SII software school: Lesson 4

SII analysis

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Centro de Investigaciones
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y Tecnológicas

IACT-SII: Previous lessons wrap up

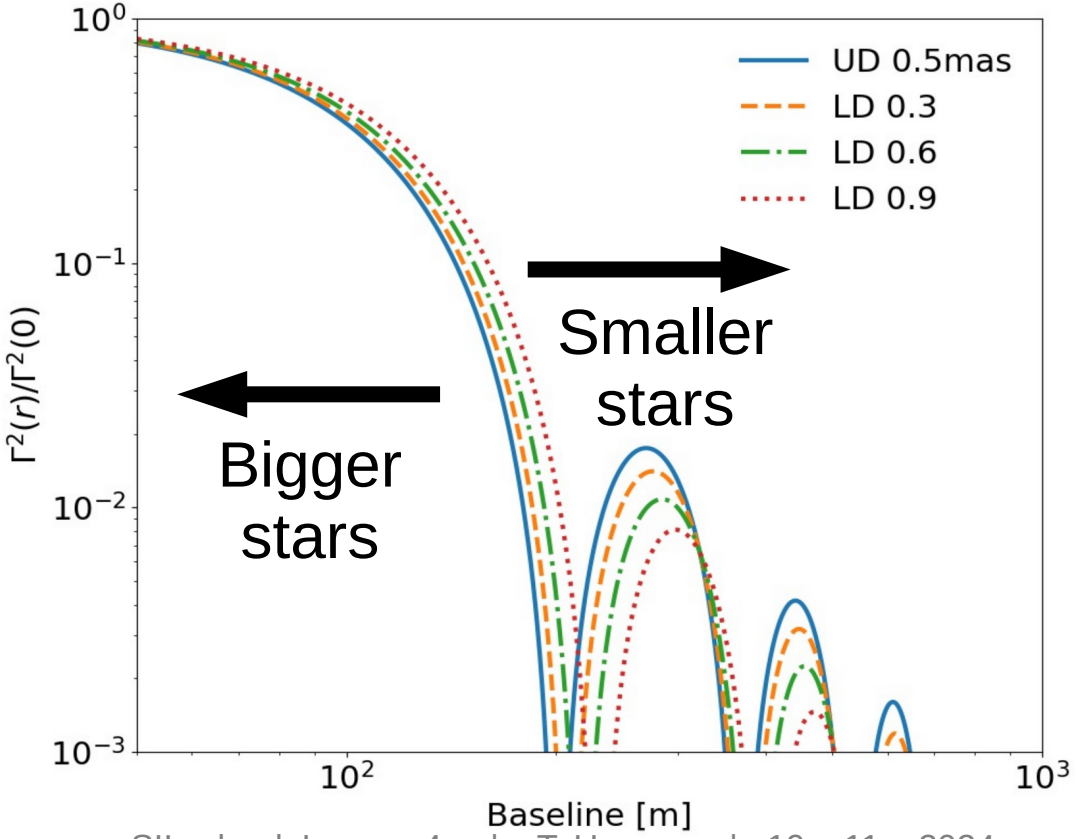
- Steps of an analysis that should be doable by the analyzer:
  - Downloading/synchronizing + reduction
    (also LST1 data!)
  - Source analysis of a single correlation channel
  - Run-level visualization and run/analysis reports
  - Understanding the meaning of ZBC
  - Create a ZBC calibration file from any analysis, and use it in other analyses

IACT-SII: Lesson IV

- Reminder of what ZBC is, and when/how we expect it to change
- Review of what is the content of analysis result files
- Combined analysis:
  - Why do we need it? When does it make sense?
  - Multi-channel analysis
- Wrap up and exercises

SII analysis theory

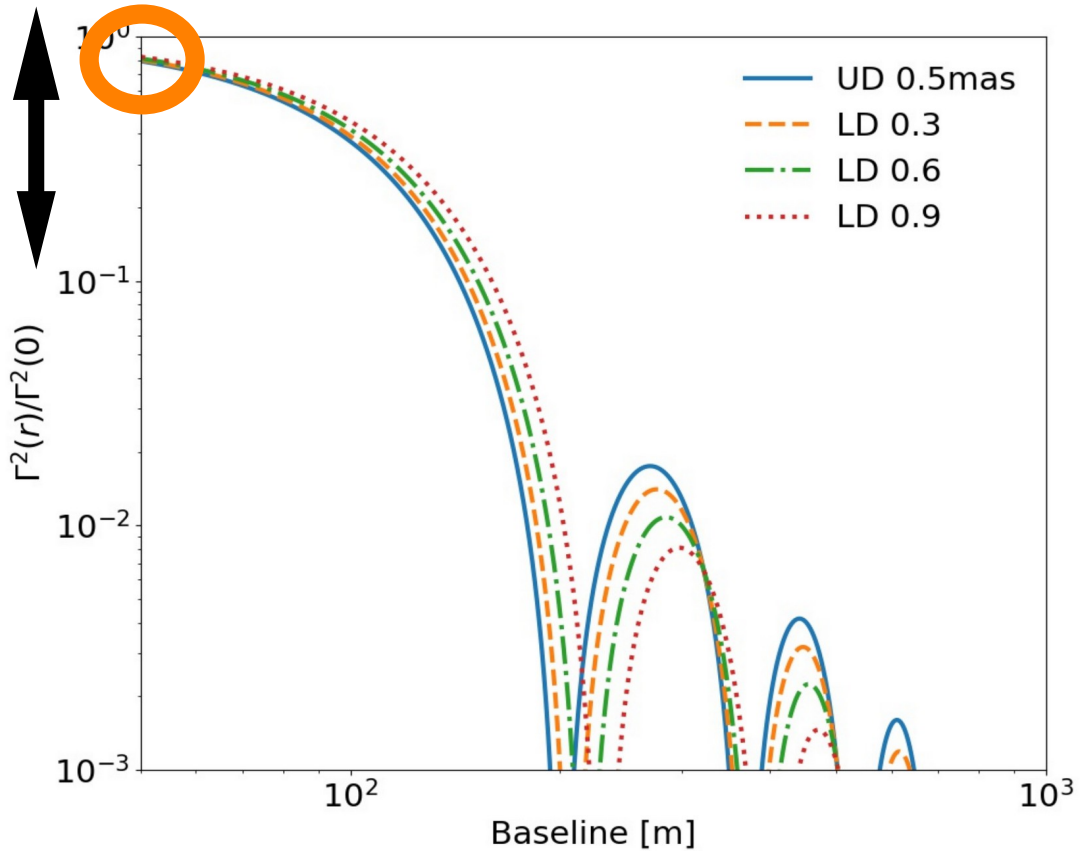
- These models generally have 2 free parameters:



SII analysis theory: zero-baseline correlation

- These models generally have 2 free parameters:

Correlation expected at 0 distance



ZBC: Things to remember

- The ZBC is fixed by **the hardware setup**.

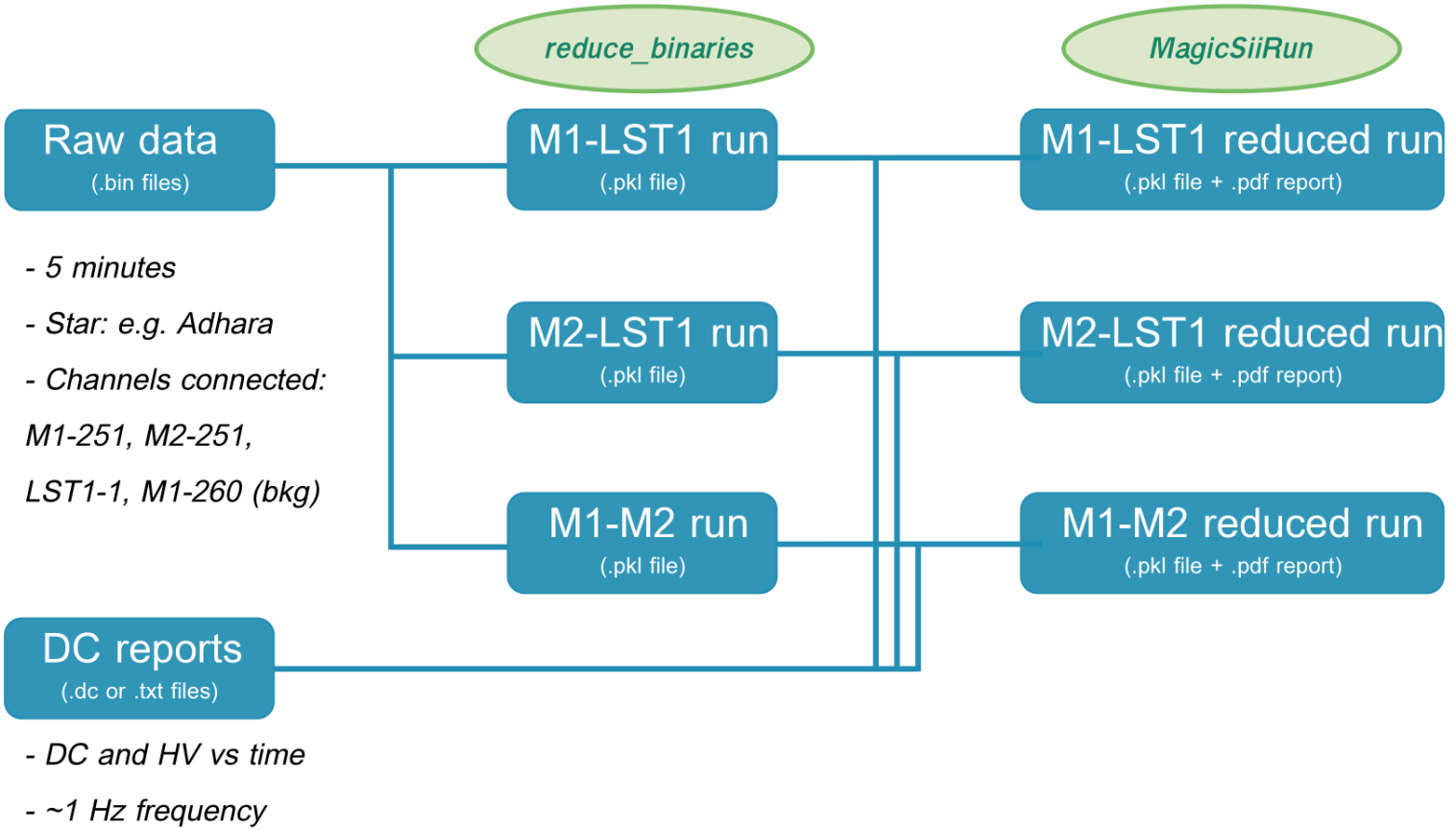
  What does this mean?

  - Measuring the correlation between different pixels (e.g. 251-251 vs 260-260) may lead to small differences in ZBC → better not to combine 251 and 260 pixels

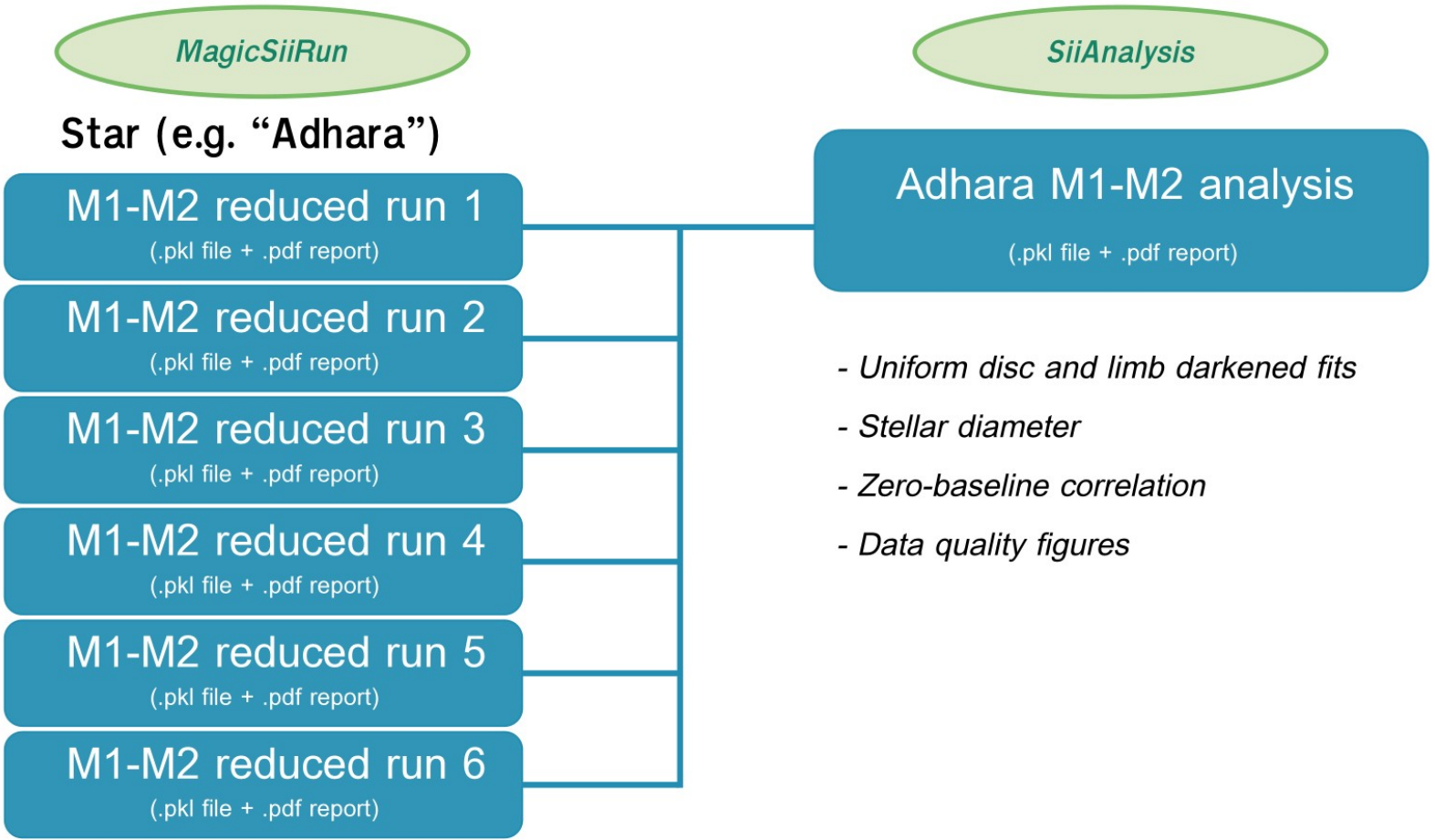
  - Differences between MAGIC pixels may be small, but MAGIC vs LST pixels will be **very different** → definitely never combine

  - PMTs degrade with time, so we expect ZBC to evolve over month/year timescales (taking this into account is work in progress!)

Interferometry data flow: run-level analysis

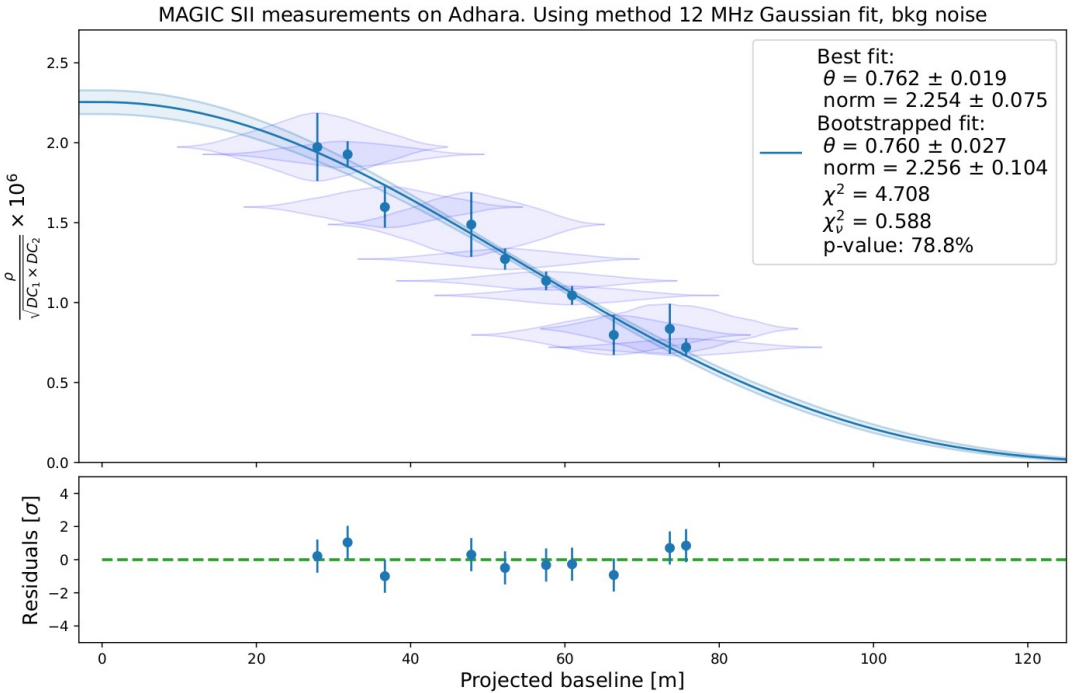


Interferometry data flow: source-level analysis



Quick reminder of analysis pickle files content

- Dramatically simplifying things, **analysis pickle files** contain this:
  - Most relevant data used to compute calibrated correlation measurements
  - Each calibrated correlation, and its baseline, UV coords, etc.
  - Fit results from the stellar diameter analyses



- **These files are the input of the combined analysis**

Why do we need a combined analysis?

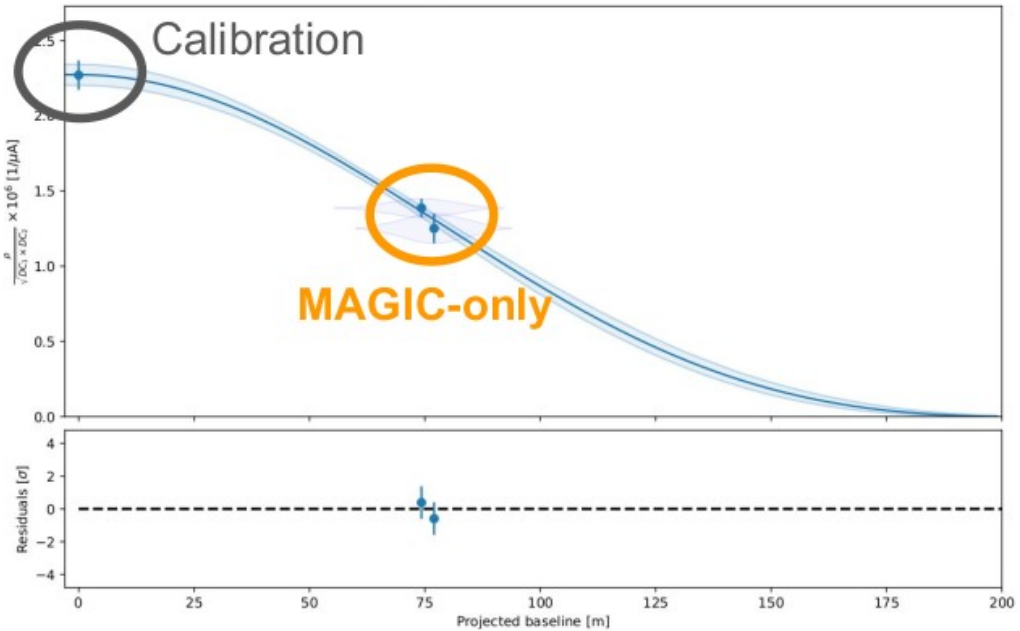
- Its simple: there are multiple situations (most situations actually!) in which the analysis results **from a single correlation pair** is not the best we can do

- Let’s review a couple of examples!!

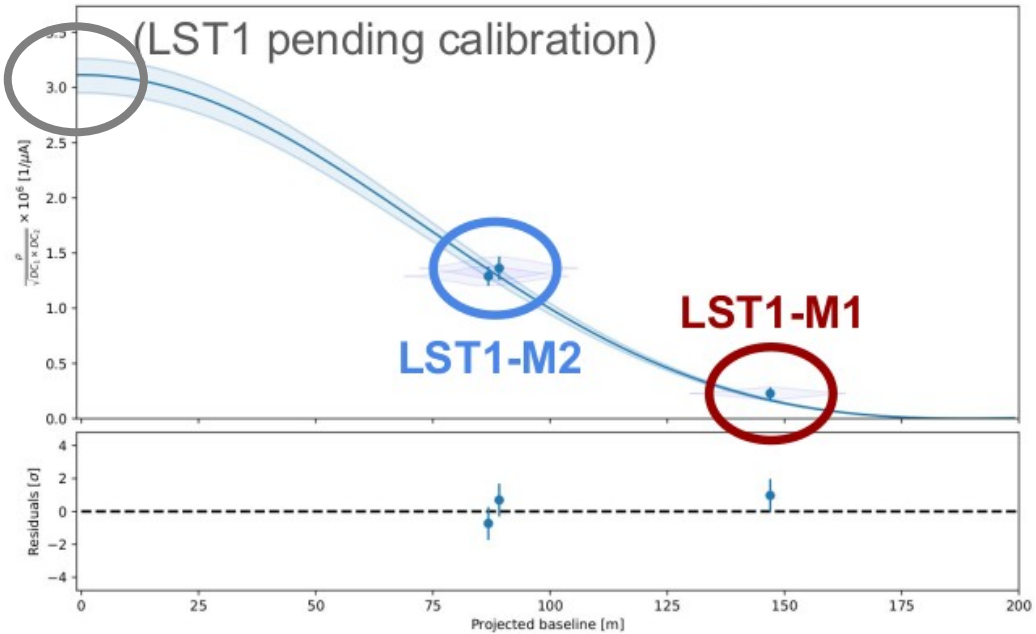
Why do we need a combined analysis?

- Example 1: determining a combined stellar diameter measurement

MAGIC-only measurement



MAGIC-LST1 measurements

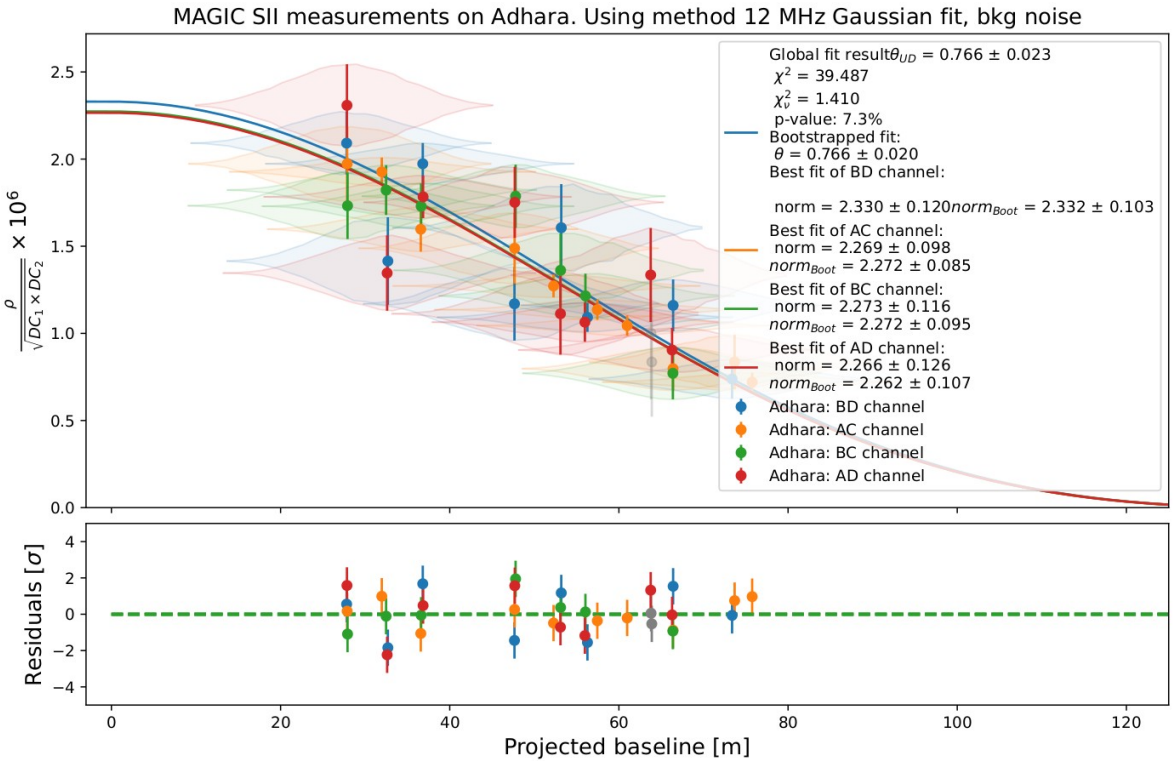


- When performing MAGIC+LST1 measurements, its clear we don't want independent stellar measurements for each correlation pair, **even if measurements have different ZBC**

Why do we need a combined analysis?

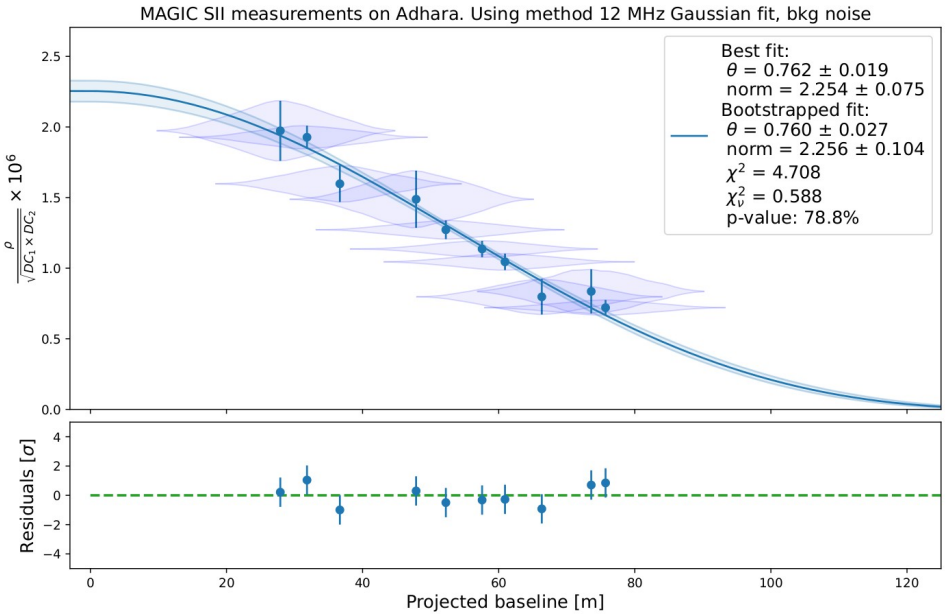
- Example 1: determining a combined stellar diameter measurement

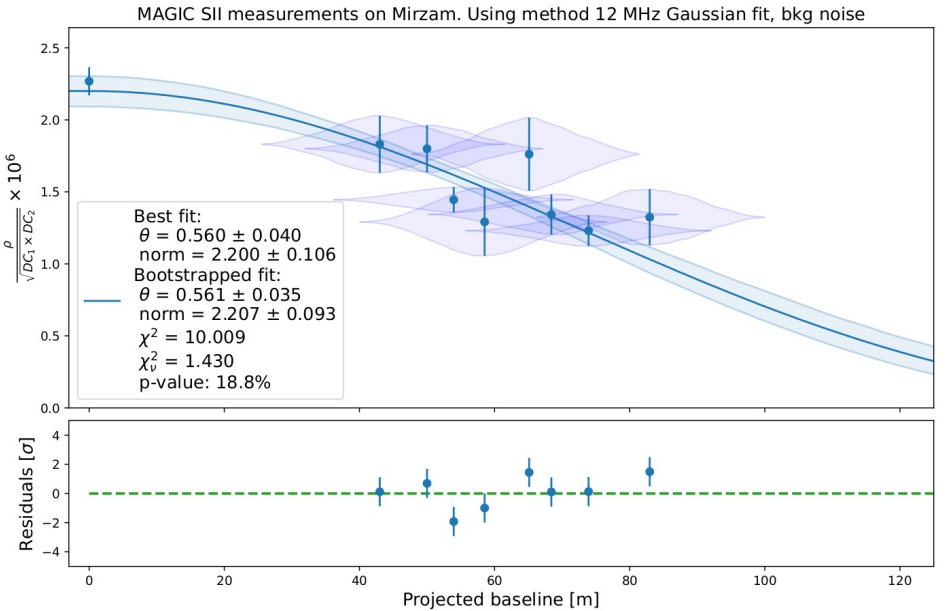
By performing a joint fit of the different correlation pairs, **each with a free ZBC but a common diameter**, we obtain the best possible astrophysical measurement we can from our data



Why do we need a combined analysis?

- Example 2: determining the ZBC

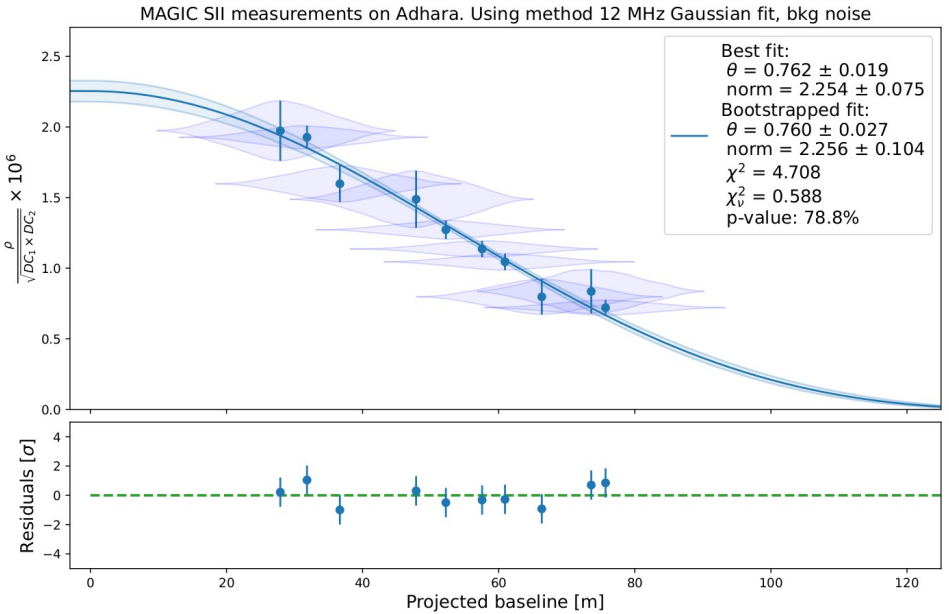


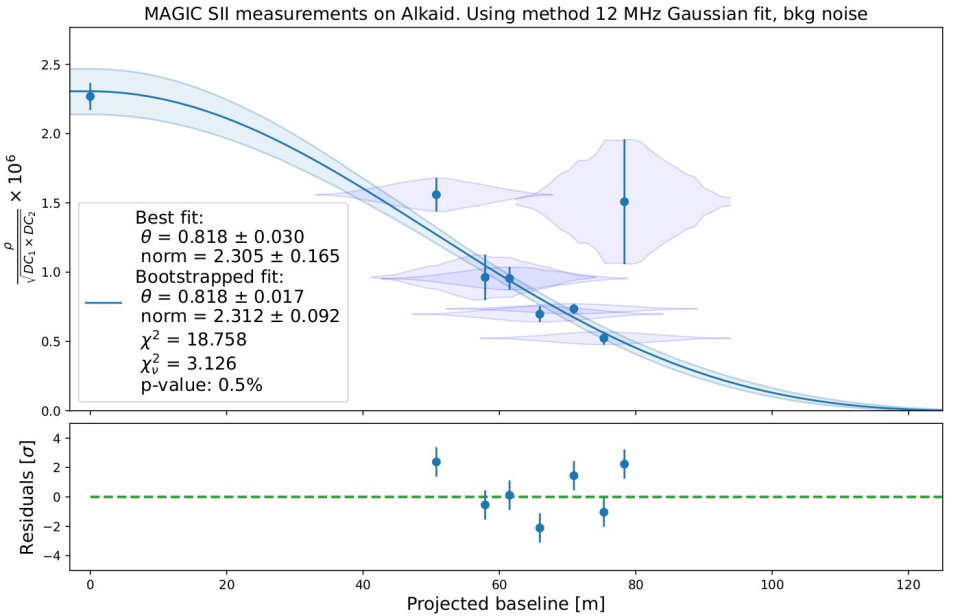


- Here, ZBC determination is clearly better with Adhara. But it is clear that Mirzam also has some degree of constraining power over the ZBC.

Why do we need a combined analysis?

- Example 2: determining the ZBC



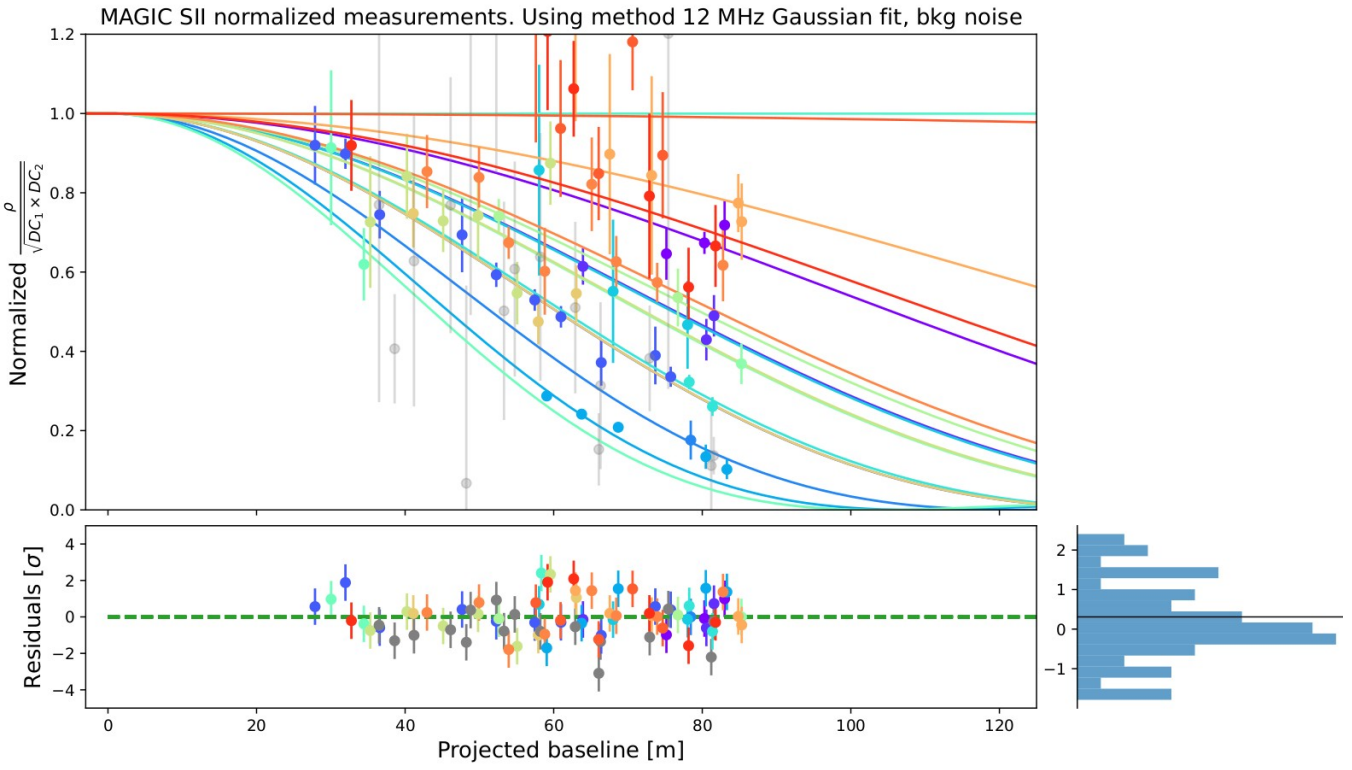


- Same with Alkaid. Adhara is better, but could Alkaid data improve the ZBC determination?

Why do we need a combined analysis?

- Example 2: determining the ZBC

By performing a joint fit of all correlation measurements, each with a free diameter **but a common ZBC**, we test the validity of the ZBC, and improve its measurement



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- Example 2: determining the ZBC

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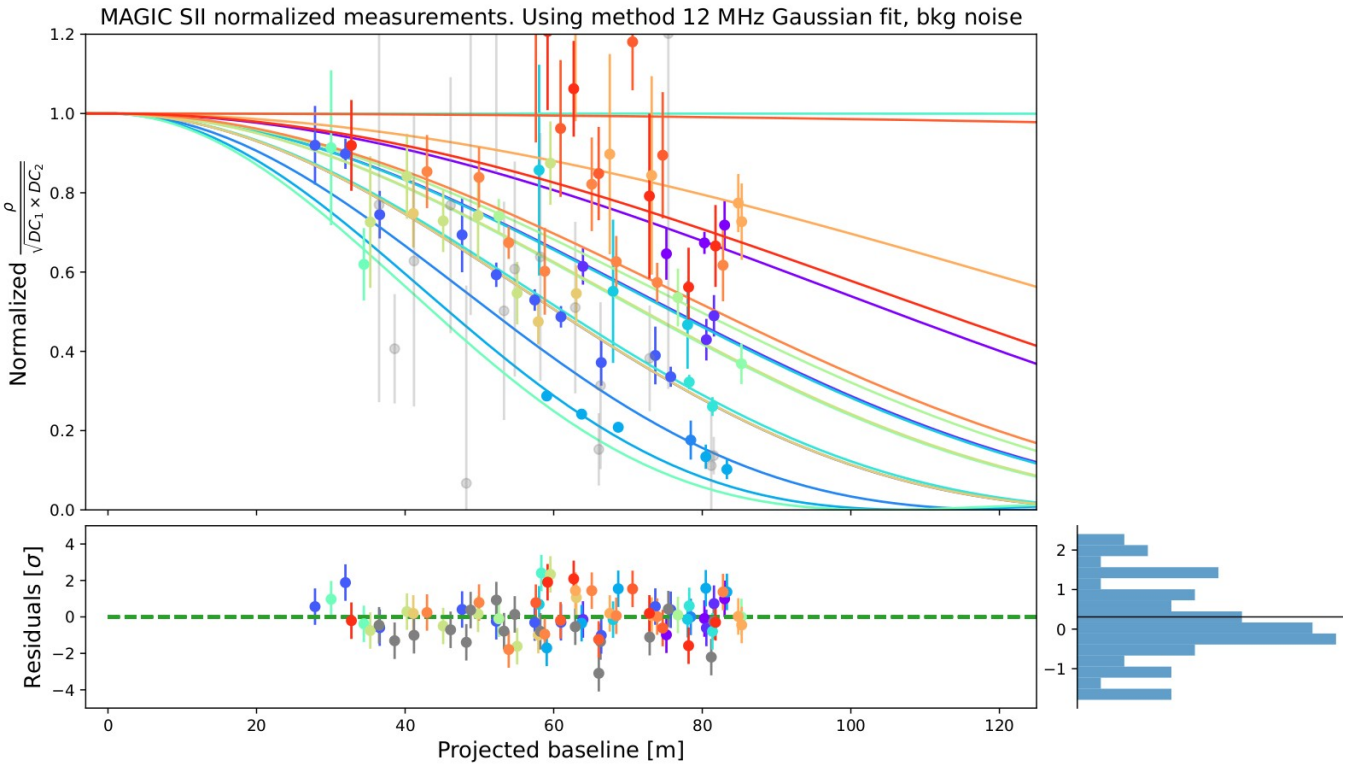


Why do we need a combined analysis?

- Its simple: there are multiple situations (most situations actually!) in which the analysis results **from a single correlation pair** is not the best we can do

- Several situations require a combined analysis:
  - Improving the ZBC determination between a single-source analysis
  - Performing an astrophysical measurement from multiple correlation pairs

- One could also think of more complex combined analyses: e. g. measuring the time evolution of the ZBC

Performing a combined analysis

- **DISCLAIMER!**
  - The combined analysis was done until now with devoted python scripts
    - This meant each combined analysis required a bit of python programming
  - For this course I created a new method, using configuration files as the `sii_production` stage
  - Please be patient as some things may not yet be ideal! I still need to work on meaningfull plots… Apologies!

Performing a combined analysis: old ways...

• The “old way” of performing a combined analysis is by using a couple of python scripts within magic_spysii/scripts:

- run_all_combined_analyses.py: Performs source-level combined analysis to compute a combined stellar diameter measurement
- run_zbc_combined_analysis.py: Performs a simultaneous fit of all observations, adding both ZBCs and diameters as free parameters

• If you want to use these you probably need to 1) understand them, 2) modify them slightly so they do what you want

Performing a combined analysis: new way!

- The new method we implemented (very recently!) is the following:

```
> sii_combined [combined analysis config file]
```

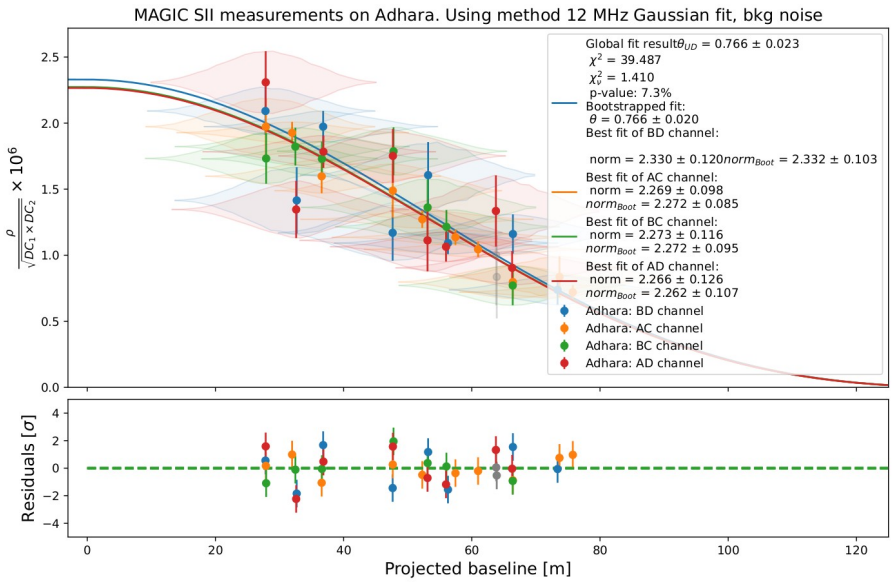
- As in the case of the `sii_production`, the main objective is for you to understand well the meaning of the different configurations implemented within the input card

  - **Tarek's hands on**: Take a look to the configuration file!

- This method is currently working, but plots are not yet very helpfull (sorry!)

Performing a combined analysis

• No matter which method you use, you will be able to extract ZBC files from the pickle data products of the combined analysis. As now several ZBC measurements may be contained within a single pickle file, you will need to specify which ZBC you want



Example: In the performance paper we used combinations from 4 different pixels to measure Adhara

A combined analysis allows decent determination of all ZBCs.

You may extract a ZBC by:

```
> extract_zbc_file [ANALYSIS FILE].pkl
--channel [ZBC TAG]
```

IACT-SII: Lesson IV wrap up

- There are multiple occassions in which you may need to combine measurements from different correlation pairs

- Performing a combined analysis is simple:

  - Generate analysis results with sii_production

  - Select them with the right wildcard

  - Choose the sources to be used, and which “tags” should be used as “free parameters” (independent ZBCs)

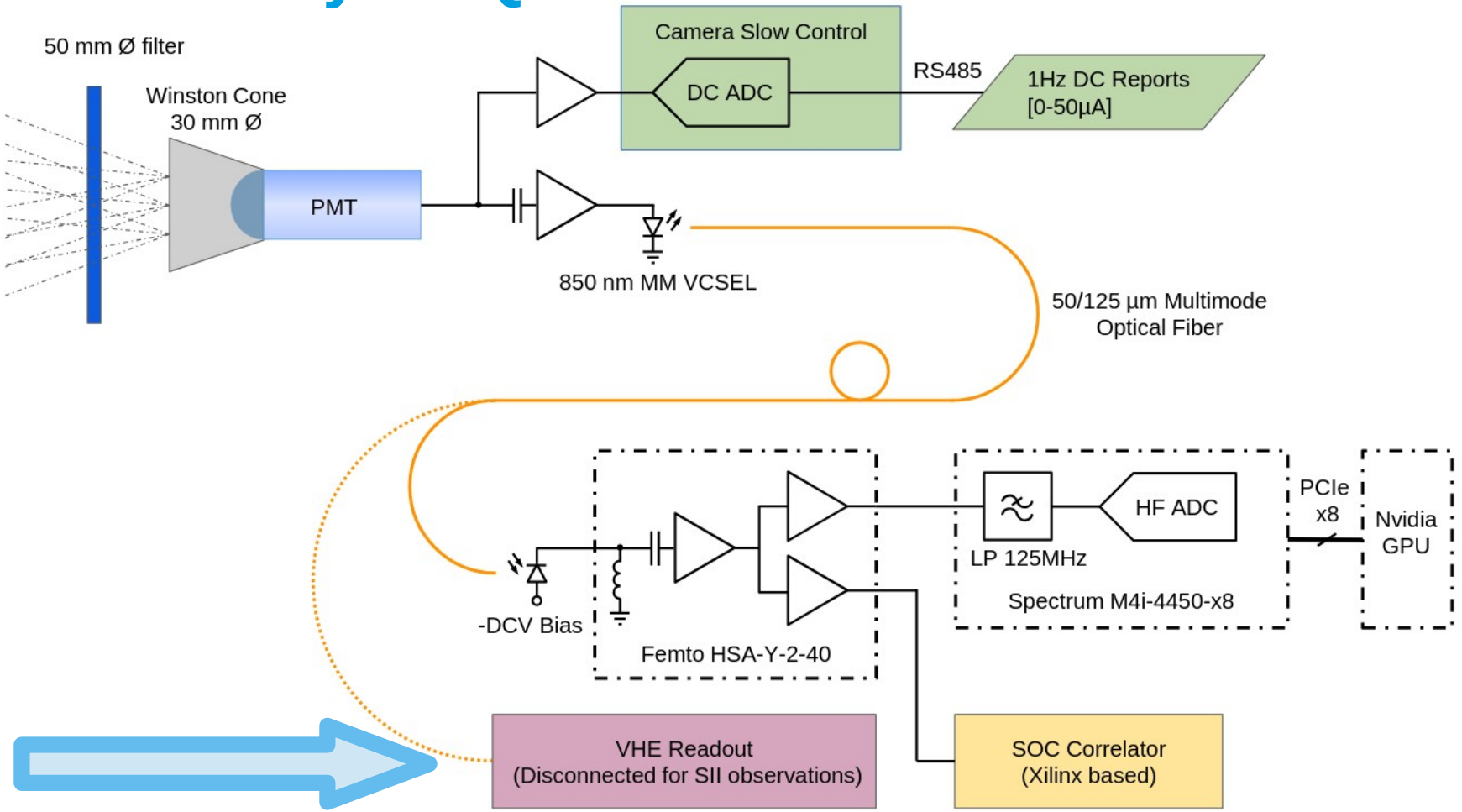
- This analysis always assumes time stability and radial symmetry! (careful with fast rotators, binaries...)

IACT-SII: Lesson IV – Proposed exercises

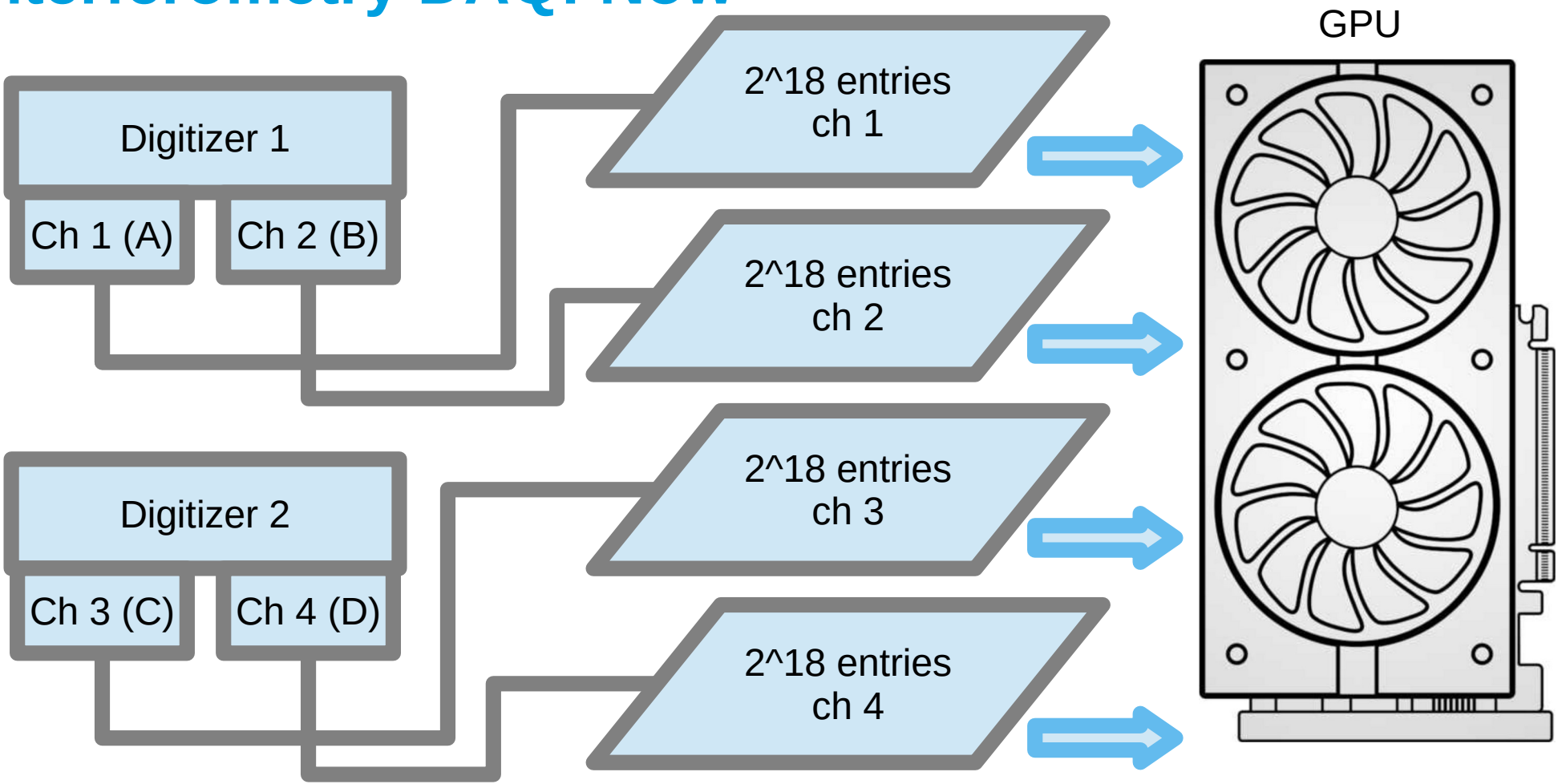
- Perform (or think about how you would do) **any combined analysis** you may want. Some examples:
  - Divide your data in time periods, and test the stability of the ZBC
  - Analyze many sources, and compute a ZBC using them all
  - Calculate M1-LST1 and M2-LST1 ZBC, exploiting the enormous dataset we have of MAGIC-only data
- Please share any result you may obtain! Is the combined ZBC statistically better than the one you had before? Did you find ZBC to be stable in time?


BACKUP

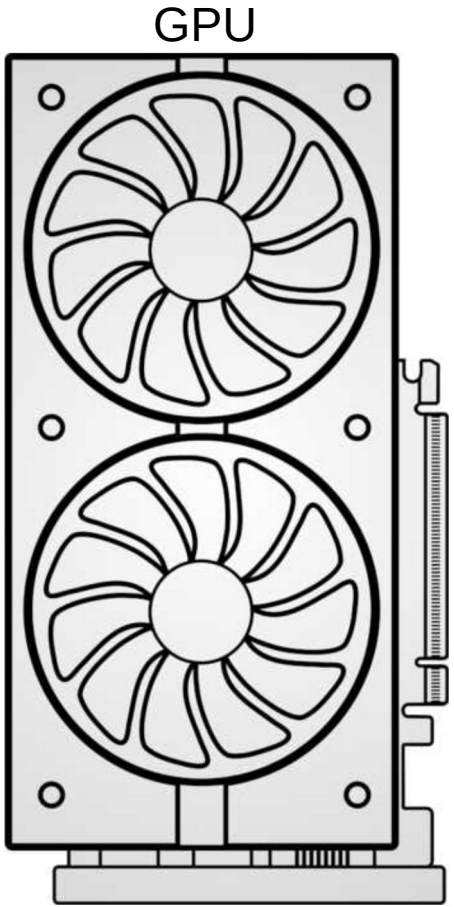
Interferometry DAQ



Interferometry DAQ: Now



Interferometry DAQ: Now



- Current DAQ computes:
  - Cross-correlation between each channel pair (via FFTs)
  - Auto-correlation of each channel
  - Certain useful parameters (mean and std dev of each channel)
- Current DAQ “accumulates” these, and writes the average correlation/mean/std dev every 500 cycles

ZBC: The constant of our system

- From HB&T, we know that the expected correlation:

$$\overline{c(d)} = \langle \Delta i_1(t) \Delta i_2(t) \rangle = e^2 A^2 \alpha^2 n^2 |\gamma_d(0)|^2 \Delta\nu \Delta f \qquad (4.28)$$

- After dividing by the flux, the remaining correlation should be:

$$\frac{\overline{c(d)}}{flux} \propto \frac{|\gamma_d(0)|^2}{\Delta\nu \Delta f}$$

- But as with our setup, our “flux” is the DCs (different gain than the correlation):

$$\frac{\overline{c(d)}}{\sqrt{DC^1 DC^2}} \propto \frac{|\gamma_d(0)|^2}{\sqrt{G^1{}_{DC} G^2{}_{DC}}\, \Delta\nu \Delta f}$$

Any time evolution in the DC gain will be a **systematic**