameters related to the atmospheric conditions and light transmission in the atmosphere. For such a purpose the *Events Rate* (at I files level) was monitored for each run, together with the *Zenith Angle* (in order to correct for the Zenith angle dependance of the Events Rate) . Both the cumulative distribution of Events Rate, and the Events Rate vs. the Time, were obtained. Then an Events Rate threshold of 175 Hz was required and runs with lower values were discarded.

Furthermore the main Image Parameters were also monitored, in order to reject data with anomalous Parameters distributions. The following parameters were studied: mean Size, mean

| Year | Day | Exposure (hours) | Av. Zenith An. (deg) | Ev. Rate (Hz) |
|---|---|---|---|---|
| 2007 | 11/3 | 1.9 | 23 | 80 |
| | 16/3 | 0.30 | 27 | 150 |
| | 10/8 | 0.44 | 27 | 220 |
| | 11/8 | 0.54 | 26 | 210 |
| | 12/8 | 0.61 | 26 | 200 |
| | 13/8 | 0.54 | 27 | 210 |
| | 14/8 | 0.61 | 27 | 200 |
| | 15/8 | 0.37 | 29 | 210 |
| | 16/8 | 0.55 | 26.5 | 180 |
| | 17/8 | 0.93 | 25 | 230 |
| | 19/8 | 0.91 | 25 | 200 |
| | 20/8 | 1.25 | 25 | 175 |
| | 21/8 | 0.78 | 25 | 140 |
| | 1/9 | 0.44 | 27 | 230 |
| | 2/9 | 0.53 | 26 | 240 |
| | 3/9 | 0.65 | 25.5 | 200 |
| | 4/9 | 0.62 | 26 | 190 |
| | 5/9 | 0.30 | 29 | 210 |
| | 6/9 | 0.50 | 28.5 | 220 |
| | 8/9 | 0.52 | 27.5 | 220 |
| | 10/9 | 0.40 | 27 | 225 |
| | 11/9 | 0.46 | 28.5 | 220 |
| | Tot. 07 | 11.97 | | |

Table 1: Table of Days, Exposures, Average Zenith Angle and Events Rate.

| Year | Day | Exposure (s) | Av. Zenith An. (deg) | Ev. Rate (Hz) |
|---|---|---|---|---|
| 2008 | 5/3 | 836 | 30 | 115 |
| | 7/3 | 1801 | 28 | 193 |
| | 8/3 | 1896 | 28 | 182 |
| | 9/3 | 2047 | 27 | 197 |
| | 11/3 | 2306 | 27 | 208 |
| | 12/3 | 2942 | 27 | 160 |
| | 13/3 | 3084 | 26 | 133 |
| | 5/4 | 4373 | 20 | 209 |
| | 12/4 | 1542 | 17 | 195 |
| | 15/4 | 2827 | 19 | 201 |
| | 17/4 | 1531 | 17 | 198 |
| | Tot. 08 | 24185 | | |

Table 2: Table of Days, Exposures, Average Zenith Angle and Events Rate for 2007 for March 2008

| Period | PSF (mm) |
|---|---|
| March 07 | 13 |
| August 07 | 13 |
| September 07 | 10.6 |
| March-April 08 | 10.6 |

Table 3: Table of Periods and optical PSF values

Dist, mean Width, mean Length; where all the events of a run were used to calculate the mean parameter value. A relatively small number of runs had large values of mean Width and mean Length, which are visible as "spikes" in the plot of the mean Width (Lenght) vs the Run Number. Those runs were rejected.

The total accepted exposure, after data quality selection was 63187s (17.5 hours). The relevant plots are reported in a dedicate Appendix 1, in a separate document. The list of rejected data is here below:

1. all files from March 2007;
2. all files from $21^{st}$ of August 2007;
3. files from $14^{th}$ of August 2007 from 02665850 to 02665899;
4. files from $19^{th}$ of August 2007 from 02702080 to 00270219;
5. all files from $5^{th}$, $12^{th}$ and $13^{th}$ of March 2008;

# 3 Data Analysis Method

The Hadronness parameter measures with which degree an event is similar to an hadronic one, i.e. to an event generated by the a cosmic ray shower initiated by a charged cosmic ray. The Hadronness parameter is used in order to reject the dominant hadronic events background. Then Hadroness of each event, as also the event Energy, was reconstructed. RF.

The reconstruction is based on the use of the Random Forest (RF) algorithm as it is implemented within the Osteria executable fo the MARS package. The RF was trained with MonteCarlo simulations of gamma rays and with experimental hadronic background. MC simulations with the proper psf tag were used for each subsample. MC with psf = 13mm and 10.6mm were used respectively for August and September 2007 data. The experimental data are part of the same observations for which the RF matrix was created. A Size threshold of 100ph.e. was set for the RF training. No source dependent cut were used within Osteria. The calculation of Hadronness, Energy and the other source dependent parameters were performed with the Melibea executable.

The present analysis uses the *timing* parameters, which means: RMSTime and P1Grad were used to train the RF.

The performed analysis is based on the use of the Alpha parameter with wobble observations:

- the *ON source* sample was obtained by calculating all the position dependent parameters in respect of the source position and using all the recorded events;
- the *OFF source* or Reference sample was obtained by calculating all the position dependent parameters in respect of the ANTI-source position and using all the recorded events;
- the events were selected by means of cuts on the Hadronness, Alpha and Dist parameters. (Anyhow OFF sample events which satisfied the selection criteria not used for ON sample, and viceversa.)

The Alpha parameter distribution of the selected events was obtained both for the ON and the Reference samples. From these Alpha distributions the event excess and the excess significance were computed.

Data were divided into two bands:

- low band, with 125ph.e. $<$ Size $<$ 400ph.e., which corresponds to a reconstructed energy of 130 to 240 GeV ;
- high band, with 400ph.e.$<$ Size, which corresponds to a reconstructed energy above 240 GeV.

| Band | Exposure | On Events | Off Events |
|---|---|---|---|
| 130-240GeV | 5486 | 108 | 23.8 |
| above 240GeV | 5486 | 334 | 24.7 |

Table 4: Table of Results with Crab Data

For each band the selection were optimized with Crab nebula data, as explained in the section 5. The analysis was repeated for each band. It was performed on the total sample and on the single nights samples. Alpha distributions for the total sample are in fig 1 and 2. Alpha distributions for the night-by-night analysis are reported in dedicated Appendix, in a separate document. The analysis results are in table 3.

# 4 Crab Nebula Data Analysis

Observations of Crab Nebula were used in order to optimize the selection cuts. The total exposure was 5486 s.

The Crab data were analyzed with the same method and tools used for the 1722+119. The value of the Hadronness upper cut was changed from 0.01 to 1 and for each trial:

- event excess, residual background and significance of the signal were obtained;
- sensitivity, i.e. the minimum flux (in Crab Units) detectable in 50 hours, was calculated.

The Hadronness cut optimization was performed for both analysis bands. For the high band (Size above 400phe) a sensitivity of better than 1.5% of Crab was found for Hadronness cut at 0.04 and Alpha cut at 7deg; for the low energy band (125phe $<$ Size $<$ 400phe) a sensitivity better than 5% of Crab was found for Hadronness cut at 0.02 and Alpha cut at 9deg. The plots of the sensitivity as function of the Hadronness cut for both bands are reported here below.

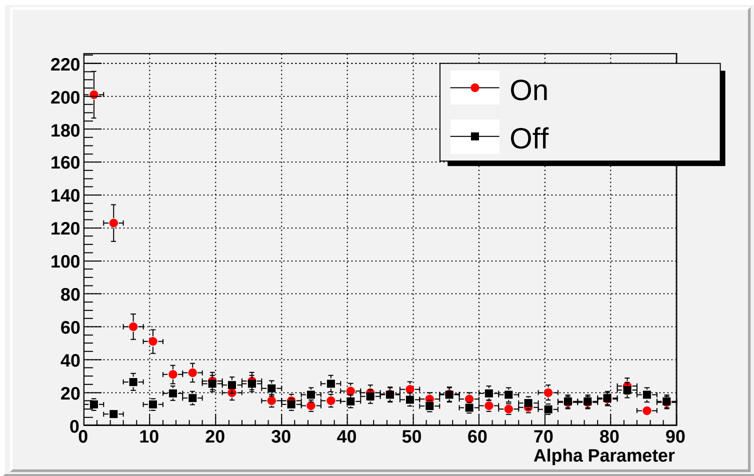


Figure 1: Crab Nebula data. Alpha parameter distribution for the high band

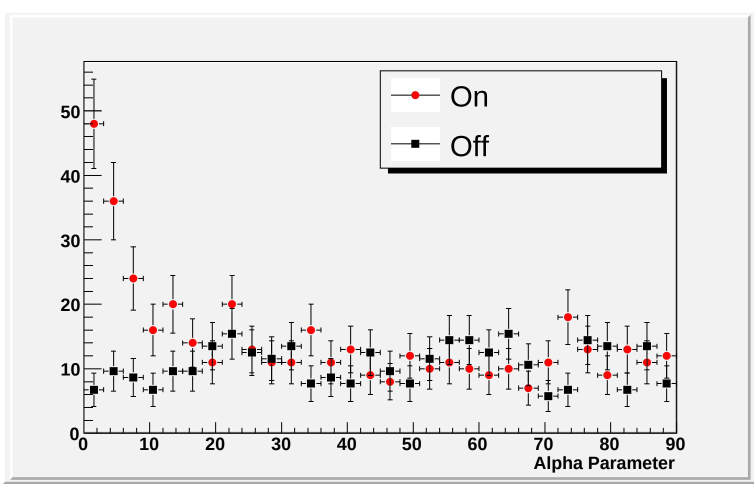


Figure 2: Crab Nebula data. Alpha parameter distribution for the low band

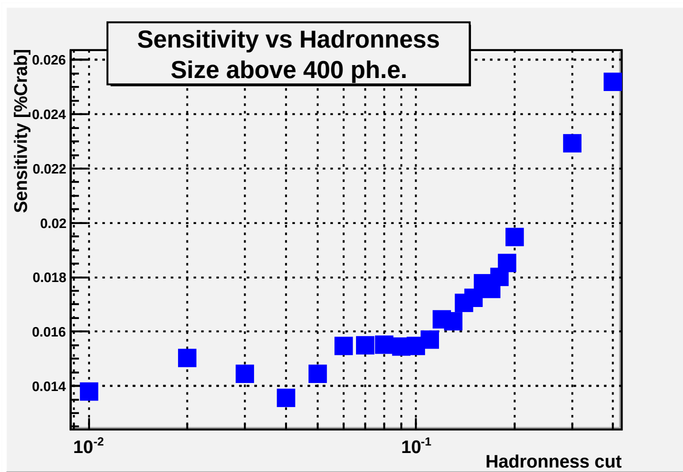


Figure 3: Sensitivity for the high band

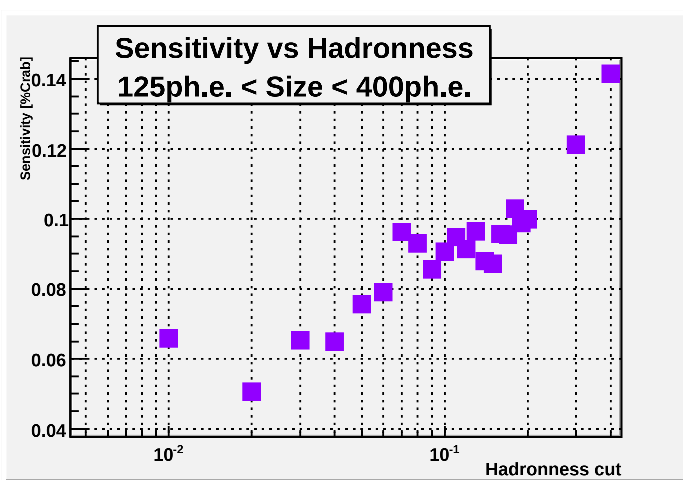


Figure 4: Sensitivity for the low band

| Sample | Band | Exposure | On events | Off Events | Significance |
|---|---|---|---|---|---|
| Tot | 130-240GeV | 63187 | 838 | 797 | 1.0 $\sigma$ |
| Tot | above 240GeV | 63187 | 679 | 615 | 1.8$\sigma$ |
| 2007 | 130-240GeV | 46107 | 725 | 679 | 1.2 $\sigma$ |
| 2007 | above 240GeV | 46107 | 460 | 410 | 1.7 $\sigma$ |
| 2008 | 130-240GeV | 17081 | 113 | 118 | -0.3 $\sigma$ |
| 2008 | above 240GeV | 17081 | 219 | 205 | 0.6 $\sigma$ |

Table 5: Table of Results on H 1722+119 data

# 5 Results

The analysis of the total sample (63187s = 17.5h) was performed both for low and high bands. The results are reported in table 5. The event excesses have significance compatible with statistical fluctuations. Two upper limits ($2\sigma$) to the $\gamma$ ray flux from H 1722+119 can be set:

- $\Phi_\gamma$(130GeV<E<240GeV)$<$ 3.4% Crab Units;
- $\Phi_\gamma$(E>240GeV)$<$ 1.0% Crab Units.

A further analysis was performed on the sub-samples taken during optical high activity. Optical observations were performed with the 1.03m telescope of the Tuorla Observatory and the KVA telescope at La Palma. Data were kindly provided by Dr. Kary Nilsson. Optical activity of the source during the 2007 MAGIC observations were higher than for 2008, as can be seen in fig 9. The results of the analysis for the 2007 and 2008 samples are reported in the table 5. The excess rate for 2007 is slightly larger than for 2008.

The analyses of single night samples were also performed for both low and high band. In table 6 and 7 the results are listed. In Fig 8 and 9 the distributions of the significance obtained with the single night samples are shown. A Gaussian fit of the low band significance distribution provides a mean of 0.1$\pm$0.2 and a sigma of 1.0$\pm$,0.15 while a fit of the high band provides a distribution mean of 0.2$\pm$0.2 and a sigma of 0.8$\pm$.0.3 No single night excess is significantly outside the Gaussian distribution.

No signal was found from the source.

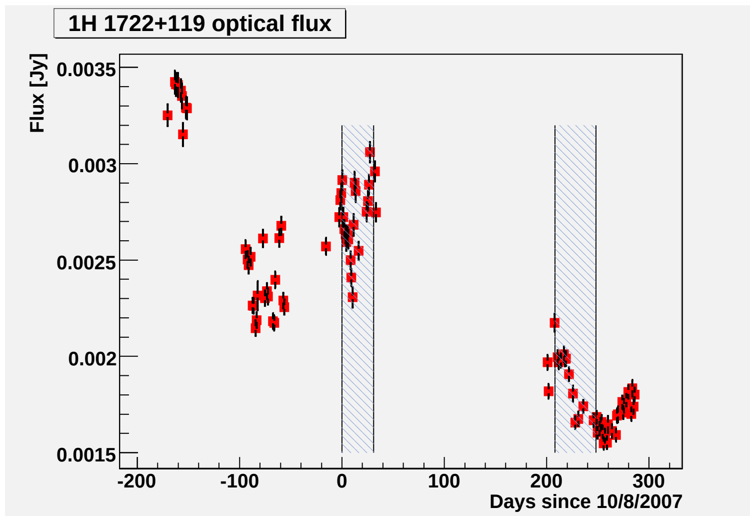


Figure 5: Optical lightcurve of H 1722+119. Shadowed are the MAGIC observation periods. Optical observations were performed with the 1.03m telescope of the Tuorla University and the KVA telescope at La Palma

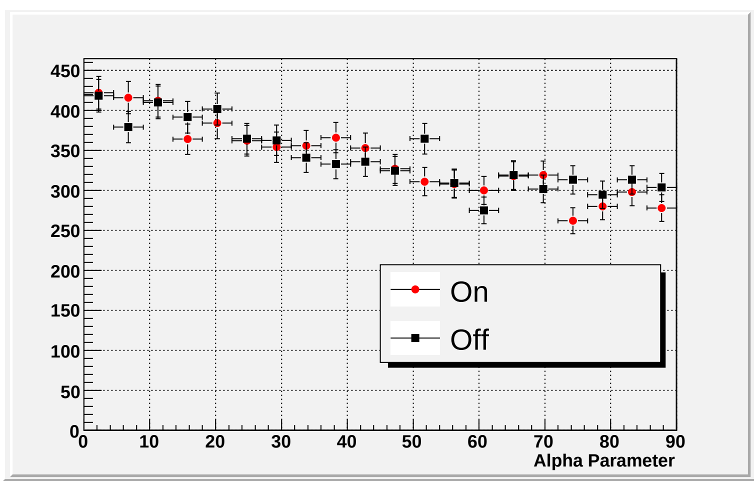


Figure 6: Alpha distribution for the total sample, low band.

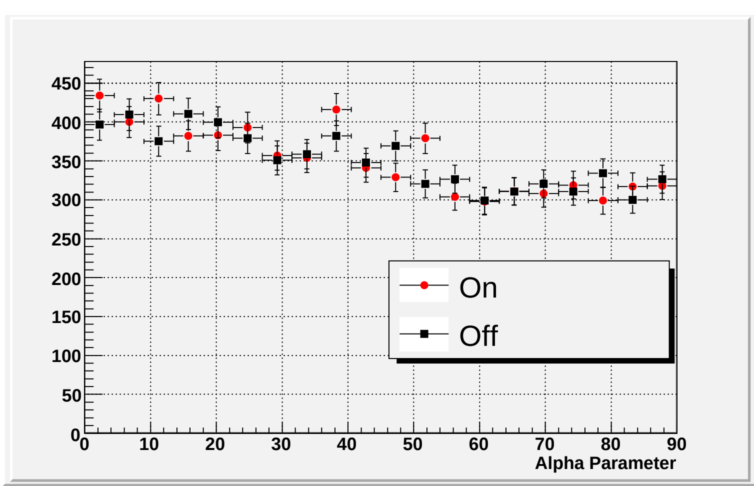


Figure 7: Alpha distribution for the total sample, high band.

| Day | On Events | Off Events | Significance std.dev. |
|---|---|---|---|
| 20070810 | 24 | 18.7 | 0.8 |
| 20070811 | 10 | 9.1 | 0.2 |
| 20070812 | 9 | 13.1 | -0.8 |
| 20070813 | 22 | 19.7 | 0.3 |
| 20070814 | 18 | 17.3 | 0.1 |
| 20070815 | 33 | 46.6 | -1.5 |
| 20070816 | 59 | 42.7 | 1.6 |
| 20070817 | 147 | 145 | 0.1 |
| 20070819 | 101 | 106 | -0.3 |
| 20070820 | 225 | 220 | 0.25 |
| 20070901 | 6 | 8.3 | -0.6 |
| 20070902 | 10 | 5.2 | 1.2 |
| 20070903 | 19 | 15.0 | 0.7 |
| 20070904 | 12 | 16.1 | -0.7 |
| 20070905 | 7 | 12.9 | -1.1 |
| 20070906 | 10 | 7.1 | 0.7 |
| 20070908 | 15 | 10.6 | 0.9 |
| 20070910 | 15 | 12.8 | 0.4 |
| 20070911 | 16 | 7.1 | 1.8 |
| 20080307 | 9 | 6.4 | 0.7 |
| 20080308 | 7 | 6.6 | 0.1 |
| 20080309 | 13 | 15 | -0.35 |
| 20080311 | 10 | 17.5 | -1.4 |
| 20080405 | 57 | 60.4 | -0.3 |
| 20080412 | 18 | 18.2 | 0.0 |
| 20080415 | 38 | 33.7 | 0.5 |
| 20080417 | 18 | 16.7 | 0.2 |

Table 6: Table of Days, On Events, Off Events and Significance. For low band (Size between 125 and 400 ph.e.)

| Day | On Events | Off Events | Significance std.dev. |
|---|---|---|---|
| 20070810 | 9 | 16.6 | -1.5 |
| 20070811 | 9 | 8.7 | 0.05 |
| 20070812 | 12 | 9.9 | 0.4 |
| 20070813 | 16 | 19 | -0.5 |
| 20070814 | 8 | 11 | -0.6 |
| 20070815 | 10 | 20 | -1.95 |
| 20070816 | 25 | 16 | 1.4 |
| 20070817 | 73 | 39 | 3.3 |
| 20070819 | 41 | 39 | 0.25 |
| 20070820 | 102 | 89 | 0.9 |
| 20070901 | 16 | 10 | 1.1 |
| 20070902 | 10 | 9.2 | 0.2 |
| 20070903 | 29 | 18 | 1.6 |
| 20070904 | 15 | 15 | -0.06 |
| 20070905 | 12 | 21 | -1.5 |
| 20070906 | 22 | 20 | 0.3 |
| 20070908 | 24 | 16 | 1.2 |
| 20070910 | 26 | 22.5 | 0.5 |
| 20070911 | 14 | 21 | -1.2 |
| 20080307 | 19 | 12 | 1.3 |
| 20080308 | 17 | 20 | -0.4 |
| 20080309 | 22 | 17 | 0.7 |
| 20080311 | 30 | 27 | 0.4 |
| 20080405 | 31 | 27.1 | 0.5 |
| 20080412 | 8 | 5.4 | 0.7 |
| 20080415 | 21 | 37.8 | -2.0 |
| 20080417 | 14 | 6.9 | 1.6 |

Table 7: Table of Days, On Events, Off Events and Significance, for high band (Size above 400 ph.e.)

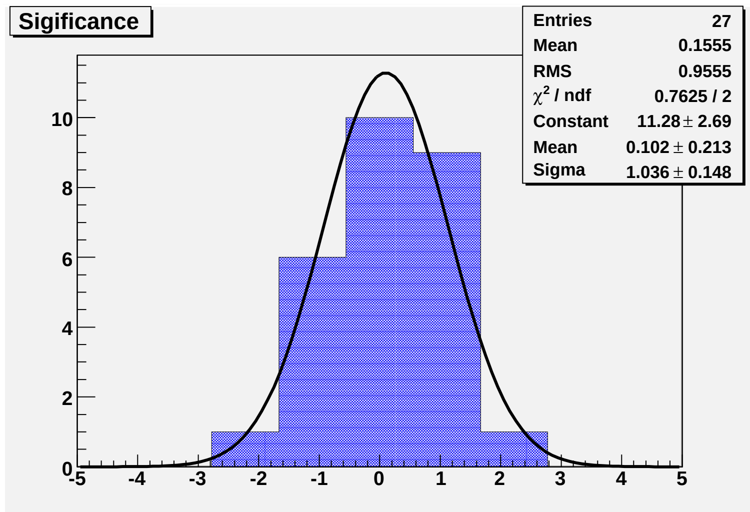


Figure 8: Distribution of Significance for the single night samples, for low band

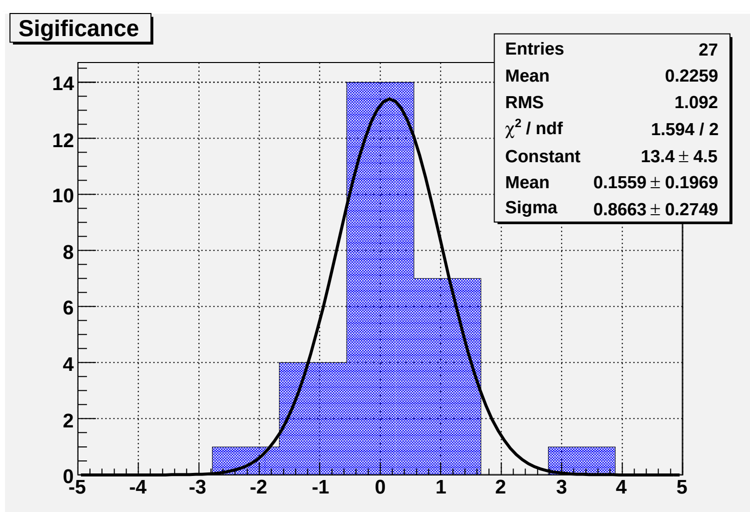


Figure 9: Distribution of Significance for the single night samples, for the high band