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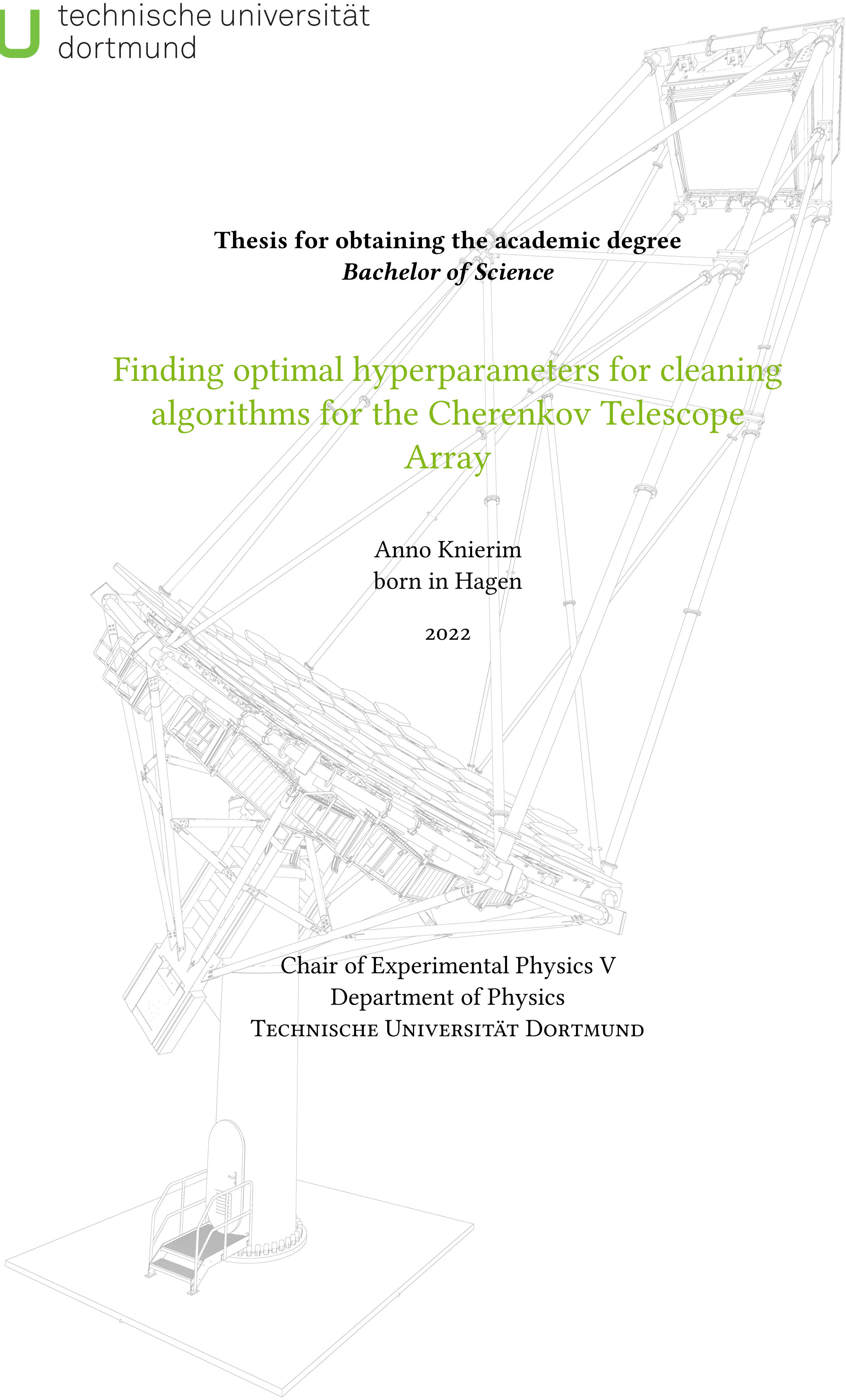

Thesis for obtaining the academic degree
Bachelor of Science

Finding optimal hyperparameters for cleaning algorithms for the Cherenkov Telescope Array

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Abstract

The abstract is a short summary of the thesis in English, and together with the German summary, it has to fit on this page.

Kurzfassung

Hier steht eine Kurzfassung der Arbeit in deutscher Sprache inklusive der Zusammenfassung der Ergebnisse. Zusammen mit der englischen Zusammenfassung muss sie auf diese Seite passen.

Contents

1 Gamma-Ray Astronomy

Astronomy, being one of the oldest sciences, is a vast field of study dating back to the Babylonians. From the earliest days of civilization, astronomers have been studying the stars and the planets to understand the universe. It, therefore, is no surprise that astronomy spawned a great number of discoveries throughout the centuries. Whereas first observations were made by eye only, we now have access to a multitude of experiments and telescopes that deepen our understanding of the universe. With the discovery of cosmic rays (CR) by Victor Hess in the early 20th century, the new field of astroparticle physics was born [3].

From then on we found many different types of cosmic messengers, the most recent being the discovery of gravitational waves in 2015. confirm date

CR come in different types, that are either charged or uncharged, as seen in Figure 1.1. Charged particles like electrons, protons or atomic nuclei are difficult to trace back to their origin as they are deflected by the cosmic electromagnetic fields. Uncharged particles like photons or neutrinos, however, travel in straight lines, making it easier to reconstruct their origins, although photons can be absorbed by dust clouds in their way.

Since neutrinos are harder to detect due to their weak interaction with matter, photons are easier to study with space- and ground-based experiments.

Therefore, in recent years, gamma-ray astronomy has become an important research field in astroparticle physics. The term gamma-rays is generally denoted as photons with energies above 100 keV [2]. Due to this high-energy nature, gamma rays pose some of the most powerful CR in the universe and since photons at such energies cannot be produced by thermal processes, their origin can be described by higher order processes involving charged particles.

For the past two decades, ground-based Imaging Air Cherenkov Telescope (IACT) experiments like the Major Atmospheric Gamma-Ray Imaging Cherenkov (MAGIC) telescopes, the Very Energetic Radiation Imaging Telescope Array System (VERITAS) and the High Energy Stereoscopic System (H. E. S. S.) have been monitoring these very-high-energy gamma rays (VHE gamma rays) to gain an understanding of their production. This allowed us to determine different source classes inside and outside our galaxy, with the most important source class inside our galaxy being supernova remnants (SNRs) such as the Crab Nebula.

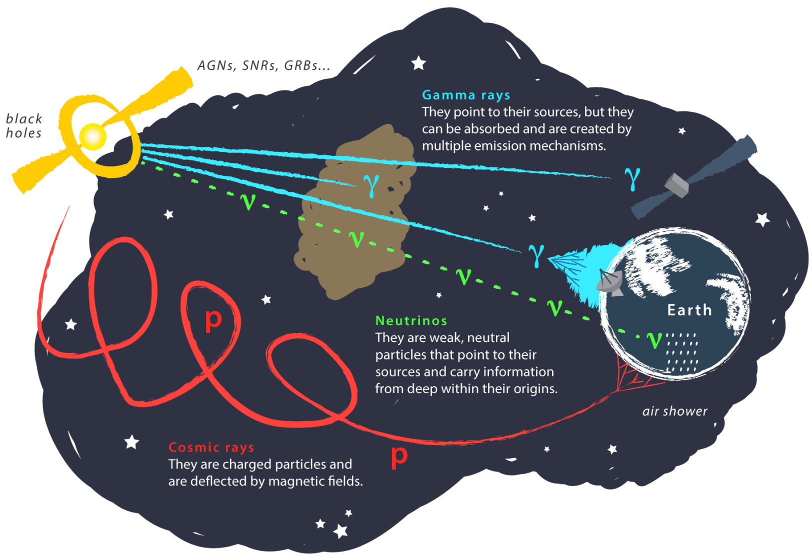

Figure 1.1: Different types of cosmic rays on their way to Earth. Charged particles like protons and electrons are deflected by magnetic fields and therefore making it hard to pinpoint the source. Only the origin of photons and neutrinos can be reconstructed directly since they are uncharged particles and therefore travel in straight lines. However, photons can be absorbed or created in multiple mechanisms. Since neutrinos only rarely interact with matter via the weak force, their detection is significantly harder than for photons [1].

IACTs and the Cherenkov Telescope Array 2

Most modern gamma-ray observations are performed with IACTs, which are ground-based telescopes or arrays of telescopes that use the Cherenkov light emitted by Extensive Air Shower (EAS) in the atmosphere. Since they are ground-based, IACTs are taking advantage of the Earth's atmosphere to get a larger effective area than space-based instruments. This is especially true for energies above 100 GeV, where the gamma-ray flux is low compared to lower energies. The cosmic ray flux is shown in ??. confirm values

The Cherenkov Telescope Array (CTA) is a new generation of IACTs that will consist of two sites, one of which will be built at the Observatorio del Roque de los Muchachos (ORM) on the Canarian island of La Palma while the other site will be built in the southern hemisphere at the European Southern Observatorys (ESO) Paranal Observatory in the Atacama desert of northern Chile.

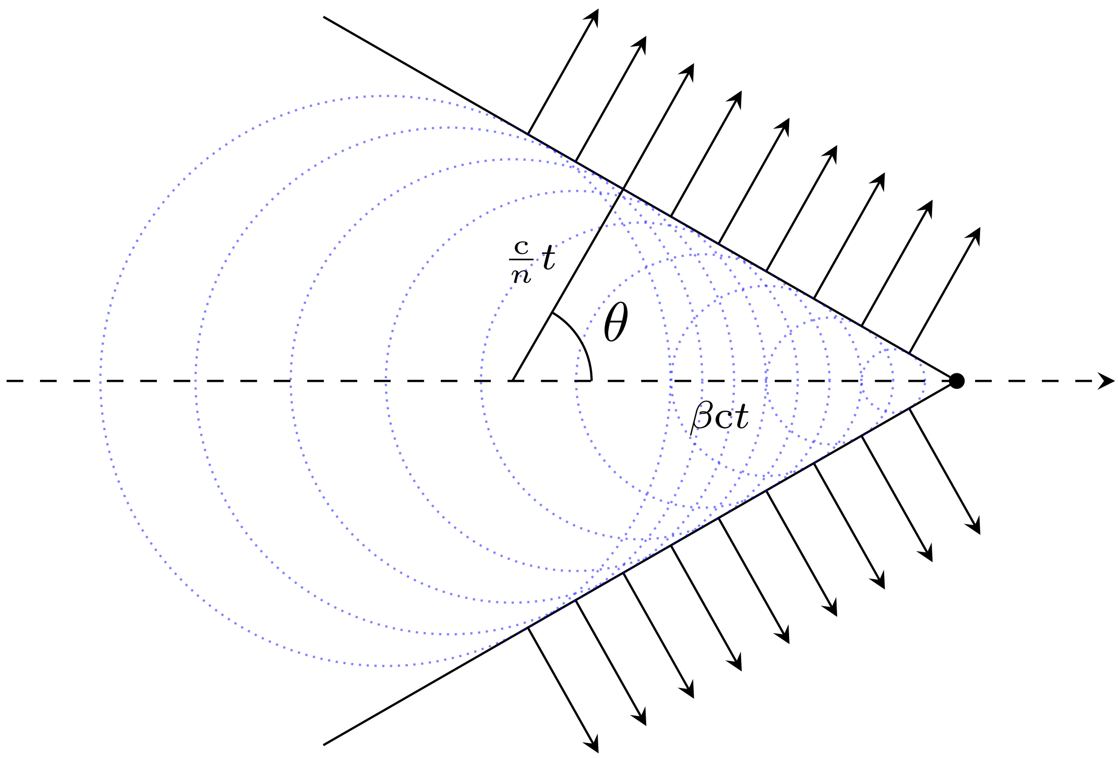

Figure 2.1

Data Preprocessing 3

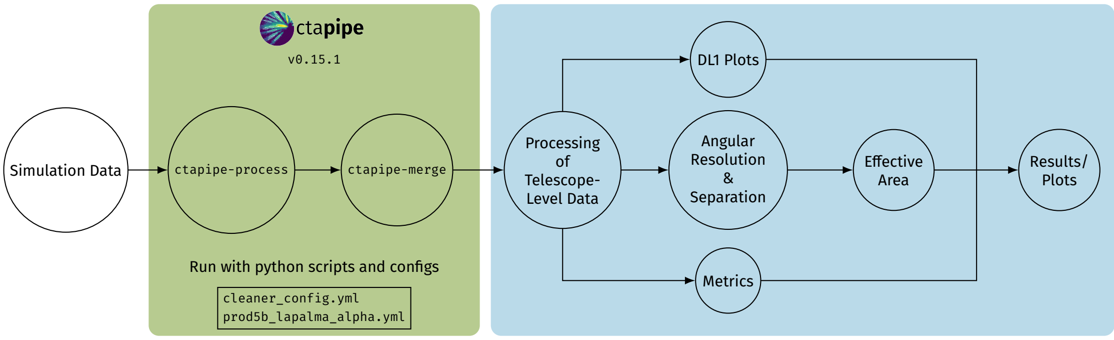

Figure 3.1: Data Preprocessing

```python
def metrics(events, output_file_metrics, unique_file_id):
    ”””Calculates the metrics for the given telescope type.

    Parameters:
    -----------
    events: astropy.table.Table
        The events table. Must contain the following columns:
        - true_image: The true image of the event.
        - image: The event image containing background noise.
    output_file_metrics: pathlib.Path
        The path to the output file for the metrics.
    unique_file_id: int
        The unique file id for the input file.
    ”””

    # initialize the metrics calculator
    metrics_calc = TprFprCalculator(
        true_image=events[”true_image”],
        image=events[”image”],
        clean_mask=events[”image_mask”]
    )

    # calculate the metrics
    metrics_data = metrics_calc.tpr_fpr()

    # write metrics data to DataFrame and then to a file
    metrics = pd.DataFrame(data=metrics_data)
    metrics.insert(loc=0, column=’unique_file_id’, value=unique_file_id)
    metrics.to_csv(
        output_file_metrics,
        index=False,
        mode=’a’,
        header=not output_file_metrics.exists()
    )
```

4 Finding Optimal Hyperparameters for the Cleaning Algorithms

4.1 Cleaning Algorithms

Write about cleaning algorithms

4.2 Hyperparameters

Write about the hyperparameters

5 Results

6 Conclusions and Outlook

Bibliography

1. J. A. Aguilar, J. Yang, and S. Bravo. *Neutrinos and gamma rays, a partnership to explore the extreme universe.* IceCube/WIPAC. 2016.
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2. S. Funk. "Ground- and Space-Based Gamma-Ray Astronomy." *Annual Review of Nuclear and Particle Science* 65:1, 2015, pages 245–277.
   DOI: 10.1146/annurev-nucl-102014-022036. https://doi.org/10.1146/annurev-nucl-102014-022036
3. M. S. Longair. *High energy astrophysics: an informal introduction for students of physics and astronomy.* Cambridge University Press, Cambridge [England] ; New York, 1981. ISBN: 9780521235136 9780521280136

Glossary

CR cosmic rays. 1

CTA Cherenkov Telescope Array. 3

EAS Extensive Air Shower. 3

ESO European Southern Observatory. 3

H. E. S. S. High Energy Stereoscopic System. 1

IACT Imaging Air Cherenkov Telescope. 1, 3

MAGIC Major Atmospheric Gamma-Ray Imaging Cherenkov. 1

ORM Observatorio del Roque de los Muchachos. 3

SNR supernova remnant. 1

VERITAS Very Energetic Radiation Imaging Telescope Array System. 1

VHE gamma rays very-high-energy gamma rays. 1

Appendix

Hier könnte ein Anhang stehen, falls Sie z. B. Code, Konstruktionszeichnungen oder Ähnliches mit in die Arbeit bringen wollen. Im Normalfall stehen jedoch alle Ihre Resultate im Hauptteil der Bachelorarbeit und ein Anhang ist überflüssig.

Acknowledgements

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