Investigating variations seen in 20 years of muon efficiency data from the H.E.S.S. Experiment

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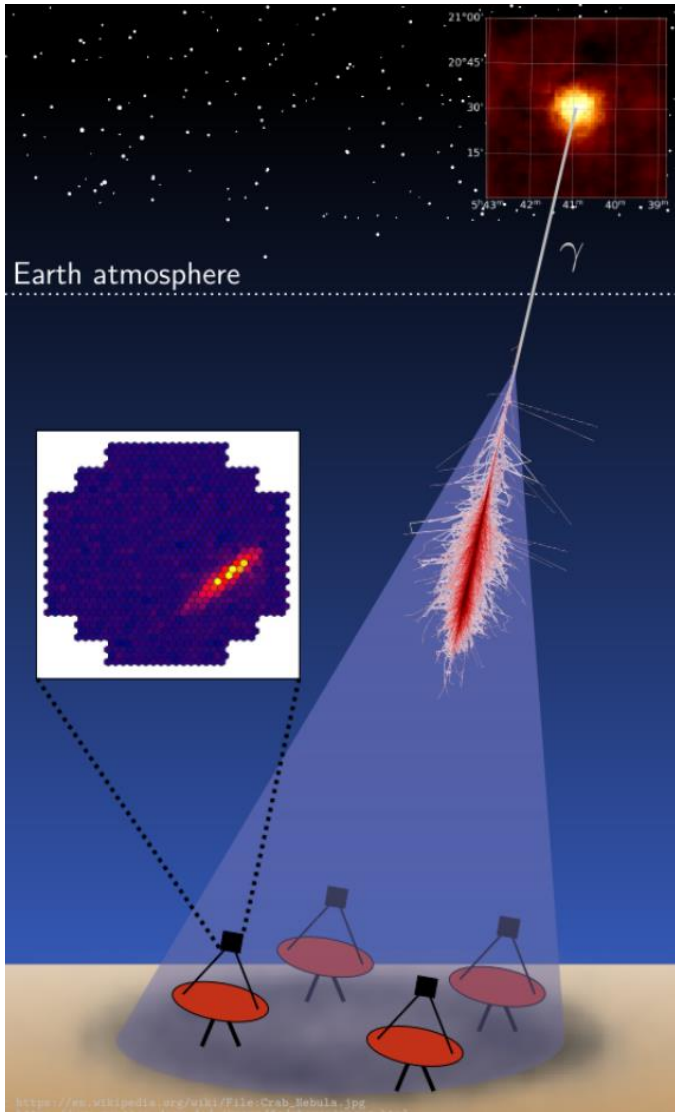
HELMHOLTZ WEIZMANN
RESEARCH SCHOOL
MULTIMESSENGER ASTRONOMY

Gamma-ray astronomy with H.E.S.S.

The **High Energy Stereoscopic System**:

- 5 imaging atmospheric Cherenkov telescopes
- Very high energy astronomy: 10s GeV – 100 TeV
- Observing since 2004



Aerosols effect on

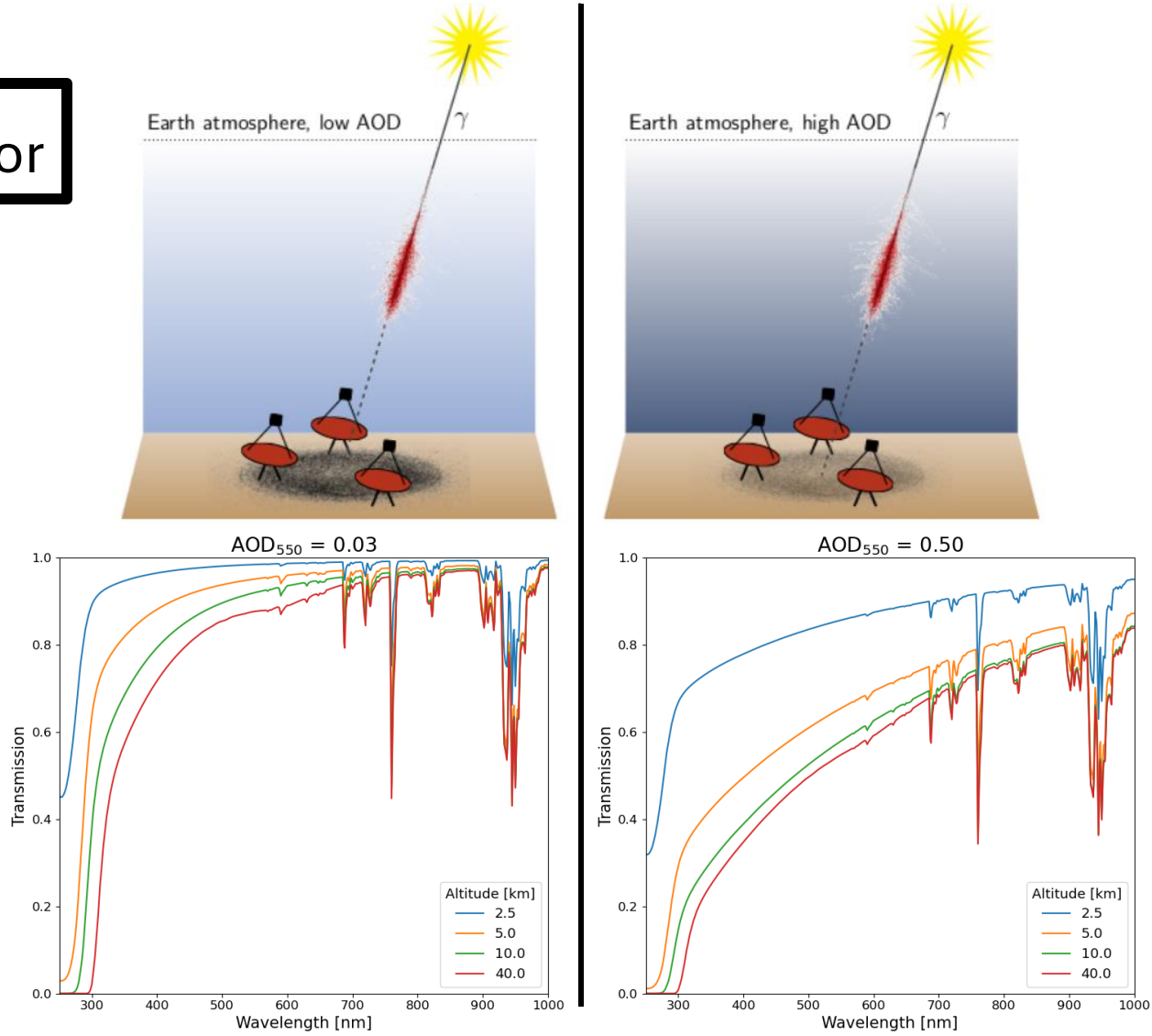
ATMOSPHERE = CALORIMETER of our detector

- Higher transparency

  shift towards lower energies

- Lower transparency

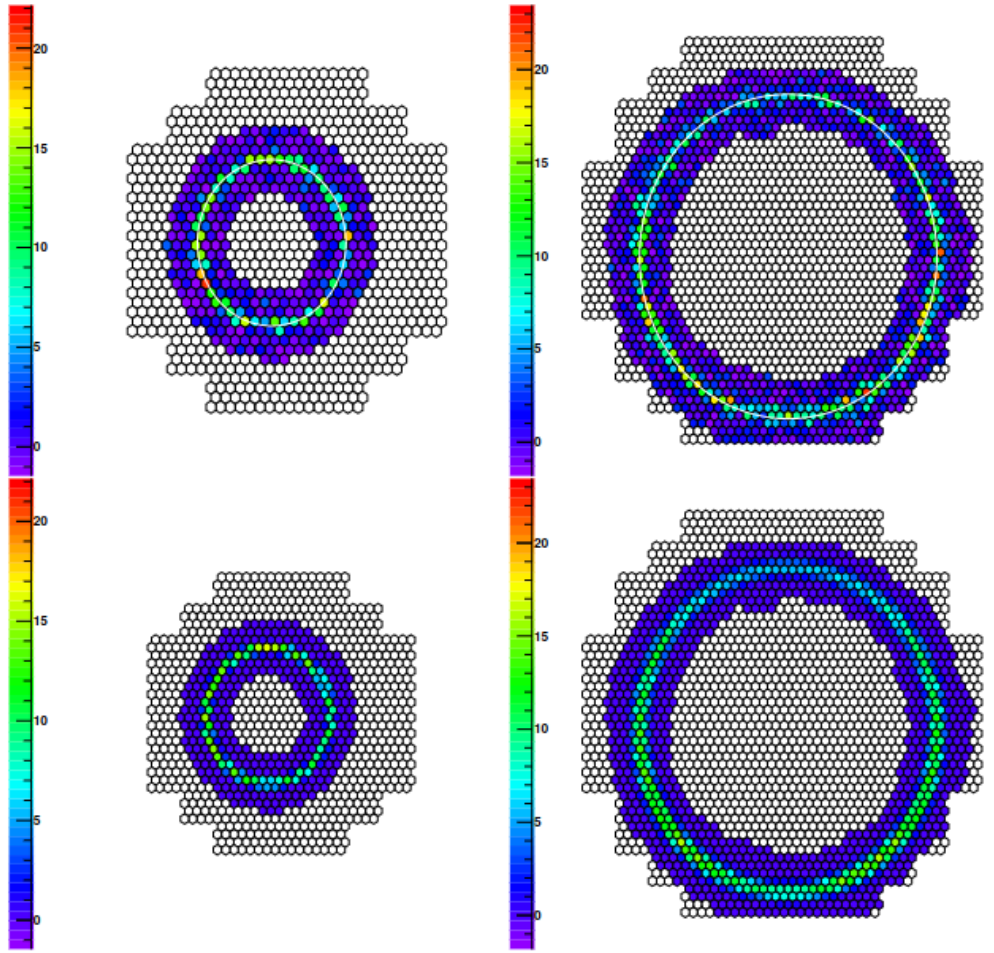
  shift towards higher energies



Optical calibration – Muon efficiency

- Muons produce **ring-like** images
- Muon **energy** well known for a given **radius**
- Ratio between reconstructed and real energy

Muon efficiency μ_{eff}



Alison Mitchell, PhD thesis, 2016

Optical calibration – Muon efficiency

- Global optical efficiency: Camera + Mirrors
- Selection / cleaning cuts: NSB, broken pixels …
- Position dependence: across camera and mirror dish
- Limited number of muons per run
- Atmospheric variables

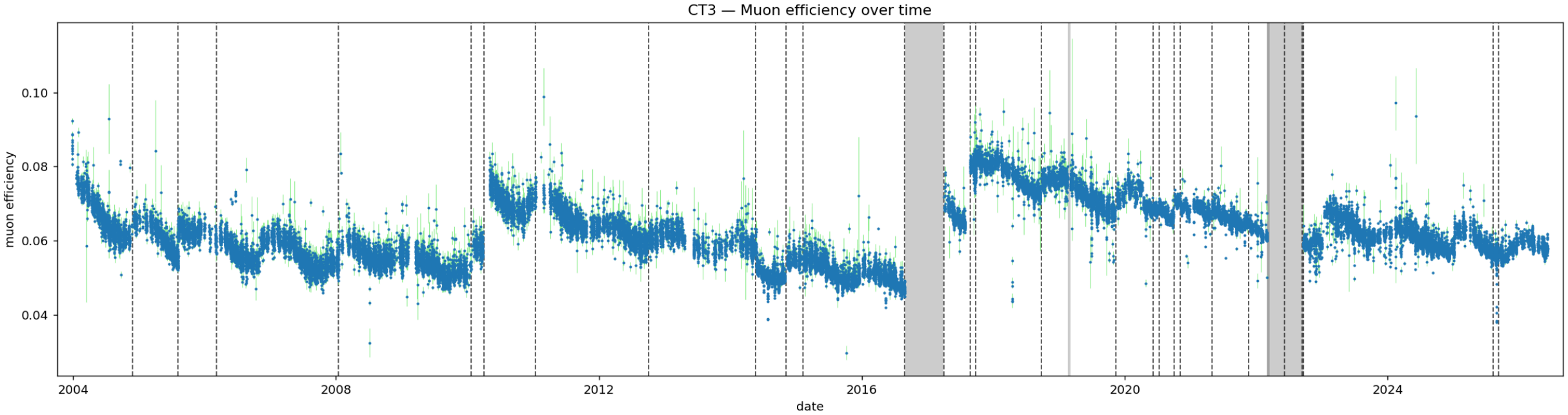
Long term muon efficiency – Hardware changes

Long term downtrend:

- Mirrors reflectivity degradation
- PMTs aging

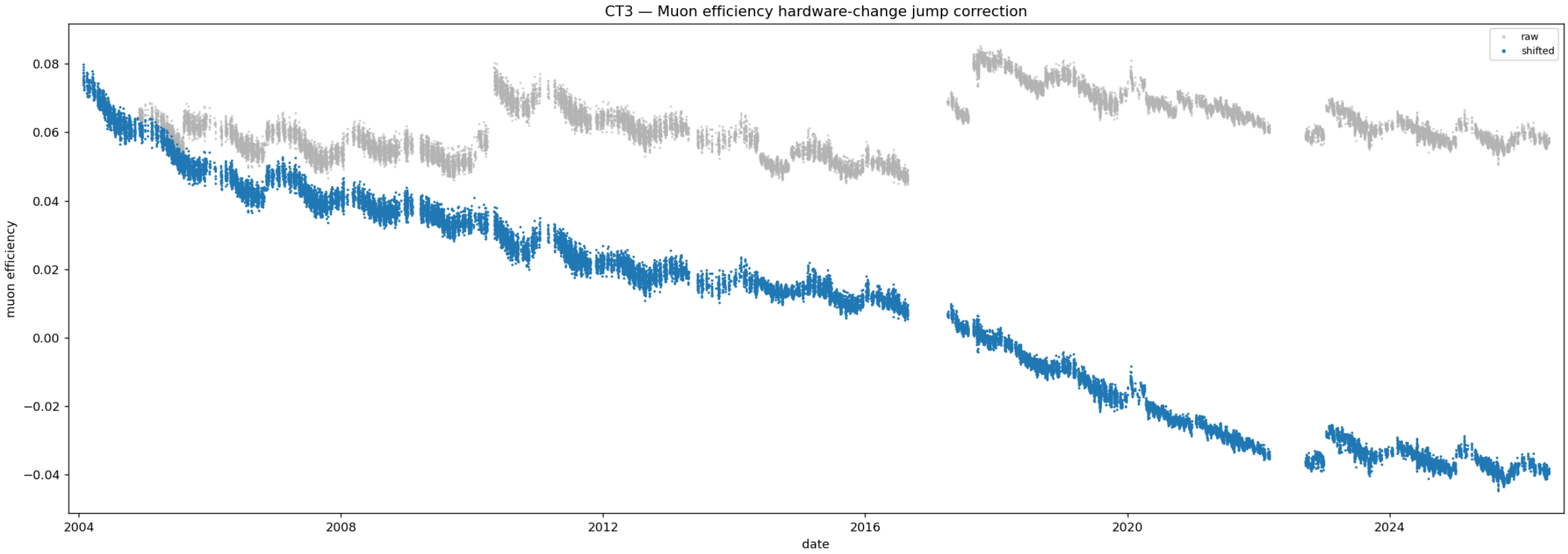
Hardware changes and calibration adjustments:

- Mirrors refurbished
- PMTs cleaned
- Gain re-adjustments
- Camera upgrades



Long term muon efficiency – Hardware changes

Correcting by known hardware changes and calibration adjustments



Long term muon efficiency – Hardware changes

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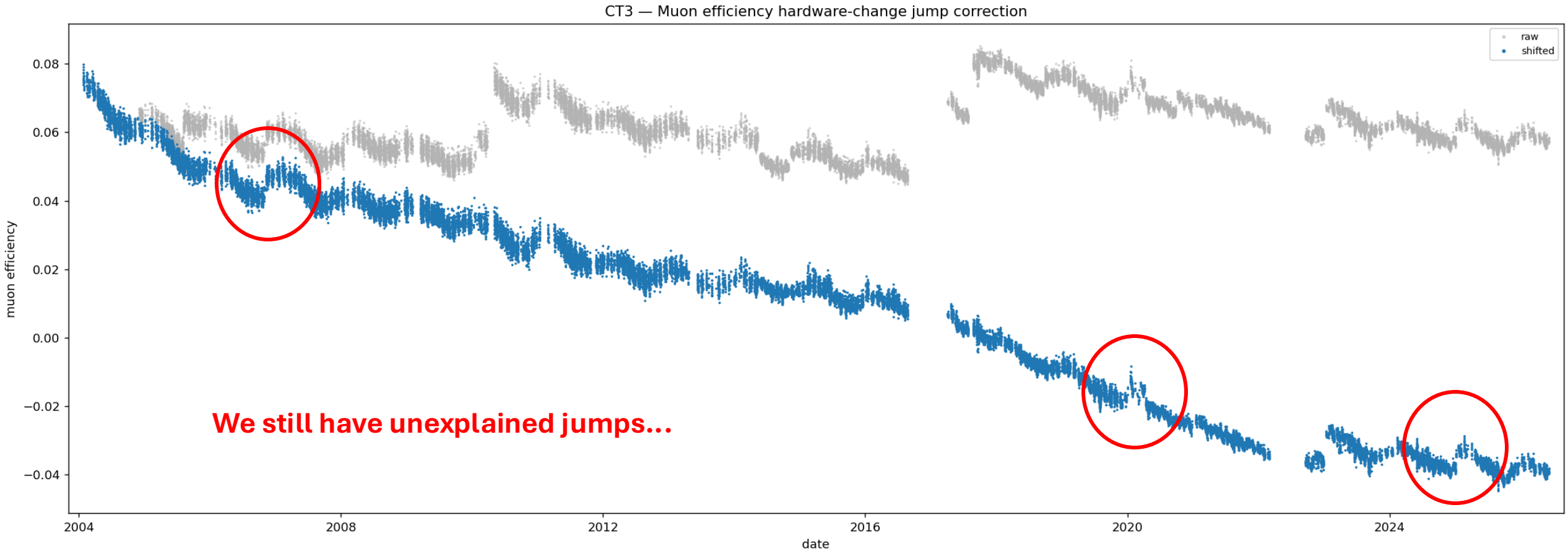
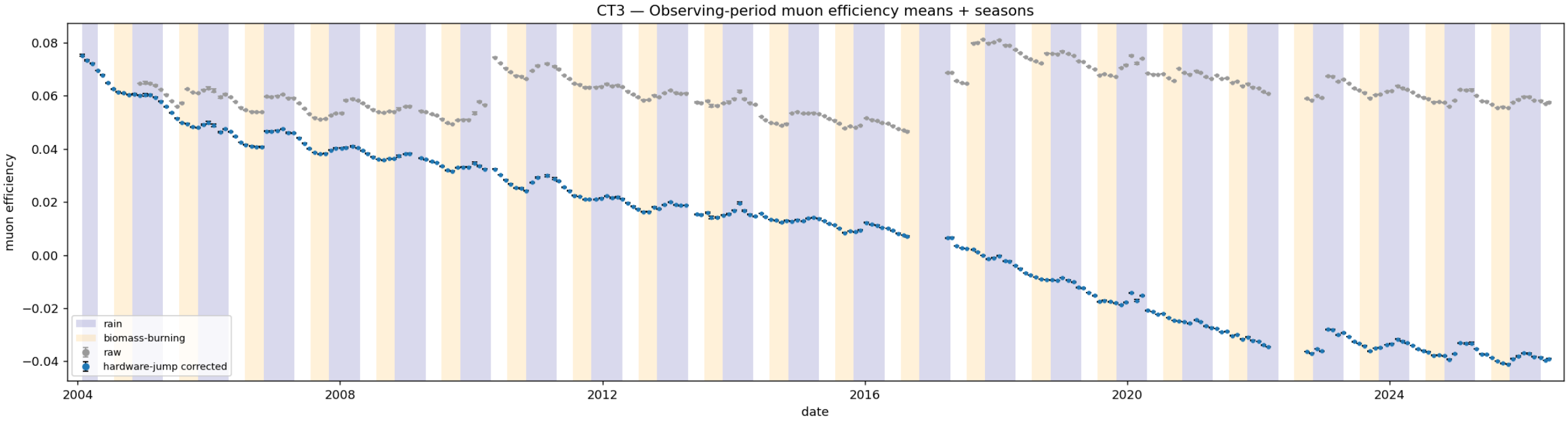


Long term muon efficiency - Rain

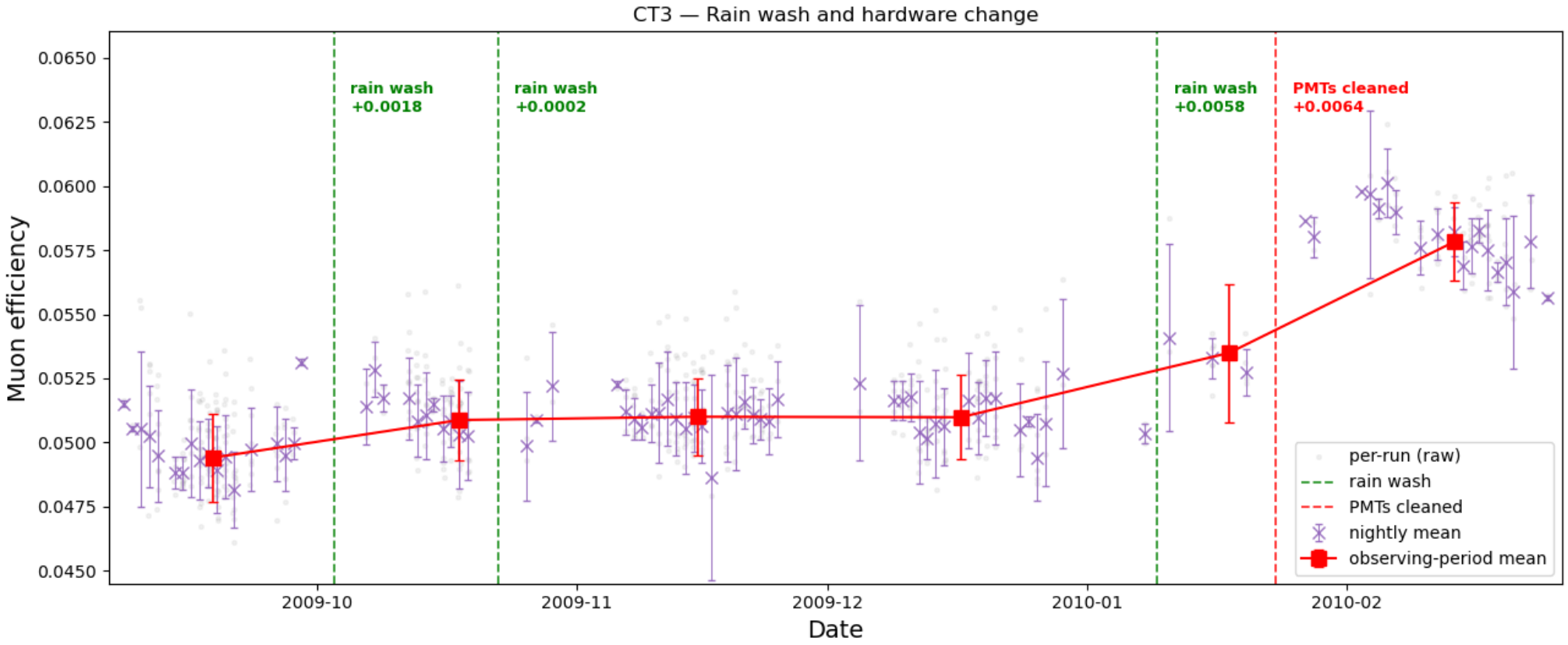
Biomass-burning season:
- August – October
- Elevated aerosol levels

Rainy season:
- November – April
- Mirrors get washed?



Long term muon efficiency - Rain

- Rain gauge at the H.E.S.S site

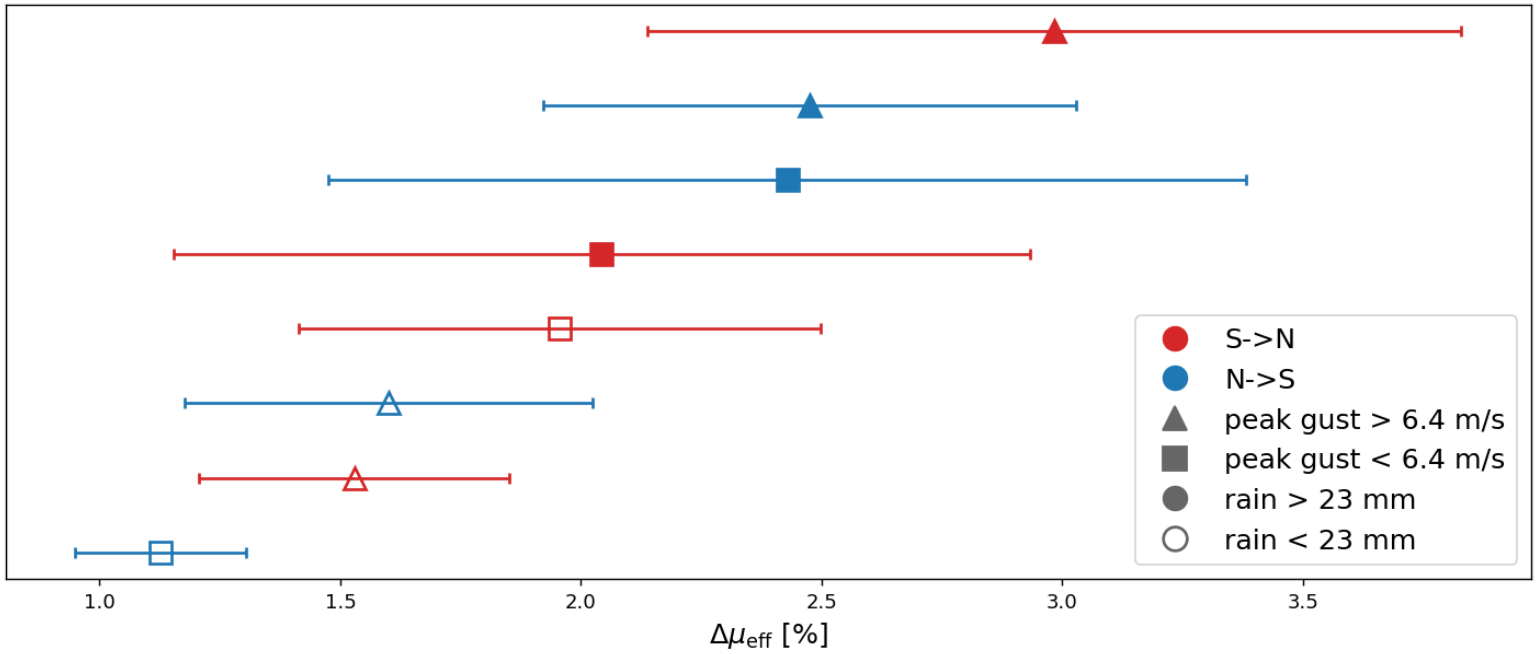


Rain washes the mirrors!

Long term muon efficiency - Rain

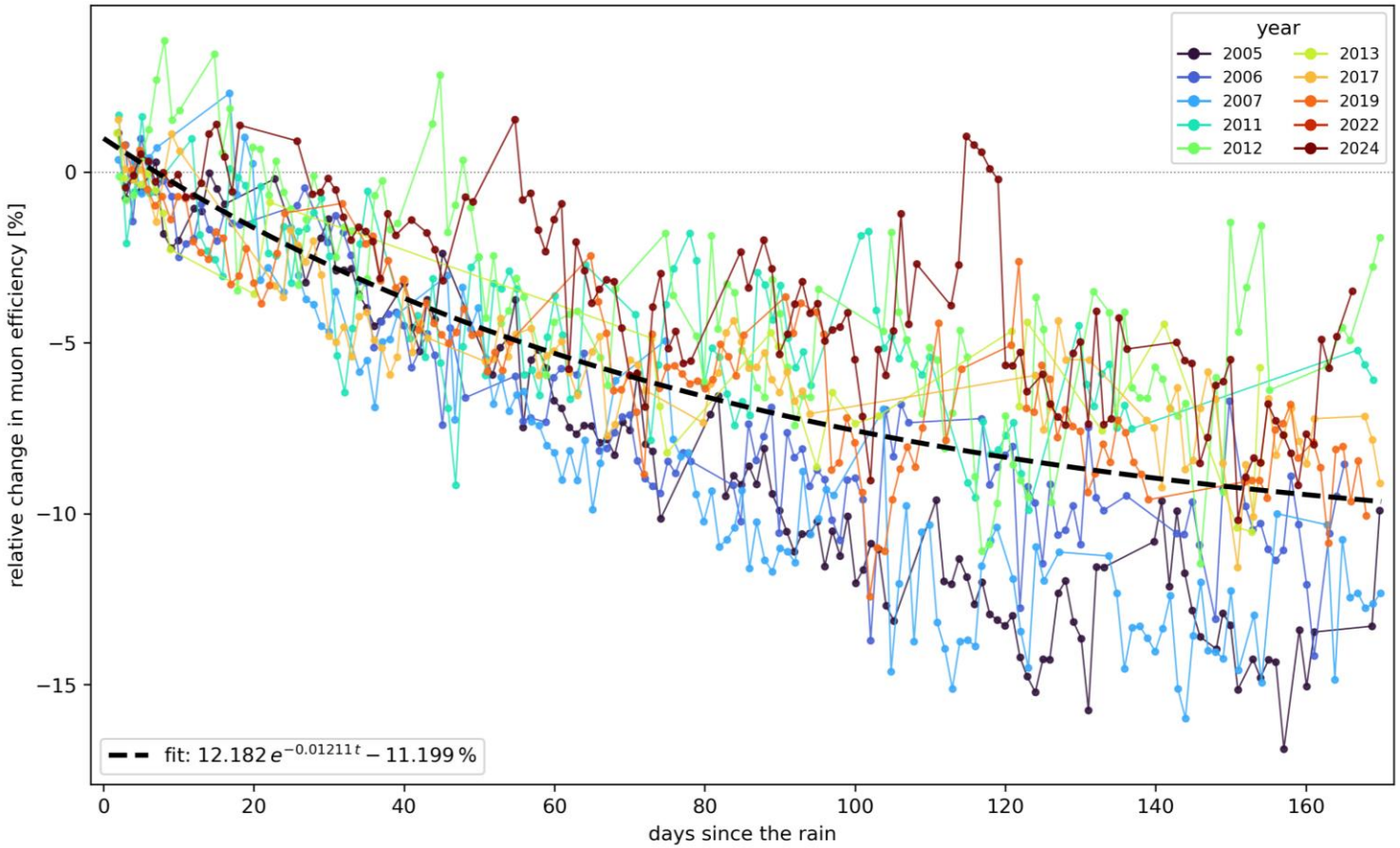
Trying to understand better the rain effect…

- Rain data is daily *(rain gauge)*
- Wind data is hourly but not local *(ERA5-Land reanalysis dataset)*
- Low number of rain events



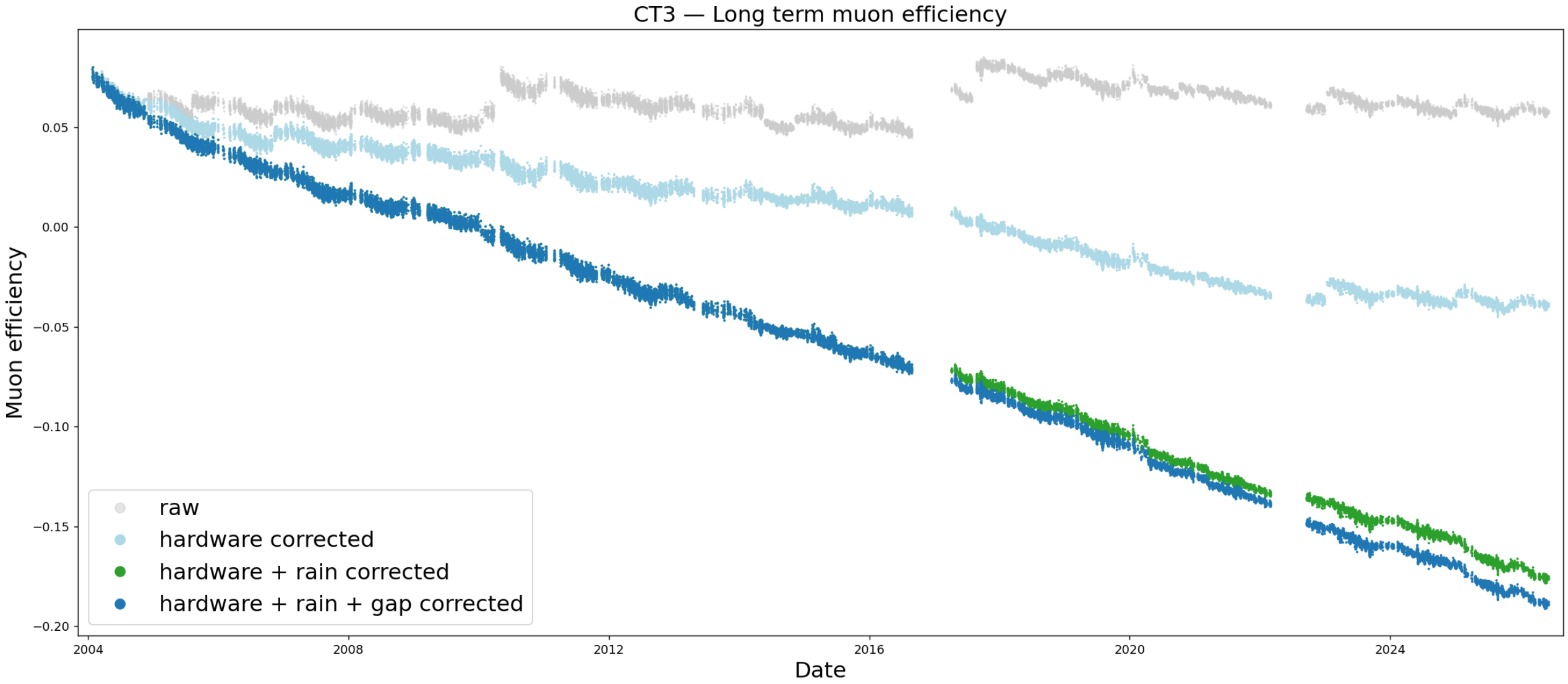
Long term muon efficiency - Rain

- Muon efficiency decreases fast
- Reaches a plateau at ~200 days
- Power-law decay after rain

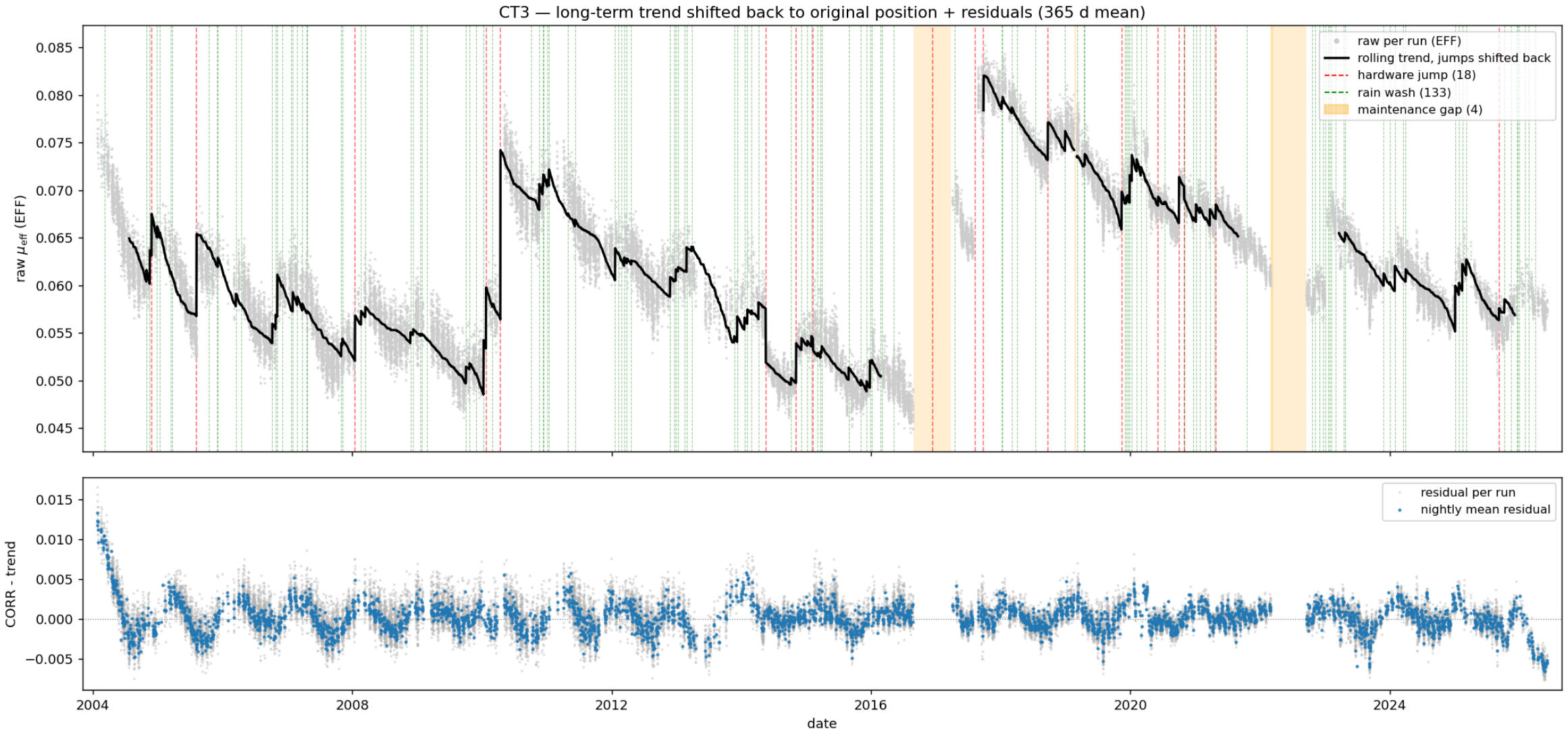


Accumulation of dust after the rain washes the mirror?

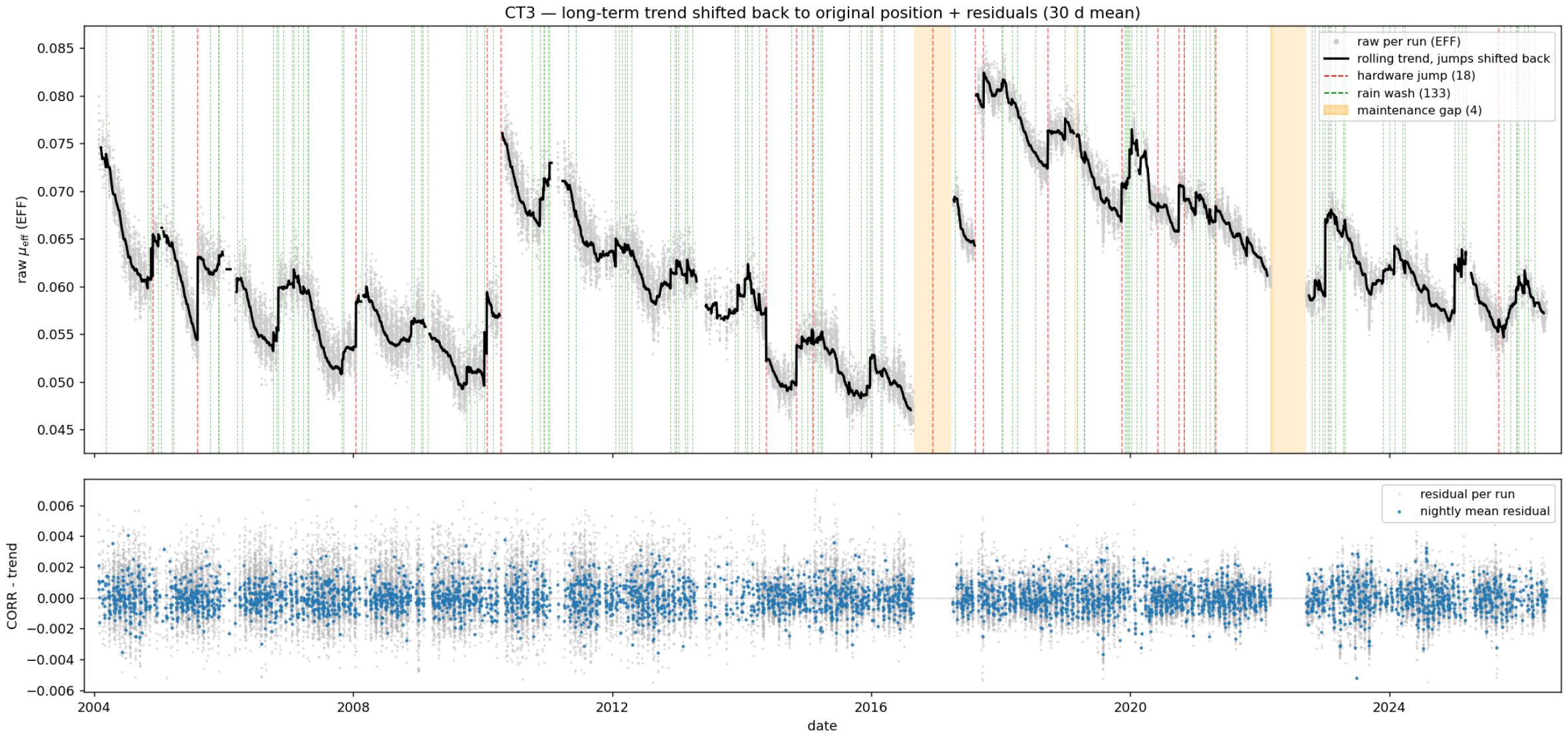
Long term muon efficiency



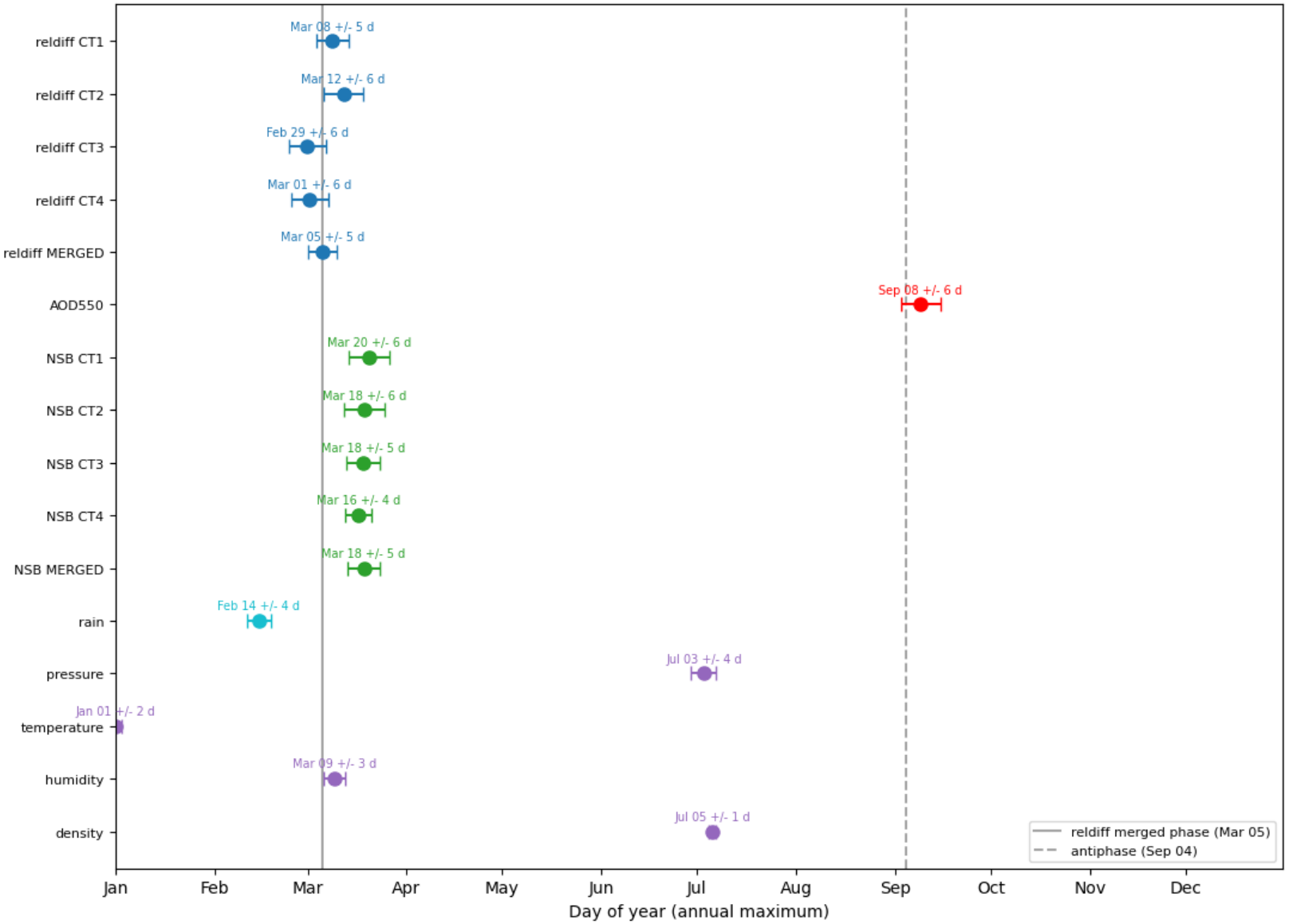
Long term muon efficiency – 365 days rolling average



Long term muon efficiency – 30 days rolling average



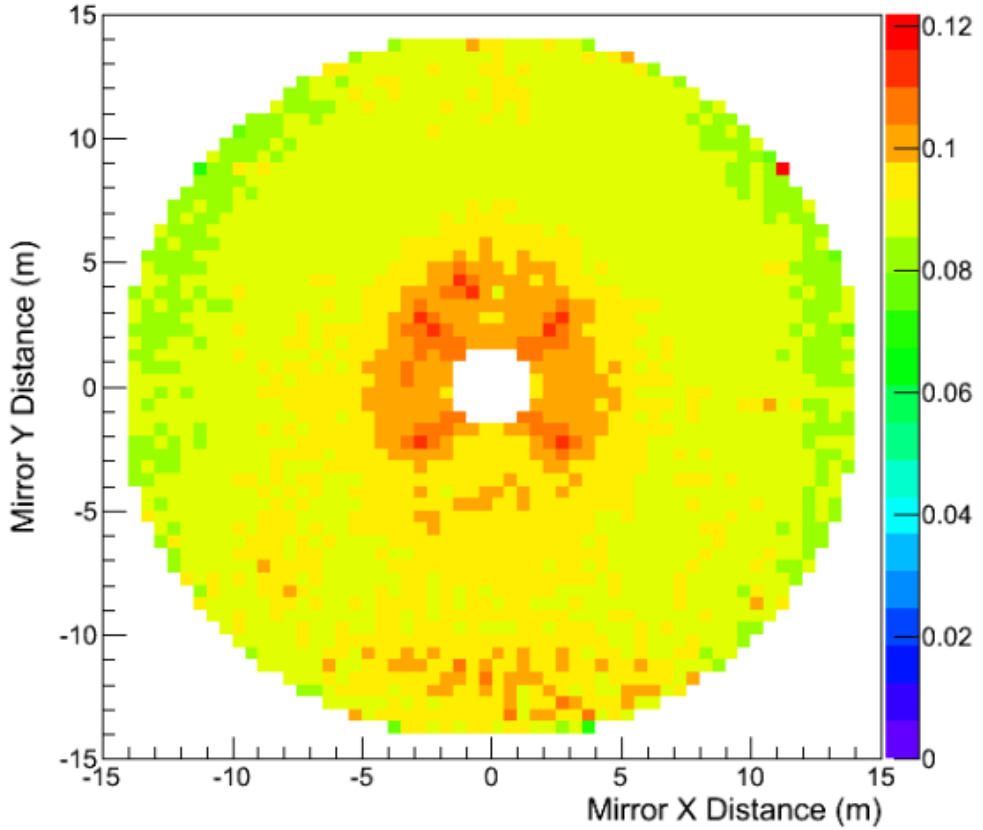
Long term muon efficiency – Periodic oscillations



Long term muon efficiency

There are still many variables probably modelling these oscillations we see:

- Night sky background (NSB)
- Aerosol optical depth (AOD)
- Temperature, pressure, humidity
- Non-homogeneous degradation of the mirrors



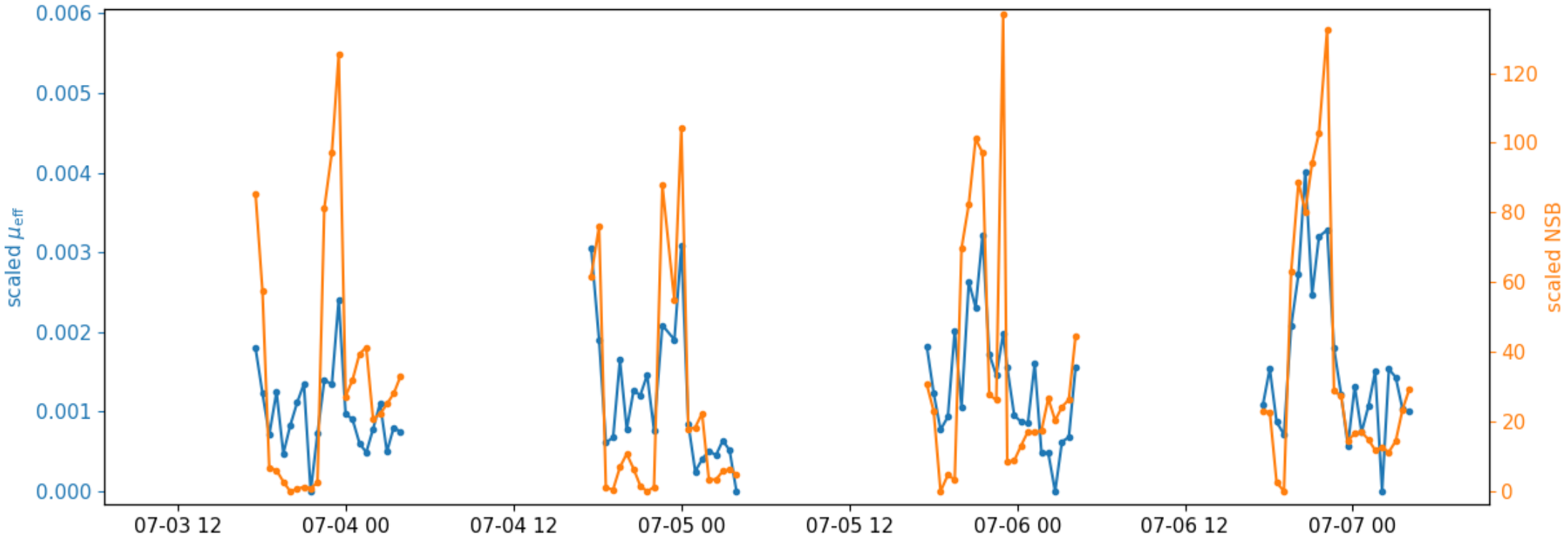
Alison Mitchell, PhD thesis, 2016

And we are also probably missing:

- Hardware changes not logged
- Rain events not registered

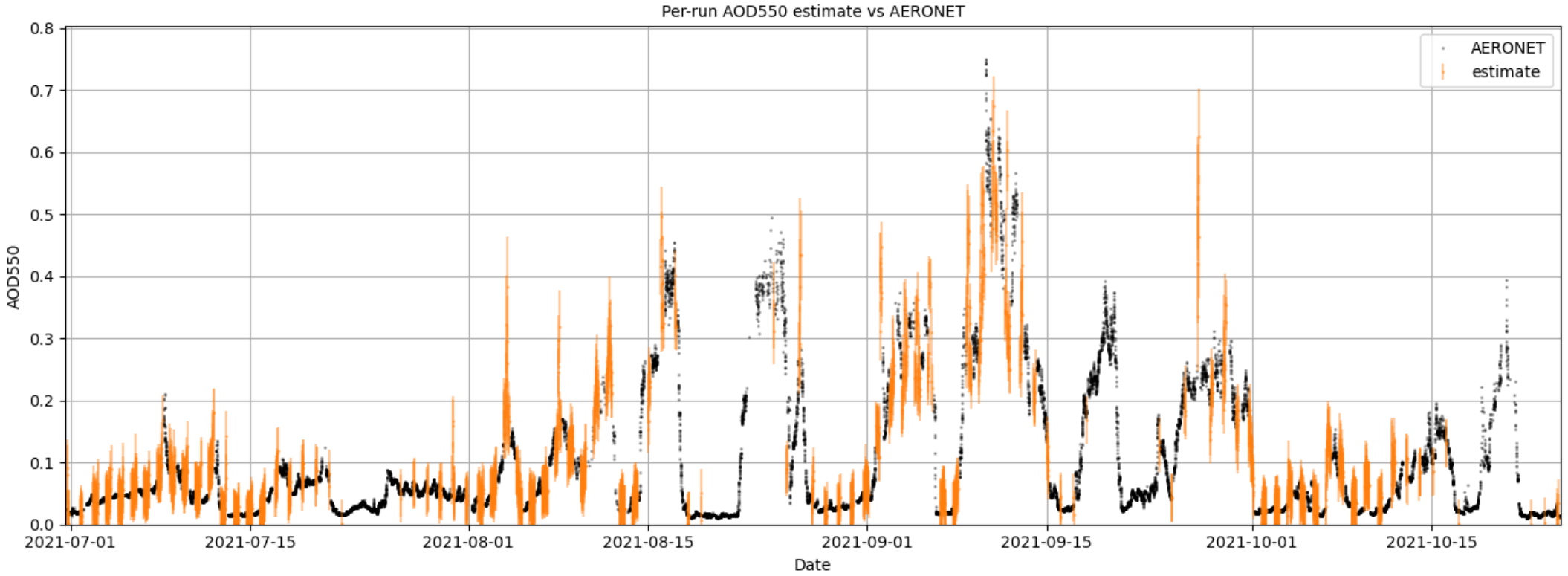
Long term muon efficiency - NSB

- There is clearly some correlation, but it does not show up everywhere
- Might be masked by other parameters affecting the muon efficiency?



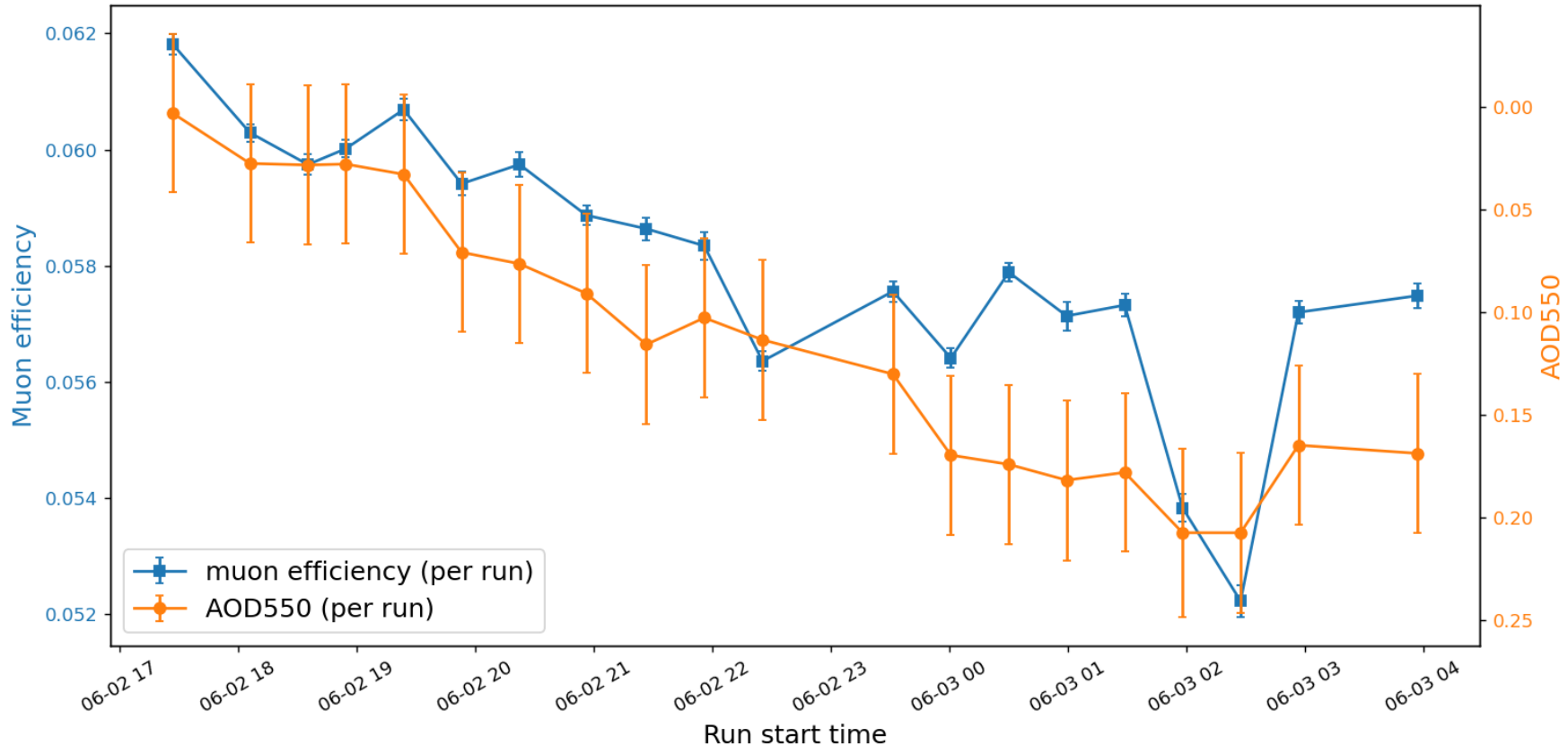
Long term muon efficiency - AOD

- AOD is very local in time
- Only data from AERONET
- Telescope trigger rate → Atmospheric transparency coeff. → AOD estimate per-run

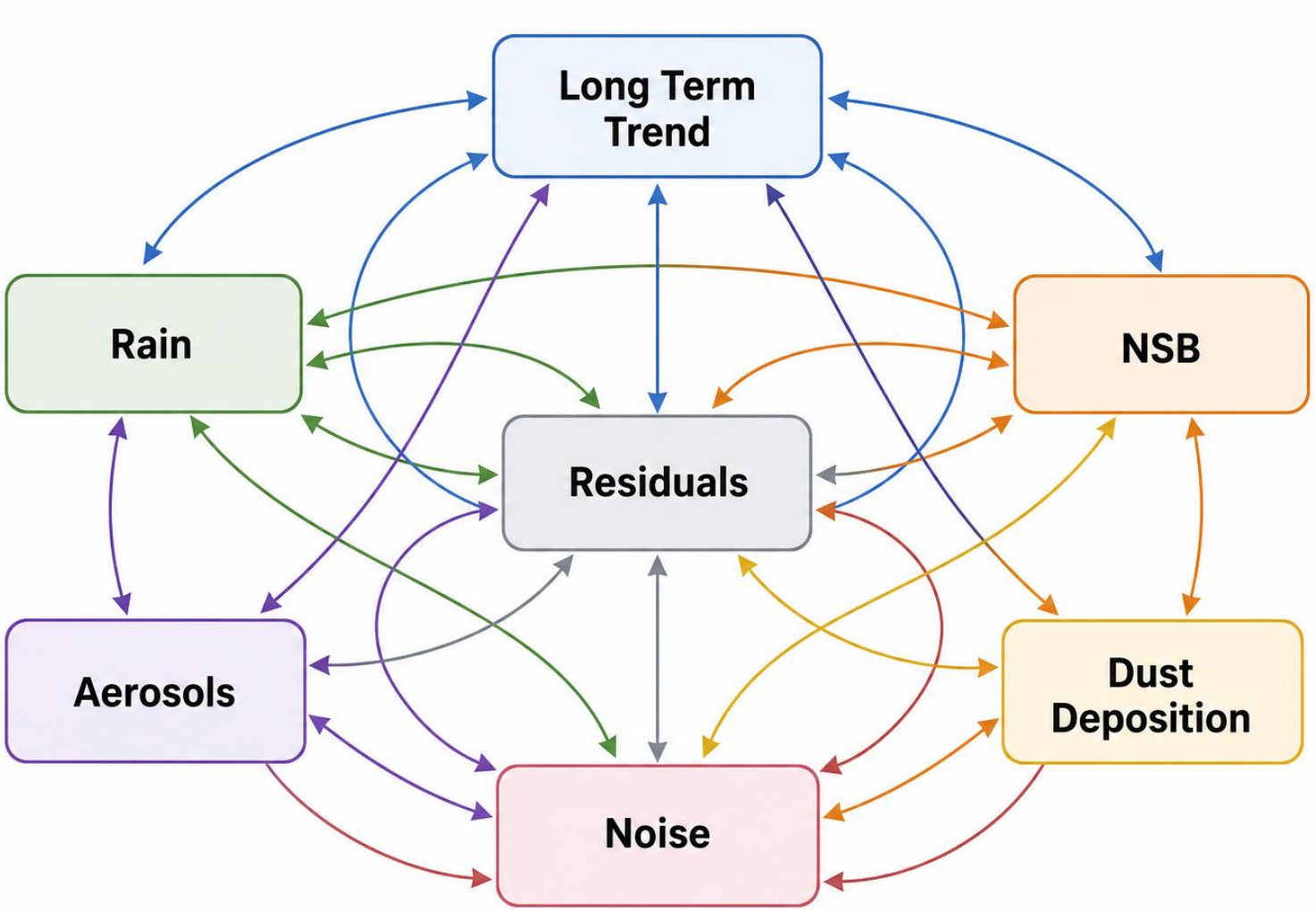


Long term muon efficiency - AOD

- Biomass-burning season (Aug – Oct) ⟶ Lowest point of the oscillations
- We also see intra-night correlations, but not always



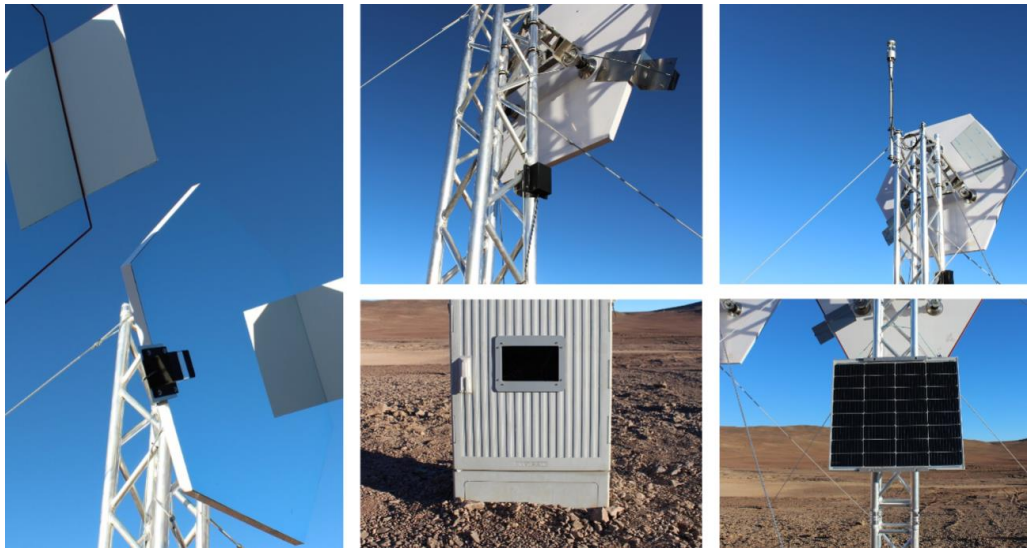
The disentanglement problem



Mirror test stand in Chile

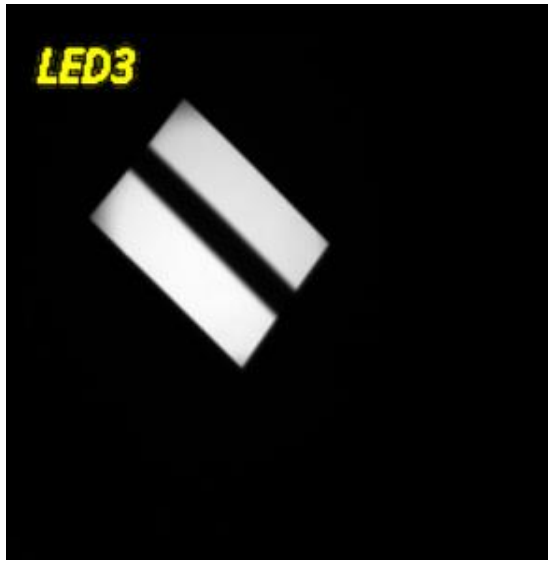
Setup:

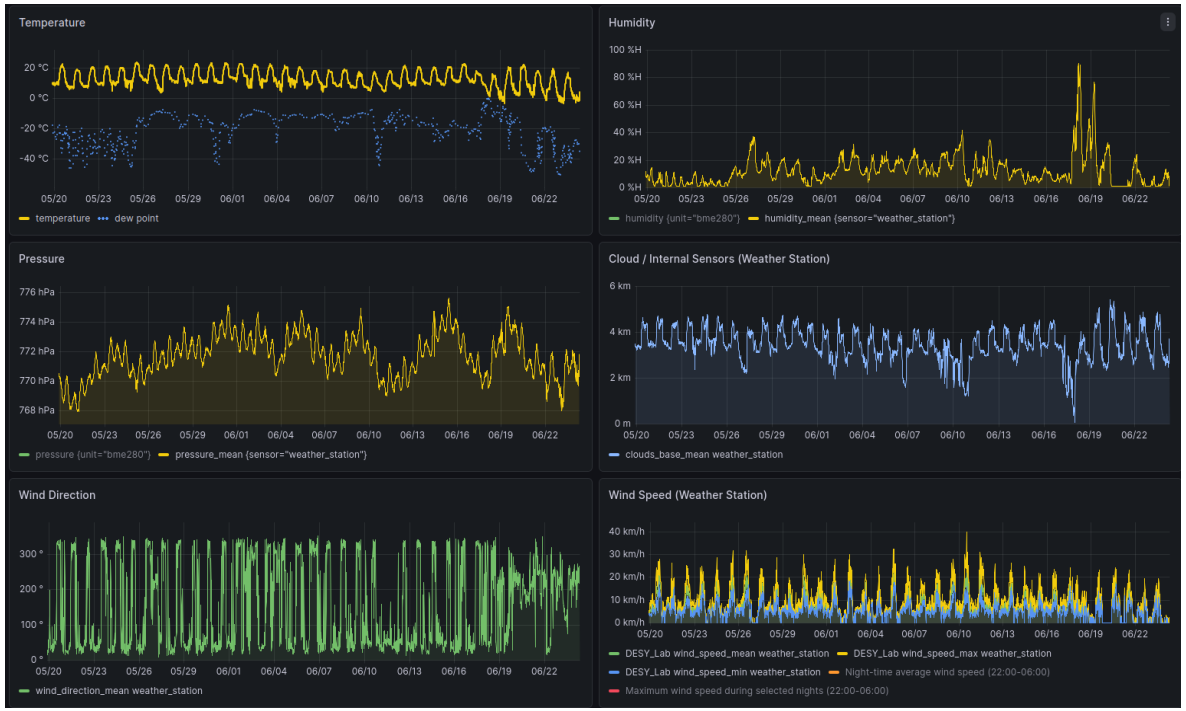
- 4 MST mirrors
- Weather station
- Dust sensors



Mirror test stand in Chile

- LED illuminates white diffuse reflector
- Night pictures of reflector + mirror
- Ratio average pixel value mirror / reflector → **"Reflectivity"**
- Study degradation of mirror's reflectivity
- Monitor atmospheric variables





Summary

- **Rain** seems to be washing the mirrors
- **Dust deposition** follows a power-law after mirrors get washed
- **NSB** and **aerosols** have an impact on muon efficiency
- Difficult to separate **residuals** from **long term trend**

Next steps...

- Model the long term trend with the found power-law
- Try to understand better the effect of NSB and AOD
- Analyse data from the mirror test stand

Thank you!