

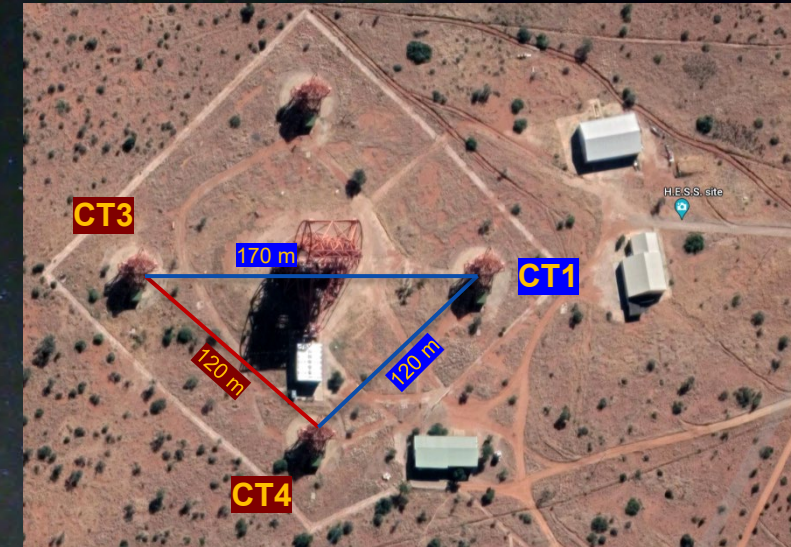
# Intensity interferometry with the H.E.S.S. telescopes

**Andreas Zmija, Naomi Vogel, Gisela Anton, Stefan Funk,**  
Christopher Ingenhuett, Alison Mitchell, Pedro Silva Batista,  
Frederik Wohlleben, Adrian Zink

SII Workshop Porquerolles,  
11 September 2024



# The H.E.S.S. intensity interferometer



**2022** April 8 to April 23  
**2023** April 25 to May 12

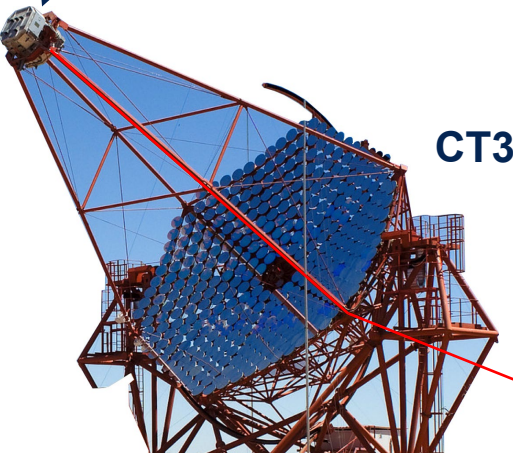
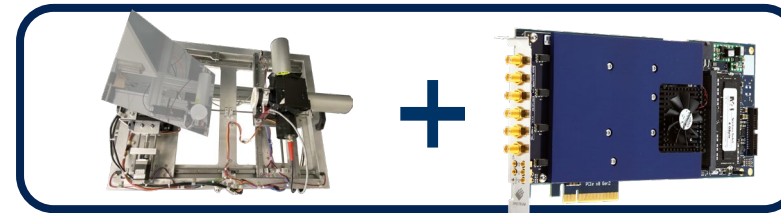
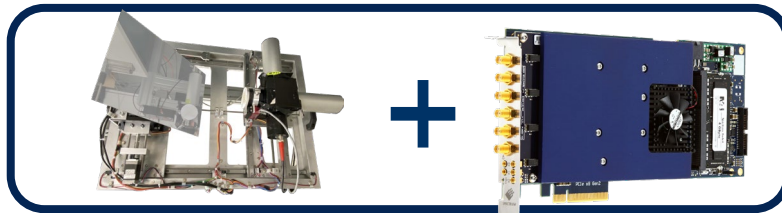
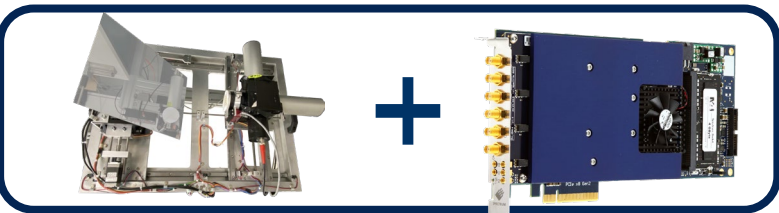
Actual baseline is a projection



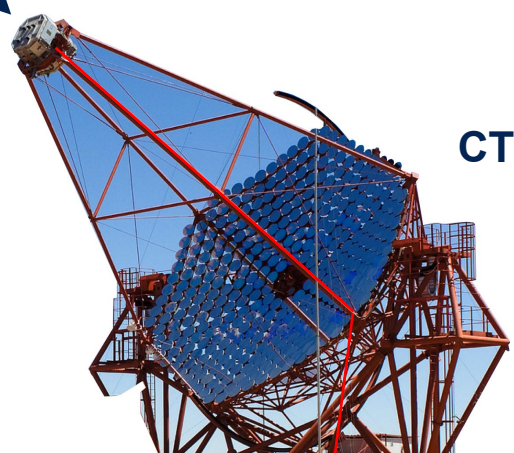


# Measurement Setup

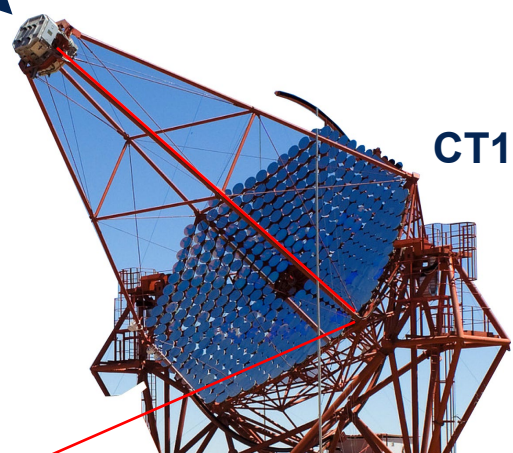
## Setup + digitizer



CT3



CT4

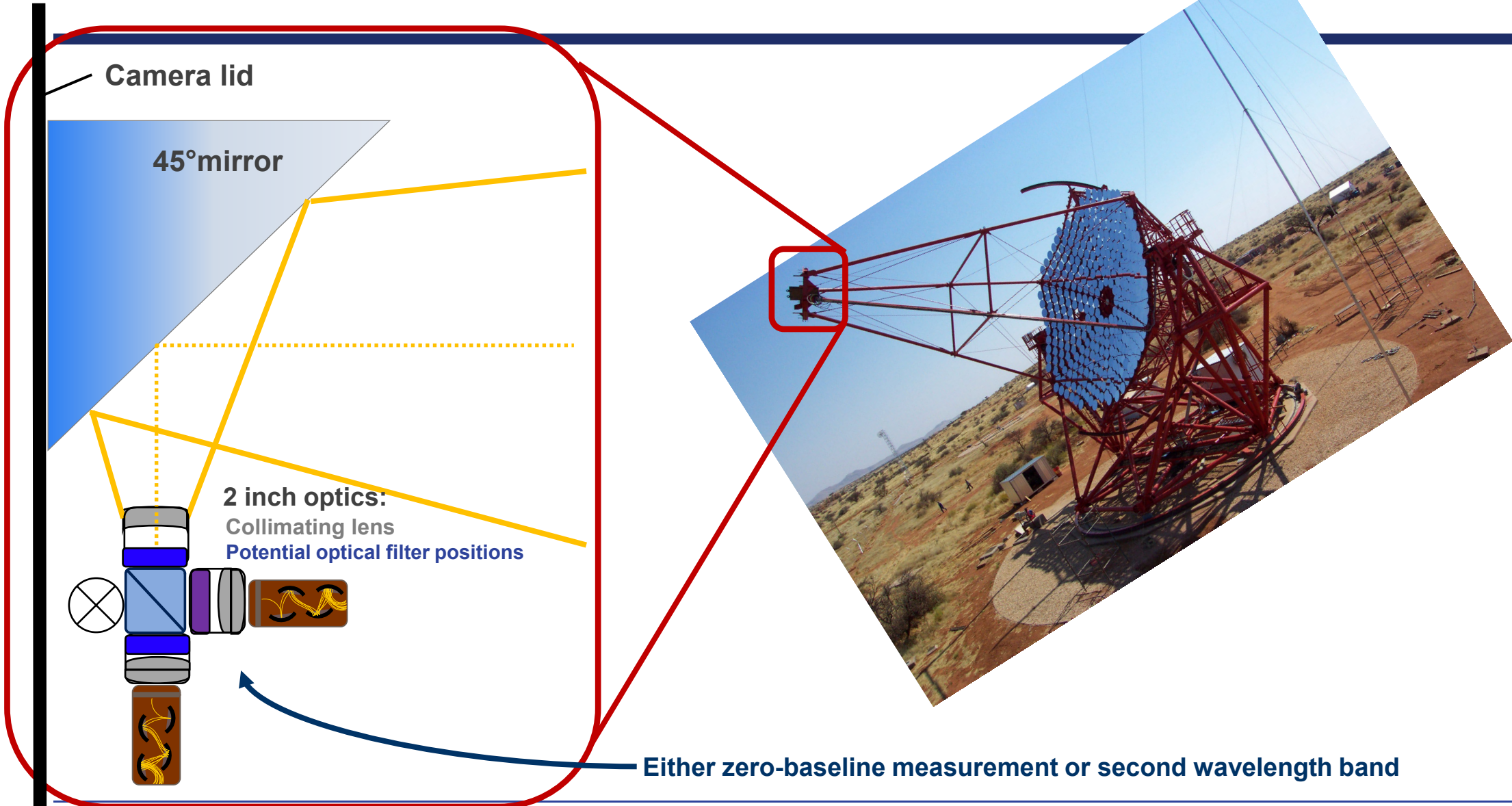


CT1

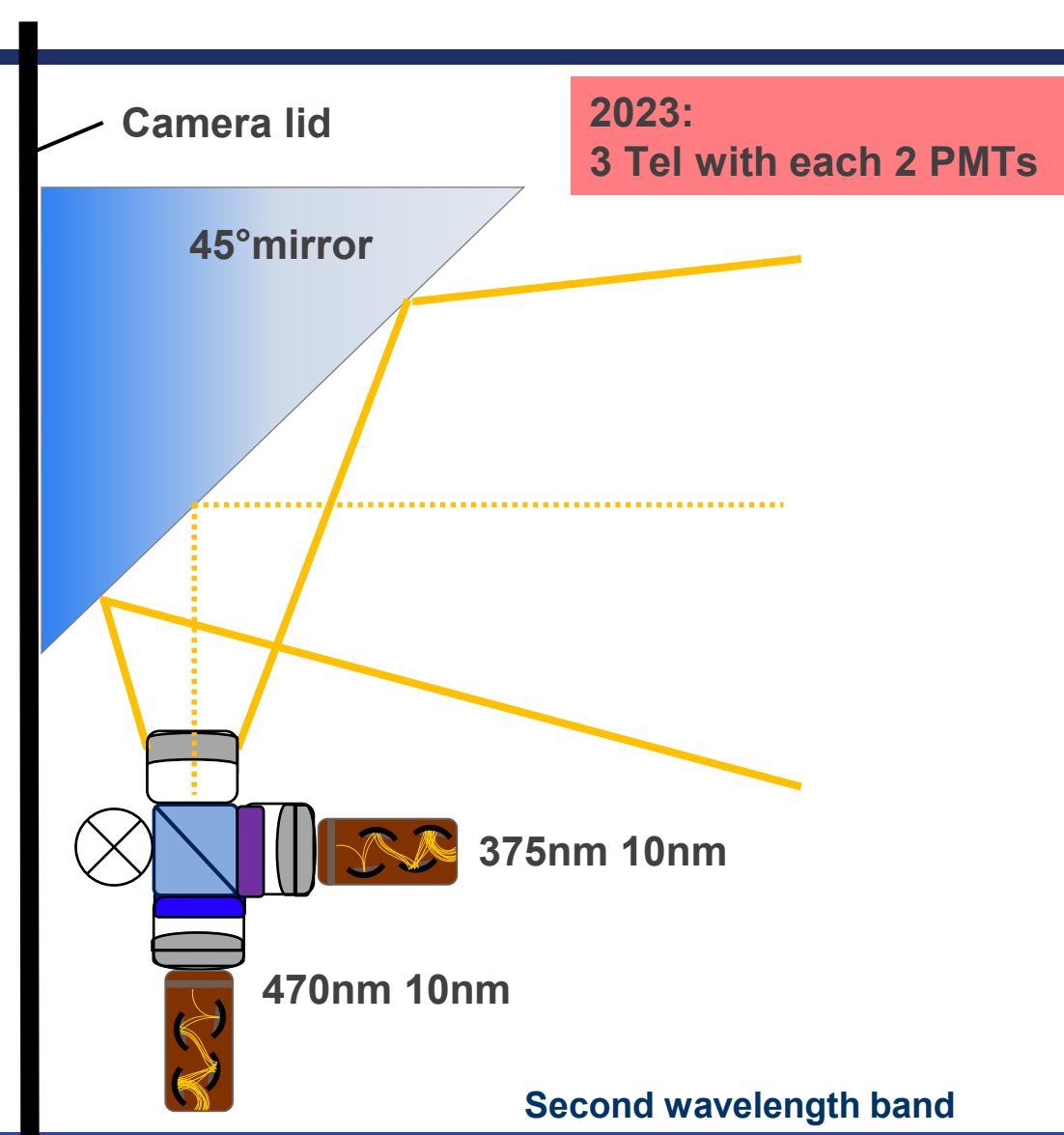
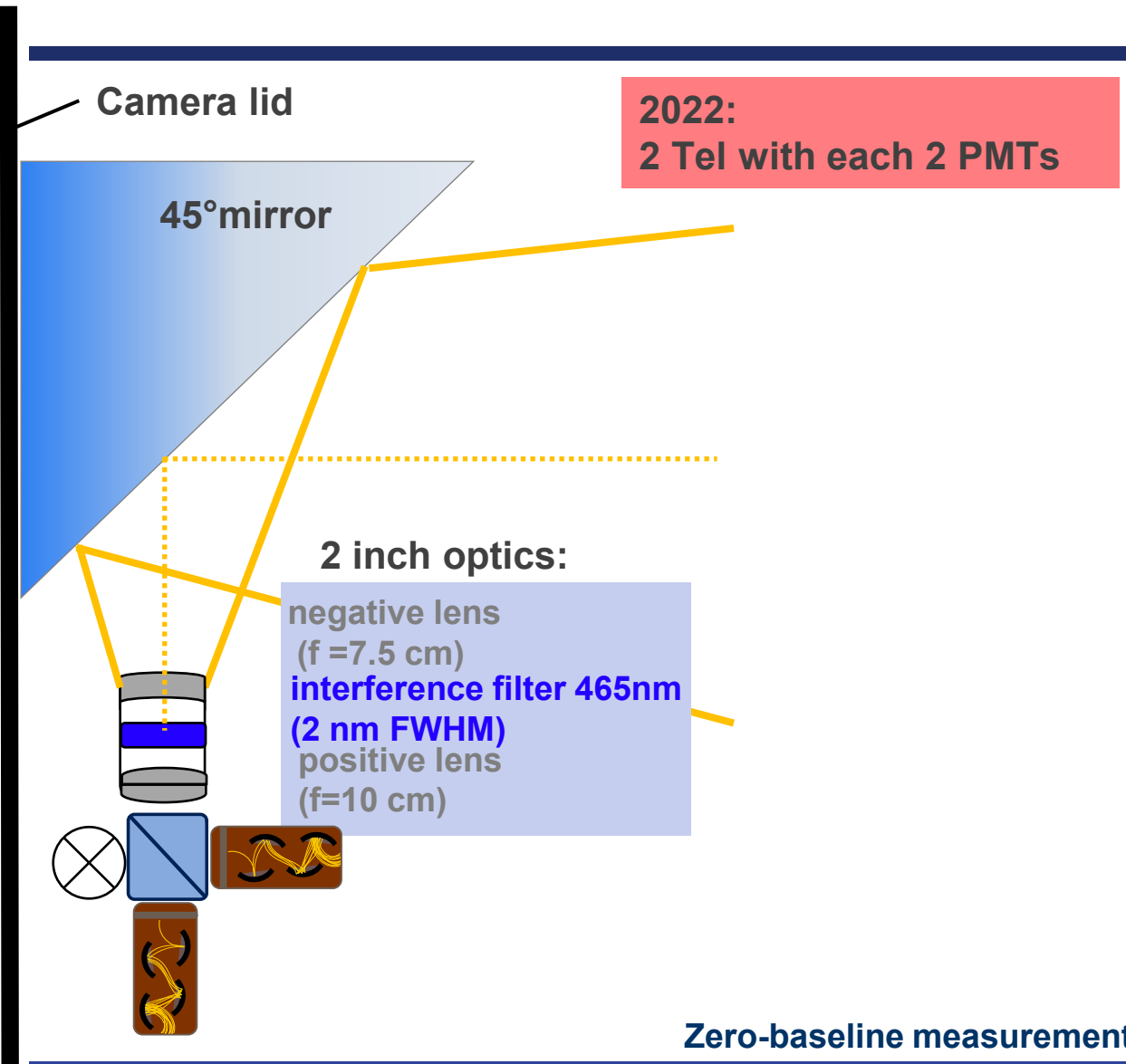
- Digitize in focal plane
- Offline correlation and analysis after measurement

Workstation

# Mechanical Setup



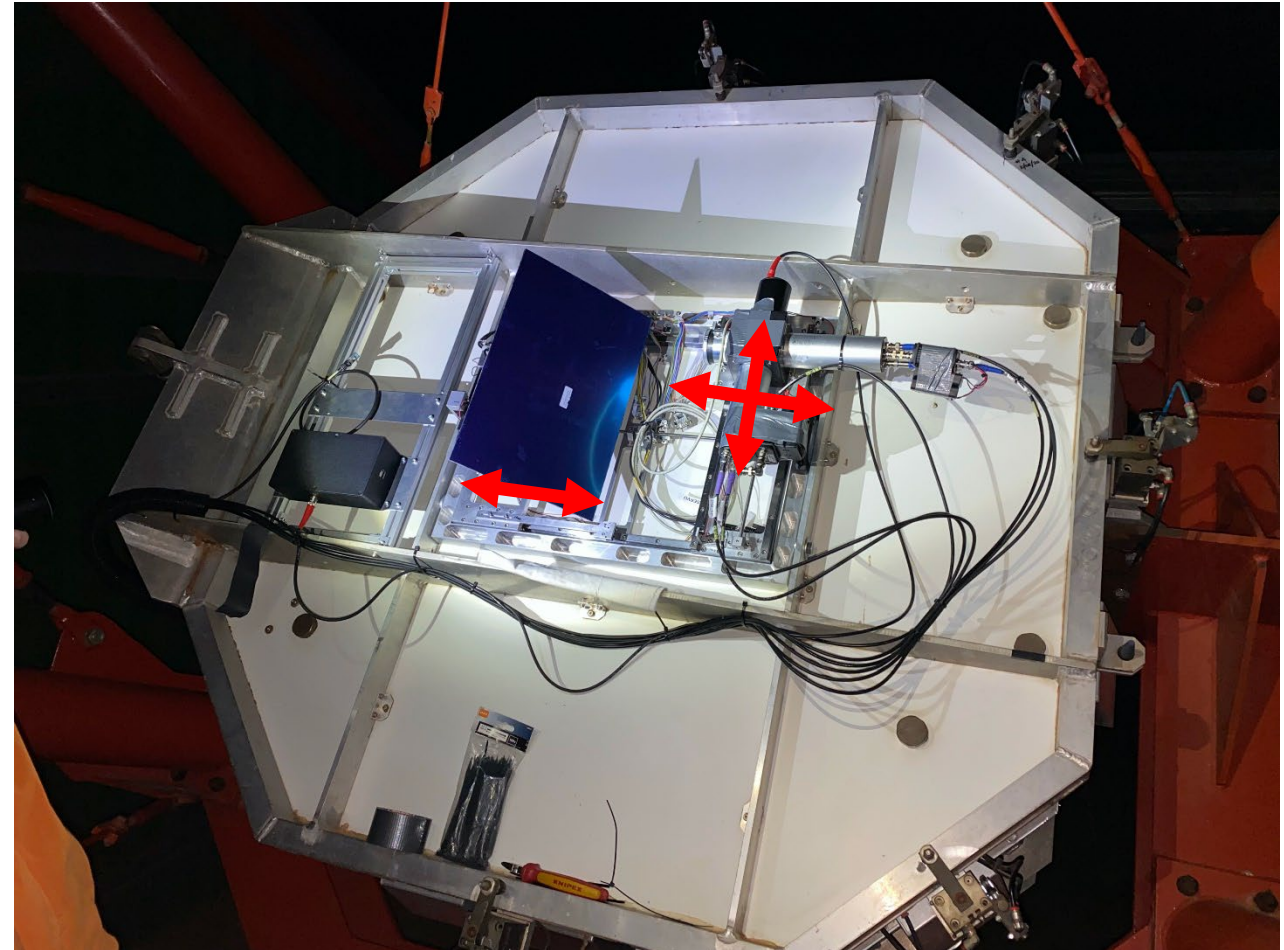
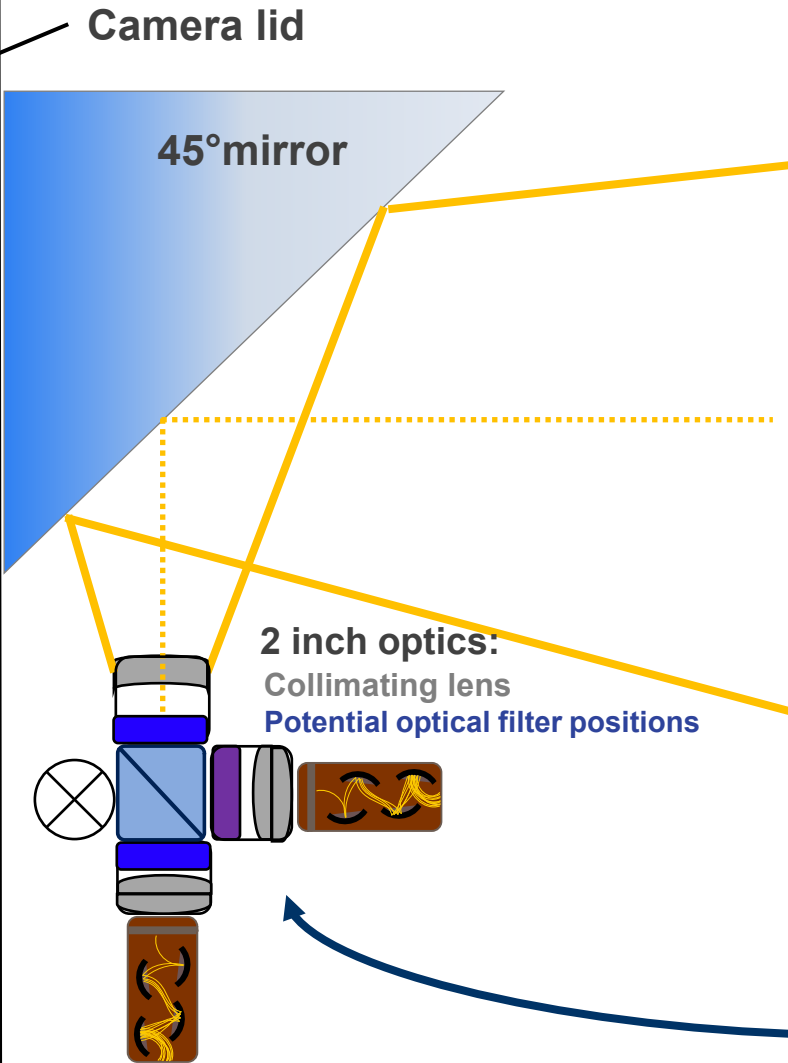
# Optical Setup – 2 colors



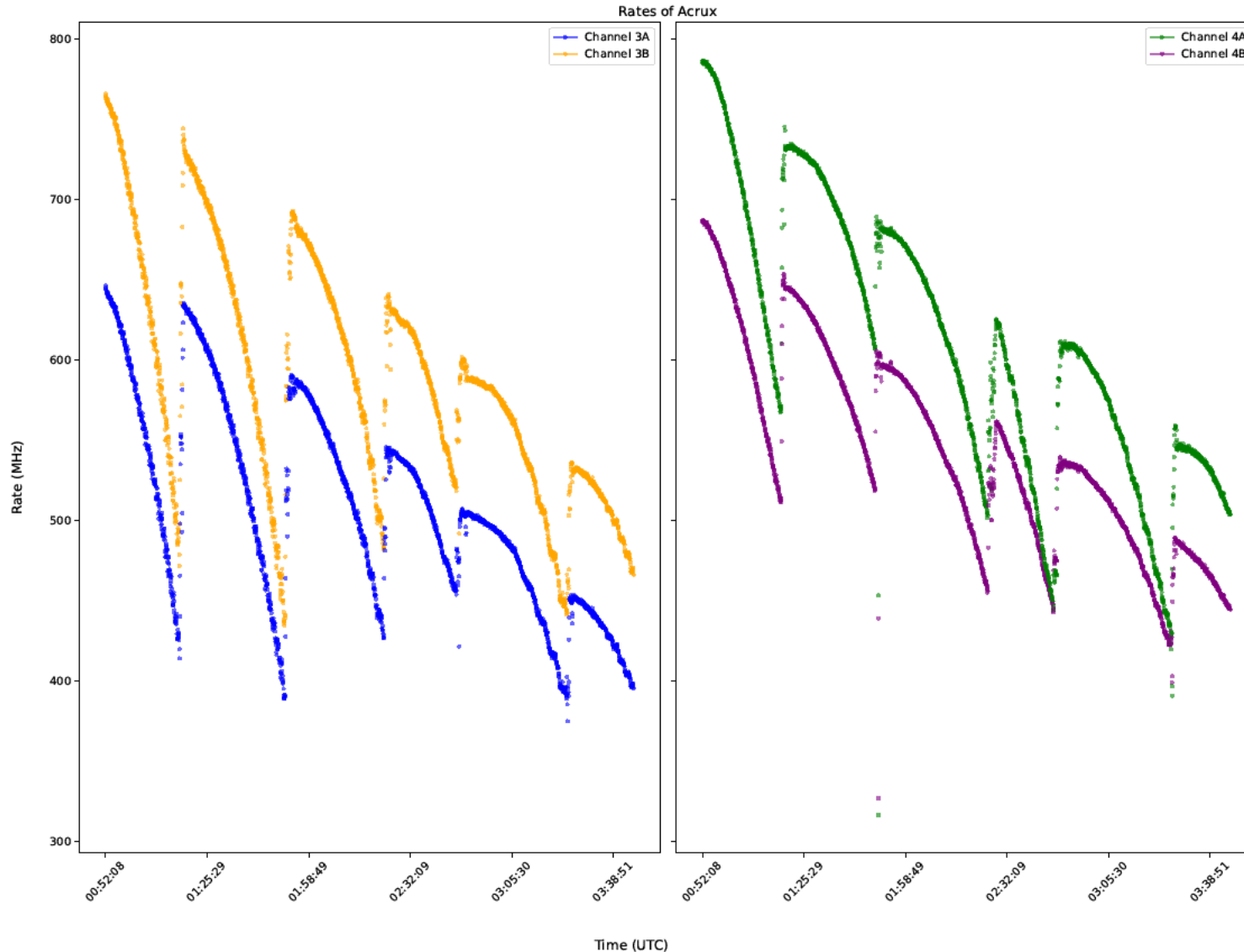


# Mechanical Setup

Mechanical setup



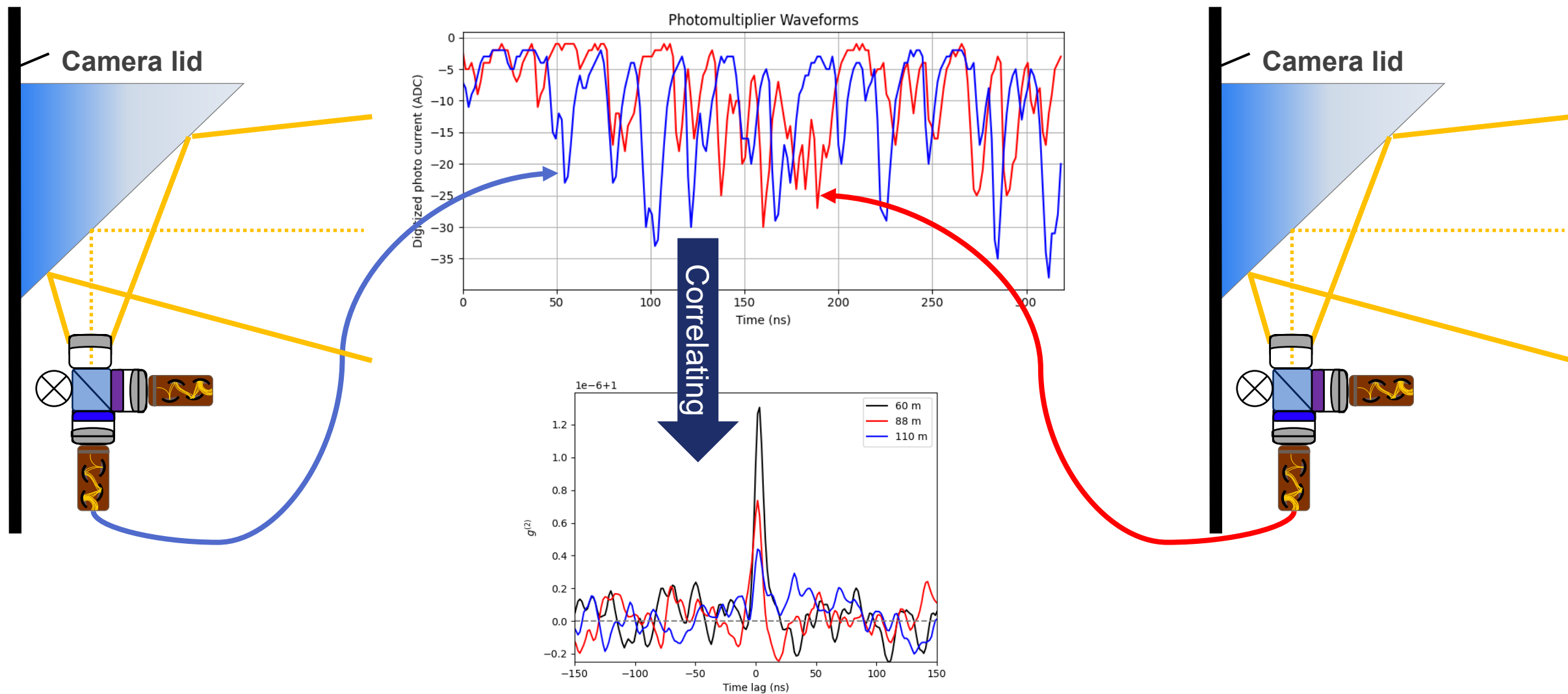
Either zero-baseline measurement or second wavelength band



- Example of rates vs time for Acrux over one night for all 4 channels in both telescopes
- In general rates depend on altitude of the star due to absorption in the atmosphere
- For setting stars (decrease of altitude) rates drop continuously over time

# Analysis

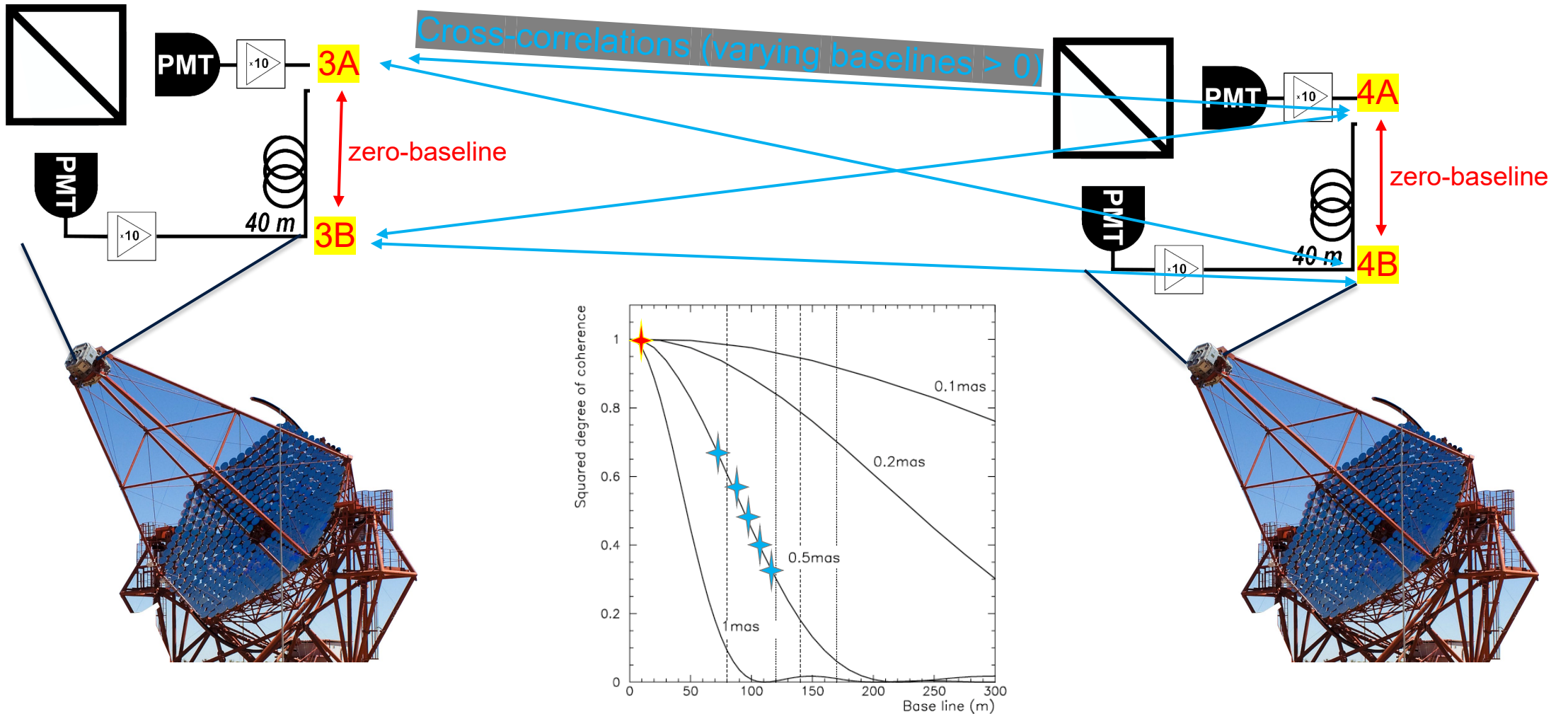
## Correlation between two channels





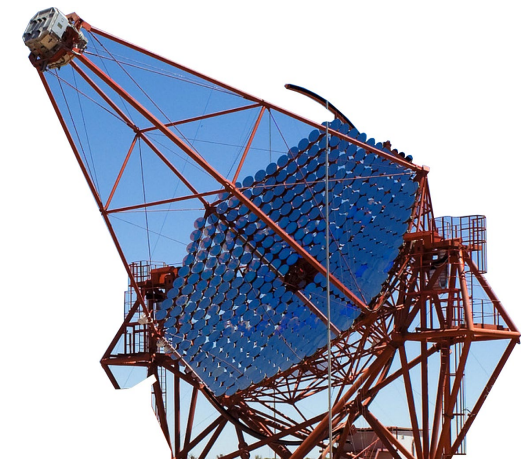
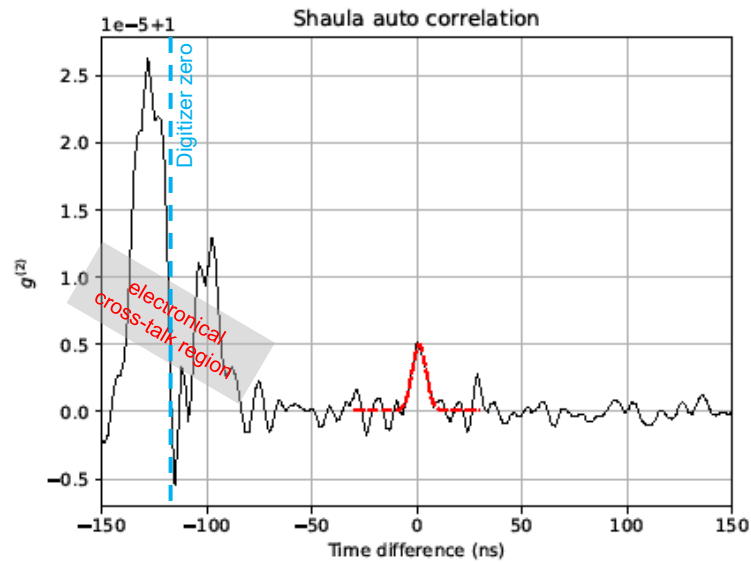
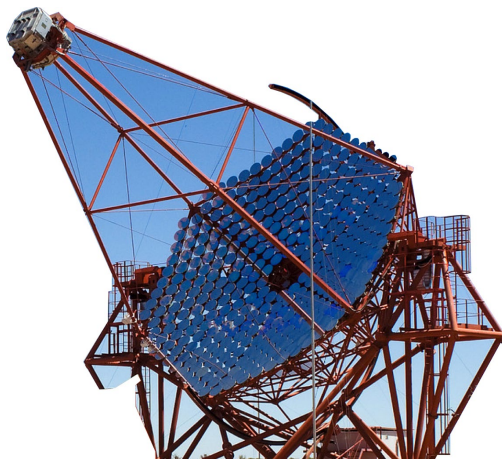
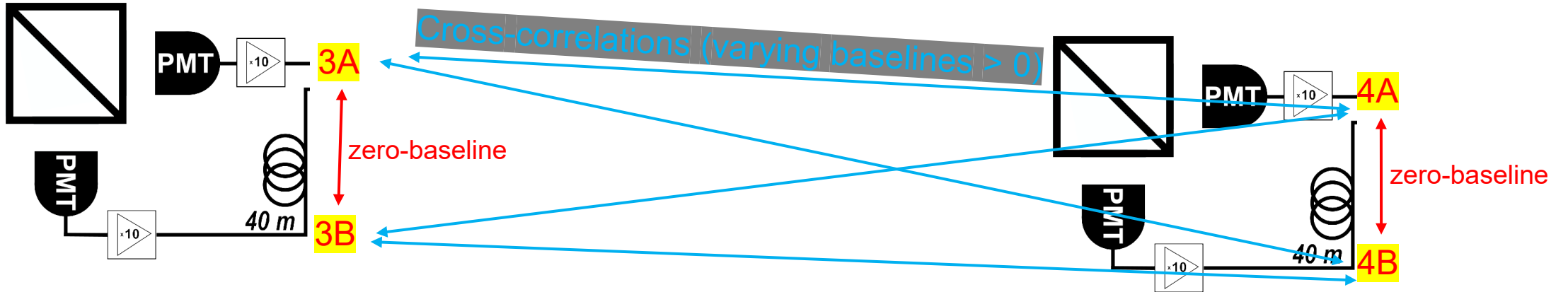
# Analysis

## Correlation channels



# Analysis

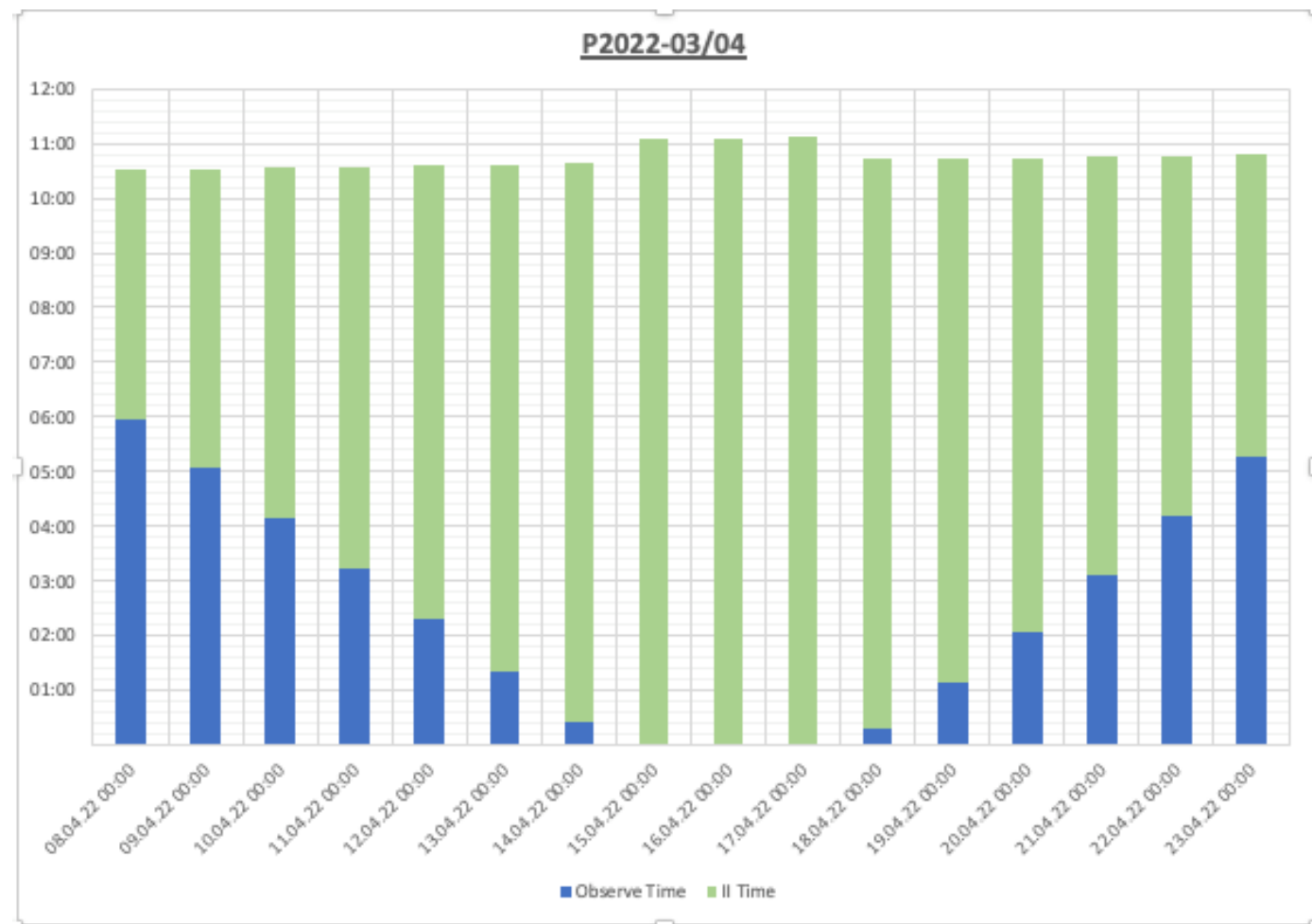
## Correlation channels – auto correlation



# Measurement Schedule

When do we measure?

- Adjust measurement time to gamma ray observations
- Intensity Interferometry during full moon
- Small field of view → insensitive to straylight of moon

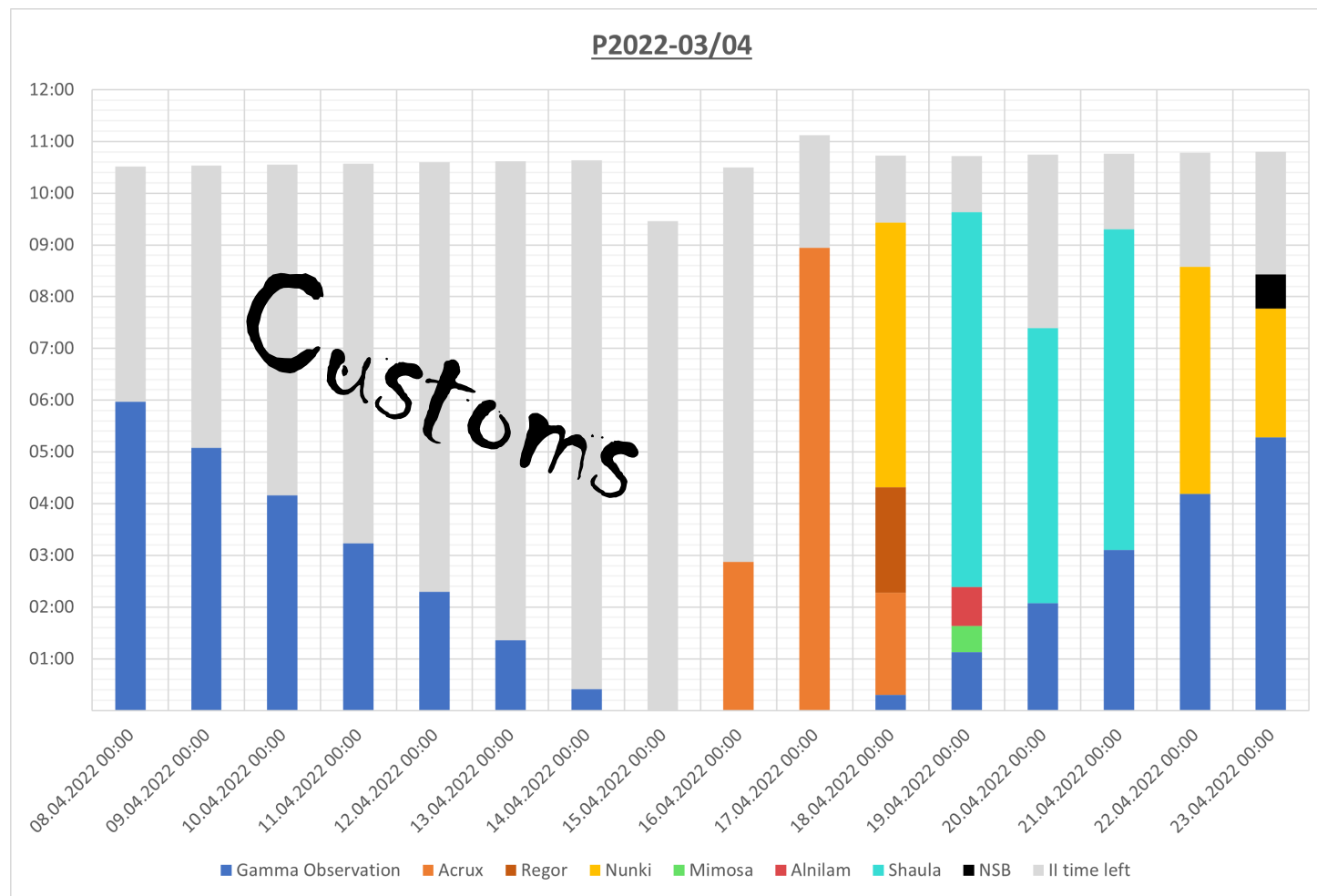




# Measurement Schedule

When do we measure?

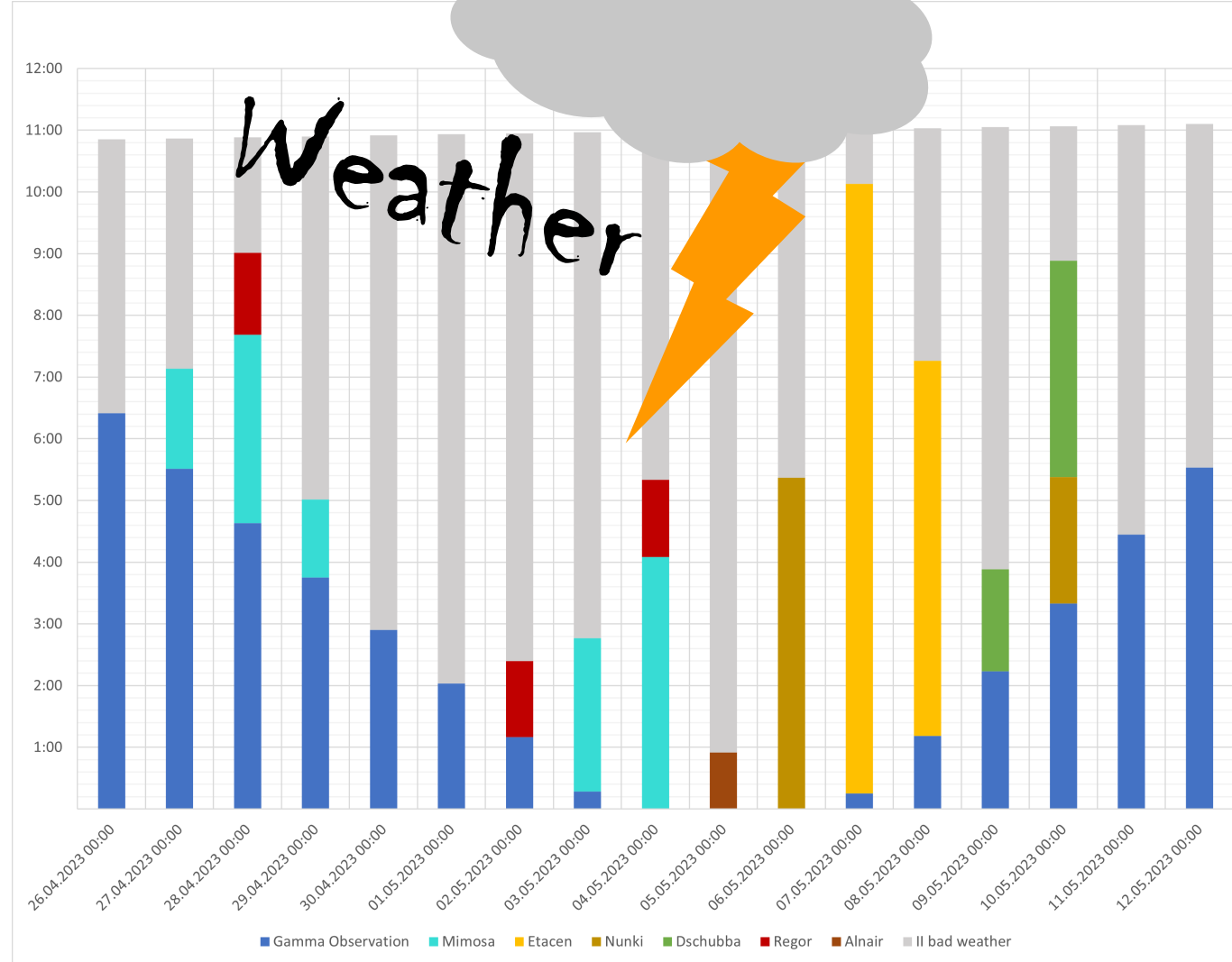
- Adjust measurement time to gamma ray observations
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# Measurement Schedule

When do we measure?

- Adjust measurement time to gamma ray observations
- Intensity Interferometry during full moon
- Small field of view → insensitive to straylight of moon



# The ECAP SII Southern Sky Survey

Dschubba ○  
2.2 mag  
(binary)

Eta Centauri  
○ 2.2 mag

Mimosa  
1.2 mag ○

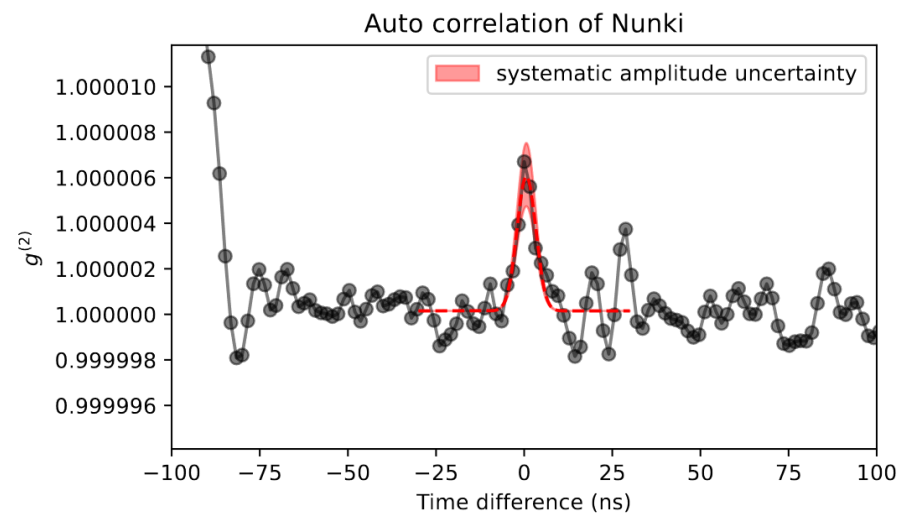
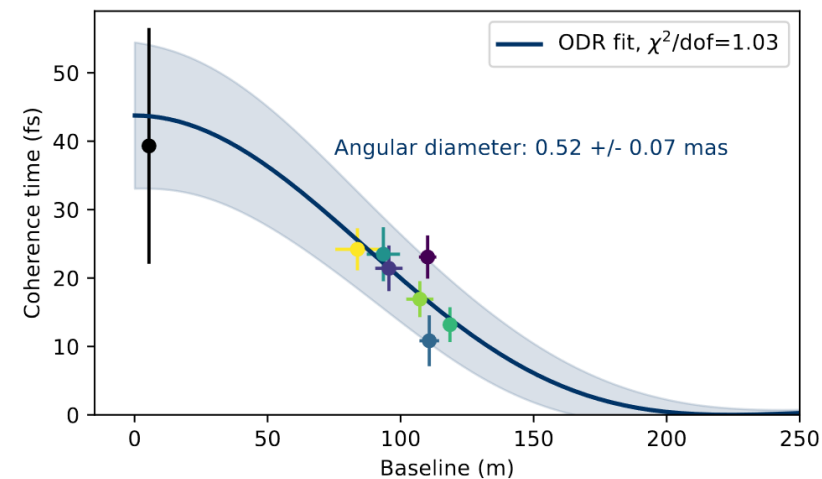
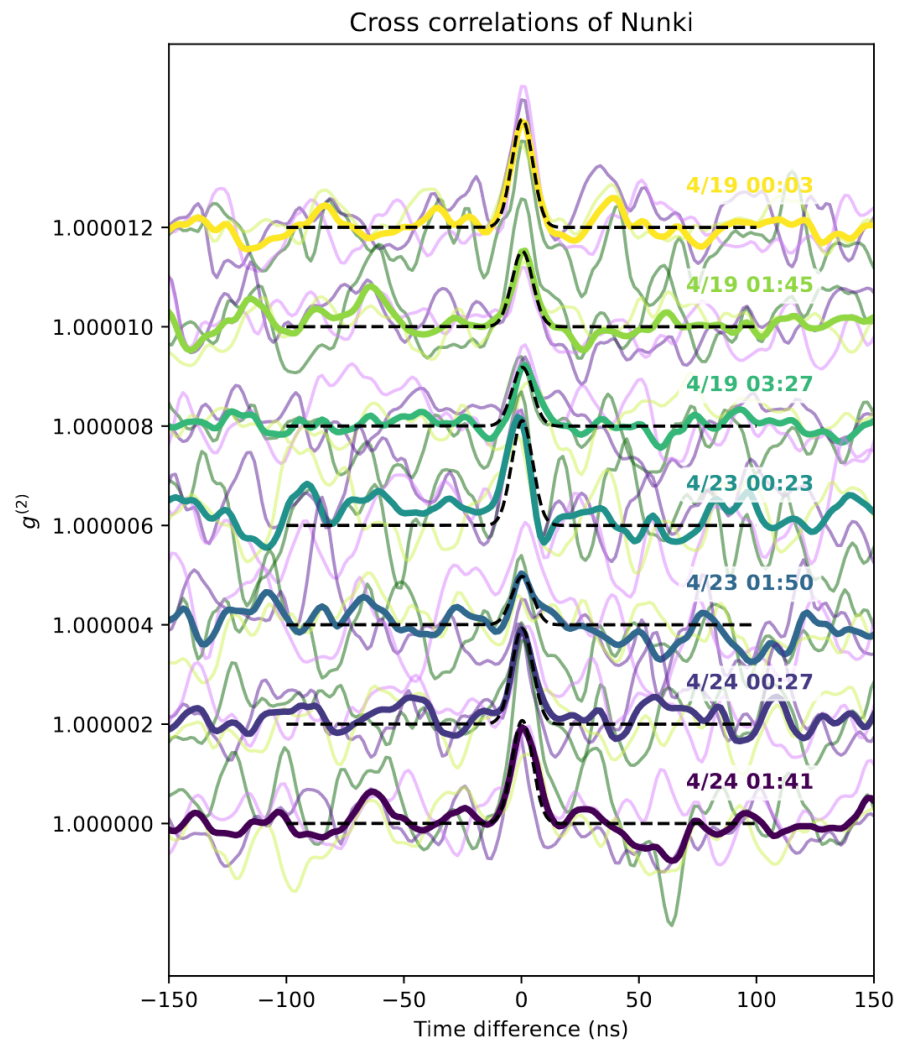
Acrux  
0.6 mag  
(multiple stars)

Shaula ○  
1.5 mag  
(binary)

Gamma Velorum  
○ 1.8 mag  
(fancy binary)

○ Nunki  
2.0 mag

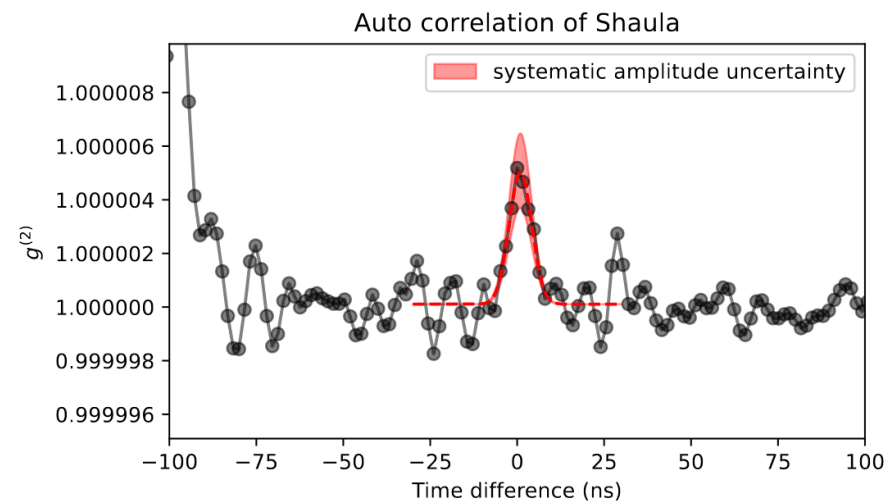
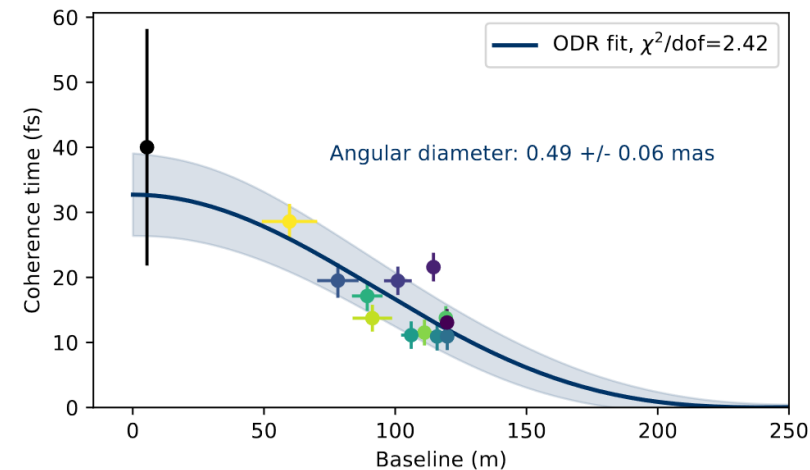
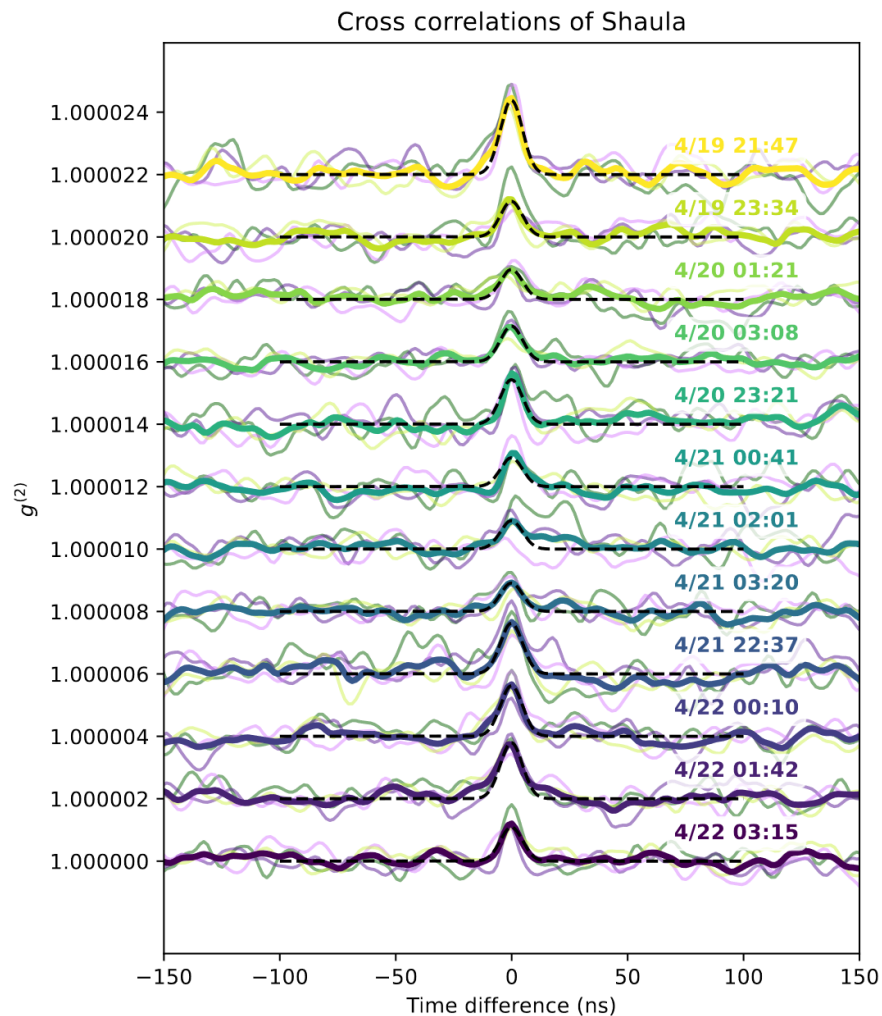




Zmija et. al. (2023) - „First intensity interferometry measurements with the H.E.S.S. telescopes.“

# 2022 Results

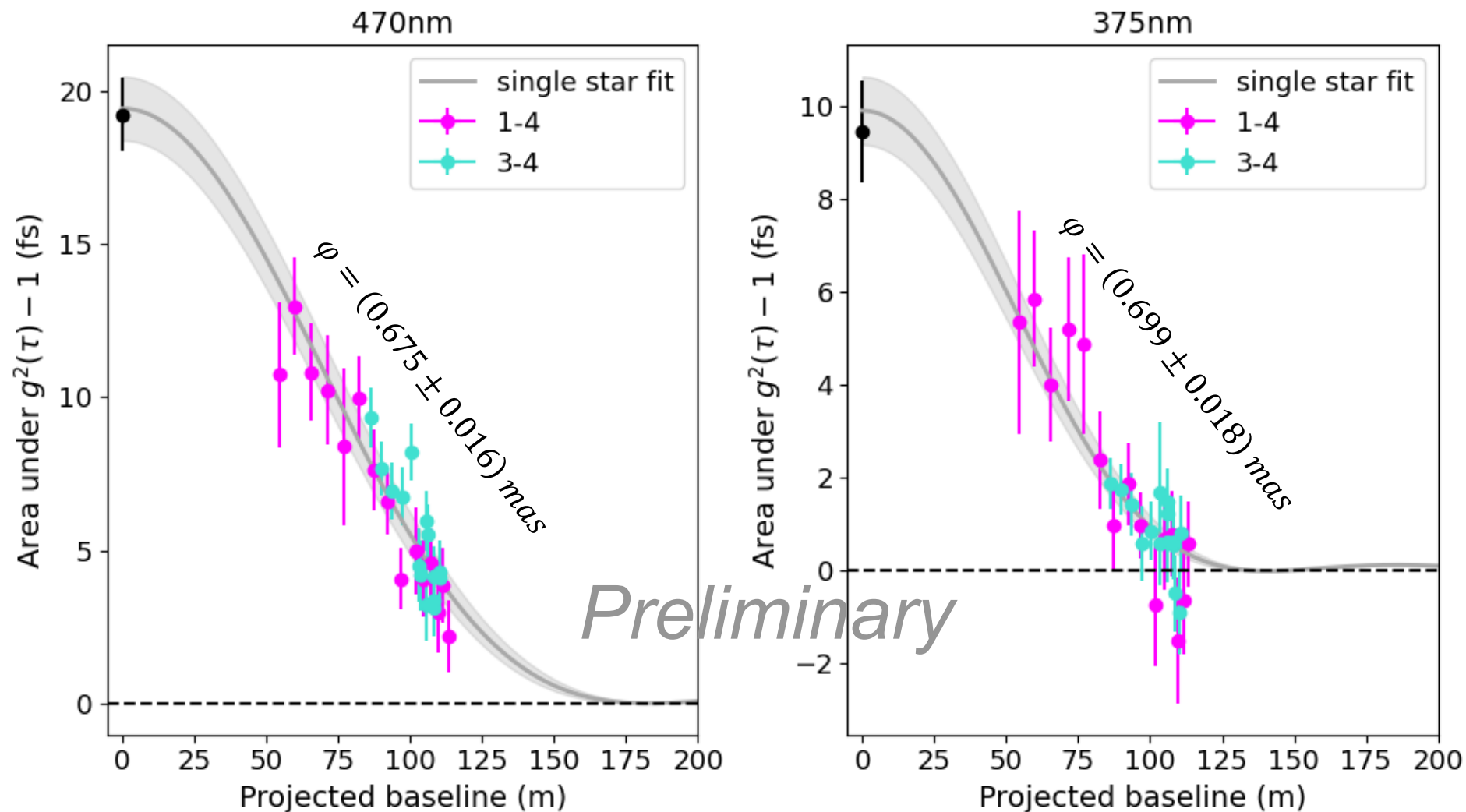
Shaula



# 2023 Results

Mimosa - Two wavelengths

Mimosa

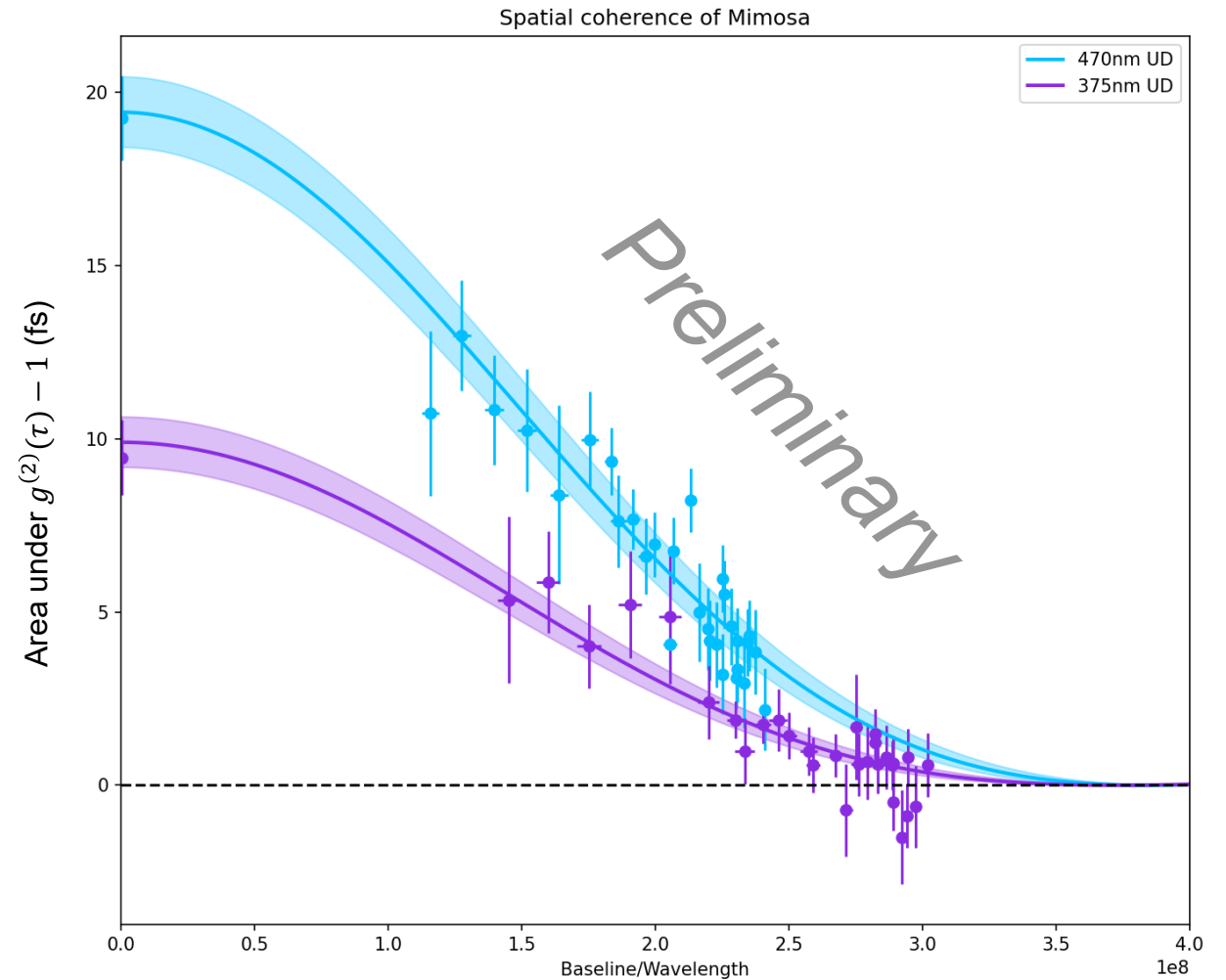




# 2023 Results

## Mimosa - Two wavelengths

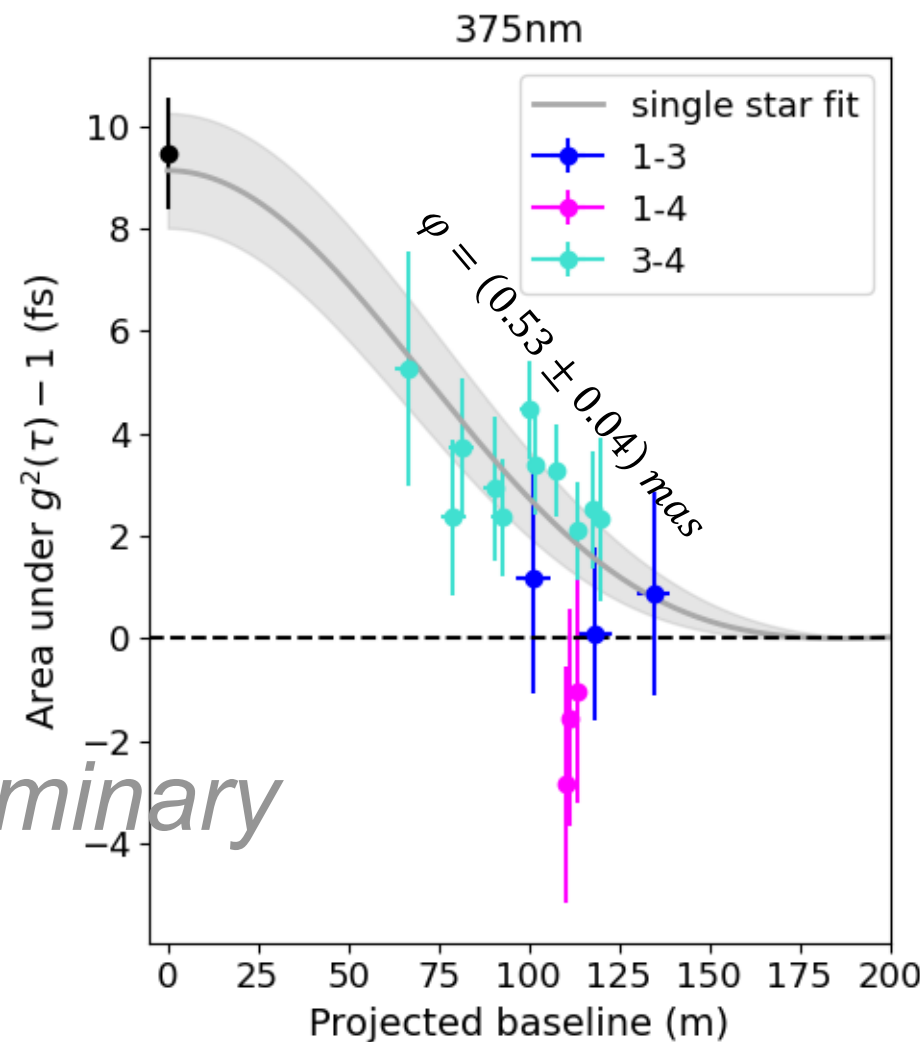
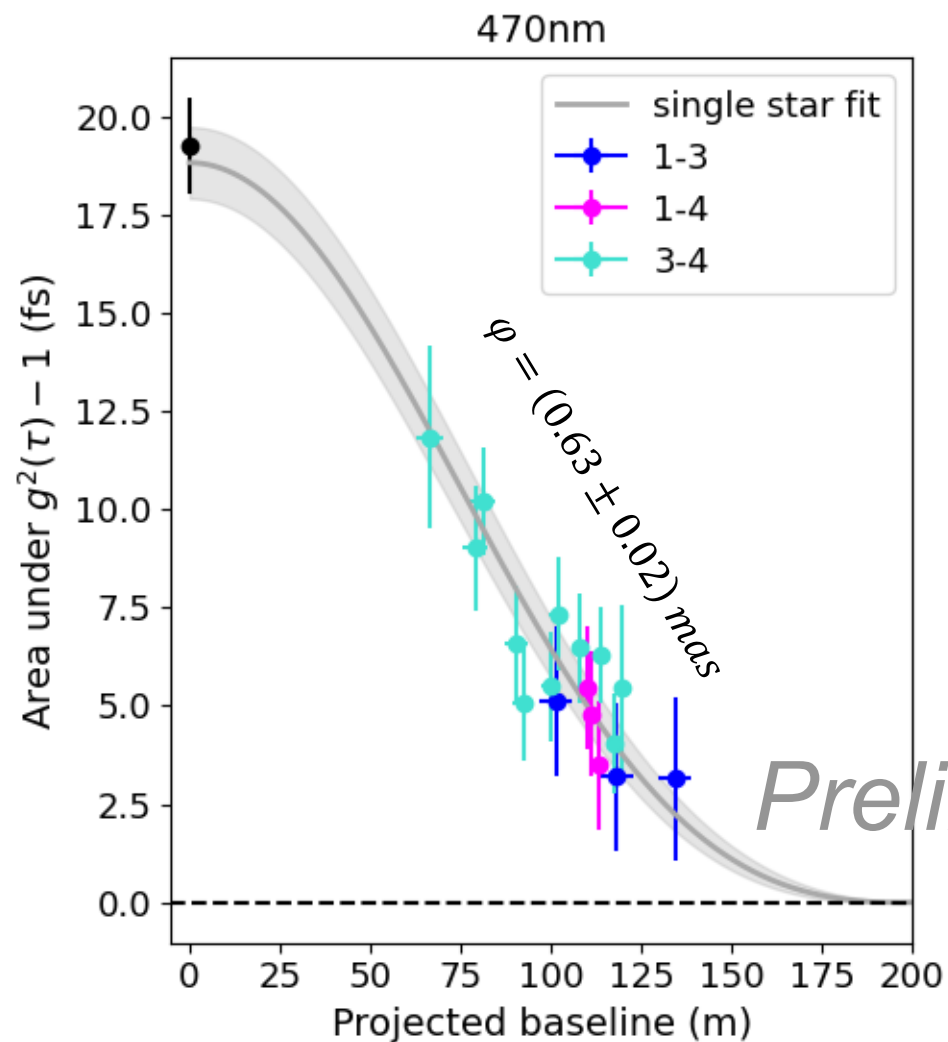
- Squared visibility scales linearly with wavelength
- Two colors effectively extend baseline range



# 2023 Results

Nunki - Two wavelengths

Nunki



Preliminary

Correlation at zero baseline = fixed parameter of our instrument

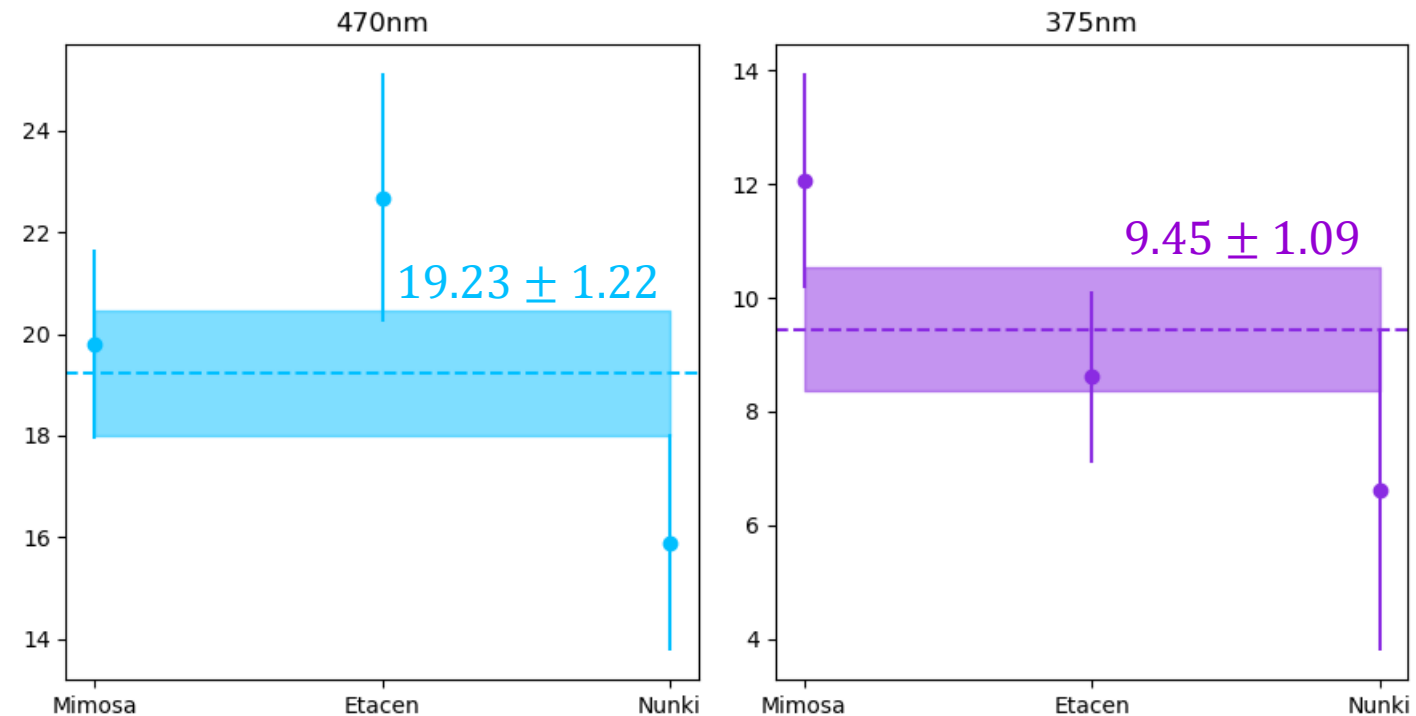
→ Set as fixed data point

→ Theory approx 31 fs and 19 fs

For each color channel:

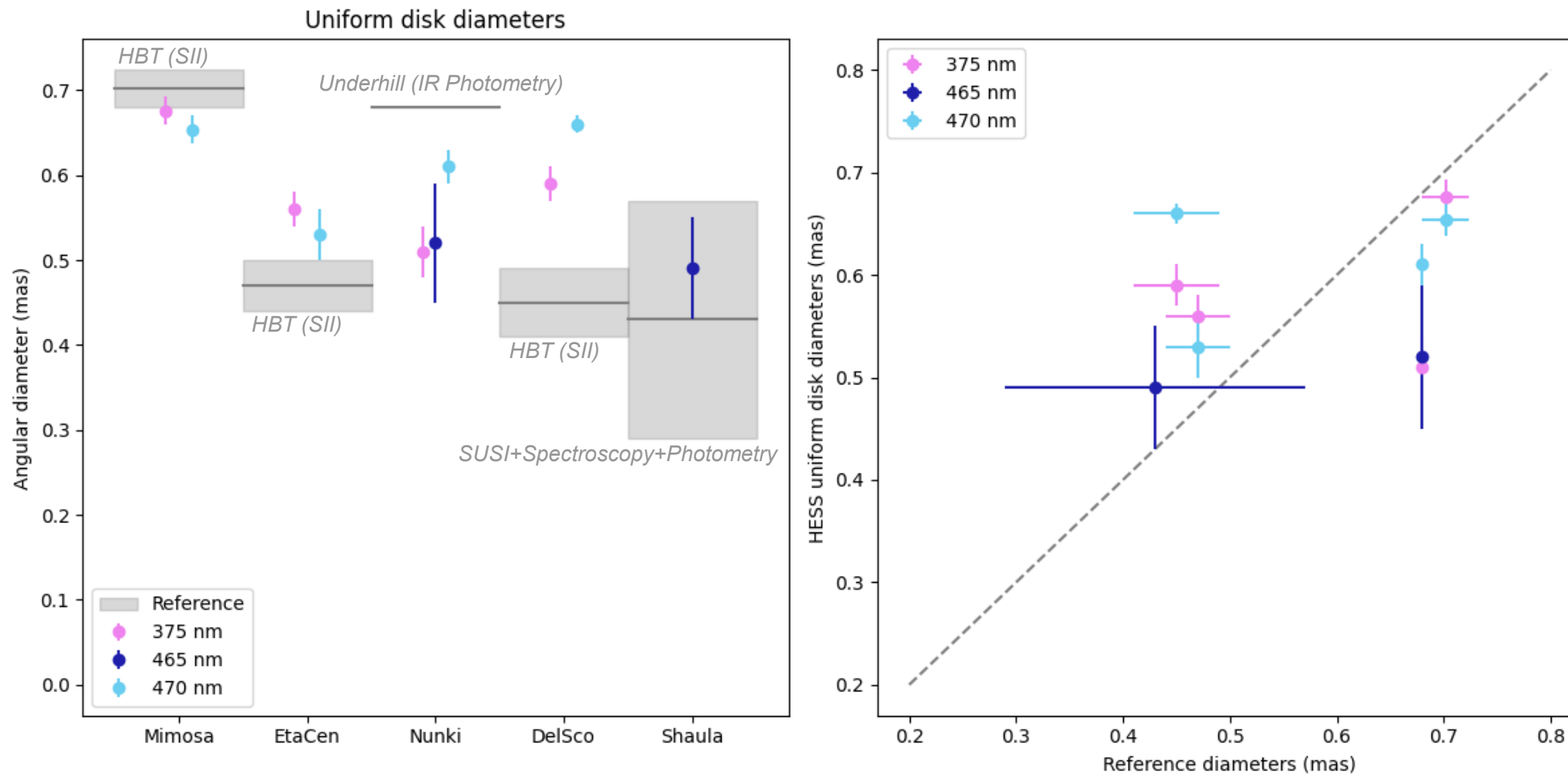
- zero baseline amplitude computed via UD fit
- Weighted average
- Insert value as data point into squared visibility curves and re-fit UD model

## Zero baseline amplitude

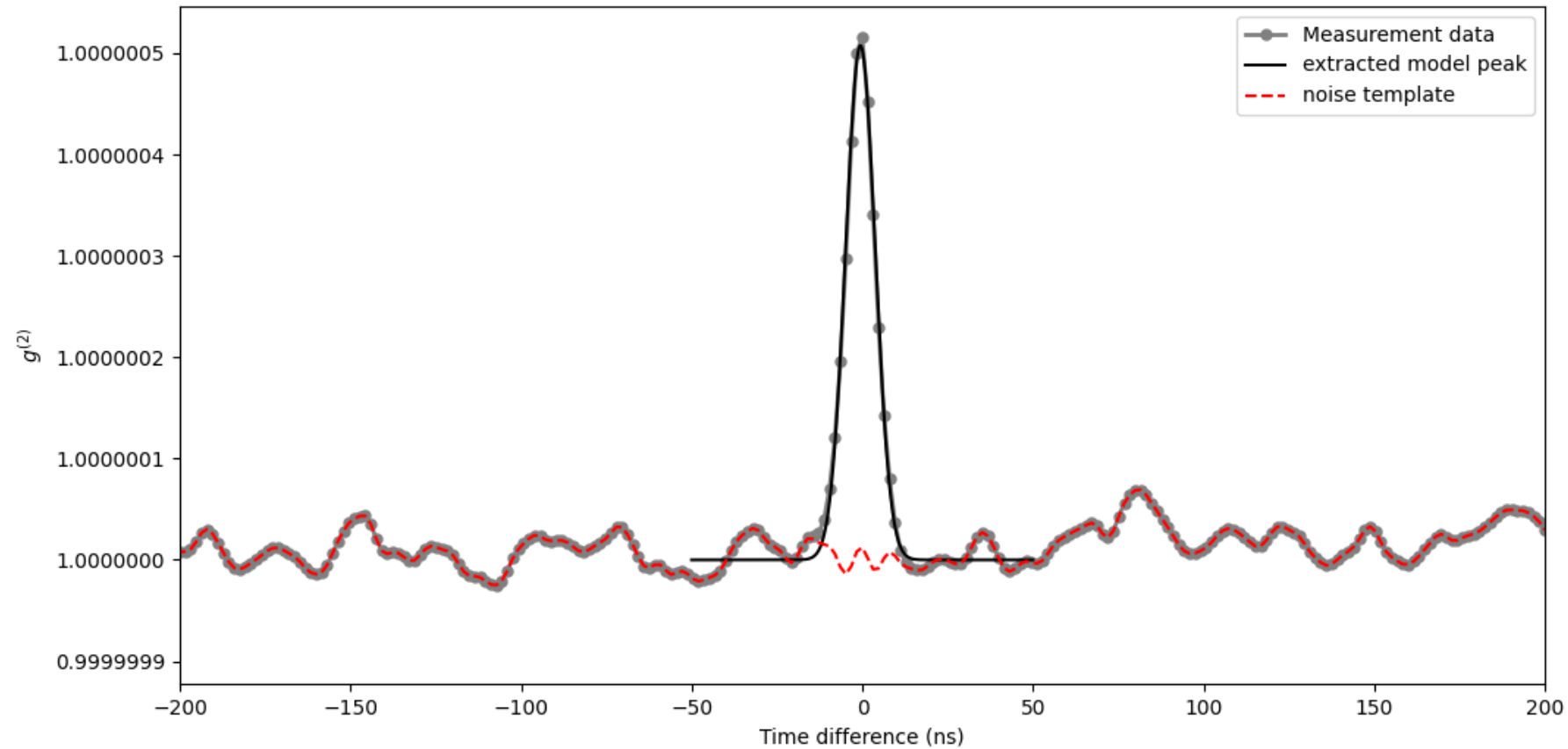




# Data comparison

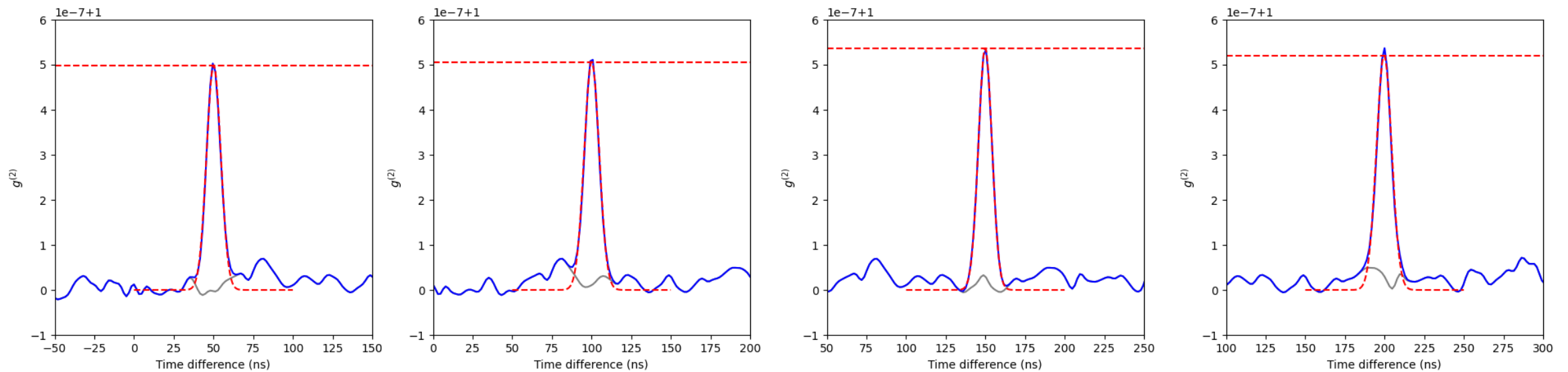


# Influence of (photon) noise to the correlation peak



# Influence of (photon) noise to the correlation peak

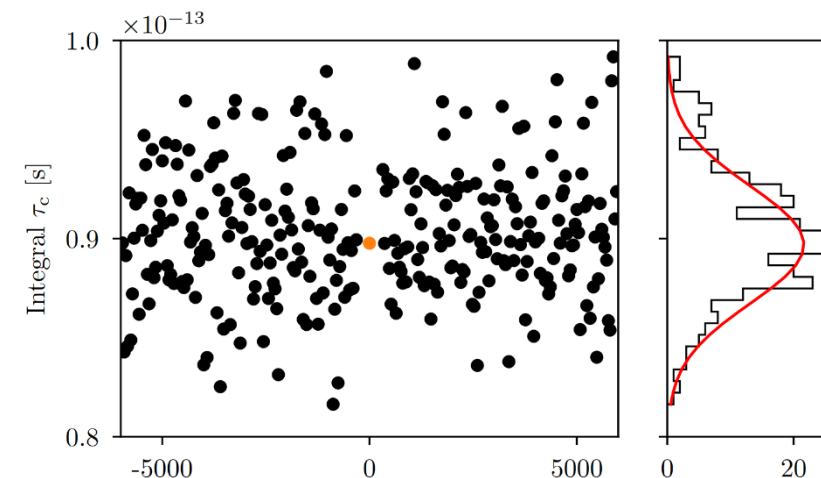
- The amplitude of the fit is influenced by the underlying noise, and so is the peak integral



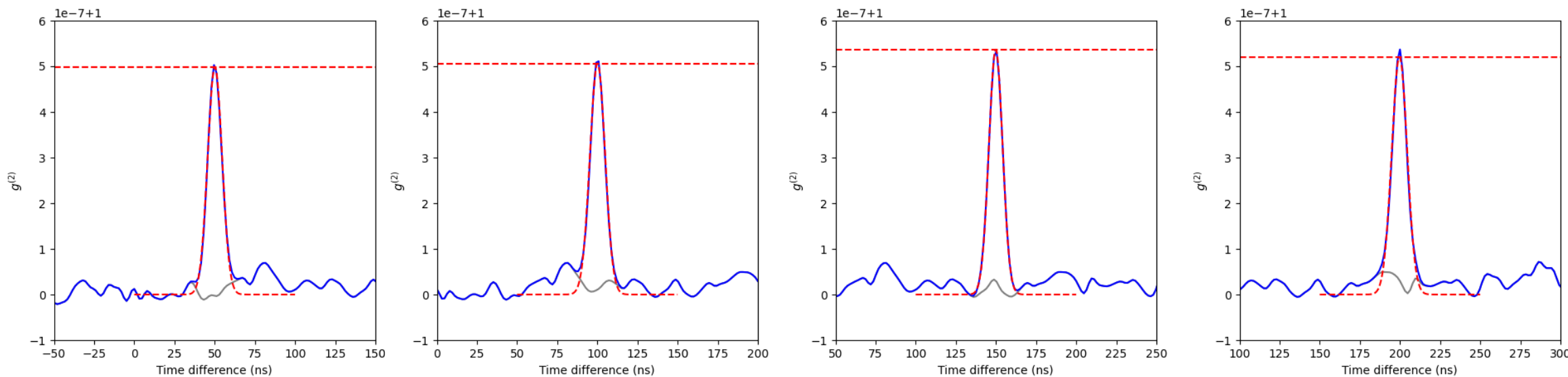


# Influence of (photon) noise to the correlation peak

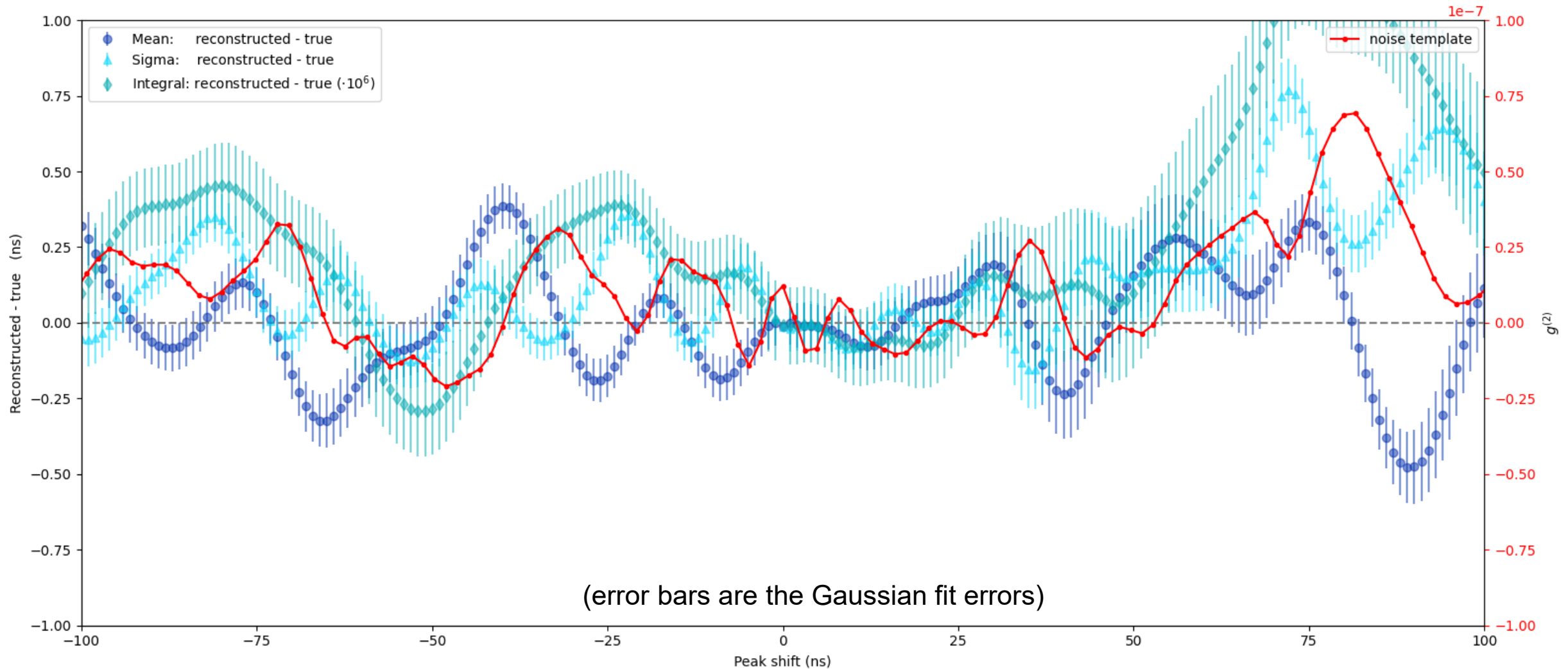
- The amplitude of the fit is influenced by the underlying noise, and so is the peak integral
- The sigma of the distribution is considered the error on the measurement



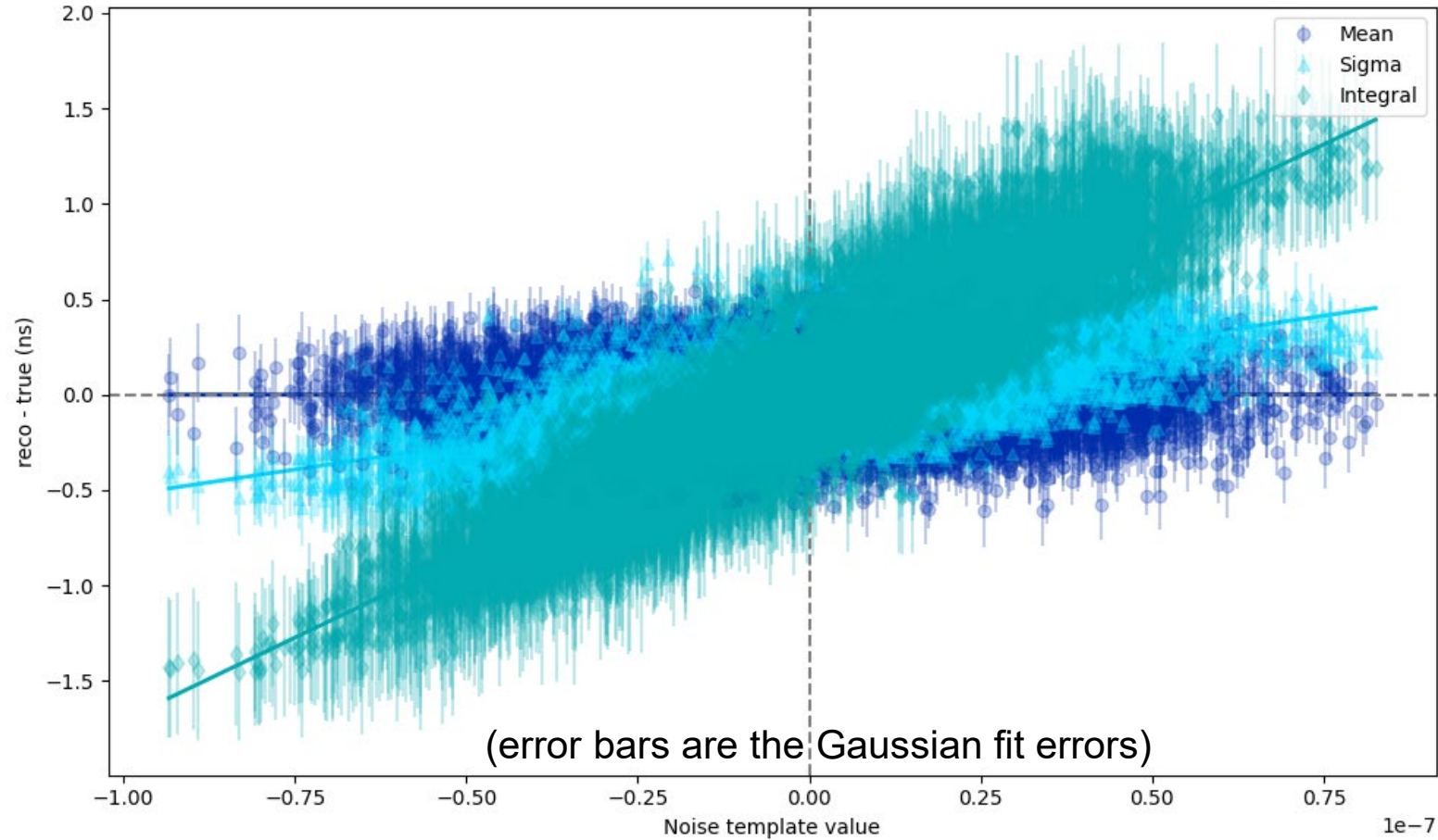
S. Weybrecht (2024): Labormessungen und Entwicklung von Datenanalysemethoden für die Intensitätsinterferometrie



# Influence of (photon) noise to the correlation peak



# Influence of (photon) noise to the correlation peak





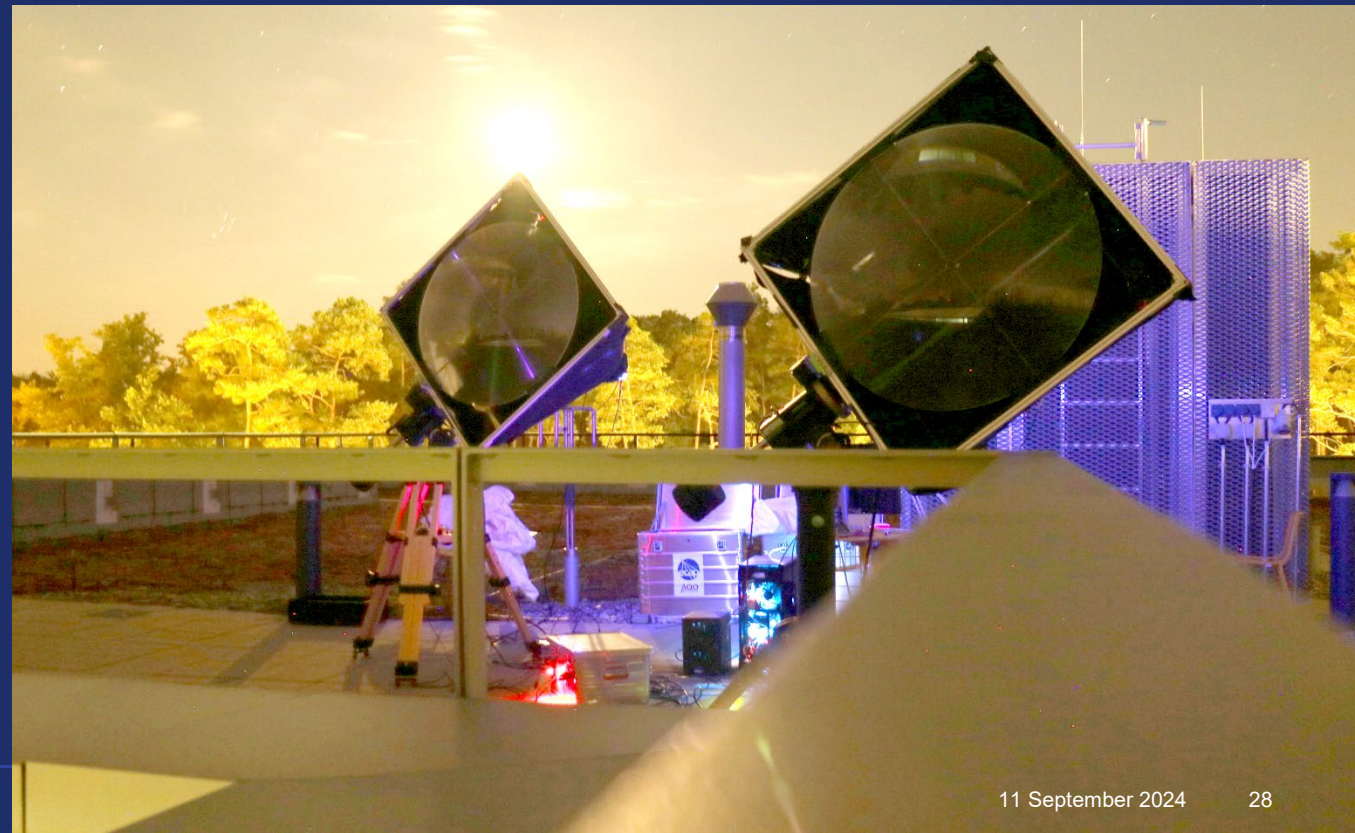
# The future of SII at H.E.S.S.

- Await decision about funding proposal
- Install setup on all 4 Phase I telescopes
- Install “permanent” setups for (partly) remote operations
- FlashCam tests at CT5 (CTA prospect)



# Intensity Interferometry @ECAP: *MI<sup>2</sup>SO*

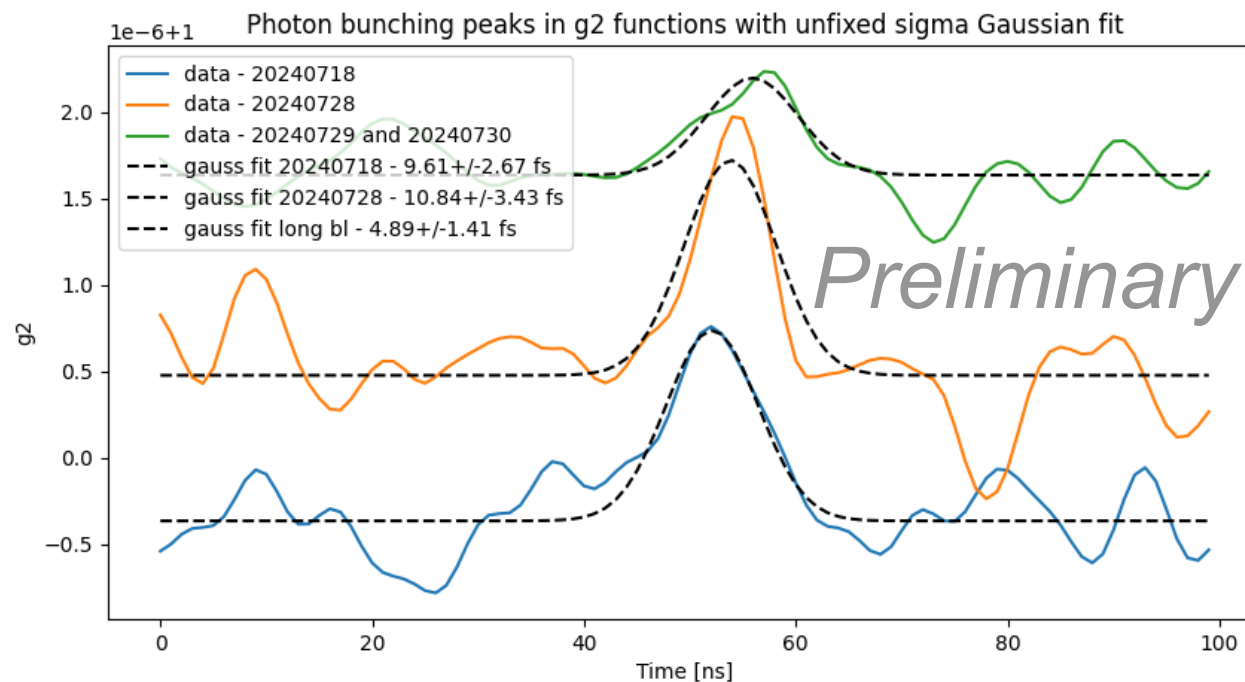
Mobile Intensity  
Interferometer for Stellar  
Observations



# The development of MI<sup>2</sup>SO

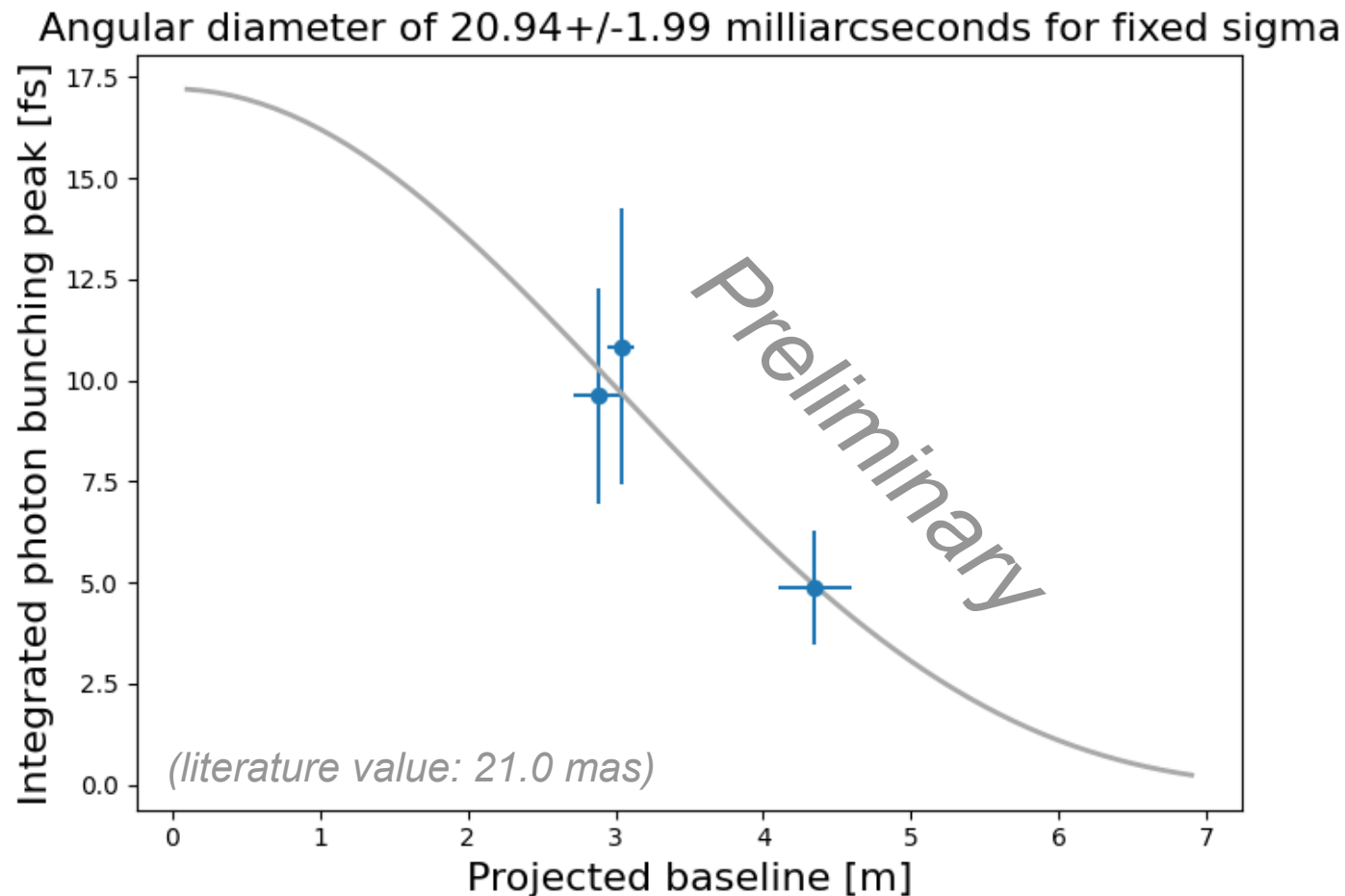


- 2 nights with short baseline, 2 nights (combined) with large baseline
- Manual rearrangement of the telescopes for baseline change



# Measurements of Arcturus in July 2024

- 2 nights with short baseline, 2 nights (combined) with large baseline
- Manual rearrangement of the telescopes for baseline change





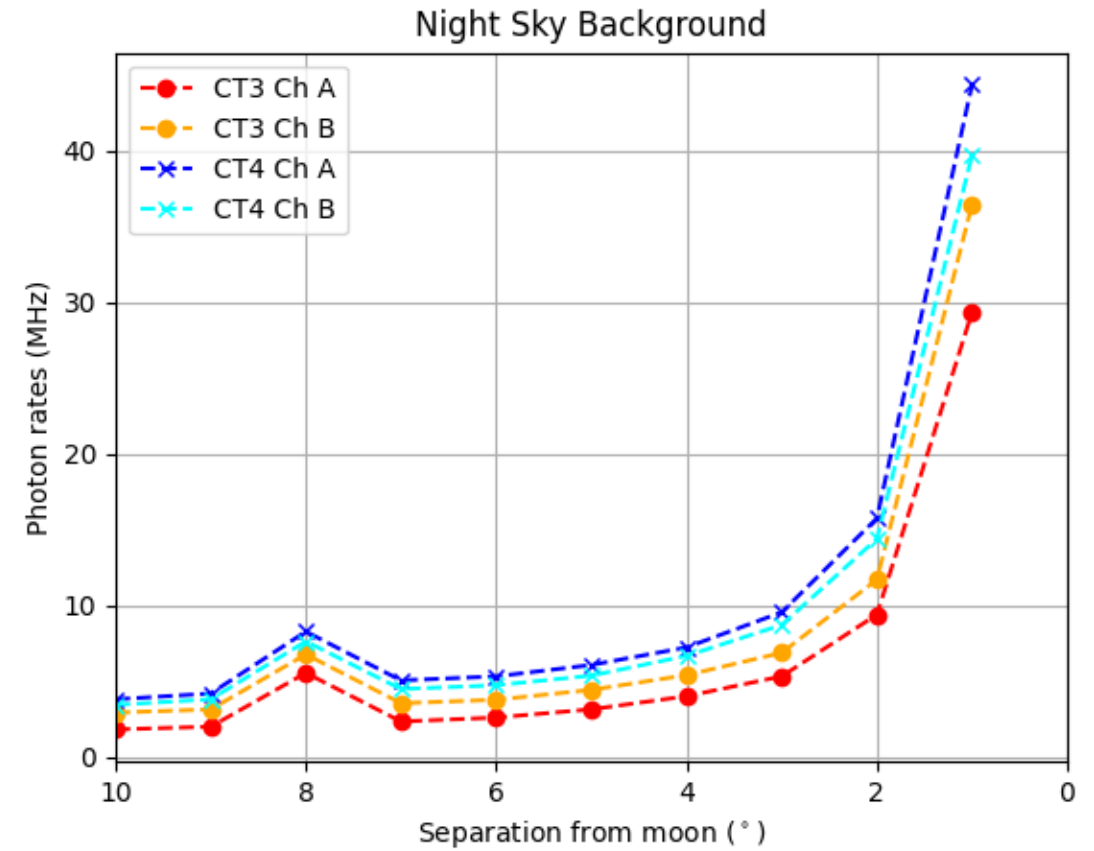
**Thank you for  
listening!**





# Results

## Moonlight measurements

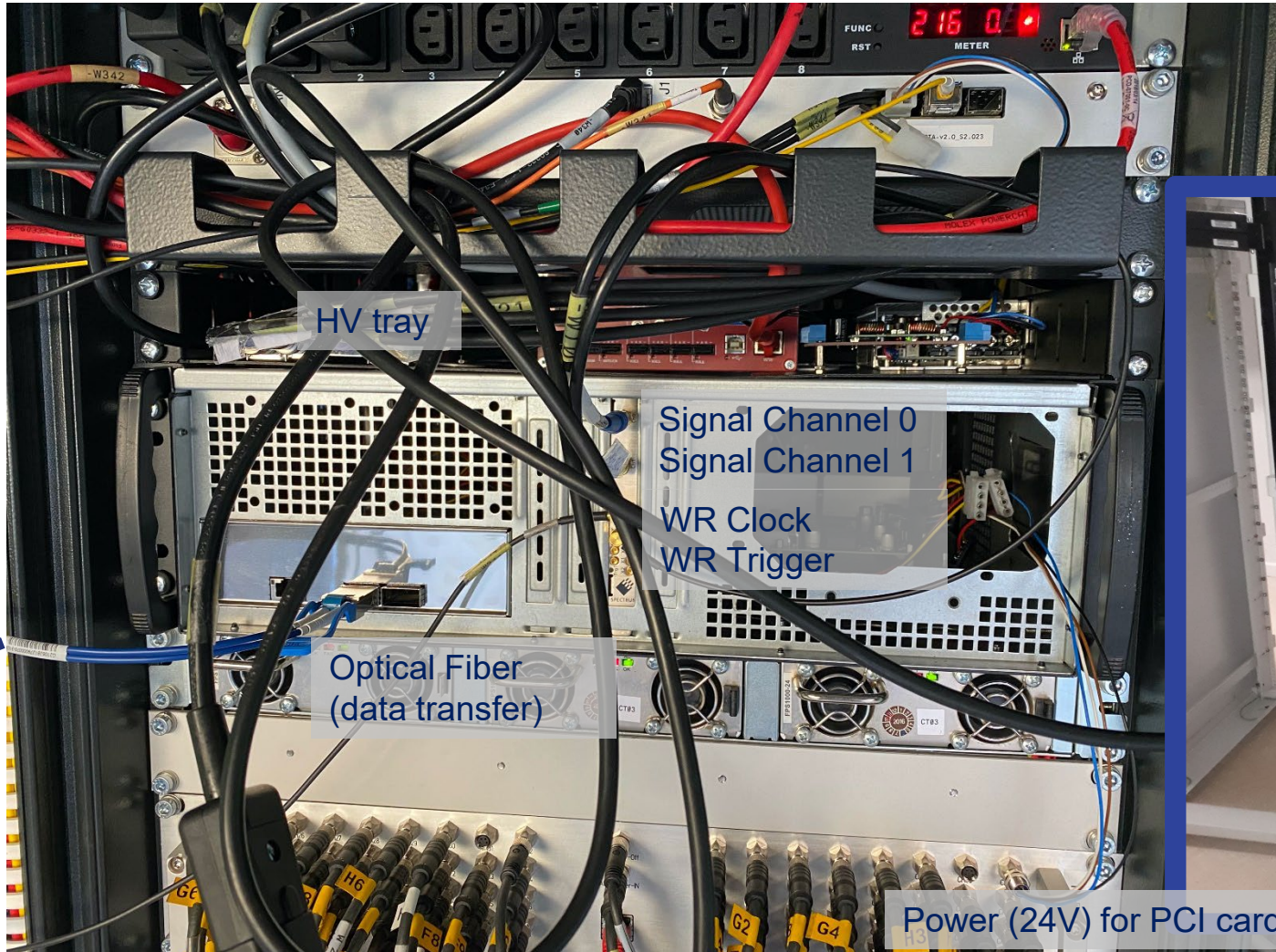


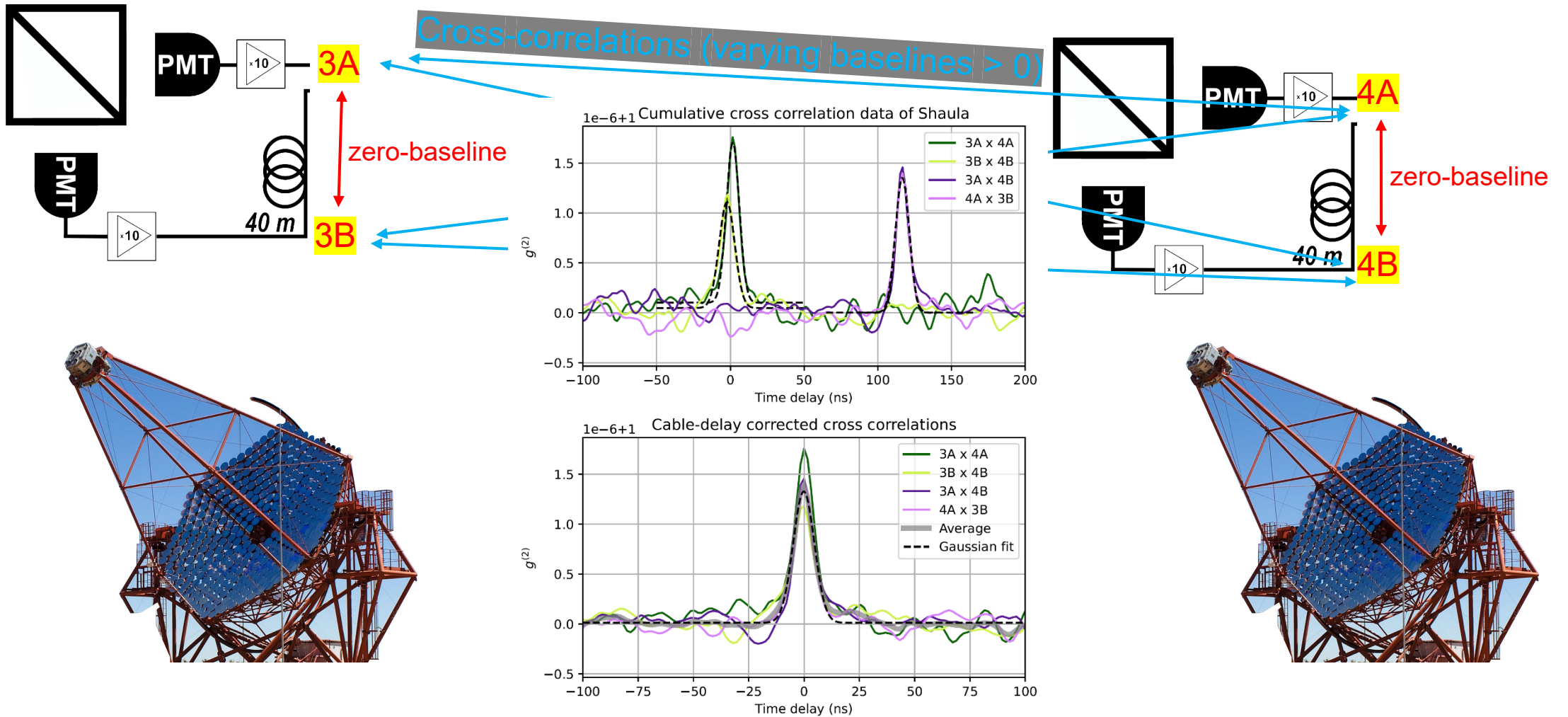


# Data transfer

Camera plane rack

and server room

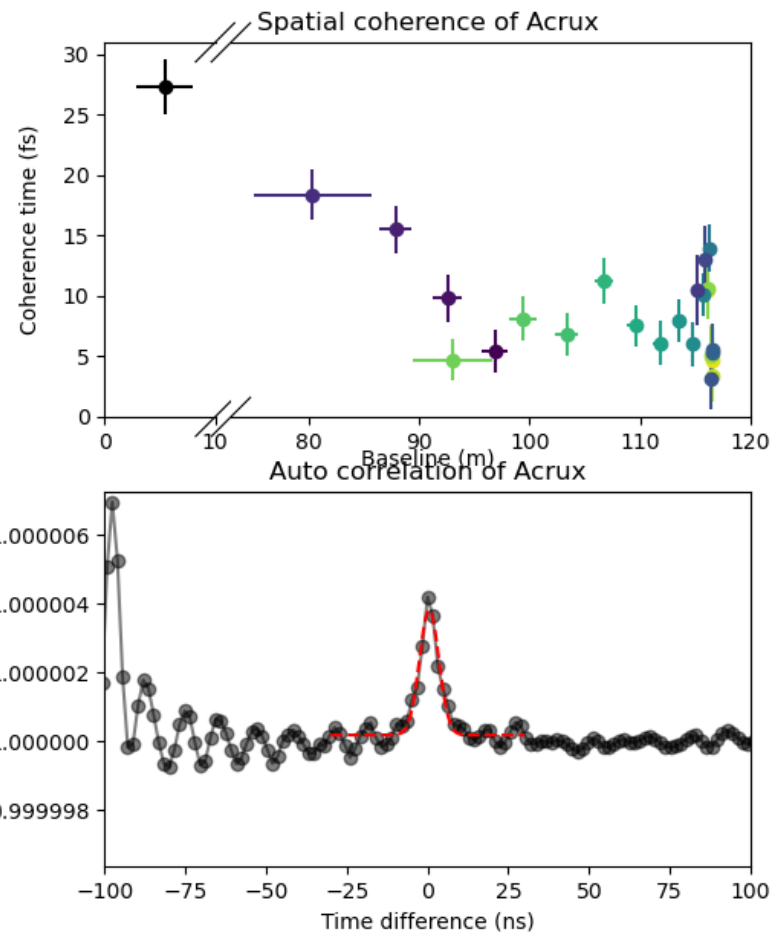
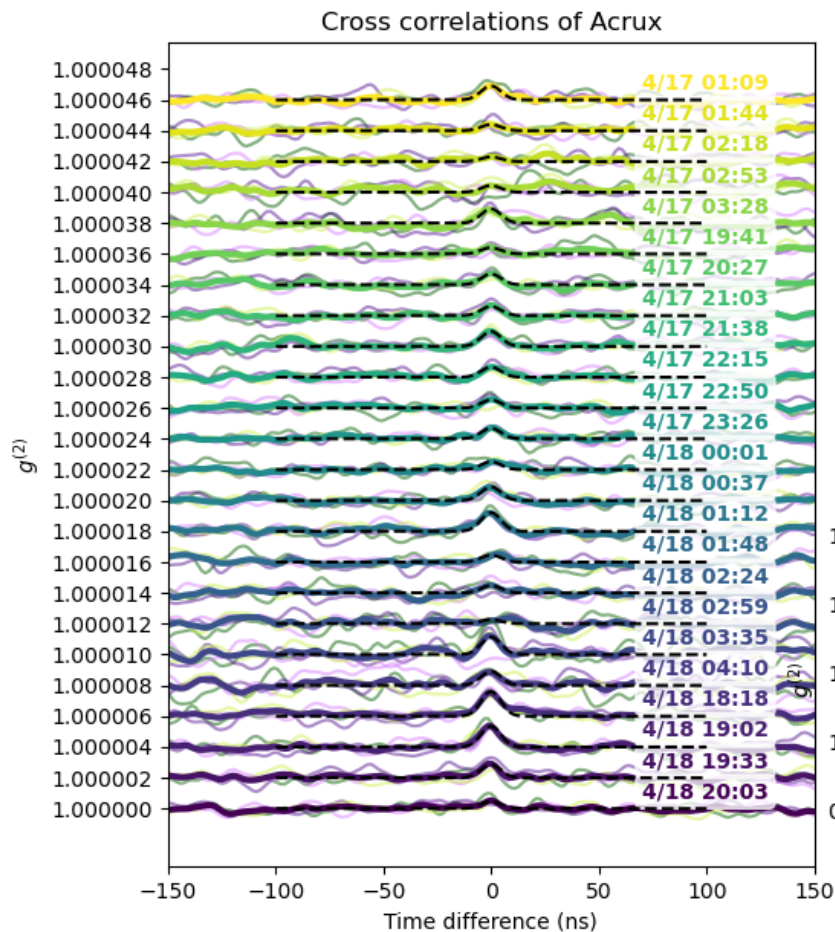






# Results

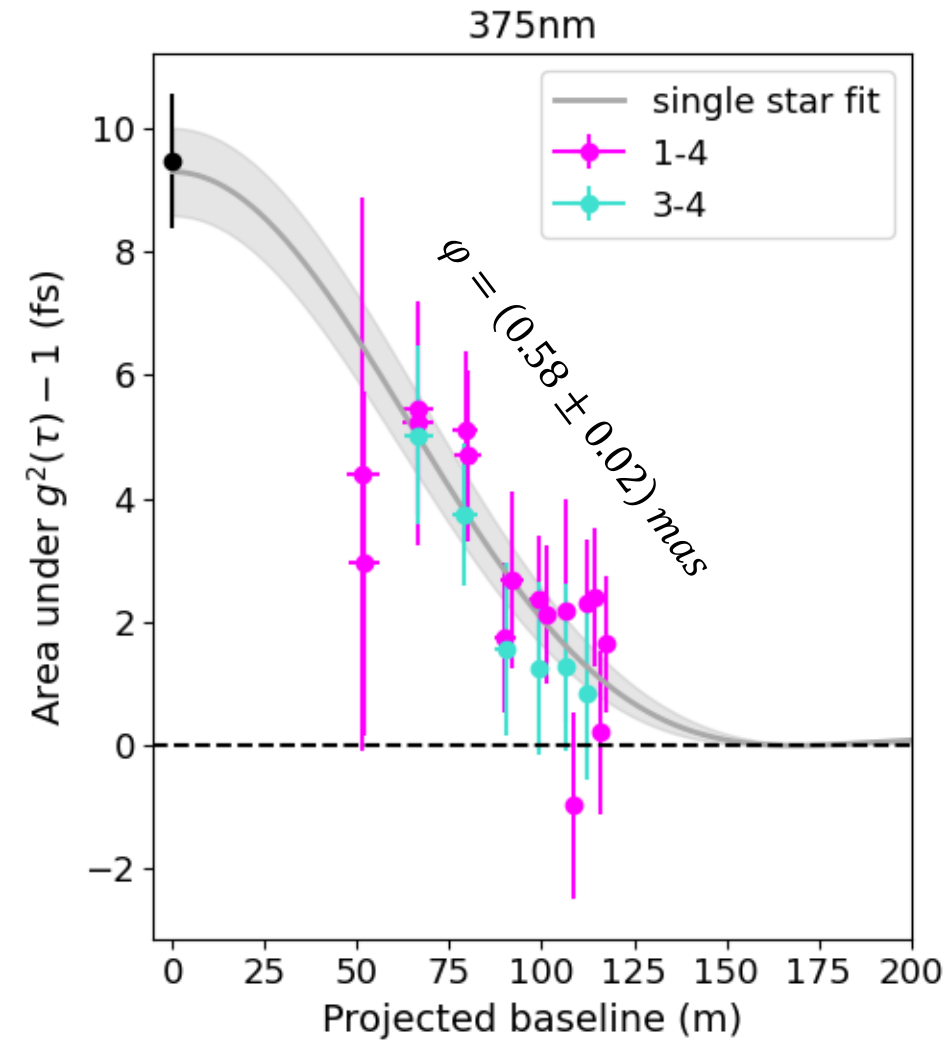
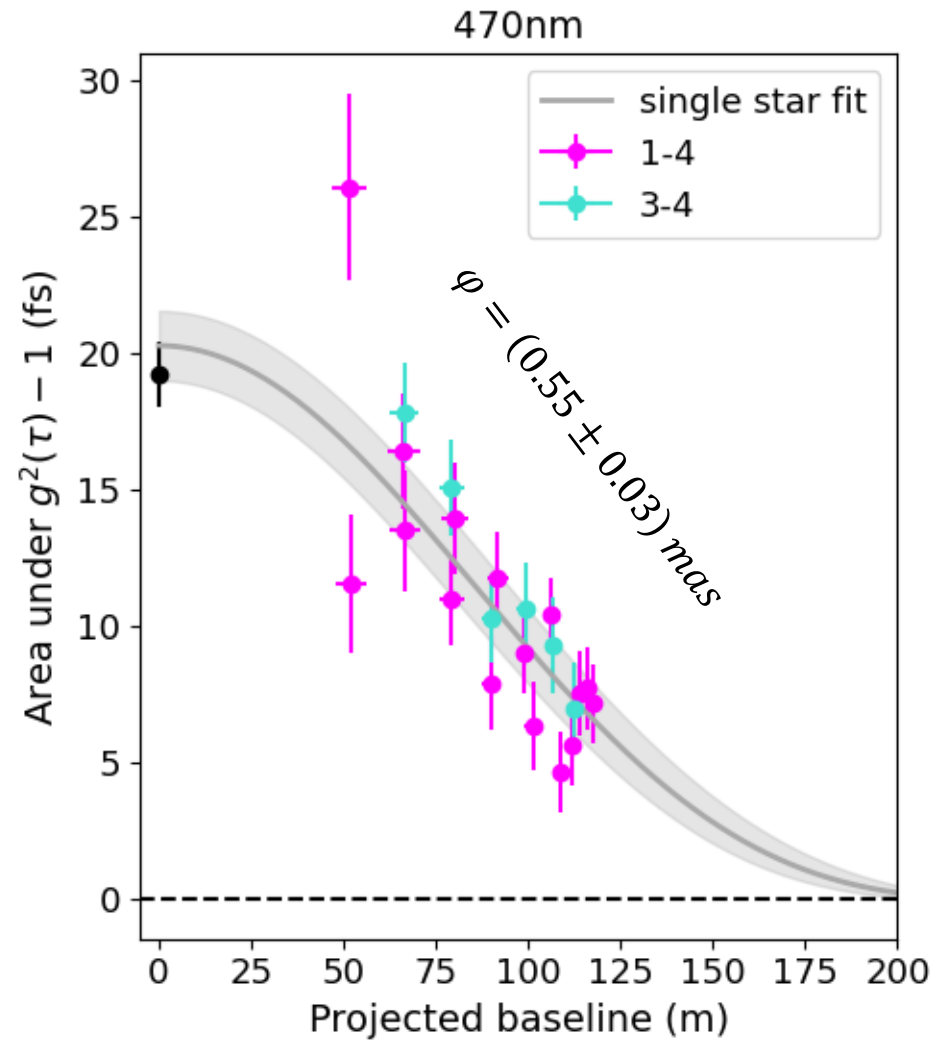
## Spatial correlations of Acrux



# 2023 Results

Eta Centauri - Two wavelengths

Etacen



### Dschubba

