To understand the sources which emit neutrinos and differentiate different types of them, an analysis is performed. This analysis contains the stacking analysis method and uses fully simulated datasets. To start of, the background needs to be generated. This consists of two different types of how the events are created. The astrophysical background events denote events from sources of a different type as the sources that are considered. So these events are of no interest and therefore form the background. The atmospheric background is more prominent than the astrophysical. These events have also an astrophysical origin, except that they interact with the atmosphere, that causes a different energy spectrum than the astrophysical ones. Both types can be assumed as isotropic, so the coordinates can are chosen as followed:

$$Dec = [-85°, 85°] \text{ and } RA = [0°, 360°]$$

With that the plot is created, which is devided into two types and shows different energy ranges (fig.1 and 2)

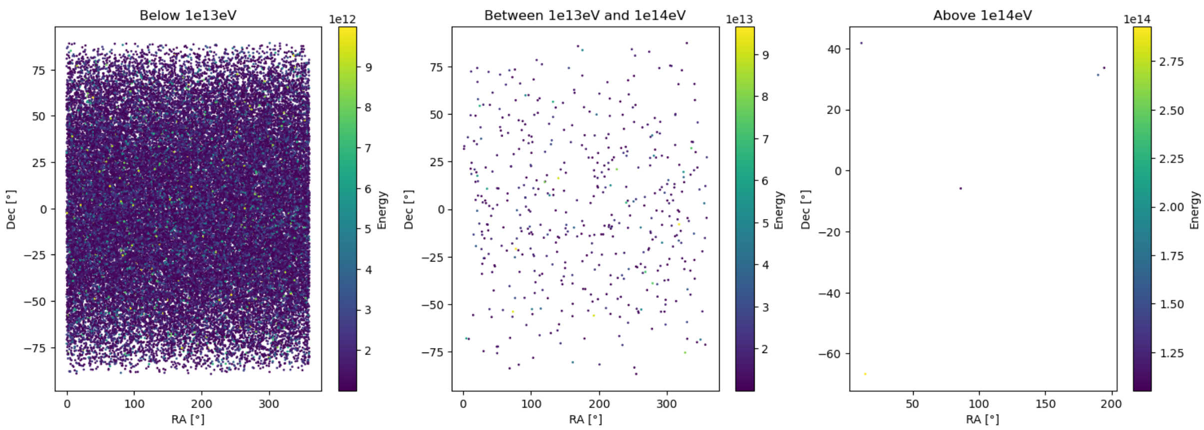

Abbildung 1: Spatial distribution of atmospheric events in differet energy bins

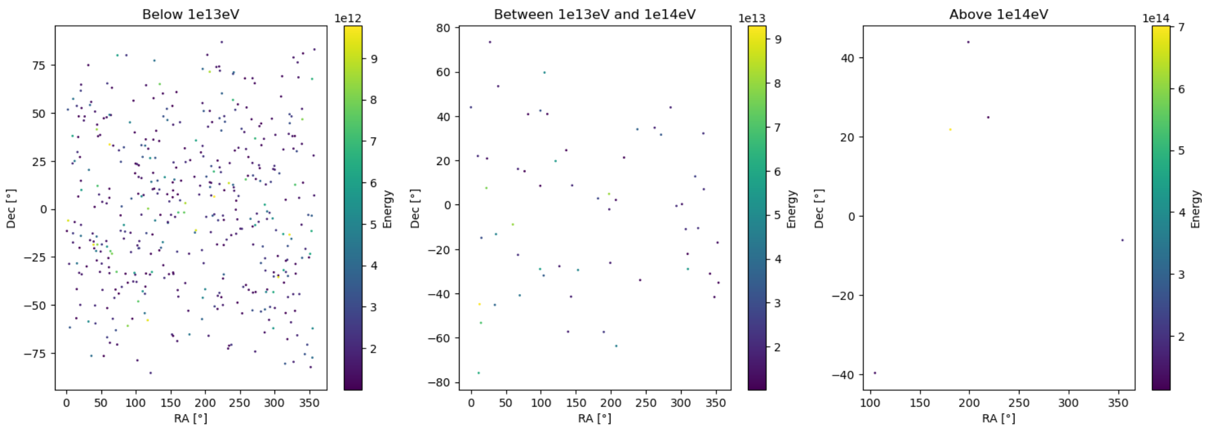

Abbildung 2: The spatial distribution of astrophysical events with color coding of the energies

This assumption does not include the poles, because this simplifies the evaluation of the data. To create a whole set of data, each event must be assigned an energy, where the lower and upper limit of this energy range are given by $E_{low} = 1$ TeV and $E_{up} = 1$ PeV.
The energy obeys the potential law $E^{-\gamma}$, where the gamma-factor is $\gamma = 1.9$ for the astrophysical events and $\gamma = 3$ for the atmospheric ones. In Figure 3, the two types of events can

be seen with the different energy distributions as a histogram. In this plot the dominance of the atmospheric events stands out.

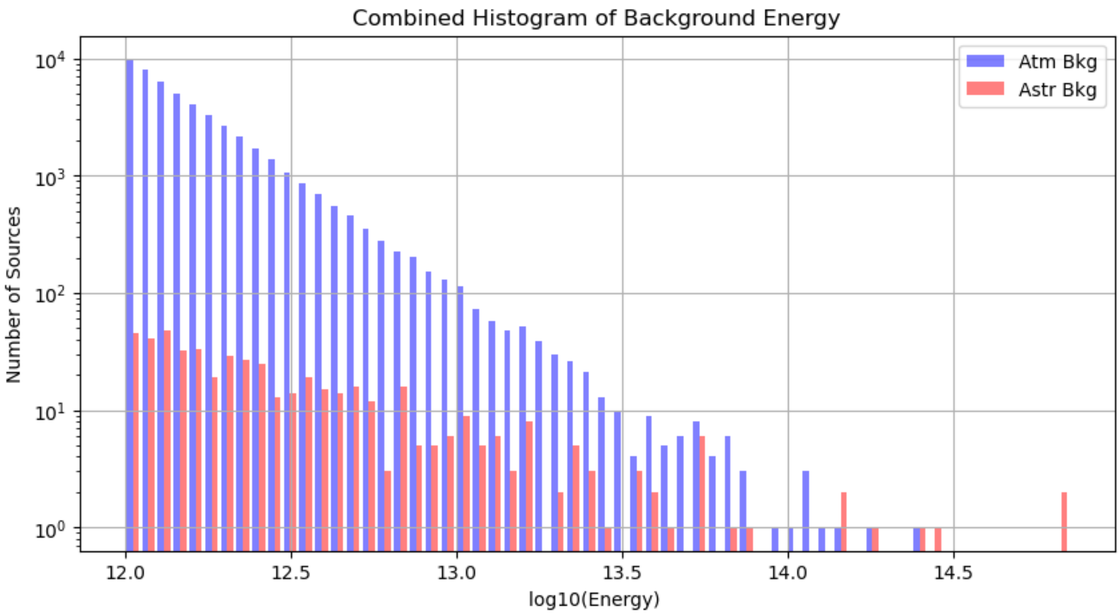

Abbildung 3: Histogram of the combined energies of both background types

To simulate the examined sources a different approach is been used. The IceCube detector can only identify fluxes of neutrino interactions, so for every source a flux is needed. To simulate these fluxes, the upper boundary is set to S_{max}, so the detector can't detect higher fluxes, than the given one. Now the fluxes are randomly chosen between 0 and the maximum S_{max} as they follow the power law $S^{-5/2}$. The problem with that simulation is, that the detector also has a lower boundary of measuring the flux, so every event under $0.1 \cdot S_{max}$ can't be detected and is identified as invisible. The distribution of the flux is shown in figure 4.

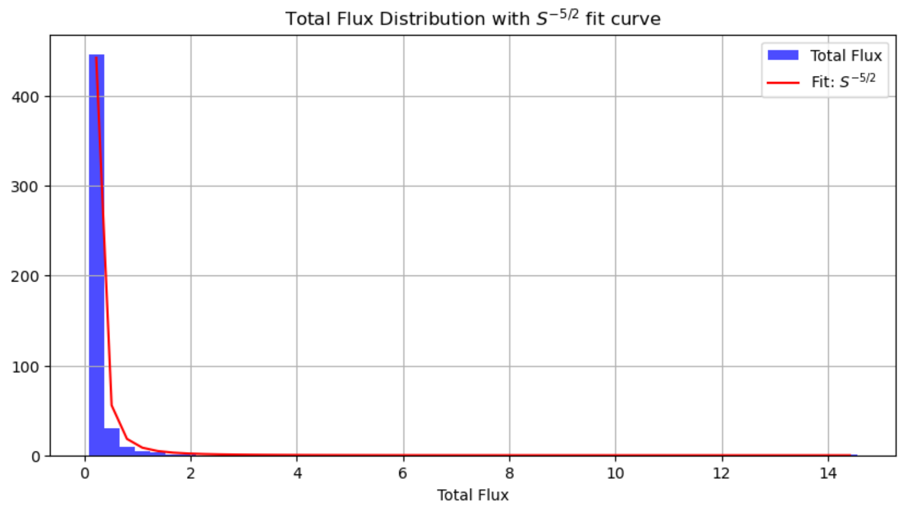

Abbildung 4: Distribution of the flux for the sources

First the assumption is made, that the sources are point like and have an isotropic neutrino emission. Later on different types of the sources can be tested. To specify the sources, every source is assigned a number of events.

To obtain the test statistic (TS), likelihood distributions (LLH) must be created. First the background LLH is created. This LLH consists of three different probability density functions (PDF) for time, the spatial part and the energy.

$$\mathcal{H}_0 = \mathcal{B} = \mathcal{B}_{time} \times \mathcal{B}_{spatial} \times \mathcal{B}_{energy} \tag{1}$$

Long-term observation allows to simplify the time PDF to the following expression, which is a constant.

$$\mathcal{B}_{time} = \frac{1}{\text{lifetime}}$$

The spatial PDF is also a constant due to the isotropic distribution of the sources across the sky, which leads to the following assumption:

$$\mathcal{B}_{spatial} = \frac{1}{4\pi}$$

Now it remains to look at the energy PDF. Here, to simplify things instead of using an energy PDF energy bins are used. For the hypotheses which should be tested we obtain the following structure:

$$\mathcal{H} = \frac{n_s}{N}\mathcal{S} + \frac{N - n_s}{N}\mathcal{B} \tag{2}$$

The calculation is performed for every bin and combined at the end. $\mathcal{B}$ stands for the background PDF, $\mathcal{S}$ for the Signal PDF, n_s is the number of signal neutrinos and N the total number of neutrinos. The Signal PDF consist of the same parts as the background PDF.

$$\mathcal{S} = \mathcal{S}_{time} \times \mathcal{S}_{spatial} \times \mathcal{S}_{energy}$$

The time and energy signal PDF's are the same, only the spatial part has to be different, because the events are not isotropic. For the simulated data, the Dec and RA coordinates are generated using a Gaussian distribution. For $\mathcal{S}_{spatial}$ the coincidence of the sources and the signal are needed. To achieve this, a square with an edge length of $10°$ is placed around the source, with some rescaling in the Dec direction, so that every box has the same area. Now we check whether each signal is inside or outside the square and only the signals inside the box are considered coincident with the source. For these events the angular distance $\vec{r}^{\,2} = (\vec{x}_{source} - \vec{x}_{event})^2$ is calculated for every source. For one source, the angular distance with the events is shown in Figure 5.

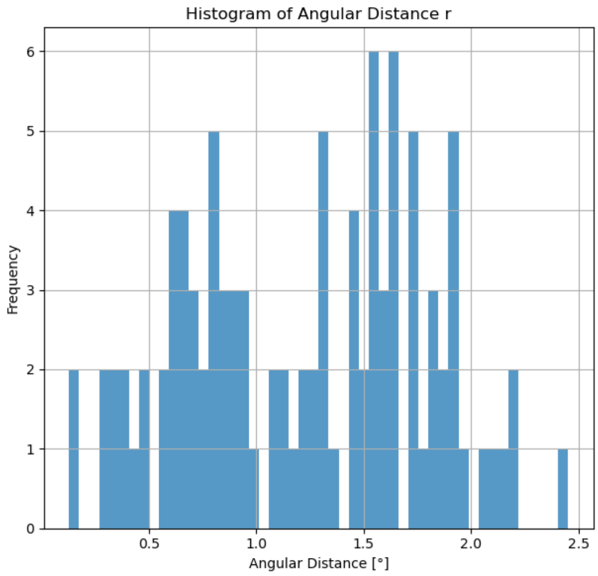

Abbildung 5: angular distance between a source and the coincident events

The angular distance is required because a Gaussian distributed point spread function is assumed as the PDF, which has $\sigma = 0.8$ as the standard deviation.

$$\mathcal{S}_{spatial} = \frac{1}{2\pi\sigma^2} \exp^{-r^2/2\sigma^2} \tag{3}$$

For one source, the following spatial distribution can be generated (see figure 6).

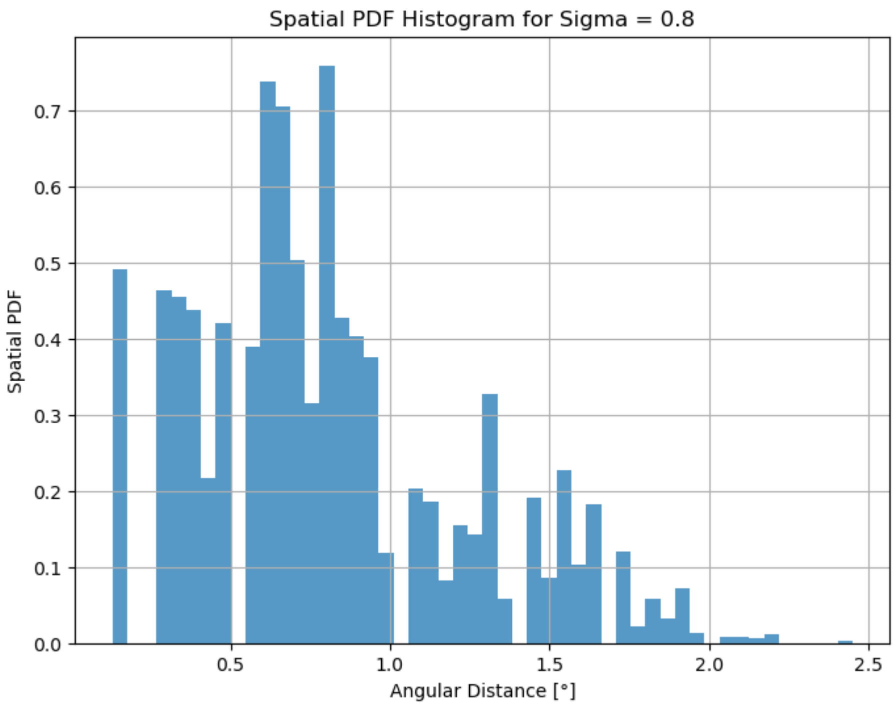

Abbildung 6: The spatial PDF for the signal for one source

To obtain the value for the TS we minimize every energy bin for n_s, because n_s is the only variable and the rest is a constant. Therefor it dosn't matter if we minimize the LLH or the TS. After that all energy bins can be put together and create the whole LLH.