CHEC-S Threshold for high NSB

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0.0	2017-08-18	Initial version	GCT	T. Armstrong	B. Name

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1 Introduction

Investigation into the effect on the required safe threshold for increasing levels of NSB for CHEC-S. This is motivated by a potential new requirement, defining that the instrument ”must be able to perform gamma ray measurements at some level at 25x nominal NSB”. Here we use the definition for safe threshold where the trigger rate from twice the assumed NSB intensity is equal to the trigger rate from cosmic rays (CR), $R_{NSB\times2} = R_{CR}$. For simplicity, the CR rate is calculated by only simulating protons, and accounting for the heavier component by assuming that $R_{CR} = 1.5 \cdot R_{proton}$.

To determine the proton rate, 5e4 showers were simulated with CORSIKA between the energy range of 200 GeV and 600 TeV (simulated with as E^{-2}). The site parameters for Paranal were adopted and the showers were set to origionate from a field of view of 10 degrees and were scattered at observation level in a 600 m radius (resampled 10 times). For record, the CORSIKA input card can be found in the Appendix.

To simulate the telescope and camera response, sim_telarray was used. Here we adopt the PROD3 configuration parameters, changing only the NSB per pixel value, the discriminator threshold and setting the following sim_telarray parameters: TRIGGER_TELESCOPES=1 TELESCOPE_THETA=20.0 TELESCOPE_PHI=0.0.

The proton rate is then calculated by finding the trigger efficiency as a function of energy (in histogram format with 20 bins per decade in energy). This is then multiplied by the solid angle over which the events were simulated, the area over which the events were scatterd and the integrated proton rate.

$$R_{proton} = S \cdot \Omega \int_{E_1}^{E_2} \phi(E)\, dE \cdot \frac{N_{trig}}{N_{sim}} \tag{1.1}$$

where $S = \pi r^2$ with r=600m and $\Omega = 2\pi \cdot (1 - cos(\theta))$ with $\theta = 10$ degrees (the corsika CSCAT and VIEWCONE parameters). $\int_{E_1}^{E_2} \phi(E)\, dE$ is the integrated proton rate (between the bin lower and upper edge) which is assumed to take the form

$$\phi(E) = 9.6 \times 10^{-2} \cdot \left(\frac{E}{TeV}\right)^{-2.70} \tag{1.2}$$

The total rate is then the sum of all the histogram bins.

For the NSB simulation, we first generate a dummy CORSIKA file containing no cherenkov light (there may be some, but at a negligable level, see the input card in the appendix). The file generated here containes 100000 headers and was used multple times for high threshold values (where the trigger rate was very low). Since the NSB value used in the sim_telarray configuration file is not a function of energy (although the determination of the baseline value does take into account the measured NSB spectrum and the wavelength response of the telescope and camera), we need only calculate the total trigger efficiency. When running sim_telarray, we need to include a few extra parameters: TRIGGER_TELESCOPES=1 TELESCOPE_THETA=20.0 TELESCOPE_PHI=0.0 FADC_BINS=100 FADC_SUM_BINS=100 DISC_BINS=100 MIN_PHOTONS=0 MIN_PHOTOELECTRONS=0. Where the min photons and photoelectrons ensure that the simulation proceeds discpite the empty corsika files. The larger FADC parameters are standard practice. Due to the definition of the safe threshold, we also have to set the NSB as twice the considered value. For each run with a discriminator threshold, the rate of NSB triggers is calculated as

$$R_{NSB\times2} = \frac{1000 \cdot FADC\_MHz \cdot N_{trig}}{FADC\_BINS \cdot N_{sim}} \tag{1.3}$$

Once R_{proton} and $R_{NSB\times2}$ are determined for a range of DISCRIMINATOR_THRESHOLD values, the safe threshold can be determined.

2 Results

The results for the safe threshold determination for different NSB intensities can be seen in Figure 2.1 and in Table 2.1. In the lower plot in Figure 2.1 the distribution has been fit with a linear function,

During initial runs, it was noticed that the linearity falied at high nsb, followed by a failure of simtel at even higher nsb. This is due to the parameter TRIGGER_CURRENT_LIMIT which disables pixels above a certain current which is itself determined by the NSB level. This was then set to a much larger value but in general would need to understand if we are able to match that, and whether or not the calculation in simtel is applicable. The current is calulated as follows:

$$DC = NSB \cdot 1 \times 10^9 \cdot RandGauss(1, gain\_variation) \cdot pm\_average\_gain \cdot adjust\_gain \cdot 1.609 \times 10^{-19} \cdot 1 \times 10^6 \tag{2.1}$$

So for the prod3 config this would be

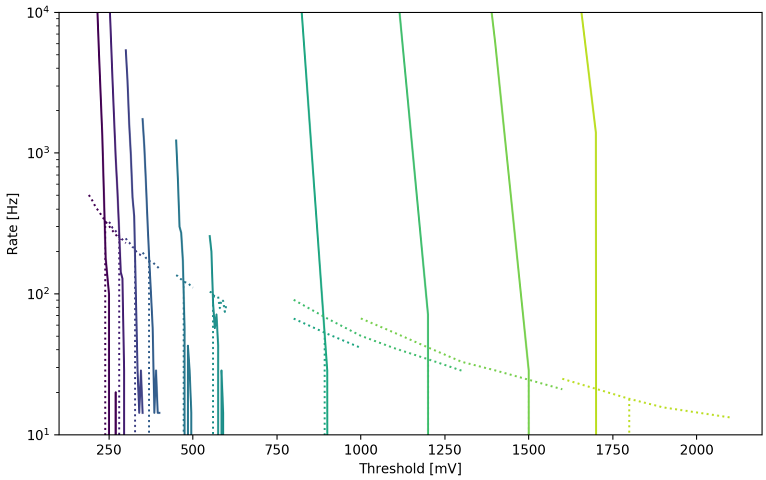
$$DC = 0.041 \cdot 1 \times 10^9 \cdot \sim 1 \cdot 1.72 \times 10^5 \cdot 1 \cdot 1.609 \times 10^{-19} \cdot 1 \times 10^6 = 1.13\ \mu\text{A} \tag{2.2}$$

and the default current limit in the GCT-S (default vaule of sim_telarray) is 20.0 μA.

NSB Intensity	Safe Threshold
MHz	mV
43.9	238.6
60.0	280.9
80.0	327.9
100.0	369.9
150.0	472.1
200.0	559.3
400.0	891.9
600.0	1199.9
800.0	1516.0
1000.0	1798.7

Table 2.1 – Safe Thresholds calculate for each NSB pixel rate

As previously noted, this study was performed using the PROD3 telescope and camera configuration files for CHEC-S which should be updated with current measurements. Once this is done, the study can be repeated. All simulations and anaysis (the later using pyhessio, used by ctapipe) were performed on the grid using the DIRAC interface, hence the calculation can be done quickly.



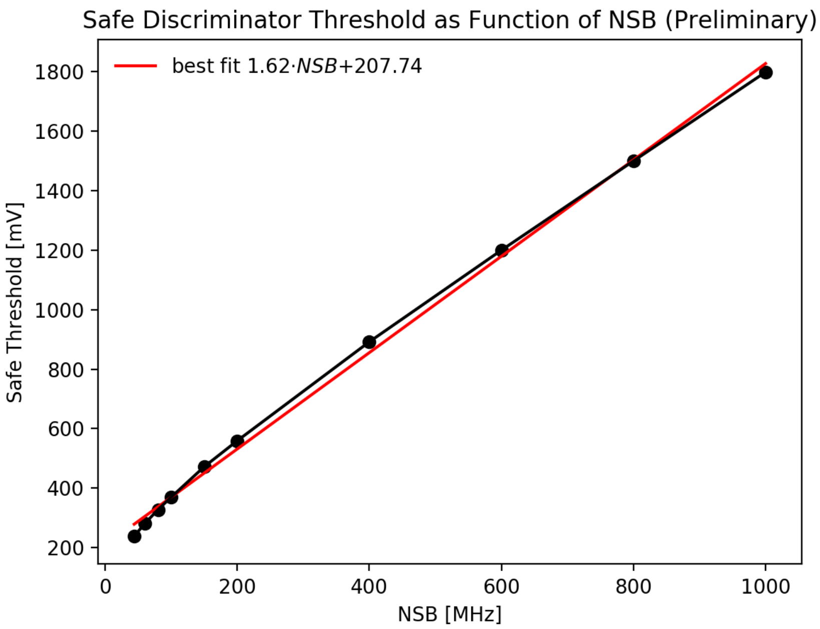


Figure 2.1 – Determination of the safe threshold. Top plot shows the rates calculated from Eqn. 1.1 and 1.3 for different NSB intensities, ranging from 43.9-MHz, the nominal value calculated for the Paranal site, and 200 MHz. The crossing point of the NSB and Cosmic Ray rate lines gives the safe threshold, the values of which can be seen in the lower plot and are given in Table 2.1

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A CORSIKA Input Cards

```
*
* ============== Proton Corsika INPUTS ======================
*
* [ Job parameters ]
*
RUNNR   1                               // Number of run, to be auto-numbered by job submission
EVTNR   1                               // Number of first shower event (usually 1)
NSHOW   10000                            // number of showers to generate
*
* [ Random number generator: 4 sequences used in IACT mode ]
*
SEED   385928125   401   0               // Seed for 1st random number sequence, to be re-generated
SEED   827619802   859   0               // Seed for 2nd random number sequence, to be re-generated
SEED   195989238   390   0               // Seed for 3rd random number sequence, to be re-generated
SEED   539053819   323   0               // Seed for 4th random number sequence, to be re-generated
*
* [ Primary particle options ]
*
PRMPAR  14            // Particle type of prim. particle (14: proton)
ESLOPE  -2.0          // Slope of primary energy spectrum (-2.0 is equal CPU time per decade)
ERANGE  200.0 600E3     // Energy range of primary particle (in GeV): protons

THETAP  20.  20.      // Range of zenith angles (degree)
PHIP   180. 180.    // Range of azimuth angles (degree): primaries coming from North
VIEWCONE 0. 10.     // Diffuse components (gammas, electrons, protons & nuclei)
*
* [ Site specific options ]
*
OBSLEV 2150.E2      // Observation level (in cm) for CTA near Paranal
ATMOSPHERE 26 Y     // Should be slightly better for Paranal than profiles 1 (tropical) or 10 (HESS)
MAGNET 21.325 -8.926   // Magnetic field at assumed site [H, Z] (muT) (about the same as for Armazones site)
*
ARRANG  0.            // Rotation of array to north [D] (degree); use zero here for any site for now
*
* [ Core range ]
*
CSCAT  10  600e2  0. // Use shower several times (protons+electrons+..., larger area for diffuse origin)
*
* [ Telescope positions, for IACT option ]
*
TELESCOPE      0.000E2      0.000E2     5.000E2     2.800E2    # Telescope   1
*
* [Interaction flags]
*
FIXHEI  0.  0          // First interaction height & target (0. 0 for random)
FIXCHI  0.             // Starting altitude (g/cm**2). 0. is at boundary to space.
TSTART  T              // Needed for emission and scattering of primary
ECUTS   0.3  0.1  0.020  0.020         // Energy cuts for particles
MUADDI  F                               // Additional info for muons not needed
MUMULT  T                               // Muon multiple scattering angle
LONGI   T  20.  F  F                    // Longit.distr. & step size & fit
MAXPRT  0                               // Max. number of printed events
ECTMAP  1.E6                            // Cut on gamma factor for printout
STEPFC  1.0                             // Mult. scattering step length factor
*
* [ Cherenkov emission parameters ]
*
CERSIZ  5.         // Not above 10 for super/ultra-bialkali QE; 7 is fairly OK; 5 should be safe.
CERFIL  F                               // No old-style Cherenkov output to extra file
```

```
CWAVLG  250.  700.                     // Cherenkov wavelength band
*
* [ Debugging and output options ]
*
DEBUG   F  6  F  1000000               // Debug flag and logical unit for output
DATBAS yes                             // Write a file with parameters used
DIRECT  /dev/null                      // /dev/null means no normal CORSIKA data written
TELFIL cta-disc-protons-sst-200000.corsika.gz       // If telescope simulation not done directly in pipe
*
*
IACT SPLIT_AUTO 8M                    // Split data with more than 15 million bunches
IACT IO_BUFFER 800MB                   // At 32 bytes per bunch this could be up to 500 MB
IACT MAX_BUNCHES 1000000               // Let photon bunch thinning set in earlier.
*
* [ This is the end, my friend ]
*
EXIT                                   // terminates input
* ========================================================



*
* =============== NSB Corsika INPUTS =======================
*
* [ Job parameters ]
*
RUNNR   1001                           number of run
EVTNR   1                              number of first shower event
NSHOW   100000                             number of showers to generate
DATBAS yes                             write a file with parameters used
*
* [ Random number generator: 4 sequences used in IACT mode ]
*
SEED    58485   430   0                seed for 1st random number sequence
SEED    63432   435   0                seed for 2nd random number sequence
SEED    20103   481   0                seed for 3rd random number sequence
SEED    59475   490   0                seed for 4th random number sequence
*
* [ Primary particle options ]
*
PRMPAR  1                              particle type of prim. particle
ESLOPE  -2.0                           slope of primary energy spectrum
ERANGE  0.1 0.1                        energy range of primary particle (in GeV)
THETAP  30.  30.                       range of zenith angle (degree)
PHIP    -14. -14.                      range of azimuth angle (degree): from South if PHIP=ARRANG
VIEWCONE 0. 0.                         can be a cone around fixed THETAP/PHIP
*
* [ Site specific options ]
*
OBSLEV 2150.E2      // Observation level (in cm) for CTA near Paranal
ATMOSPHERE 26 Y     // Should be slightly better for Paranal than profiles 1 (tropical) or 10 (HESS)
MAGNET 21.325 -8.926   // Magnetic field at assumed site [H, Z] (muT) (about the same as for Armazones site)
ARRANG  -14.                           rotation of array to north [D] (degree)
*
* [ Cherenkov emission parameters ]
*
CERSIZ  10.                            bunch size Cherenkov photons
CERFIL  F                              Cherenkov output to extra file
CWAVLG  200.  700.                     Cherenkov wavelength band
*
* [ H.E.S.S. telescopes ] (x -> North, y -> West)
*
*             X     Y    Z    R          (all in cm)
TELESCOPE     0   0    0  750        Tel. 1
*
CSCAT   1  0e2  0.                  use shower several times
*
* [Interaction flags]
*
FIXHEI  0.  0                          first interaction height & target
FIXCHI  0.                             starting altitude (g/cm**2)
ELMFLG  T   T                          em. interaction flags (NKG,EGS)
RADNKG  200.E2                         outer radius for NKG lat.dens.determ.
HADFLG  0  0  0  0  0  0               flags for hadr. interaction
```

```
ECUTS   0.3  0.1  0.020  0.020         energy cuts for particles
MUADDI  F                              additional info for muons
MUMULT  T                              muon multiple scattering angle
LONGI   T  20.  F  F                   longit.distr. & step size & fit
MAXPRT  0                              max. number of printed events
ECTMAP  1.E6                           cut on gamma factor for printout
STEPFC  1.0                            mult. scattering step length fact.
*
* [ Debugging and output options ]
*
DEBUG   F  6  F  1000000               debug flag and logical unit for output
DIRECT  /dev/null                      /dev/null means no normal CORSIKA data written
TELFIL dummy100000.corsika.gz:100:100:1              Telescope photon bunch output (eventio format)
*
* [ This is the end, my friend ]
*
*
EXIT                                   // terminates input
* ========================================================
```