



Finding optimal hyperparameters for cleaning algorithms for the Cherenkov Telescope Array

Bachelor thesis half-time talk

Anno Knierim
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E5b Astroparticle Physics
Department of Physics – TU Dortmund

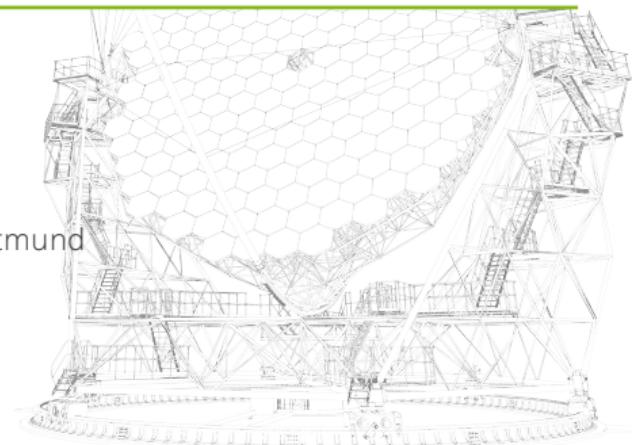


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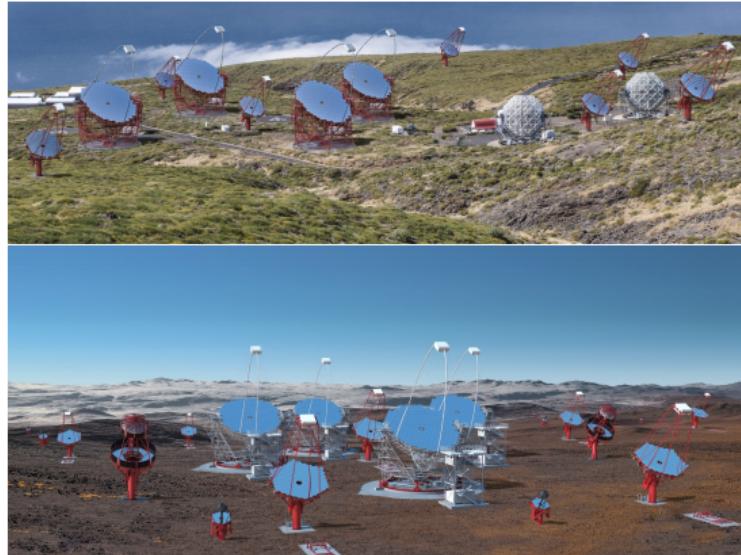
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Introduction

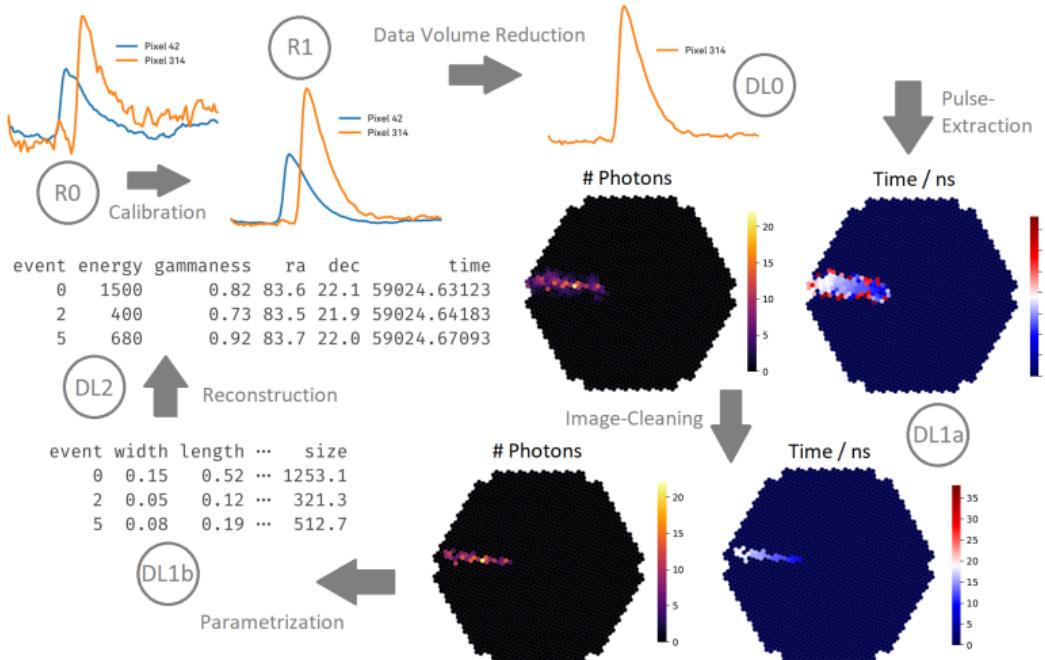
The Cherenkov Telescope Array (CTA)

- 2 sites: CTA North and CTA South
- 3 types of telescopes:
 - Small-Sized Telescope (SST)
 - Medium-Sized Telescope (MST)
 - Large-Sized Telescope (LST)



G. Pérez Diaz. CTA/ IAC. 2016. URL:
<https://www.cta-observatory.org/about/how-cta-works/>
(visited on 07/10/2022).

ctapipe



J. Hackfeld. "Analyzing the Data Volume Reduction for the LST-1 Prototype of the Cherenkov Telescope Array." MA thesis. Bochum, 2021.

Cleaning Algorithms

- TailcutsImageCleaner
- MARSImageCleaner
- FACTImageCleaner
- TimeConstrainedImageCleaner

Cleaning Algorithms

- TailcutsImageCleaner
- MARSImageCleaner
- FACTImageCleaner
- TimeConstrainedImageCleaner
 - Selects pixels that pass a picture and boundary threshold
 - Most basic implementation of the cleaning algorithms

Cleaning Algorithms

- TailcutsImageCleaner
- MARSImageCleaner
- FACTImageCleaner
- TimeConstrainedImageCleaner
 - Selects pixels that pass a `picture` and `boundary_threshold`, analogous to TailcutsImageCleaner
 - Also selects pixels that are a neighbor of a neighbor of a core pixel, if they are above the `boundary_threshold`

Cleaning Algorithms

- TailcutsImageCleaner
- MARSImageCleaner
- FACTImageCleaner
- TimeConstrainedImageCleaner

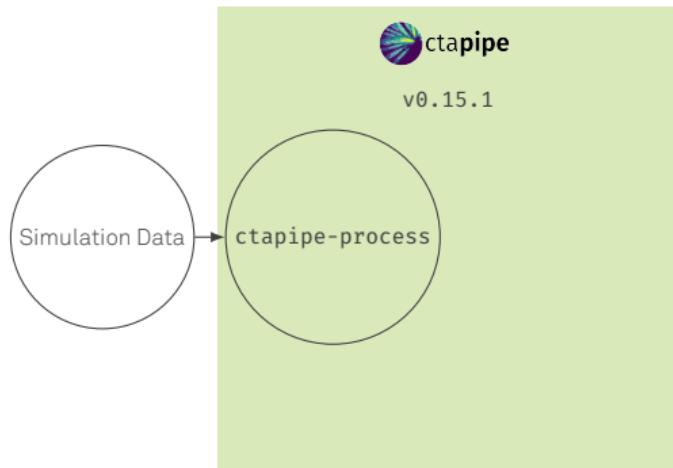
1. Finds all pixels that contain more photons than the picture threshold
2. Removes pixels with less than N neighbors
3. Adds remaining neighbors that are above the boundary threshold
4. Removes pixels that have less than N neighbors and that arrive within a given timeframe
5. Again, removes pixels that have less than N neighbors, also those that arrive within a given timeframe

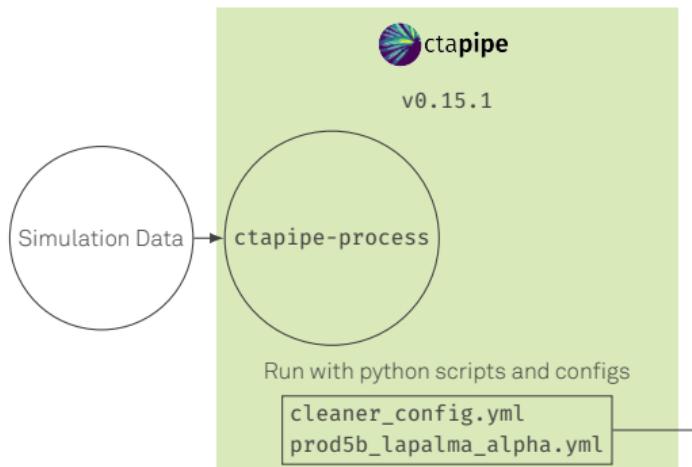
Cleaning Algorithms

- TailcutsImageCleaner
 - MARSImageCleaner
 - FACTImageCleaner
 - TimeConstrainedImageCleaner
1. Finds all core pixels above the `picture threshold`
 2. Removes pixels with less than N neighbors
 3. Removes all pixels that arrive within a time limit of the average arrival time
 4. Finds all pixels above the `boundary threshold`
 5. Removes all pixels with less than N neighbors arriving within a given timeframe

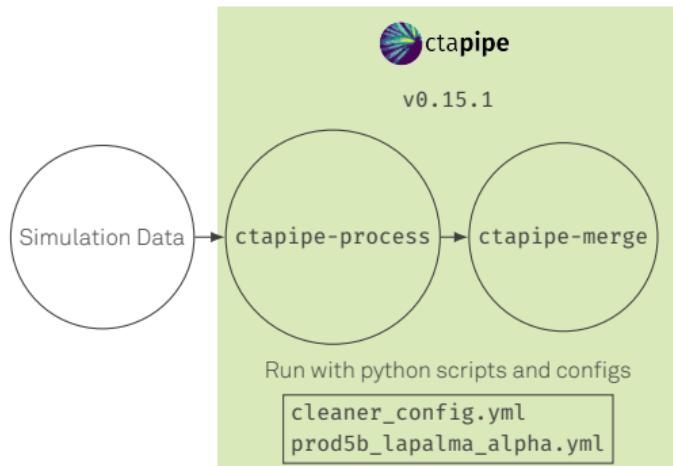
Data Processing with **ctapipe**

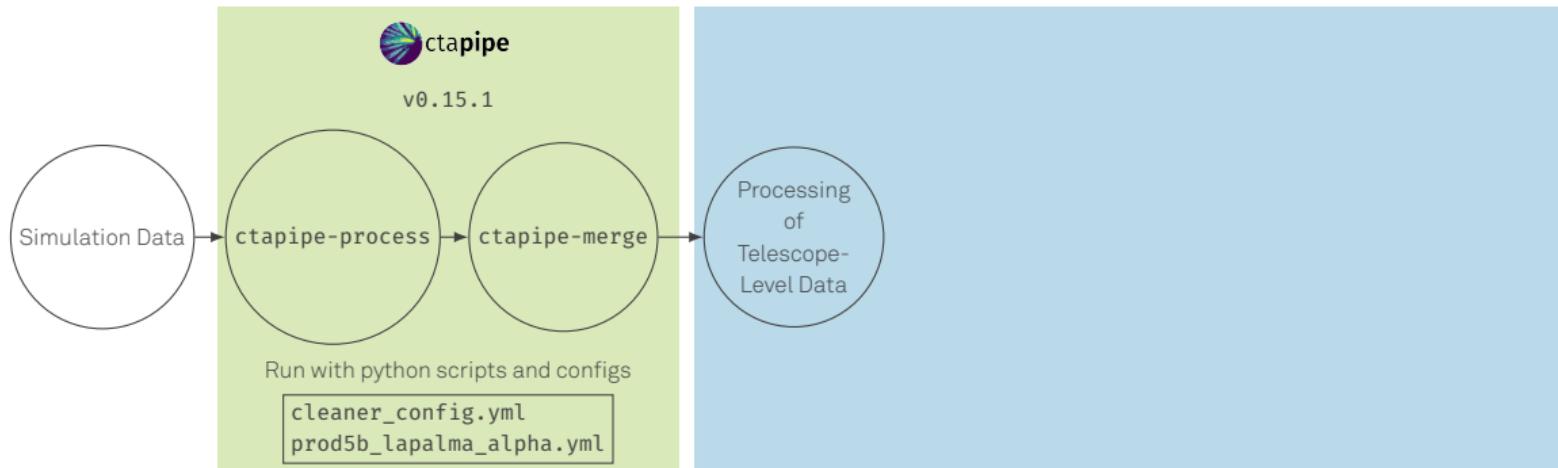


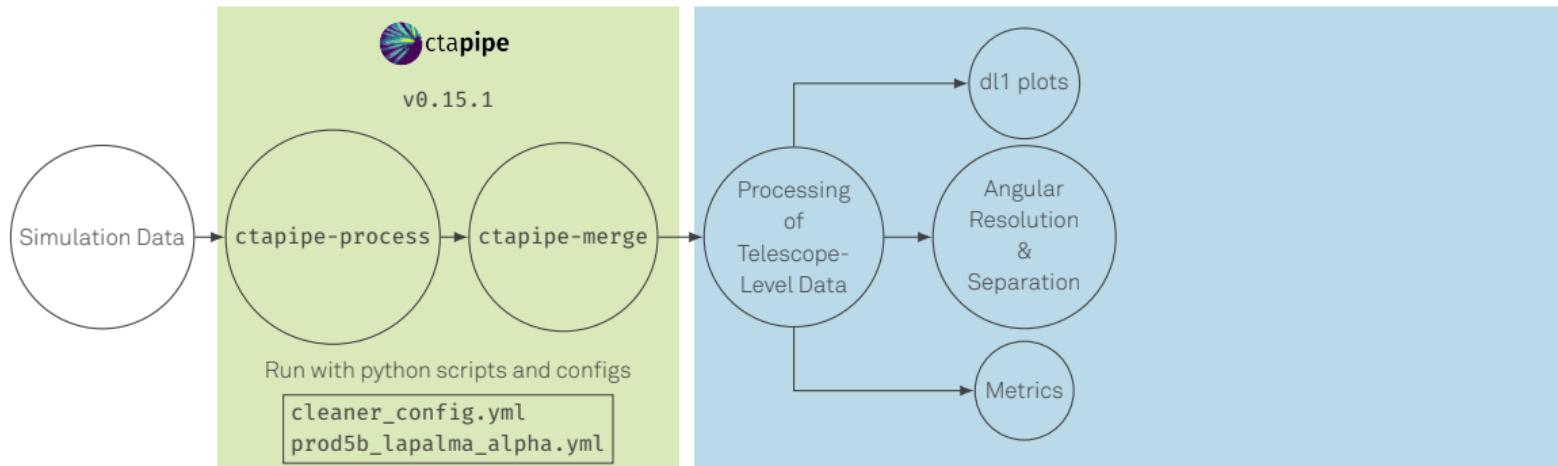


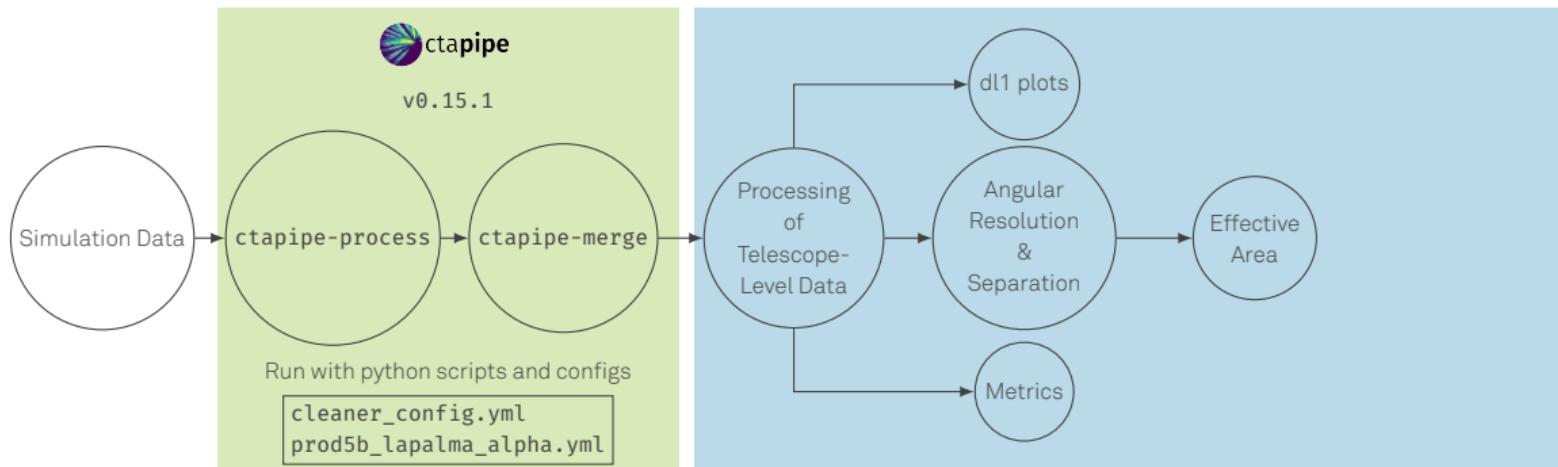


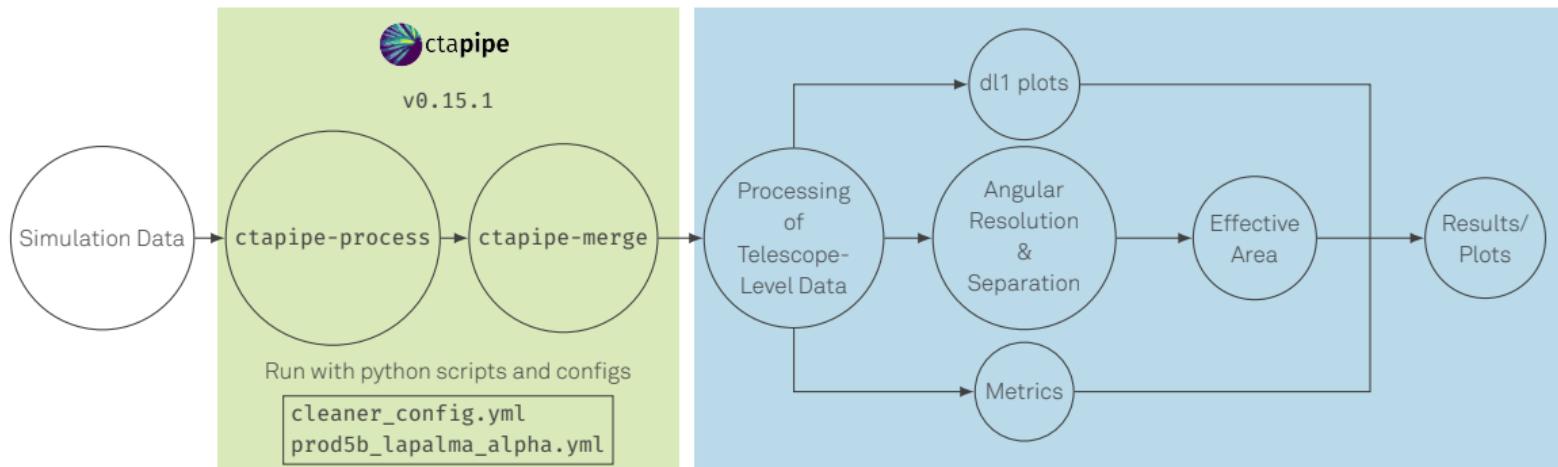
```
ImageProcessor:  
    image_cleaner_type: MARSImageCleaner  
  
MARSImageCleaner:  
    picture_threshold_pe:  
        - [type, "LST*", 8.5]  
        - [type, "MST*NectarCam", 9.0]  
    boundary_threshold_pe:  
        - [type, "LST*", 4.75]  
        - [type, "MST*NectarCam", 4.5]  
    keep_isolated_pixels: false  
    min_picture_neighbors: 2  
  
ImageQualityQuery:  
    quality_criteria:  
        - ["enough_pixels", "np.count_nonzero(image) > 2"]  
        - ["enough_charge", "image.sum() > 50"]
```





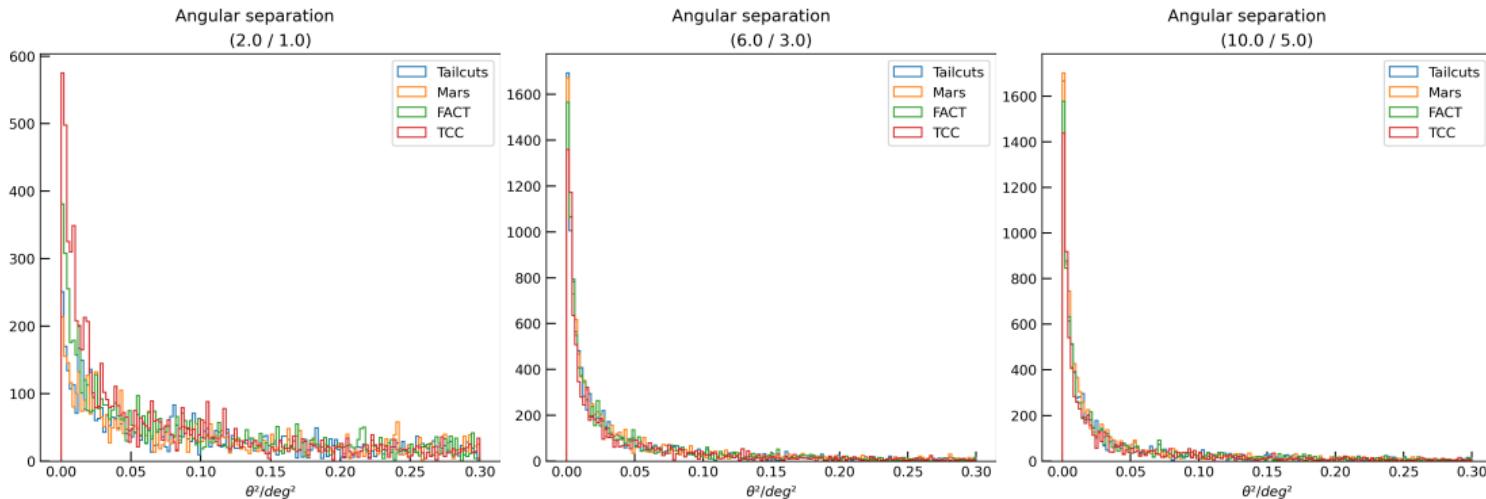




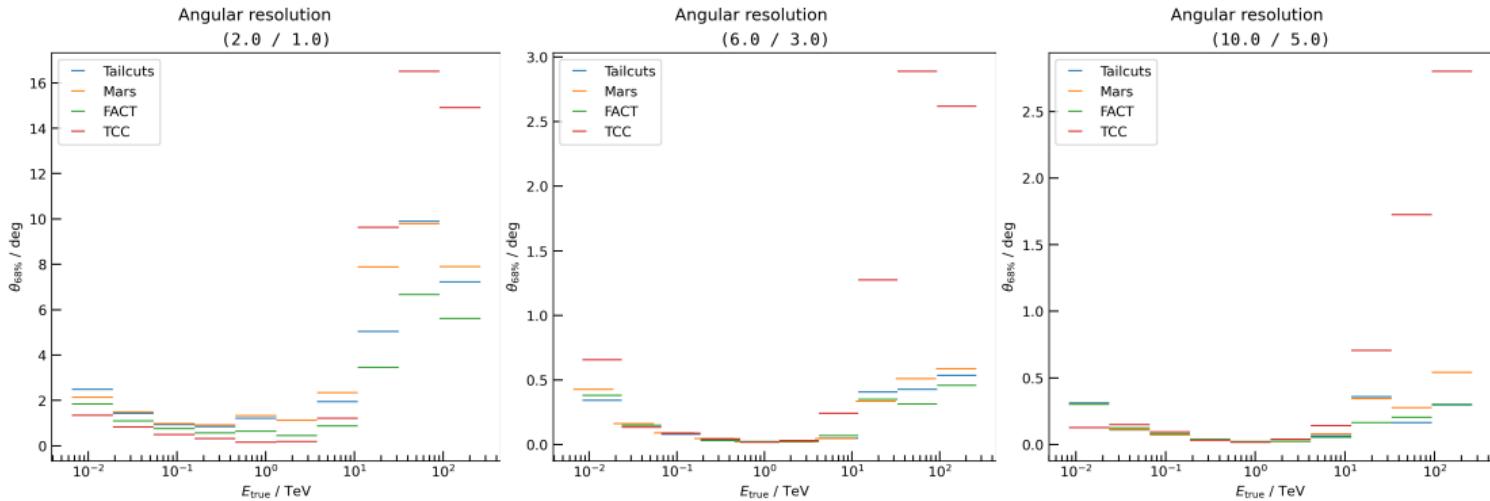


Results

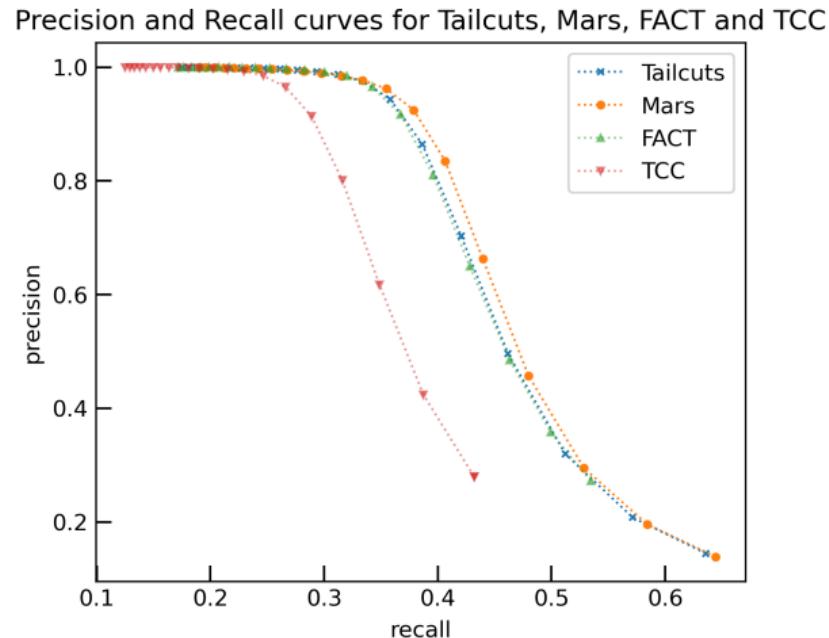
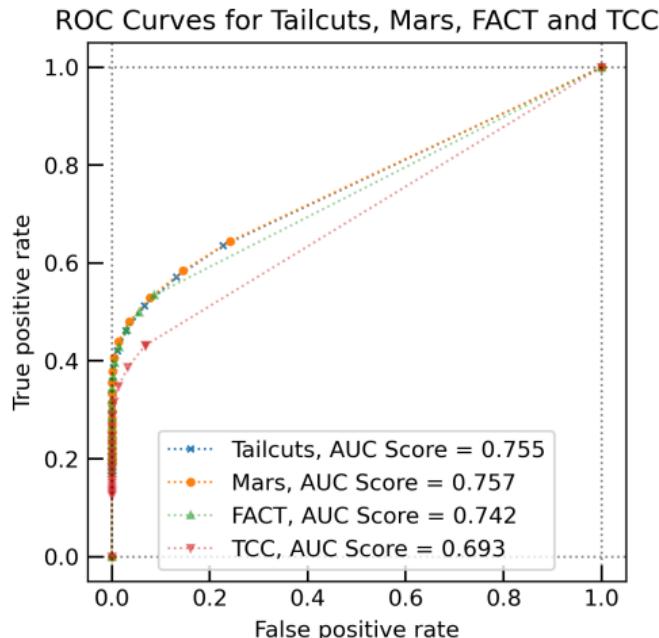
Angular Separation



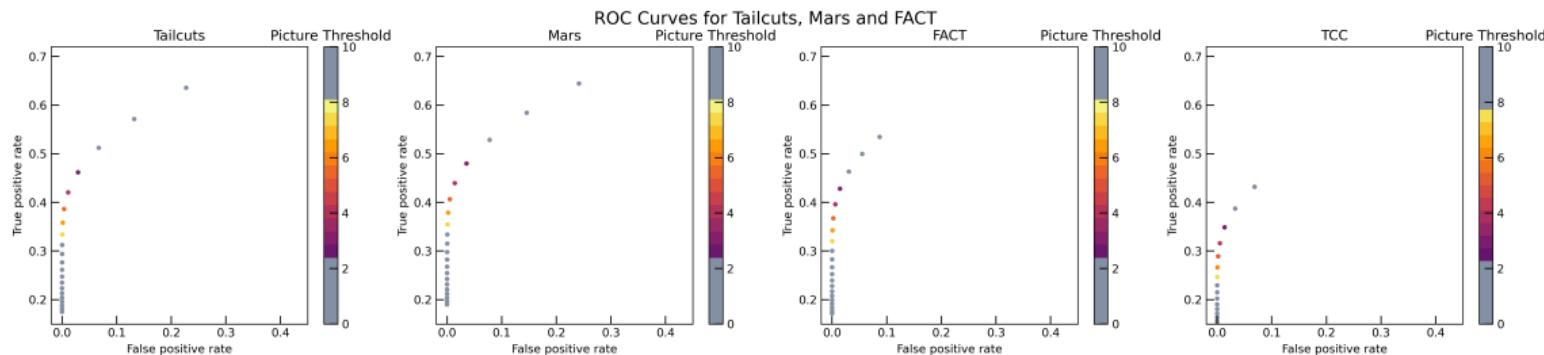
Angular Resolution



ROC curves and precision and recall curves

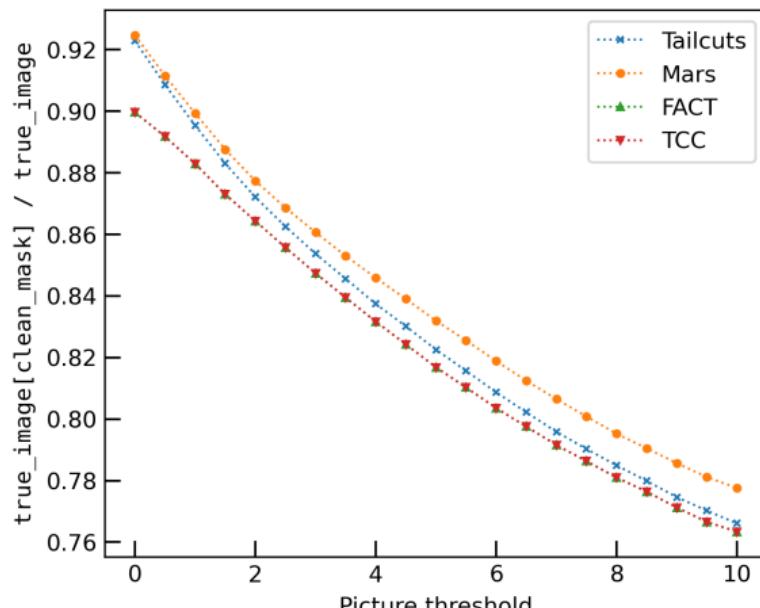
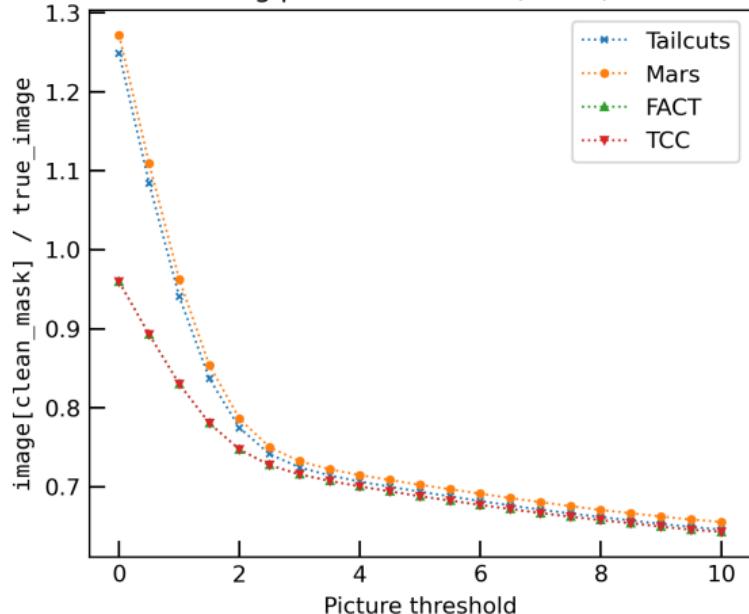


Picture Thresholds



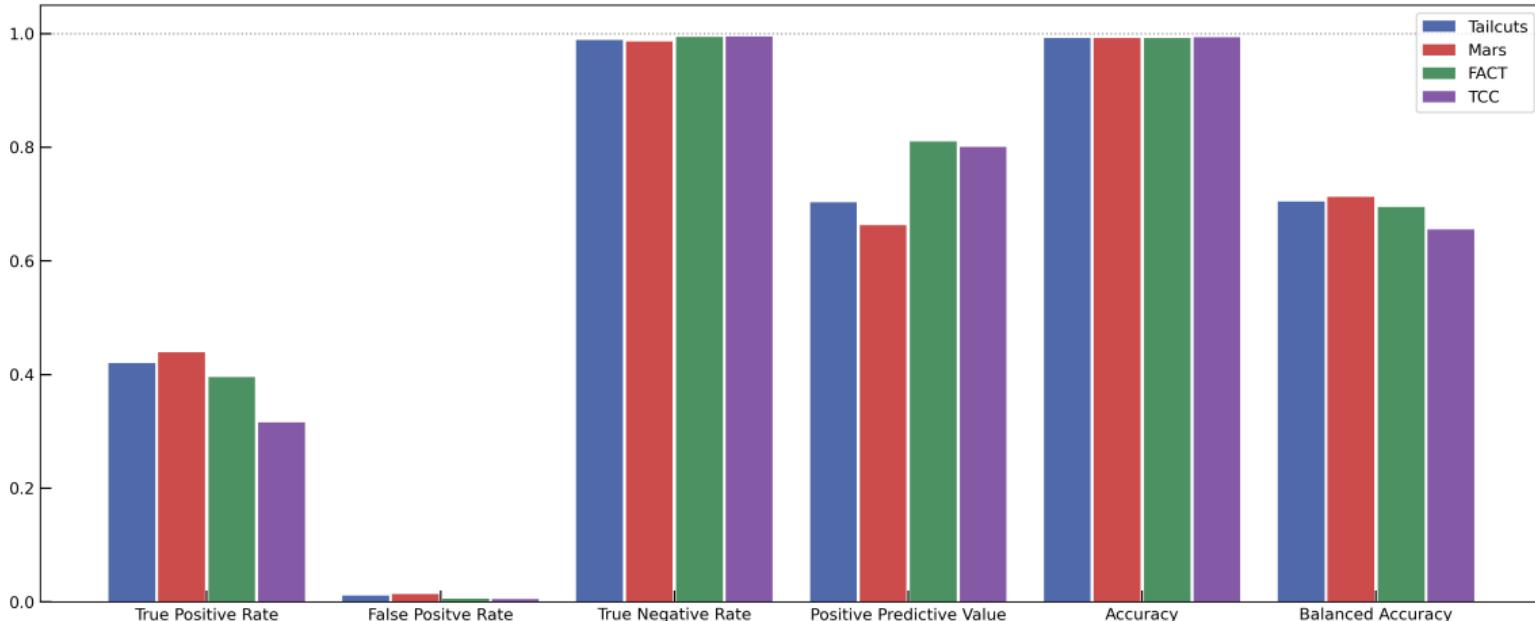
Ratio of Surviving Pixels

Ratio of surviving pixels for Tailcuts, Mars, FACT and TCC



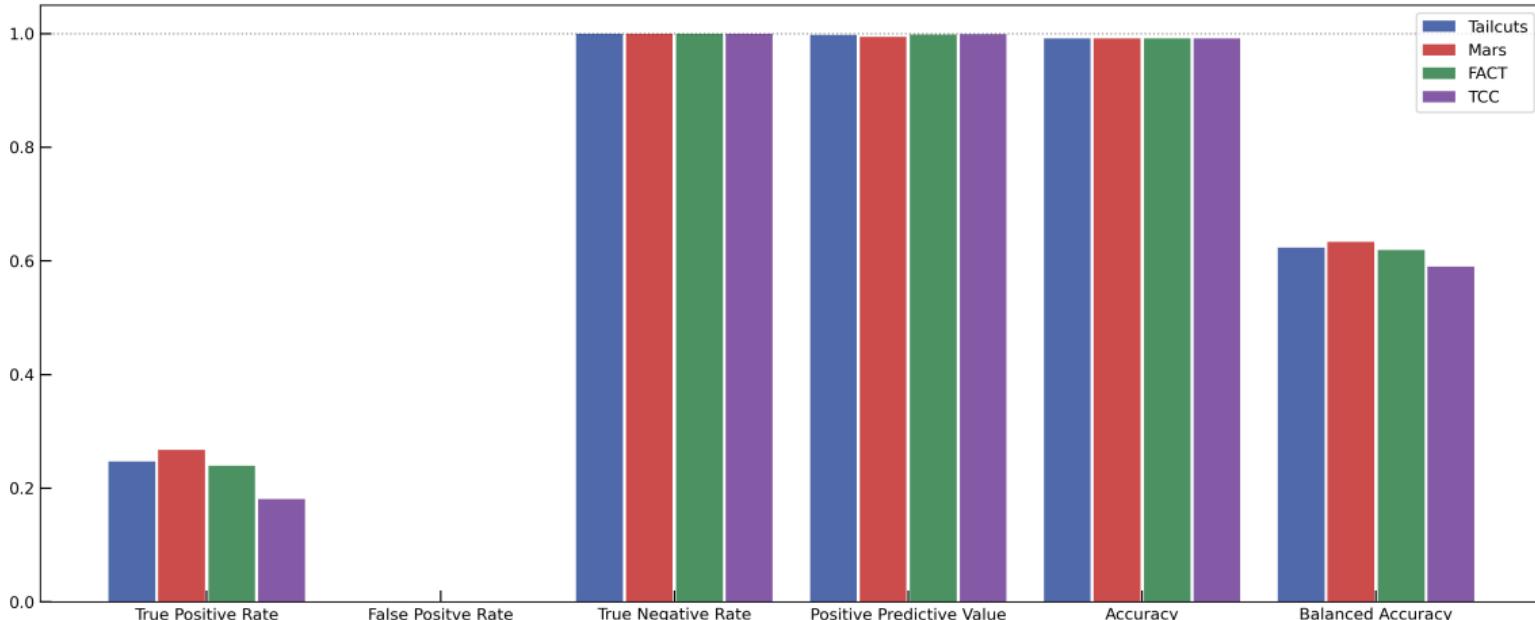
Metrics

Metrics for Tailcuts, Mars, FACT and TCC
(2.0 / 1.0)



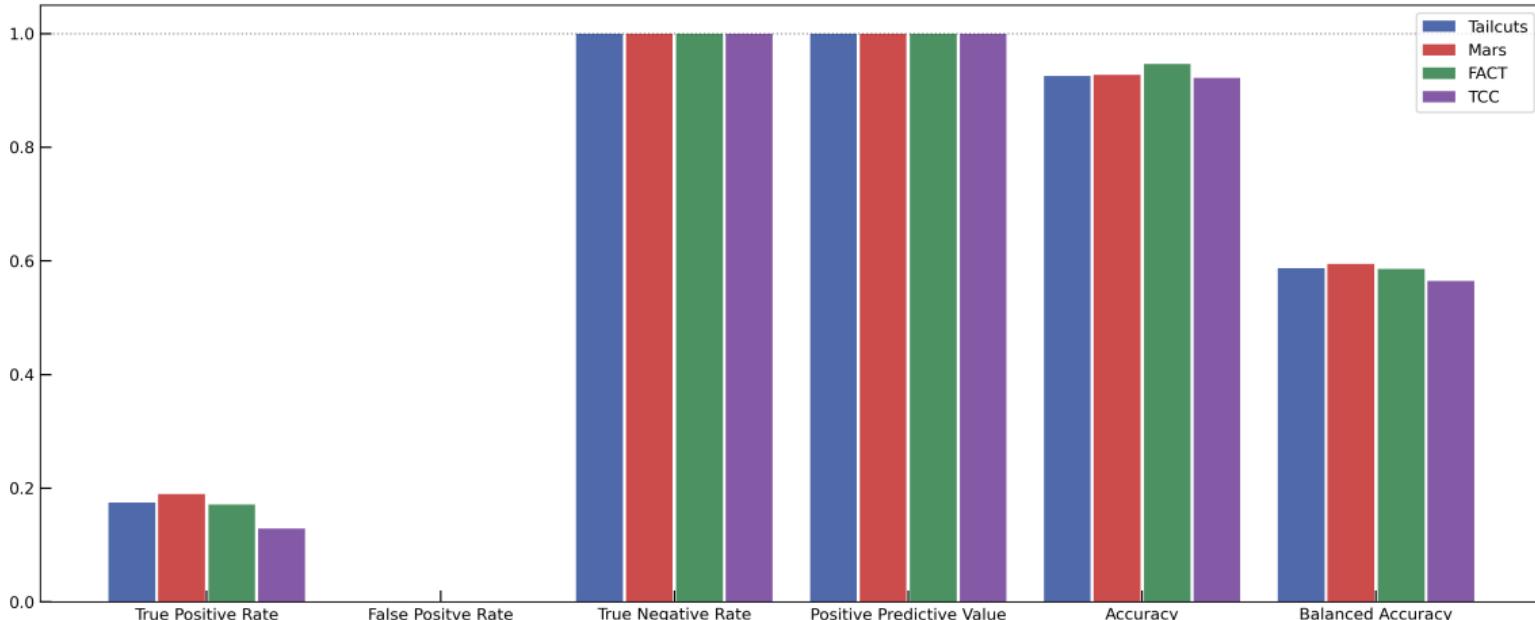
Metrics

Metrics for Tailcuts, Mars, FACT and TCC
(6.0 / 3.0)



Metrics

Metrics for Tailcuts, Mars, FACT and TCC
(10.0 / 5.0)



Outlook and Summary

Outlook

- Compare cleaners for other parameters than the `picture` and `boundary thresholds`
 - Use `sklearn.model_selection.Parametergrid` to find the best parameters for each cleaner
- Instead of letting the `picture threshold` vary from 0 to 10, use quantiles
- Vary the `boundary thresholds` as 0.25, 0.33, 0.5 and 0.75 of the `picture threshold`



Problem

- Run time and number of datasets increase with the number of parameters
 - For TailcutsImageCleaner and MarsImageCleaner alone, this results in 32 possible combinations of parameters:

```
params = {
    "picture_quantiles": (0.9, 0.99, 0.995, 0.999),
    "boundary_threshold_ratio": (0.25, 0.33, 0.5, 0.75),
    "min_number_picture_neighbors": (1, 2)
}
```

- Add only two parameters for FACTImageCleaner and this number increases to 64 possible combinations

```
fact_params["time_limit"] = (2, 5)
```

Summary

- So far, a picture threshold of ≈ 6.0 seems to be the best choice w.r.t. to the metrics
 - Has to be tested again for combinations with other parameters
- Testing other ratios than 0.5 for the boundary thresholds seems to be a rational next step
- With sklearns ParameterGrid, it is hopefully possible to find the best parameters for each cleaner

