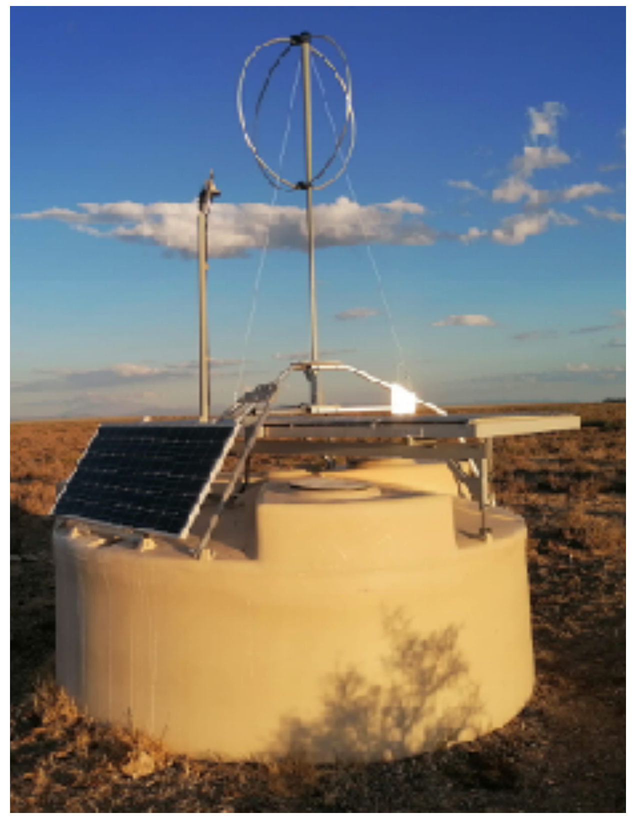
Radio Detector Operations Readiness Review



AugerPrime
Radio Detector
OPERATIONS READINESS REVIEW
Charges to the Review Committee
Review to be started in:
Malargüe, March 2025 meeting
https://indico.nucleares.unam.mx/event/2347/
(version: 20250225)

Review Committee Members
Petr Travnicek (chair)
Mauro Gajardo
Nicolás González
Frank Schröder
Ricardo Sato

Objective:
The Auger Project Management Plan defines the objective of the Operations Readiness Review as:
"A subsystem only becomes part of the operation of the Observatory when it has passed an Operations Readiness Review. This review ensures that the subsystem is in effective, stable operation, all documentation has been filed, spares are available and the staff has been trained."

The purpose of the review is to determine if the RD subsystem is ready to be included in the operation of the observatory for science production. Additionally, the review committee should asses if all the necessary material needed for operation and maintenance are existing and available.

Detailed frame of the Review:
- SALLA antenna and all mechanical components and supports;
- HF electronics of the antenna (LNA), signal digitizer and UUB electrical interface;

The review should assess, but not be limited to, the following issues:

Equipment availability and readiness
- Are components and software fully commissioned, operating reliably, and meeting performance requirements?
- Are all the hardware, power and software interfaces fully functional, compatible and operational?
- Are special tools and testing equipment required for routine maintenance present and available to the Observatory staff?
- Are the most common failures are yet known, understood and have a mitigation plan?
- Is there a long-term plan for component repairs or replacement?
- Has a reliable source for all spare parts, tools, and consumables been identified for future procurements? Are spares available on site as required?

Data Management
- Is RD data well integrated into the data stream?
- Is the RD data consistent and reliable ?
- Is the communication interface with UUB stable?
- Can CDAS handle the volume of data produced by RD?
- Is the monitoring of RD in place and well understood?

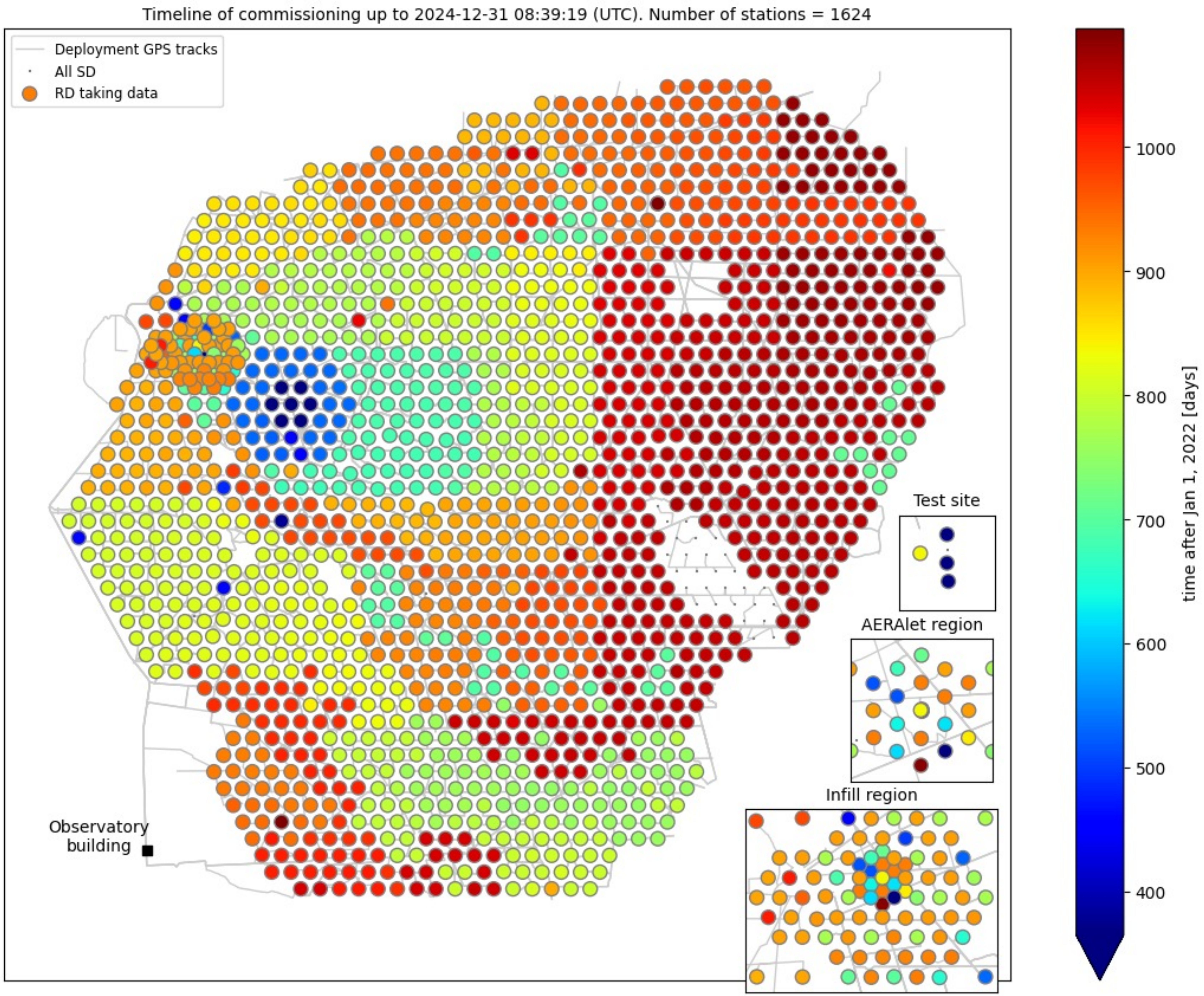
Technical Documentation
- Are drawings, schematics, and any other relevant documents complete and posted to CERN EDMS and/or PMS?
- Are instructions for operating and maintaining software code, as well as the code itself, available and organized?
- Is a complete list of equipment and components including part numbers and vendor contact information available?

Procedures. The following procedures must be complete:
- General operation.
- Hardware and software troubleshooting and maintenance.
- Process for handling major repairs.
- Inclusion of safety considerations in all procedures.

Training.
- Has an appropriate number of observatory personnel been trained to operate and provide routine maintenance?

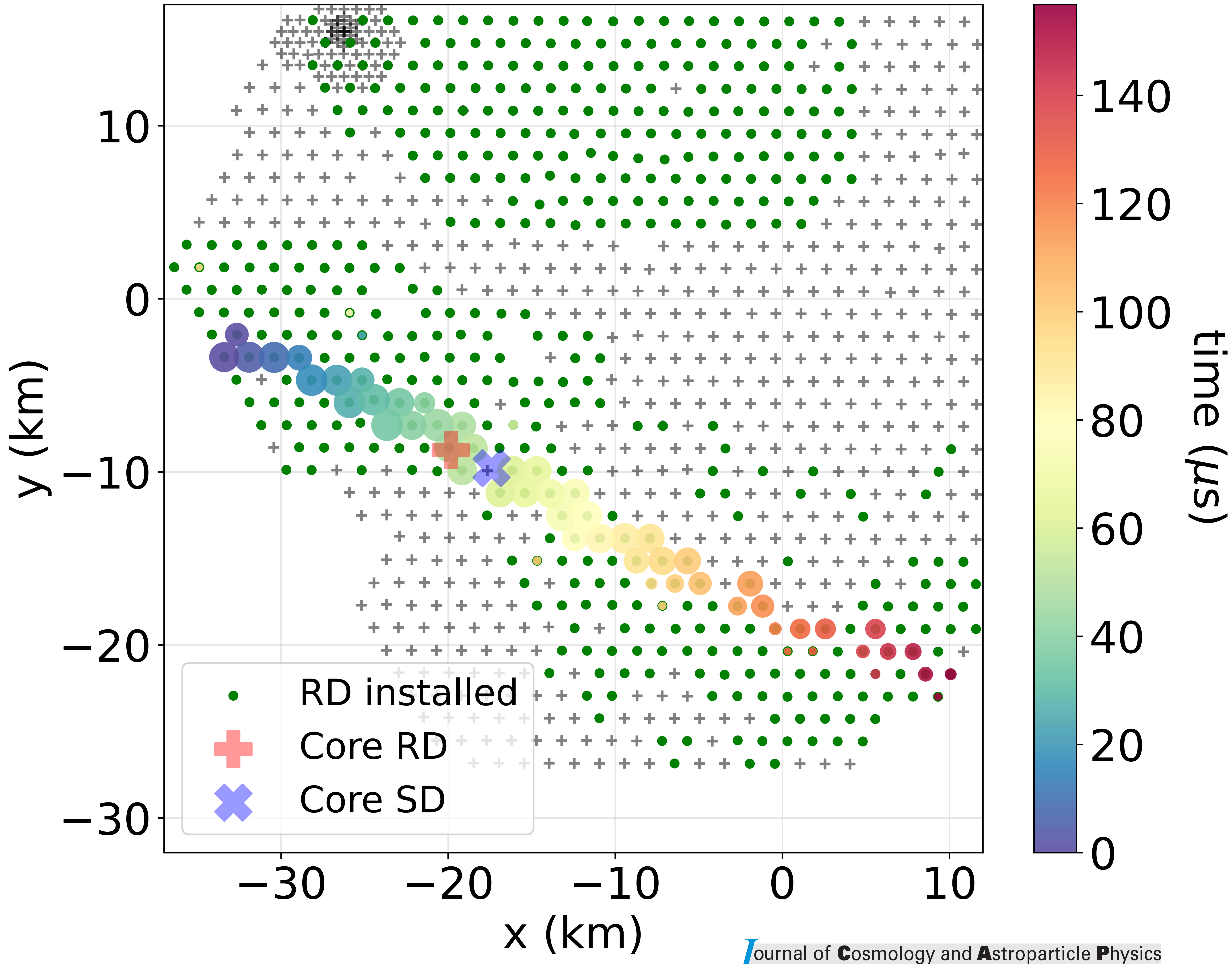
Operations costs.
- Evaluate the annual resources (person-power & costs) required for routine operation and maintenance for each subsystem, including materials and equipment. Discuss anticipated rates of failures and frequency of repairs and replacements.

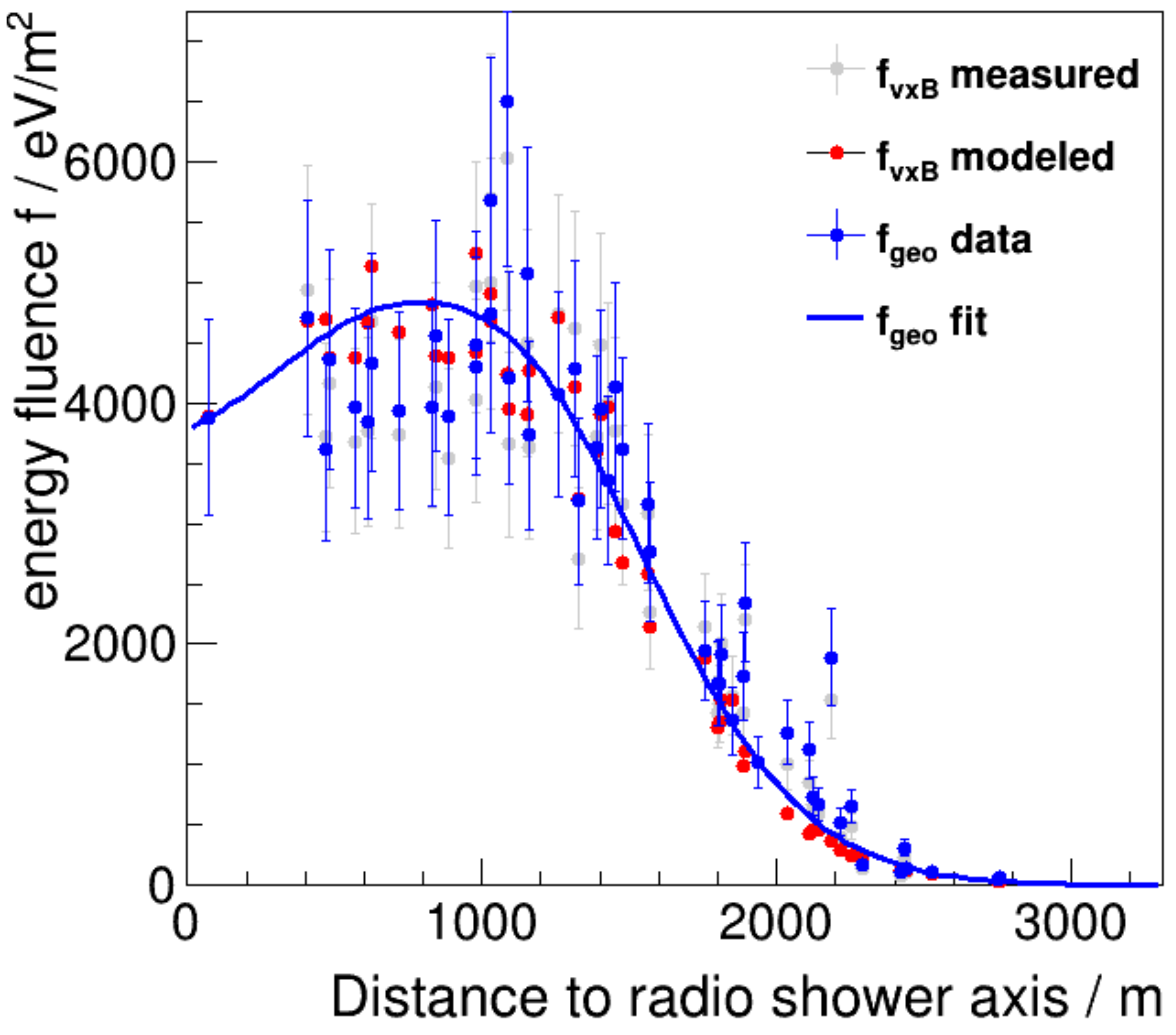
PIERRE AUGER OBSERVATORY



Radio Detector is deployed in full array

A measured cosmic ray





PIERRE AUGER OBSERVATORY

	RD	SD
Azimuth (deg)	157.0±0.1	157.0±0.1
Zenith (deg)	84.7±0.1	84.7±0.1
Energy (EeV)	36.23 ± 3.34	38.55 ± 2.92
Core X (km)	-19.8 ±0.90	-17.40±0.88
Core Y (km)	-8.73 ±0.90	-9.78±0.45

Eur. Phys. J. C (2020) 80:643
https://doi.org/10.1140/epjc/s10052-020-8216-z
THE EUROPEAN PHYSICAL JOURNAL C
Regular Article - Experimental Physics

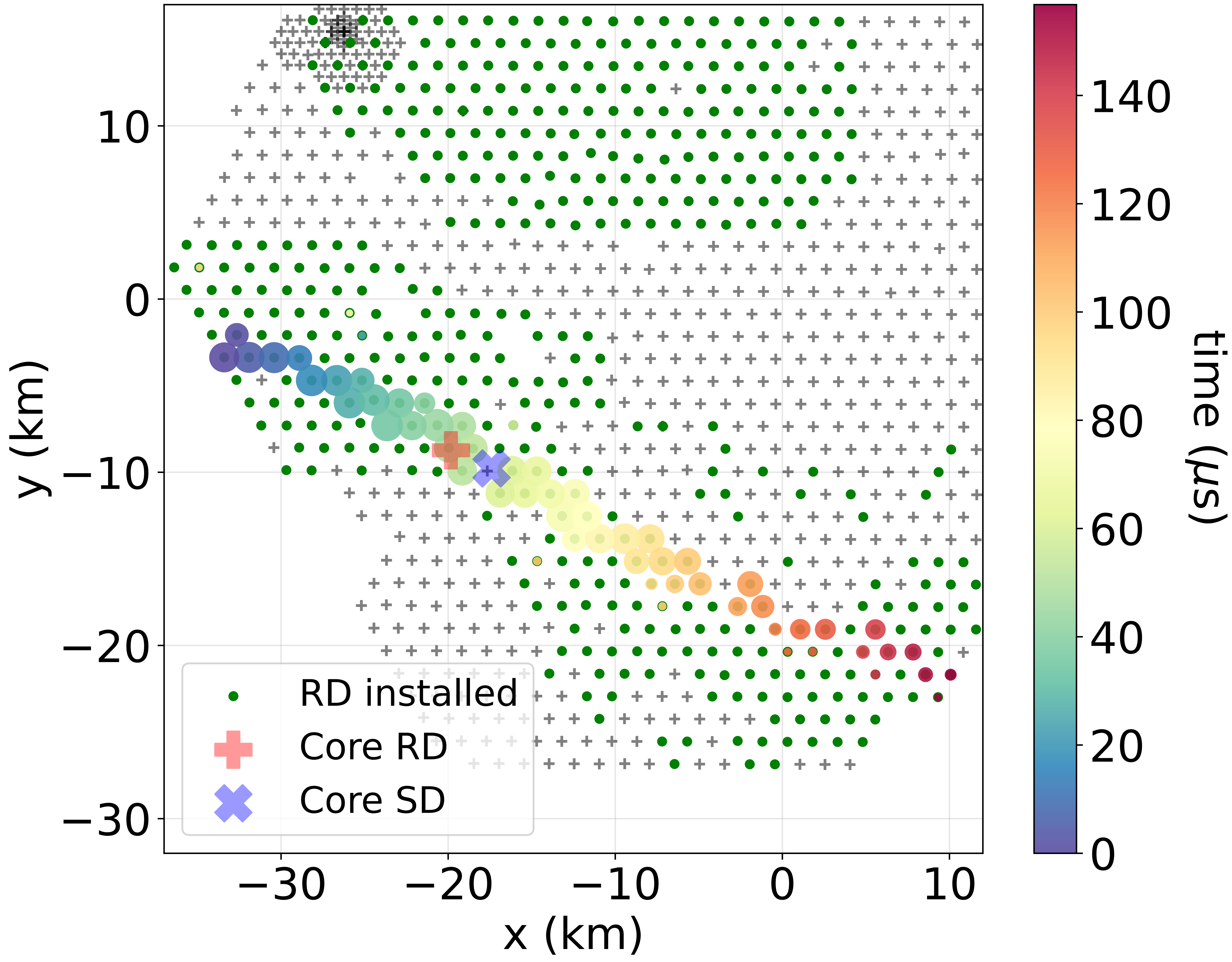
Refractive displacement of the radio-emission footprint of inclined air showers simulated with CoREAS

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Signal model and event reconstruction for the radio detection of inclined air showers

F. Schlüter[a,b,*] and T. Huege[a,c] JCAP01(2023)008

A measured cosmic ray



this is a high-energy cosmic ray

electric field ~mV/m

do you want so see something more energetic?

PIERRE AUGER OBSERVATORY

Direct lightning hit

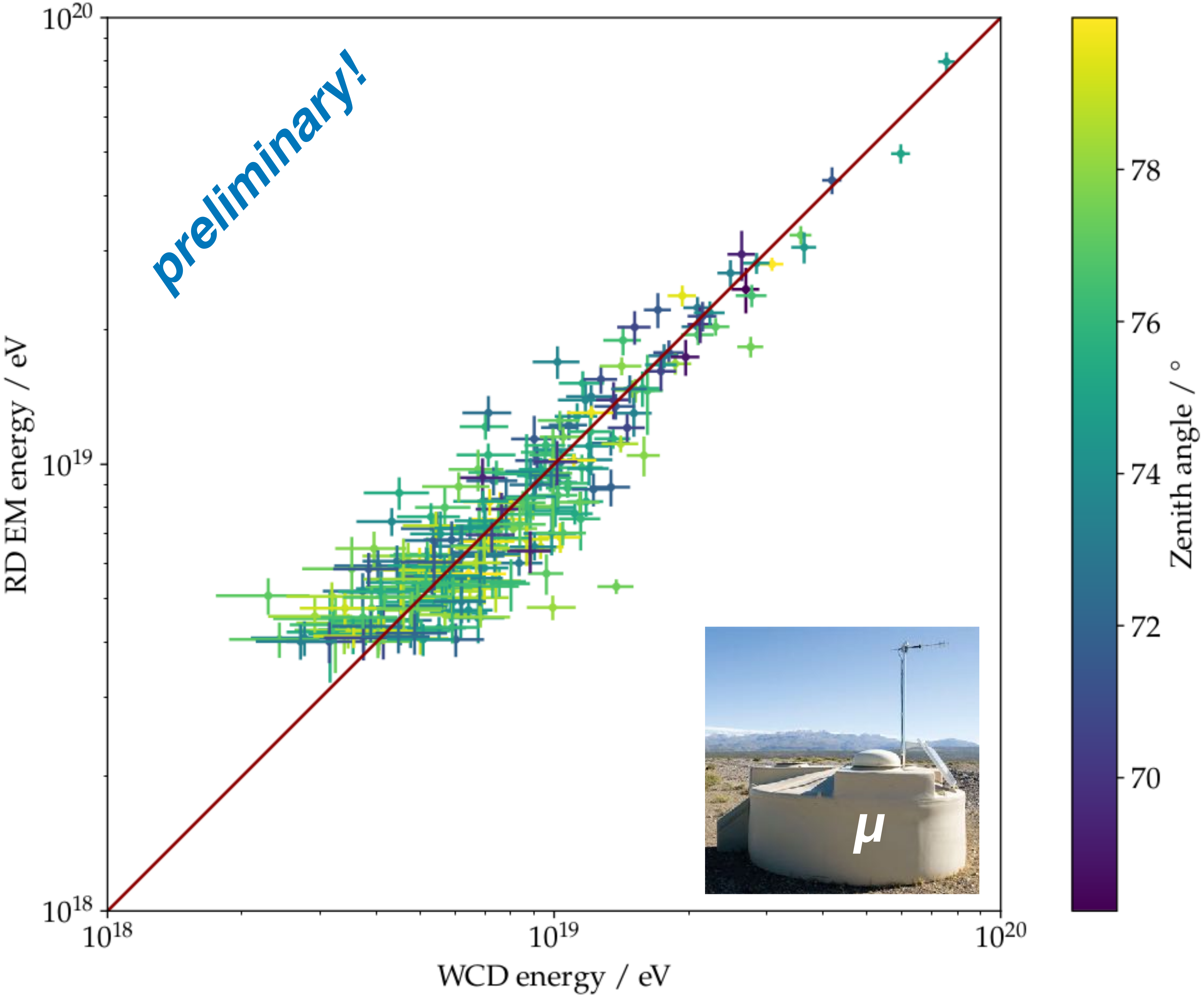
electric field ~kV/m

Luckily this is an exception and very unlikely to happen frequently

This happened also in the past with the GPS/ Leeds antenna

**(local staff estimates ~ 80/25 years
—> ~ 3-4/year)**

Correlation e/m energy with cosmic-ray energy



measurement of e/m energy by RD

measurement of muons with WCD

—> full end-to-end verification of complete chain

Radio Detector

overall status






- **hardware developed and manufactured (1700/2000 units)**
- **deployment completed**
- **end-to-end simulation of performance**
- **fully integrated in Auger analysis framework (offline)**
- **horizontal EAS reconstruction available in offline** $\sigma_E \approx 6\%$
- **monitoring and calibration tools available (need work in CDAS)**
- **1st data confirm expectations**
- **hybrid reconstruction RD —> e/m, WCD —>** μ
- **working on radio (only) trigger**
- **preparing reconstruction of gamma rays and neutrinos**

We are running a production for the ICRC2025 presentations.

Analyses ongoing.

—> Radio Detector fully operational and producing physics data.

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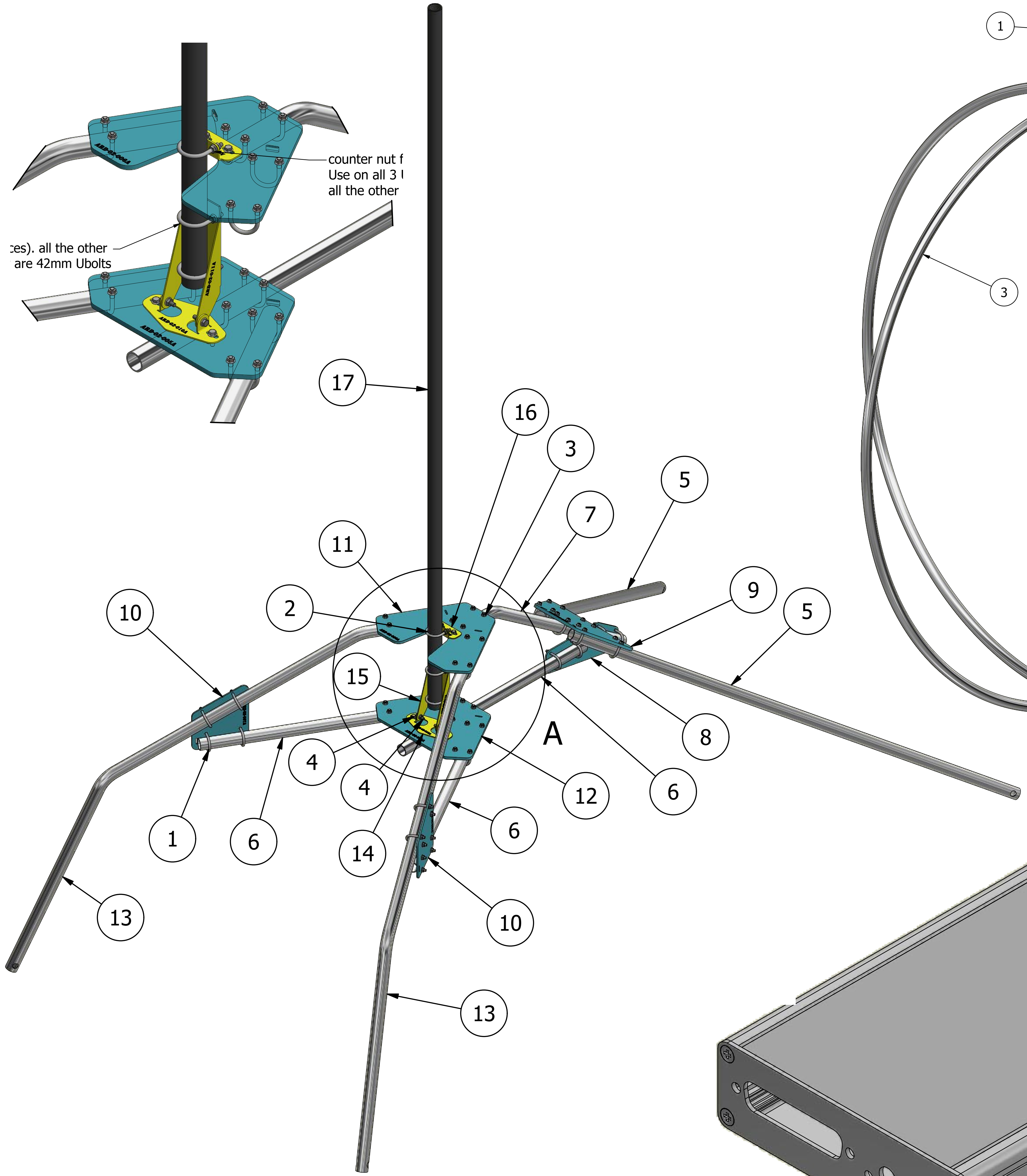
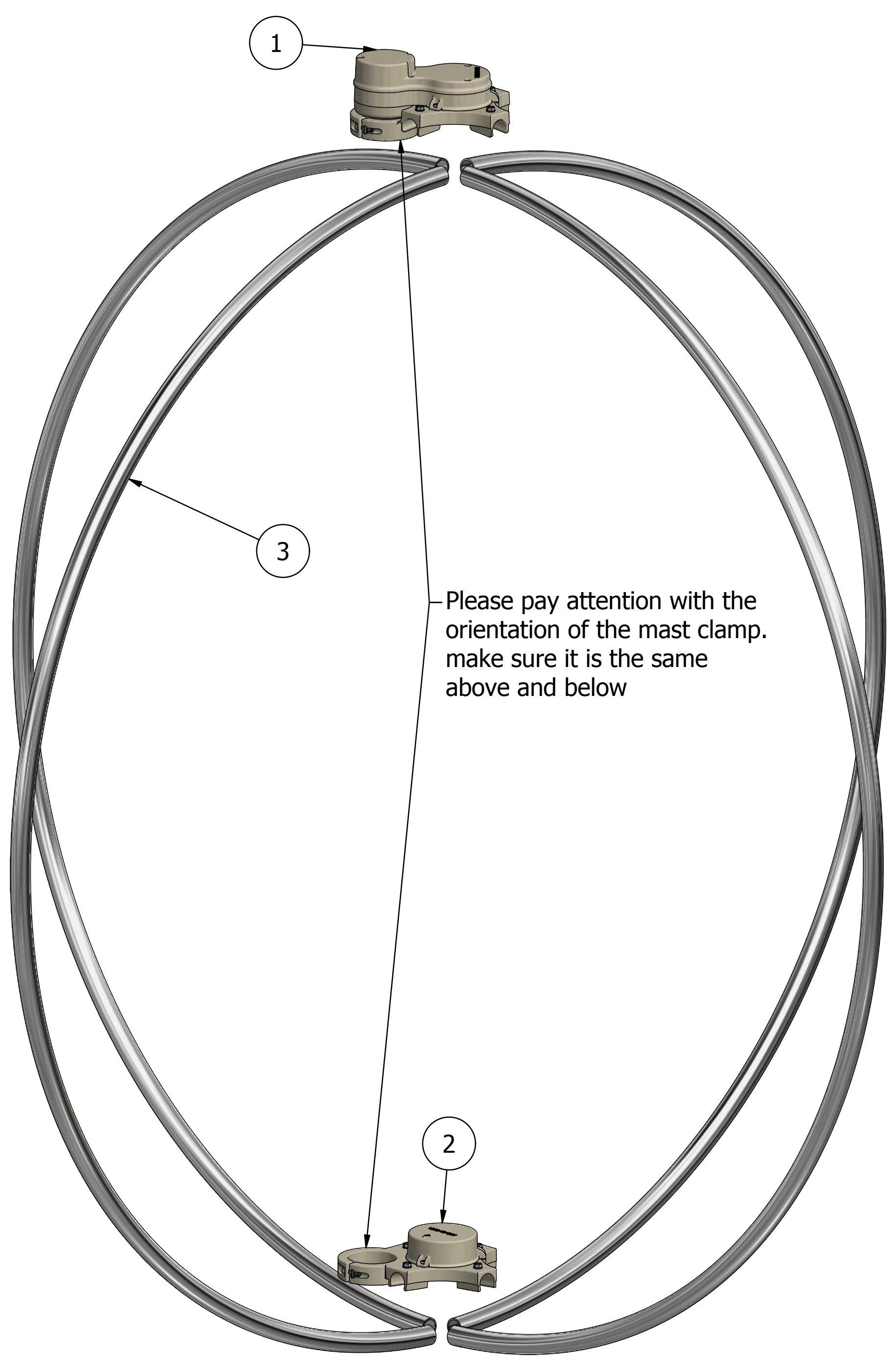
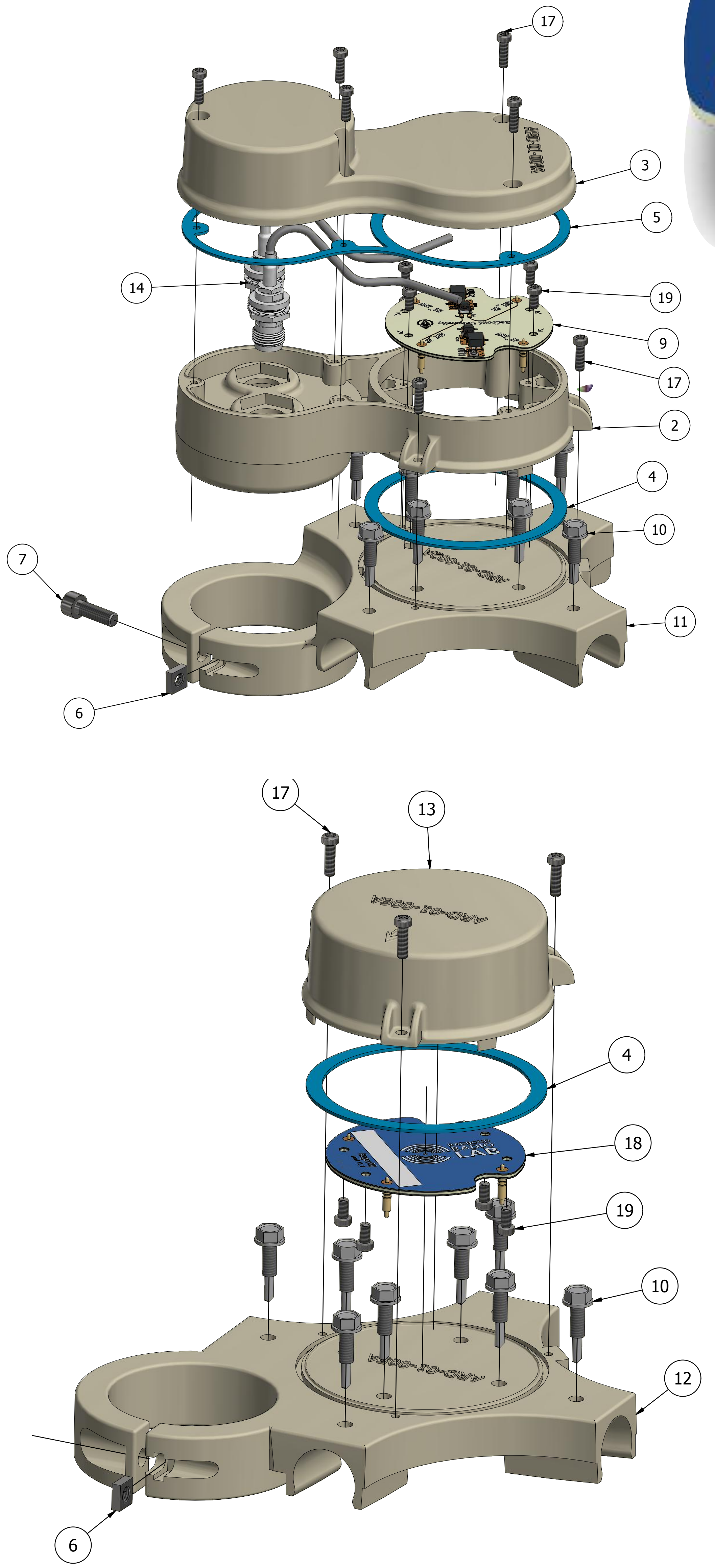
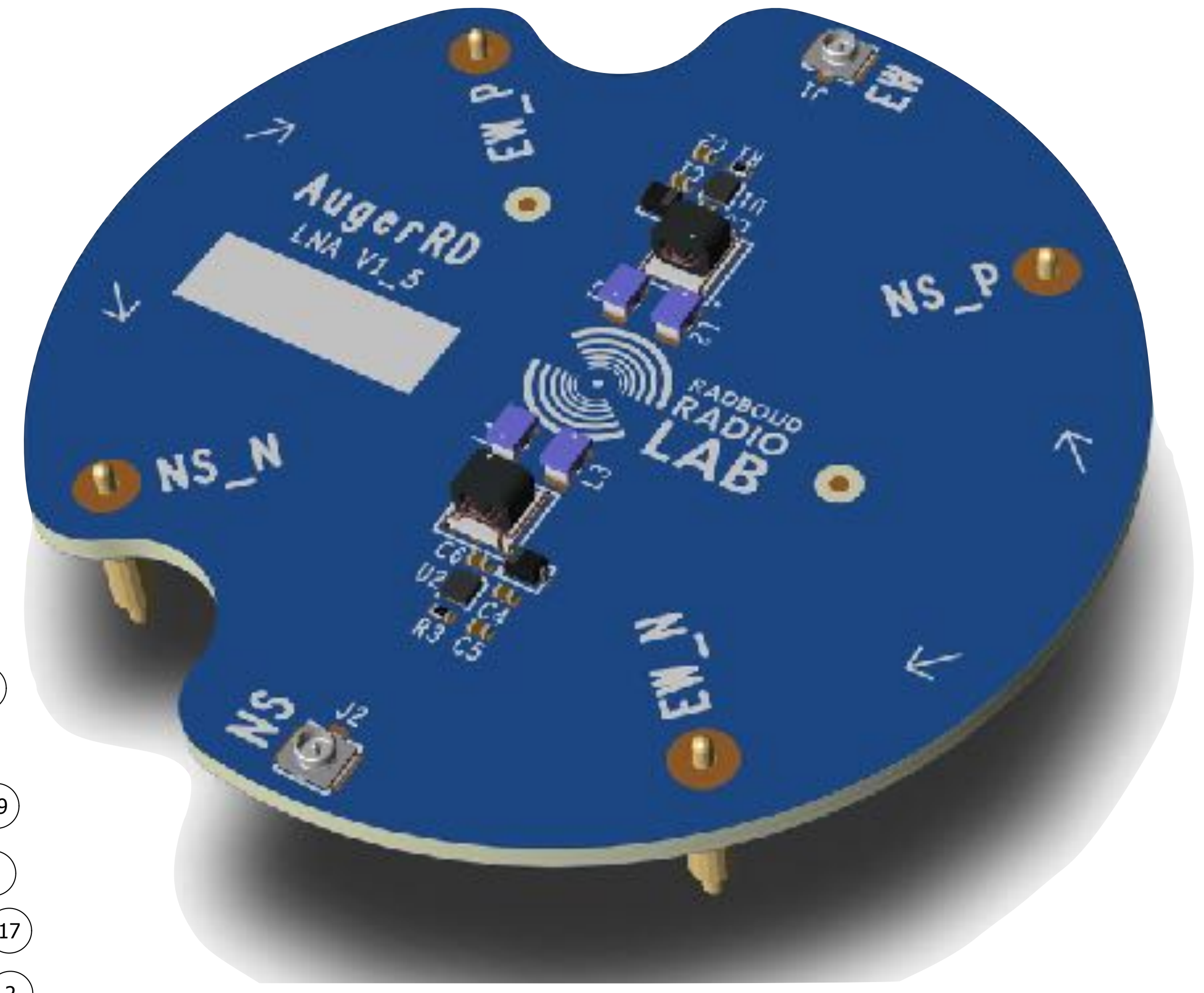
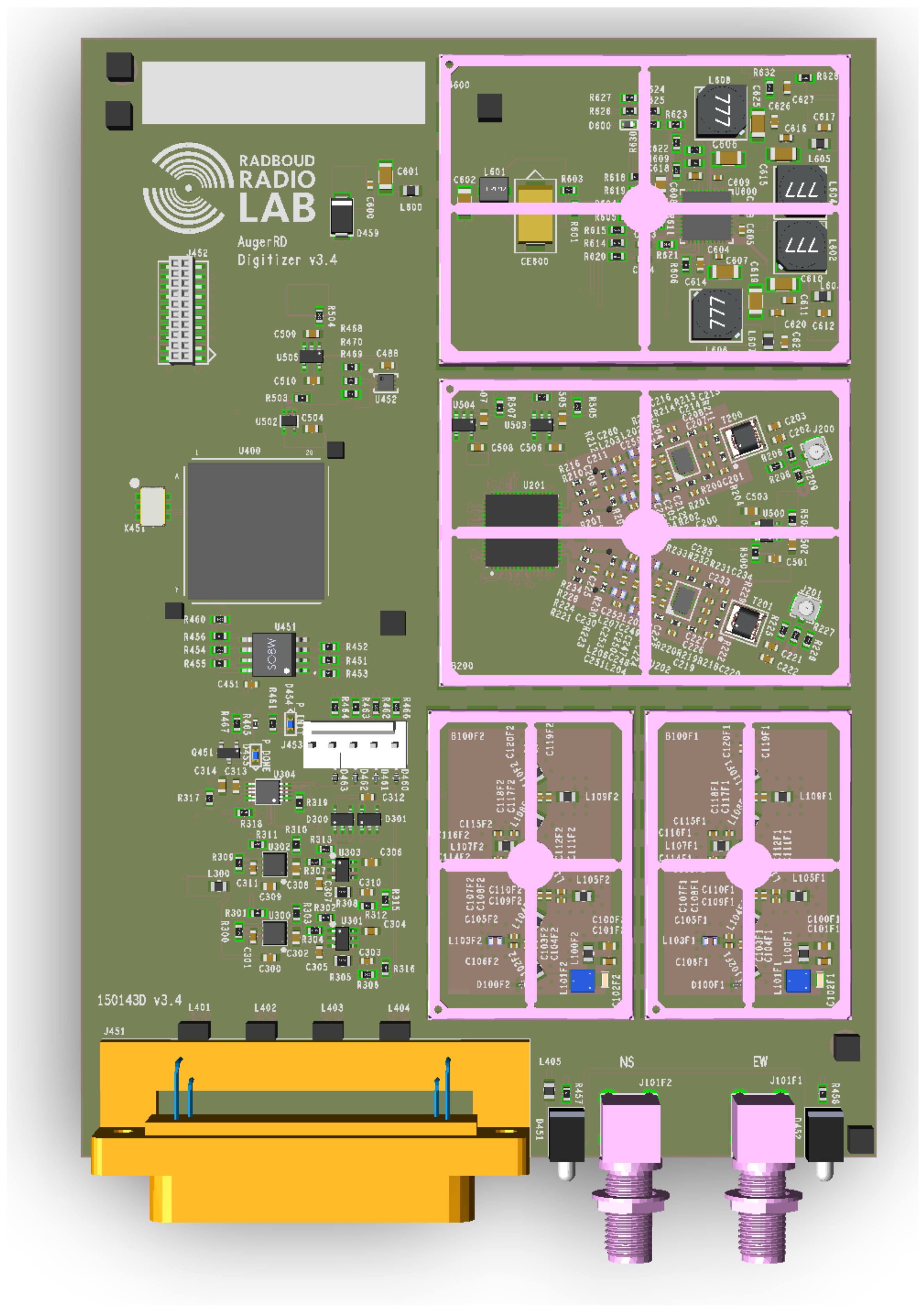
- HF electronics of the antenna (LNA), signal digitizer and UUB electrical interface;











Detailed frame of the Review:

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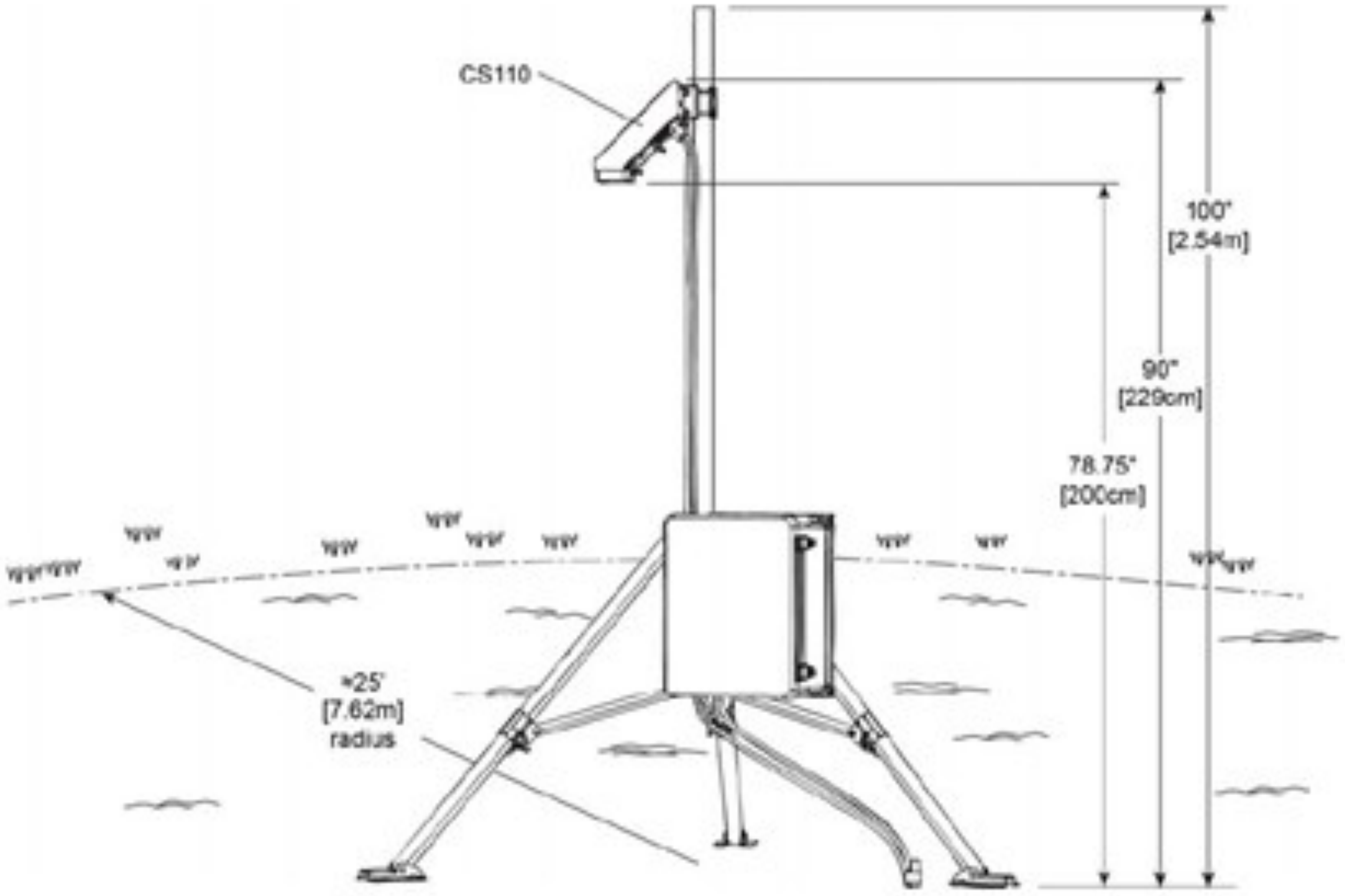
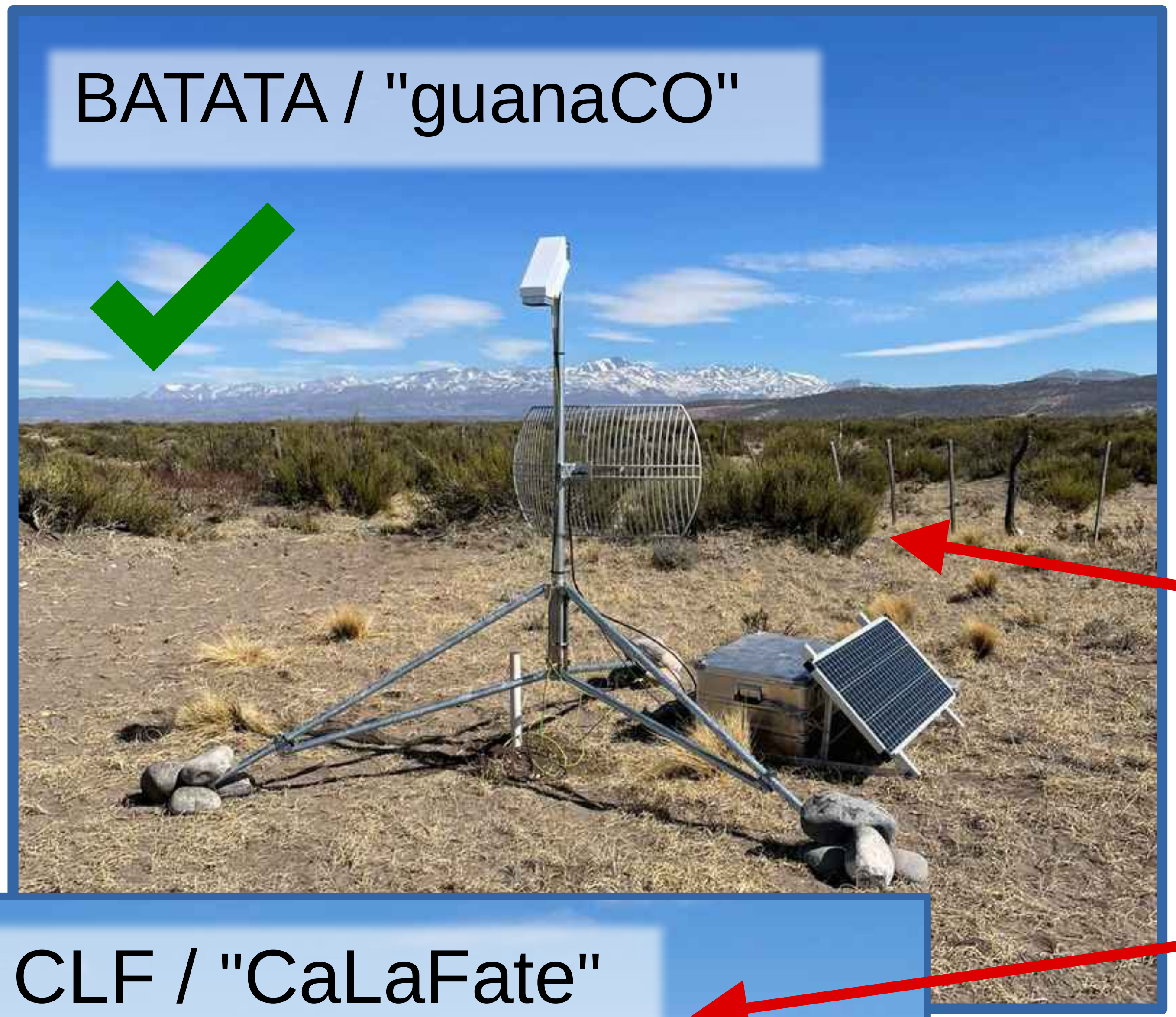
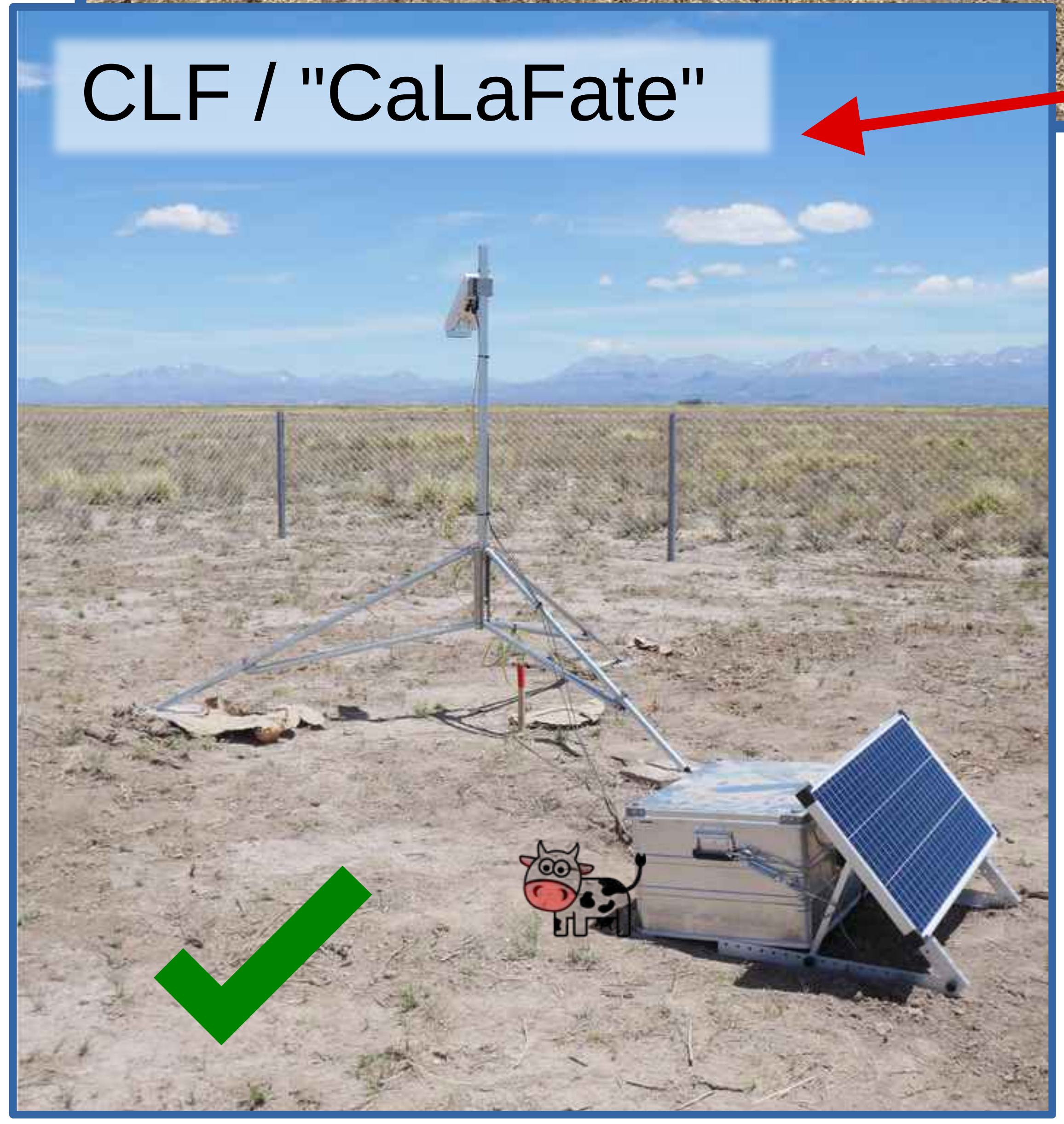
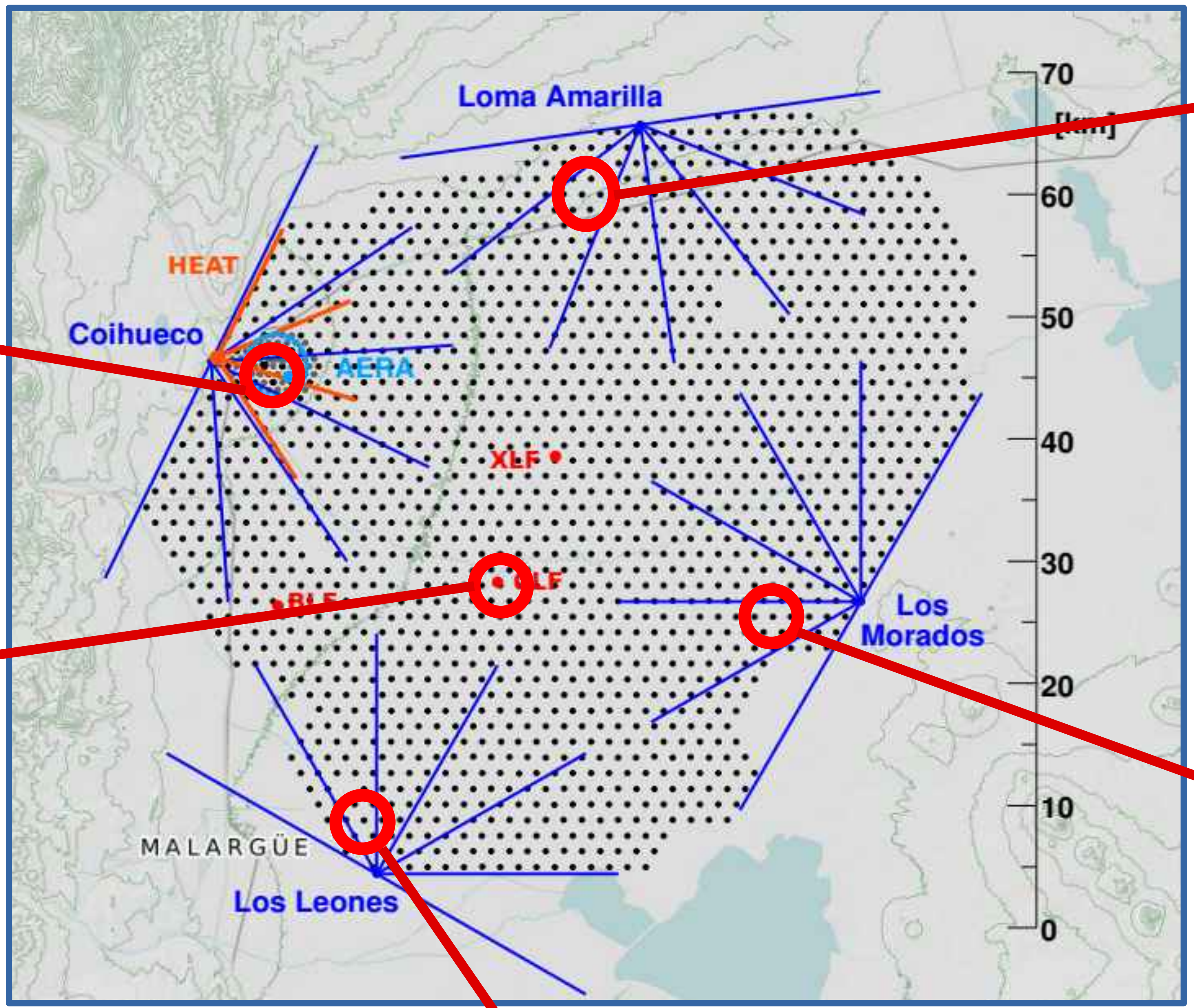
- electric field monitors

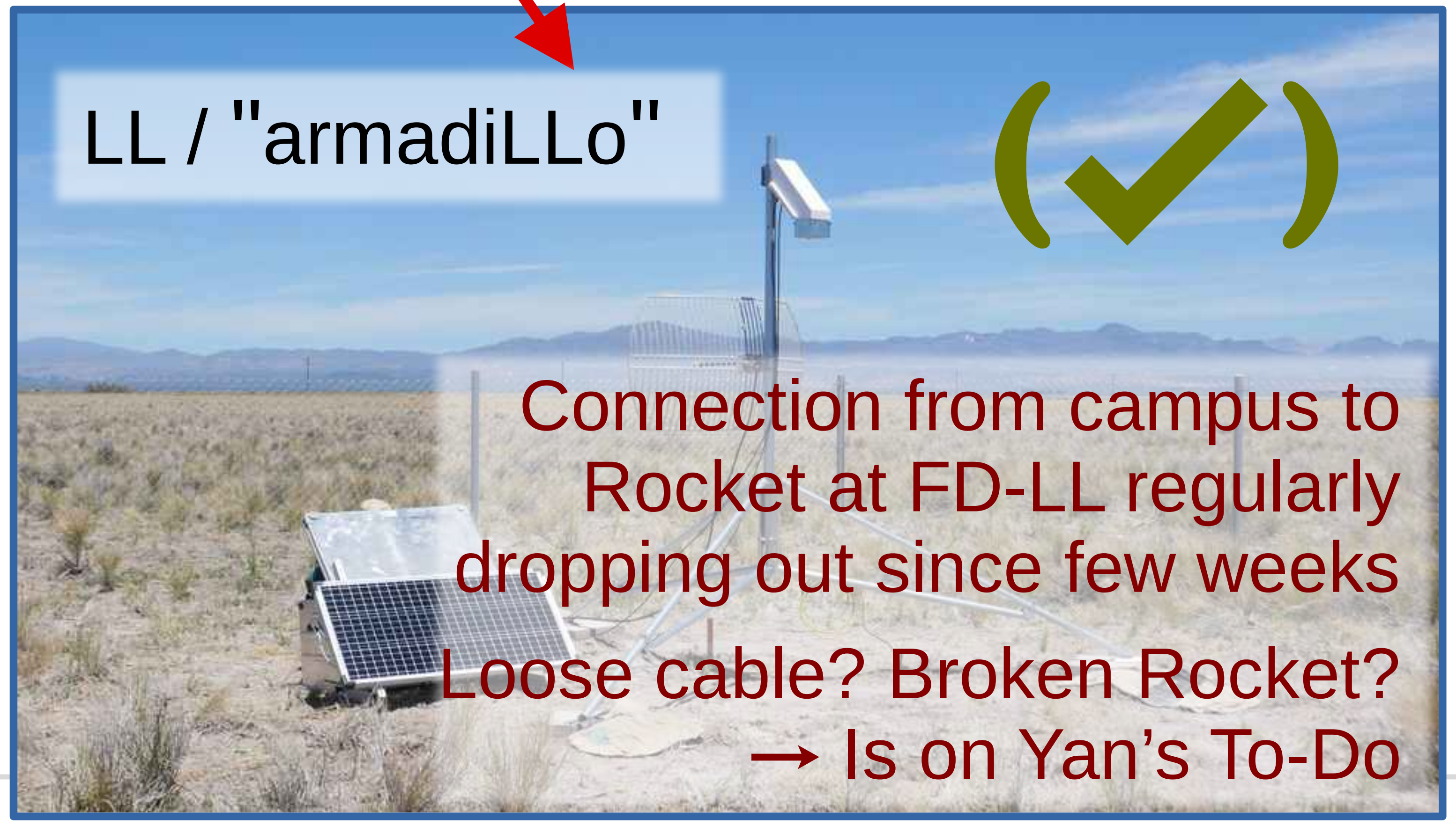


Status of E-field mill stations



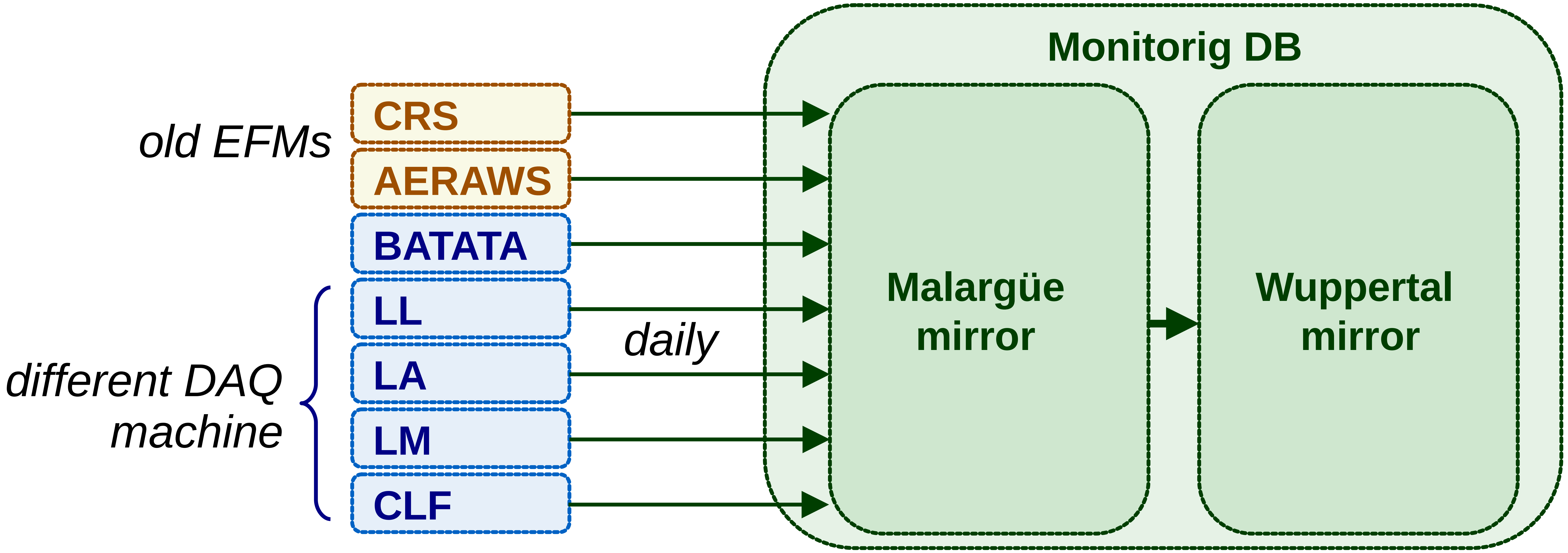






max.buesken@kit.edu

Database status



- Database syncing in place for all EFMs now
- Updated daily
- Available in monitoring DB at database *AERA*
- Connect:

```
max@thinkBook:~$ mysql -u AugerPhase2 -p -h mondb.auger.uni-wuppertal.de
Enter password:
Welcome to the MySQL monitor.  Commands end with ; or \g.
```

- Switch to *AERA* database:

```
mysql> use AERA -a;
Database changed
```

→ list all tables of the database:

```
mysql> show tables;
+------------------------+
| Tables_in_AERA         |
+------------------------+
| BeaconFreq             |
| BeaconRefPhase         |
| BeaconSettings         |
| CRSTemperatures        |
| CRSVoltages            |
| DAQFiles               |
| Field                  |
| FieldAERAWS            |
| FieldBATATA            |
| FieldBLS               |
| FieldCLF               |
| FieldLA                |
| FieldLL                |
| FieldLM                |
| FieldUptime            |
| RADC                   |
⋮
```

- Format of tables BATATA, LL, LM, LA and CLF: (CRS and AERAWS slightly different)

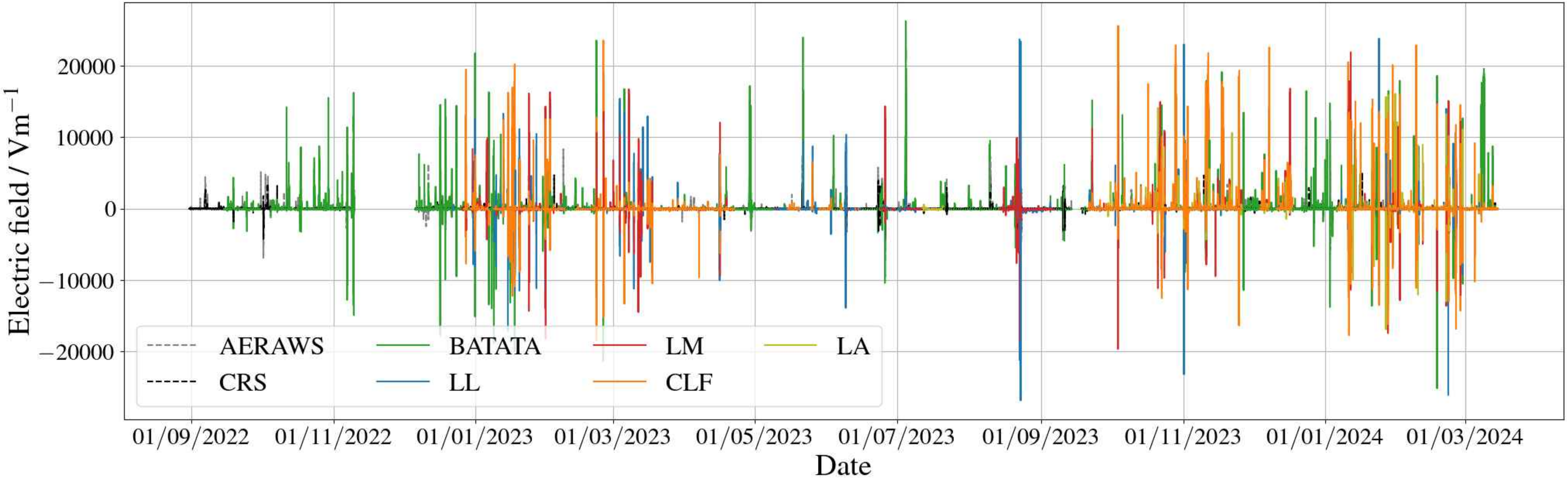
↳

```
mysql> describe FieldLL;
+----------------+------------+------+-----+-------------------+-------+
| Field          | Type       | Null | Key | Default           | Extra |
+----------------+------------+------+-----+-------------------+-------+
| TimeStamp      | timestamp  | NO   | PRI | CURRENT_TIMESTAMP |       |
| Record         | int(11)    | NO   |     | NULL              |       |
| Field          | float      | NO   |     | NULL              |       |
| IsTS           | tinyint(1) | NO   |     | NULL              |       |
| Status         | tinyint(2) | NO   |     | NULL              |       |
| Hydrometry     | float      | NO   |     | NULL              |       |
| Temperature    | float      | NO   |     | NULL              |       |
| LeakageCurrent | float      | NO   |     | NULL              |       |
| Battery        | float      | NO   |     | NULL              |       |
+----------------+------------+------+-----+-------------------+-------+
```

not filled

Place is historically fitting (old EFM data) but new EFMs are instruments of the whole array, not connected to AERA

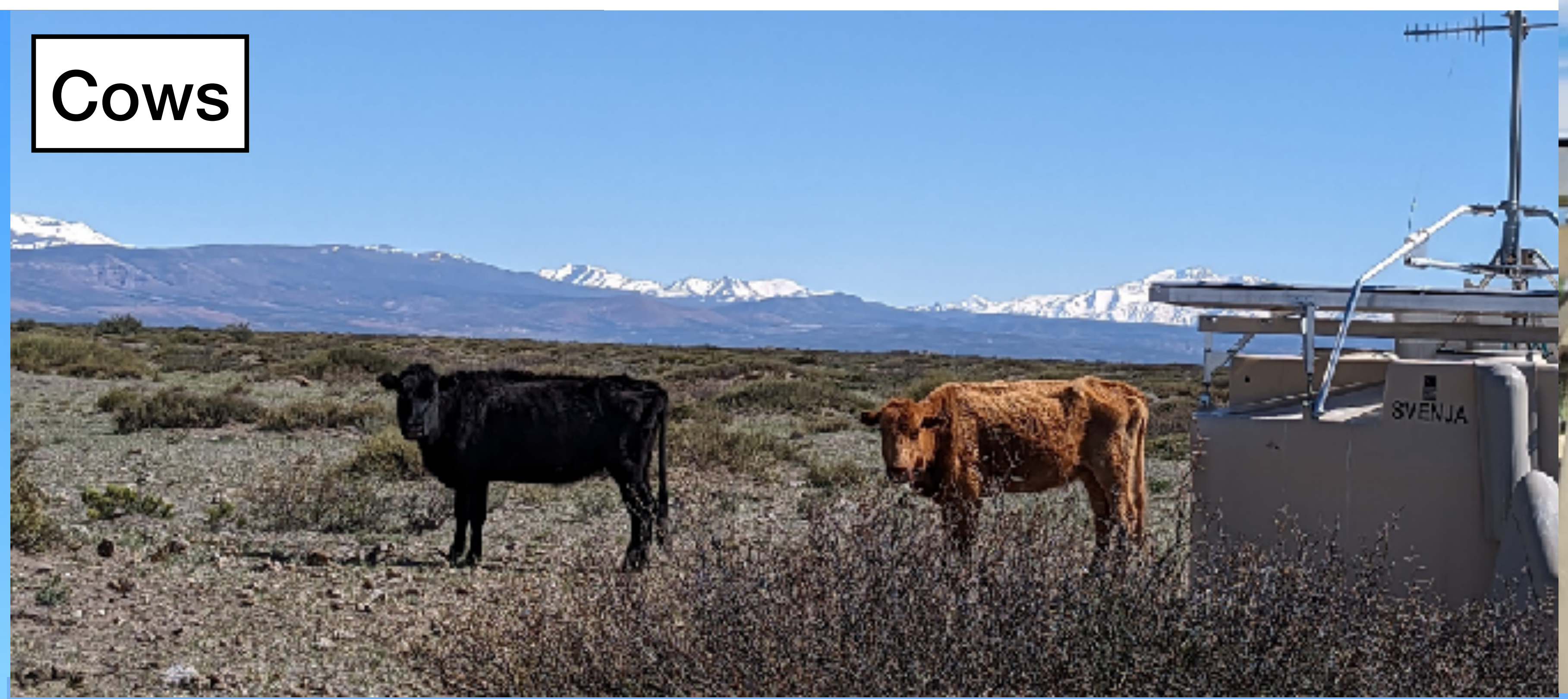
1.5 years in E-Field data



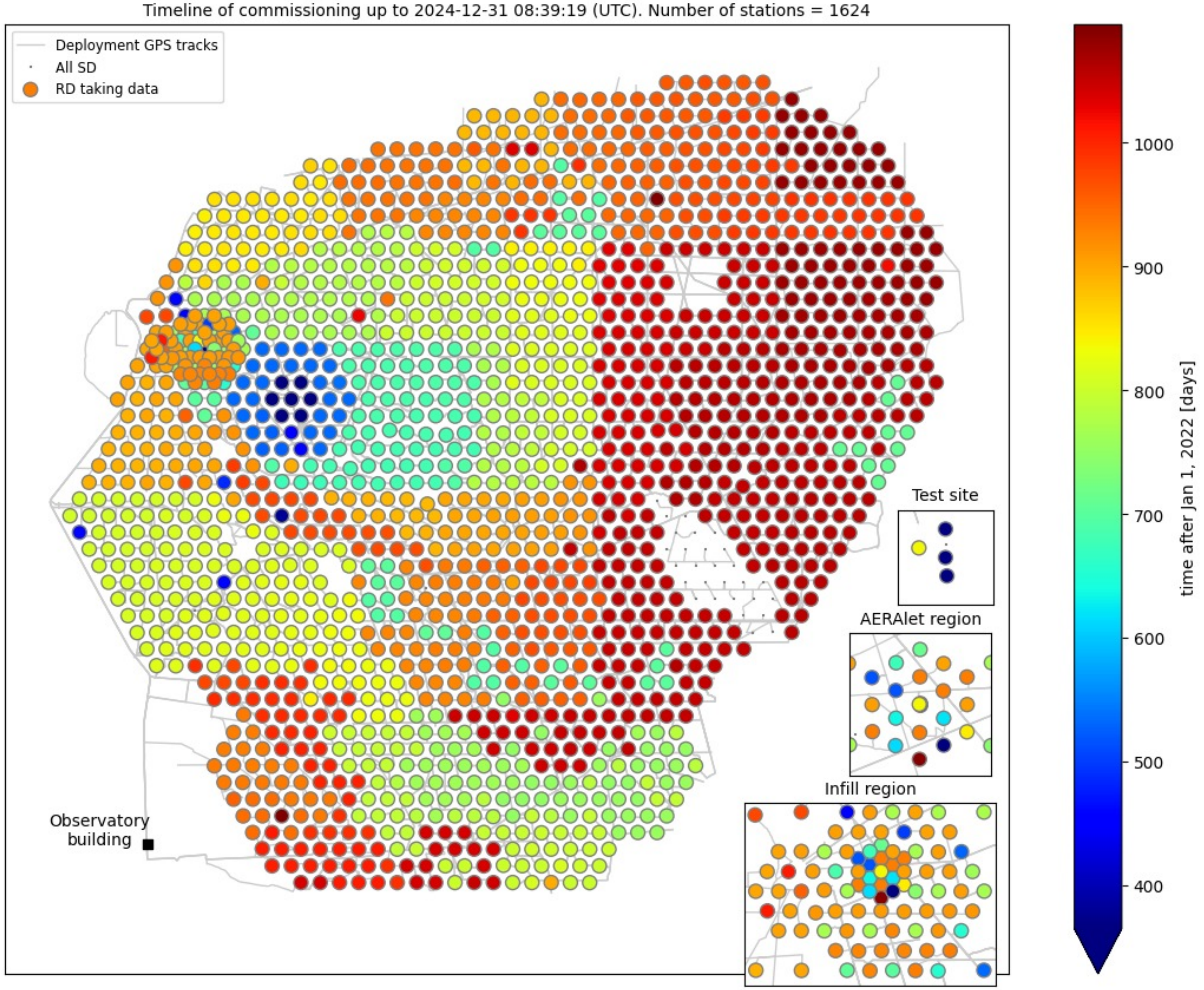
- Thunderstorm-heavy periods in austral summer clearly visible

RD Commissioning Status

Bjarni Pont — b.pont@science.ru.nl — Radio Workshop - Feb 28, 2025



Deployment finished



- First station deployed Nov 2022
- Mass deployment since June/Nov 2023
- Last electronics installed in November 2024
  - Only 1 landowner region left for the future

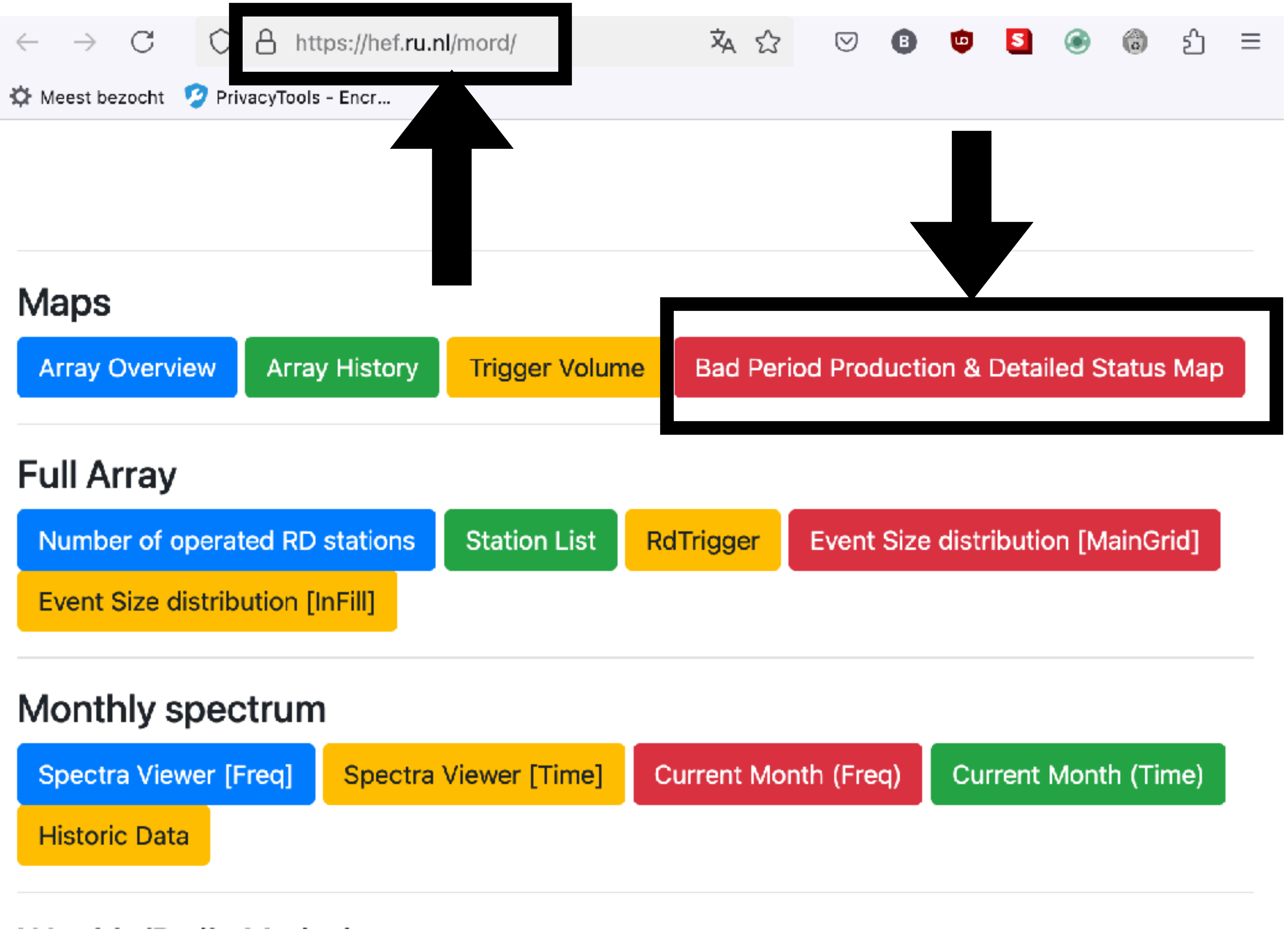
- 1624 stations have been in operation since 2022
  - Some stations moved and have a new name
  - Some are black tanks (there's always some %)
  - MoRD: as of wed feb 26, 1590 operational

- Weekly status reports from the field: https://www.auger.unam.mx/AugerWiki/RD_commissioning

Data available on MoRD: Spectrograms & bad periods

- https://hef.ru.nl/mord/Pages/[1]MaintenanceMapAndBadPeriods.html
- **Monthly production** of BadPeriods:
  - Xml format for Offline RdStationRejector (just copy paste into module. Instructions are on the MoRD page)
  - Includes:
    - Firmware issues
    - Broken LNA / low Gain
    - Station rotated (~ beyond 15deg)
- **Daily production** on MoRD of ‘Last7Days’:
  - The big status map
  - Spectrograms —>
    - All-RD spectra, after BadPeriod cut.
    - Binned per 20min (and longer for <2024)
    - Quick check of {thunderstorms, solar storms, NB-RFI emitters, etc…) at any time

Auger credentials



* https://gitlab.iap.kit.edu/auger-observatory/sandboxes/bpont/rdbadperiods

REMINDER

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Radboud University

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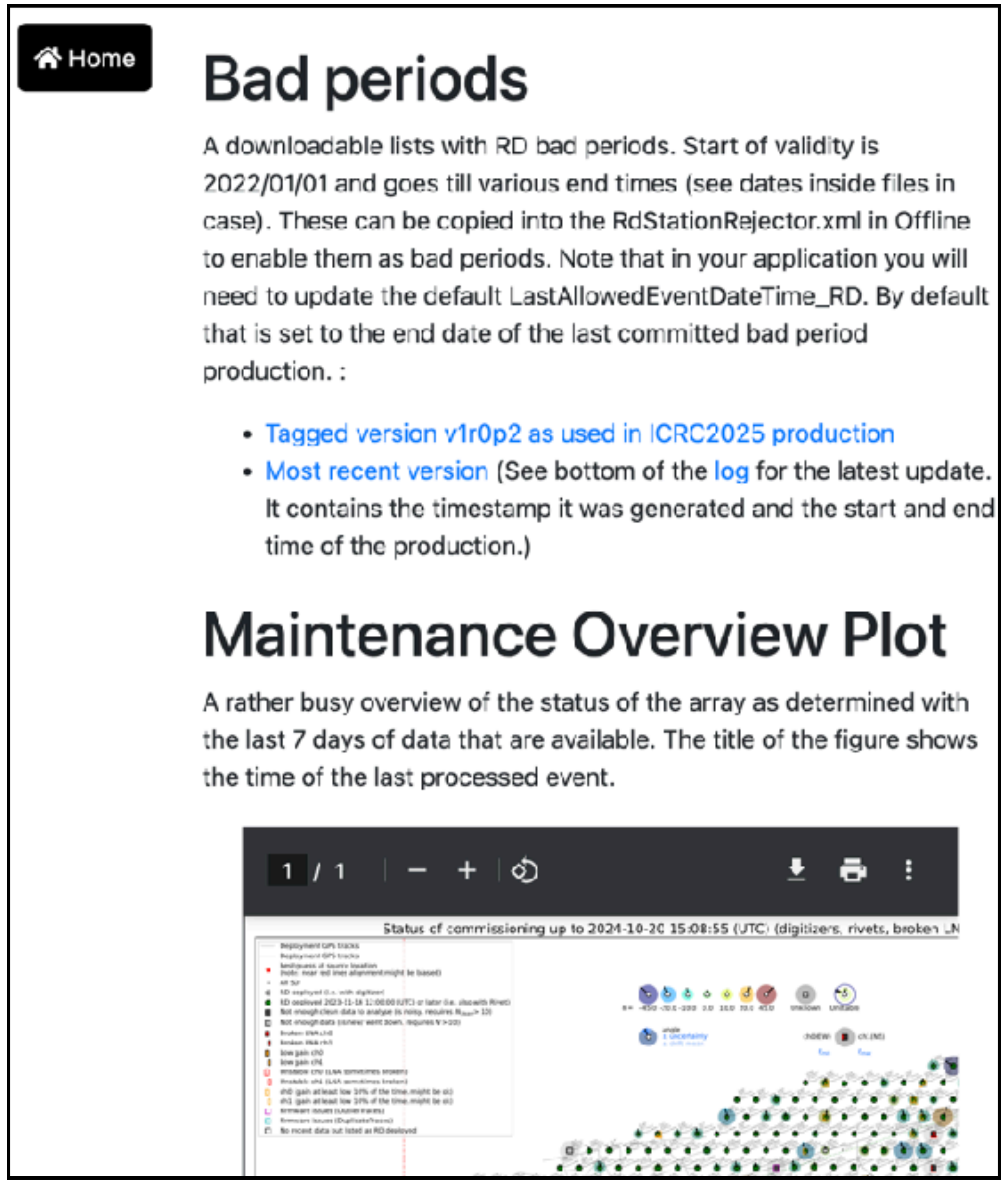
Home

Bad periods

A downloadable lists with RD bad periods. Start of validity is 2022/01/01 and goes till various end times (see dates inside files in case). These can be copied into the RdStationRejector.xml in Offline to enable them as bad periods. Note that in your application you will need to update the default LastAllowedEventDateTime_RD. By default that is set to the end date of the last committed bad period production. :

- Tagged version v1r0p2 as used in ICRC2025 production
- Most recent version (See bottom of the log for the latest update. It contains the timestamp it was generated and the start and end time of the production.)

Maintenance Overview Plot

A rather busy overview of the status of the array as determined with the last 7 days of data that are available. The title of the figure shows the time of the last processed event.

ICRC2025 tag production

Monthly updated production

Showing last 7 days

- 2022: 01 02 03 04 05 06 07 08 09 10 11 12
- 2023: 01 02 03 04 05 06 07 08 09 10 11 12
- 2024: 01 02 03 04 05 06 07 08 09 10 11 12
- 2025: 01 02 03 04 05 06 07 08 09 10 11 12
- Last7Days (direct link to the plot above for browsers not supporting th

For each month

For last 7 days

REMINDER

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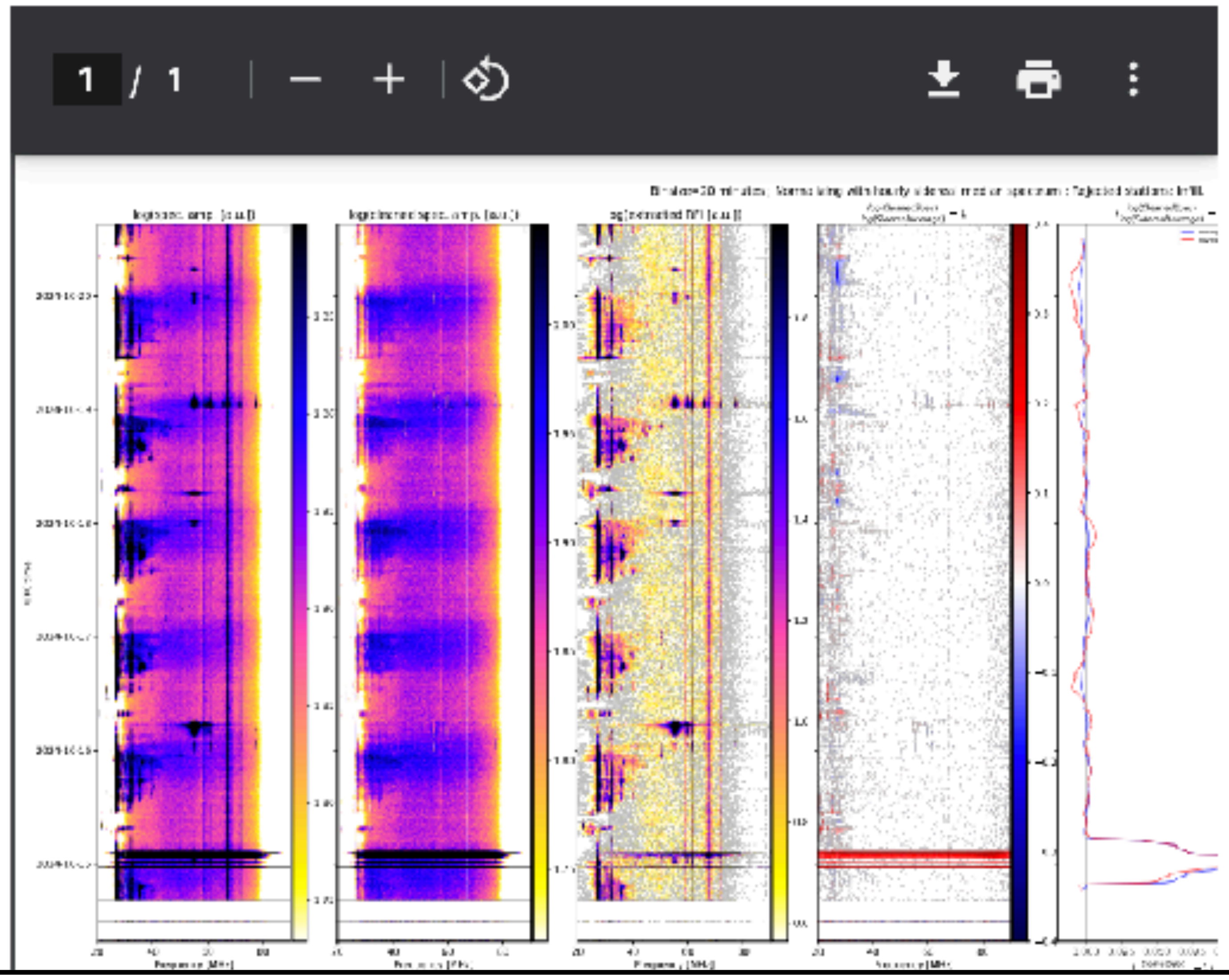
Spectrogram Plot

With 20 minute bins in time we combine all recorded traced from the CDAS data stream into a spectrogram displaying the median frequency spectrum. Here we show the spectrogram of the data of the last 7 days. Below there is a list of monthly overviews of previous months (these figures are automatically generated so some paths lead nowhere yet).



Showing last 7 days

- 2022: 01 02 03 04 05 06 07 08 09 10 11 12
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- Last7Days (direct link to the plot above for browsers not supporting the i

For each month

For last 7 days

REMINDER

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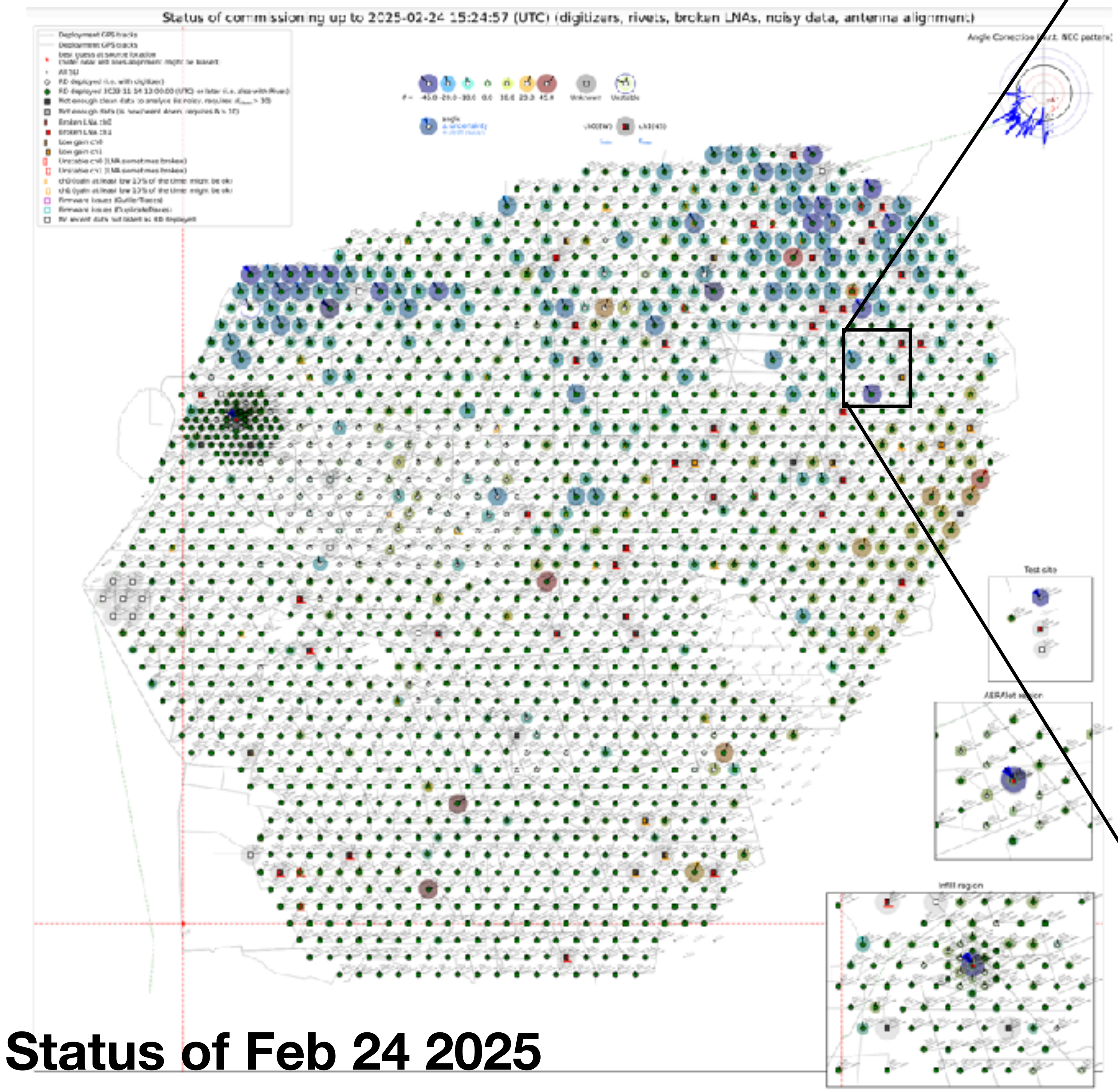
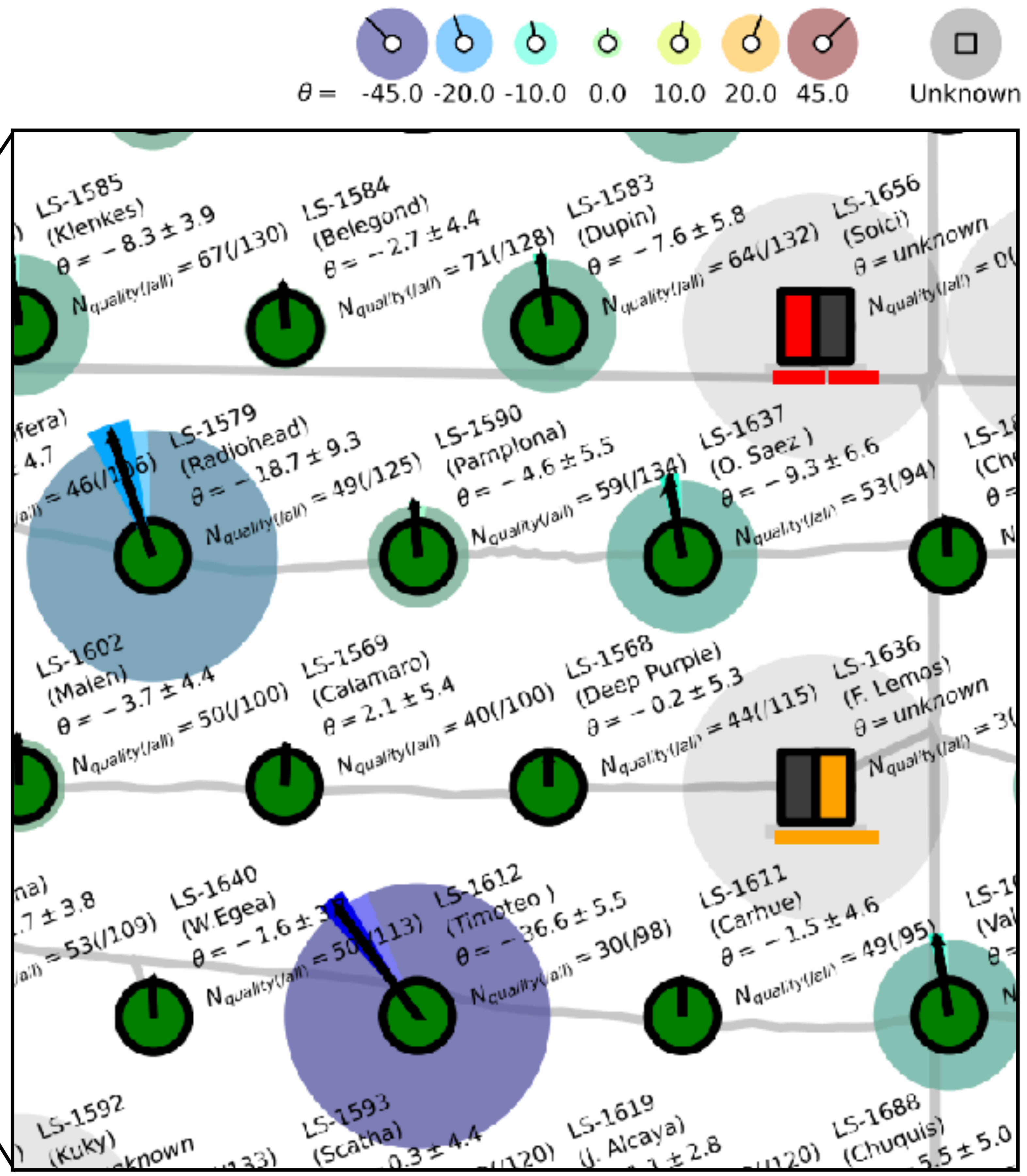
Daily ‘live’ data monitoring

- **Automated daily processing of recorded data.**
  —> iteratively improving deployment
- **Automated ‘Bad-period’ flagging**
  —> enabling us to already do physics



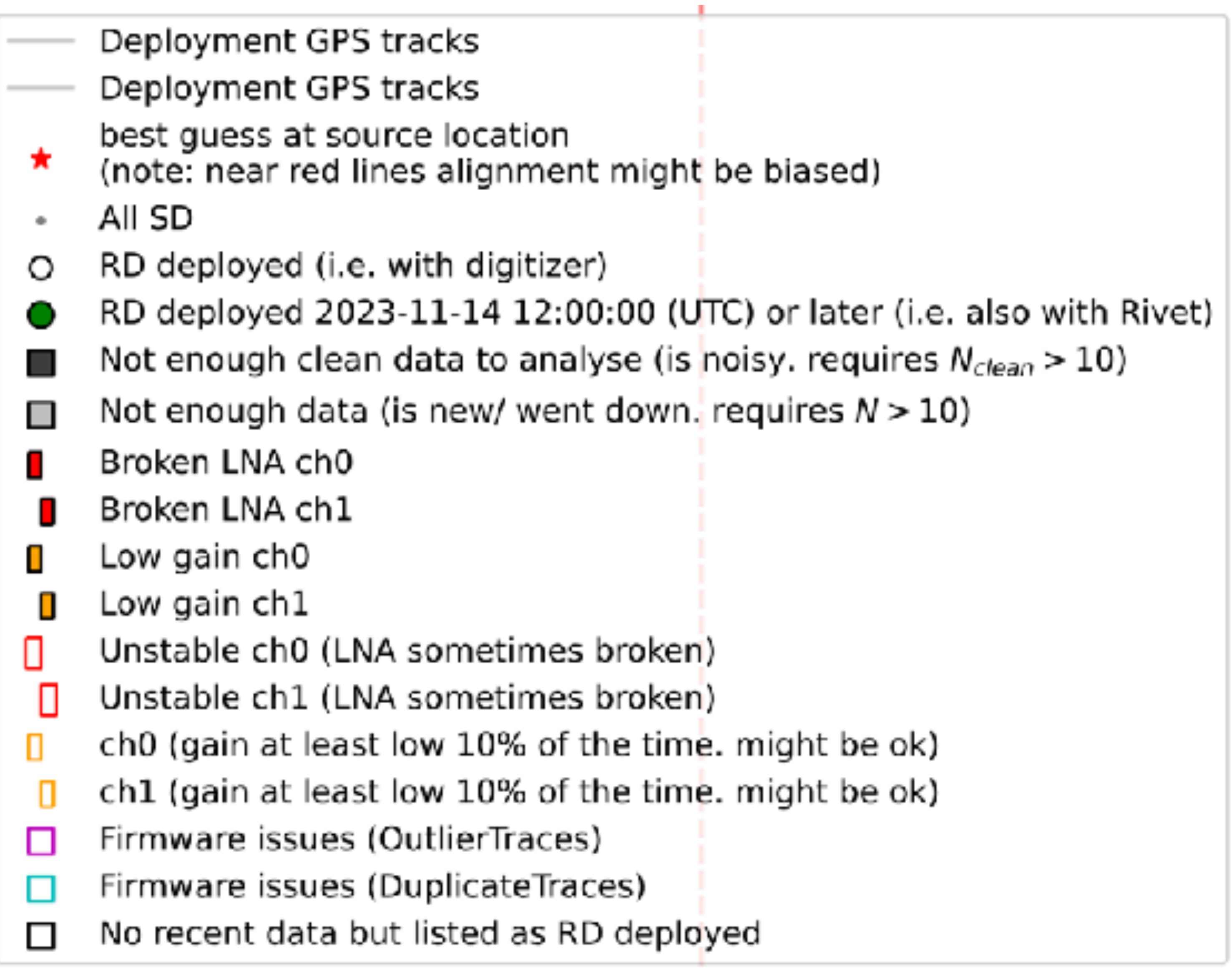
Status of Feb 24 2025



<u>combining</u>

- Which stations have been deployed / which take data
- Broken LNAs
- Low gain (LNA/Digitizers?)
- Antenna Alignment / swapped ch0-ch1 cables
- Issues with firmware version updates
- Expected data volume?
- Missing stations
- Access roads to play deployment

+ some more detailed stuff



* https://gitlab.iap.kit.edu/auger-observatory/sandboxes/bpont/rdbadperiods

Bad Periods overview: till Jan 31, 2025

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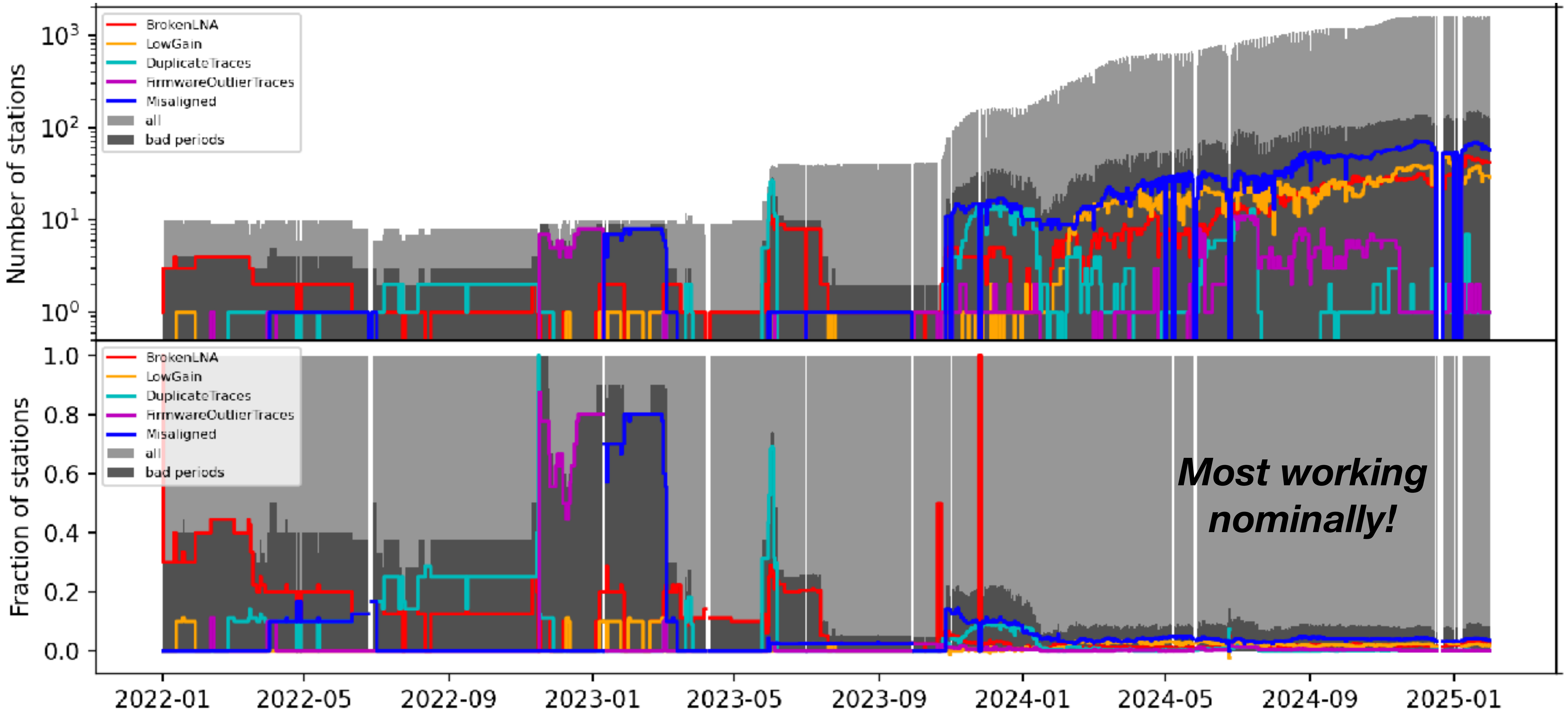
- Running as a monthly cron job on Nijmegen astronomy cluster using MoRD data stream from Nijmegen HEP cluster*
- Needs occasional babysitting. Not 100% stable.
  - Nov 2024: Data volume grew and RAM usage got too large —> job crashed—> parallelized
  - Dec 2024: Malargue TV4 channel went down for 22days —> many false rotation flags —> manual TVOutageList.txt quick-fix
  - Jan 2025: cluster NFS mounting issues —> job crashed —> mostly patched



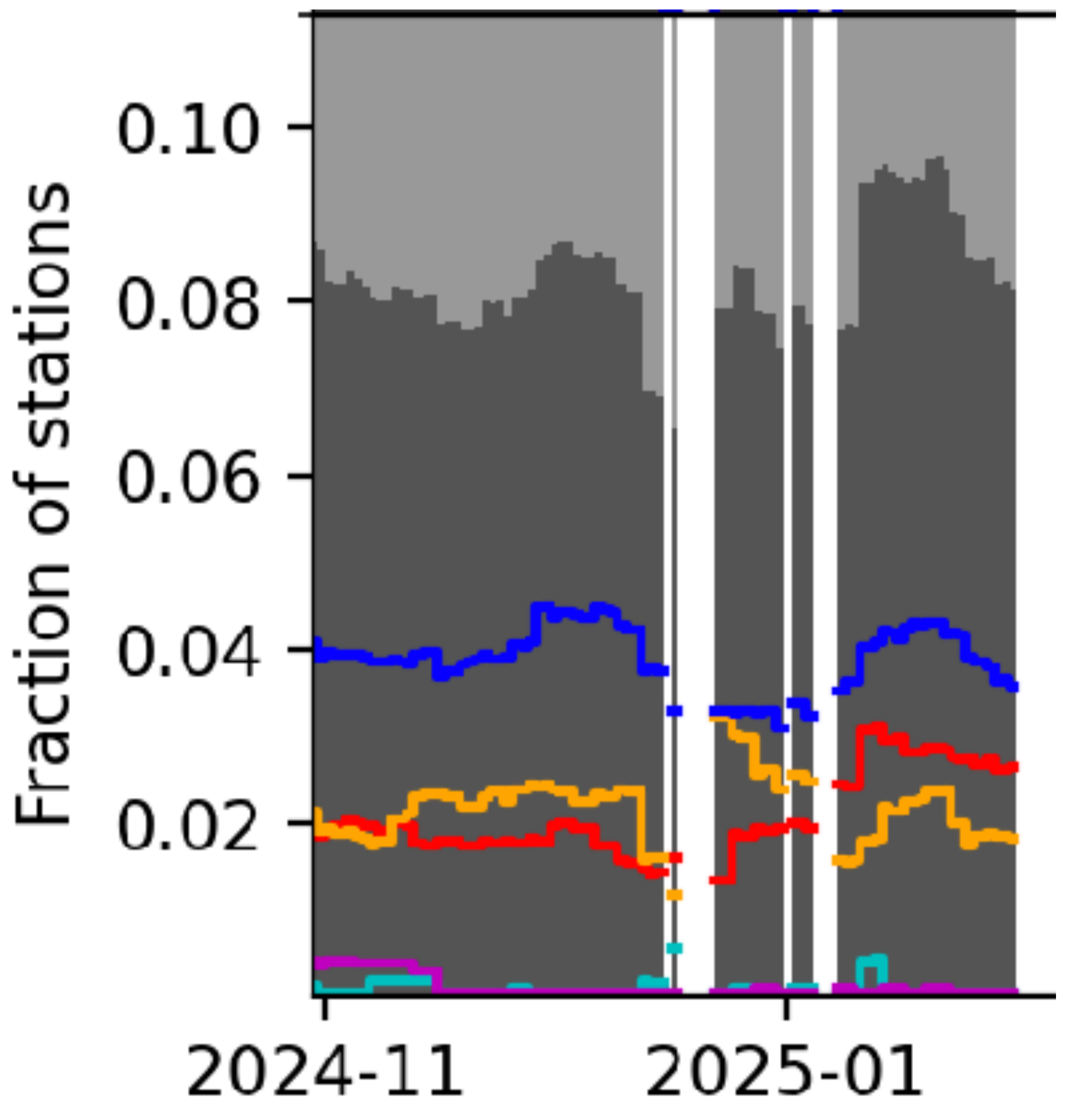
<u>~8% : total bad periods at the moment</u>

2 : Firmware issues

~3% : Dead channel (Broken LNA, dust, cables, …)

~2% : Reduced gain (dust, cables, …)

~4% : Rotated (>15deg), which incl. many gain issues



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PIERRE AUGER OBSERVATORY

Maintenance since May 2024

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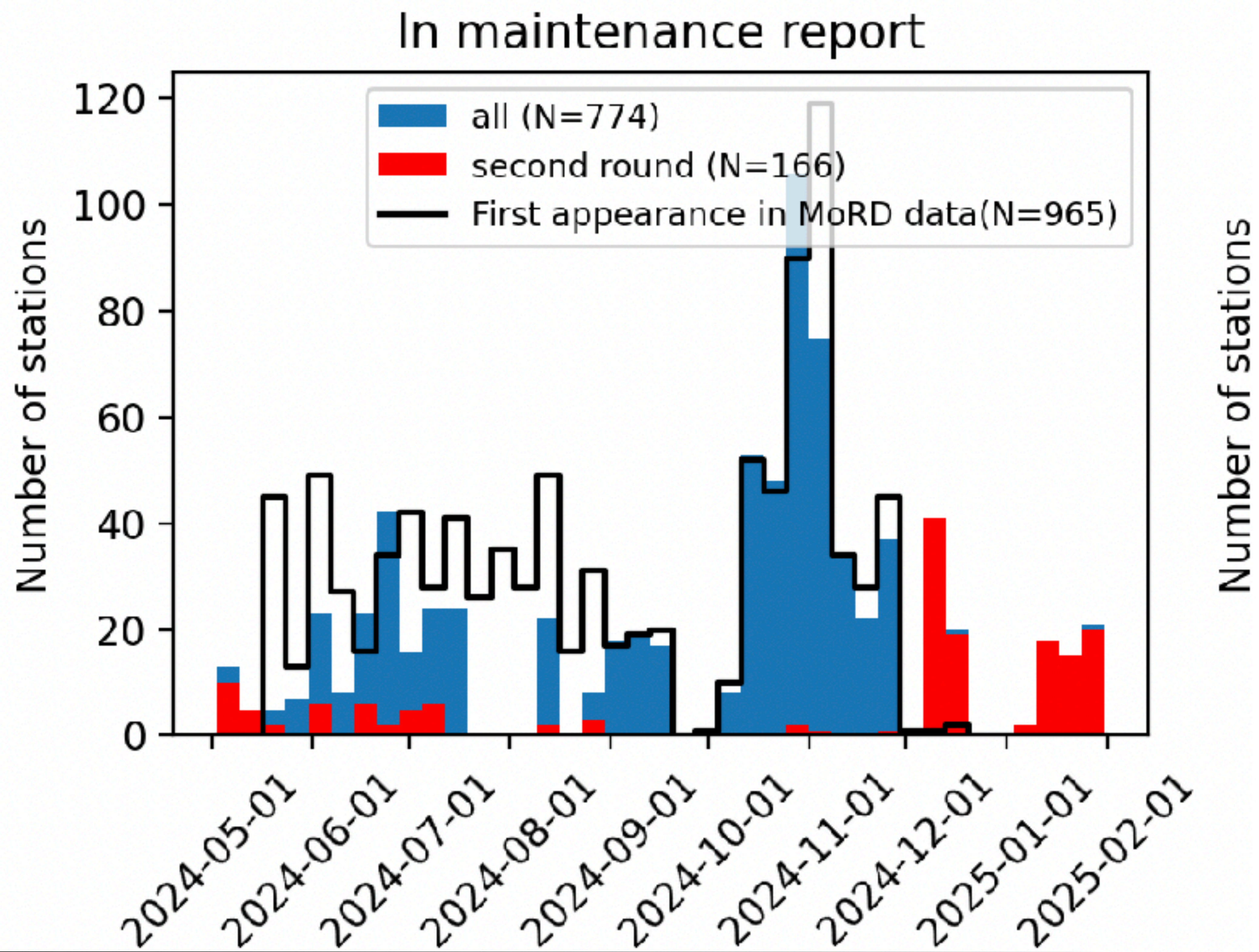
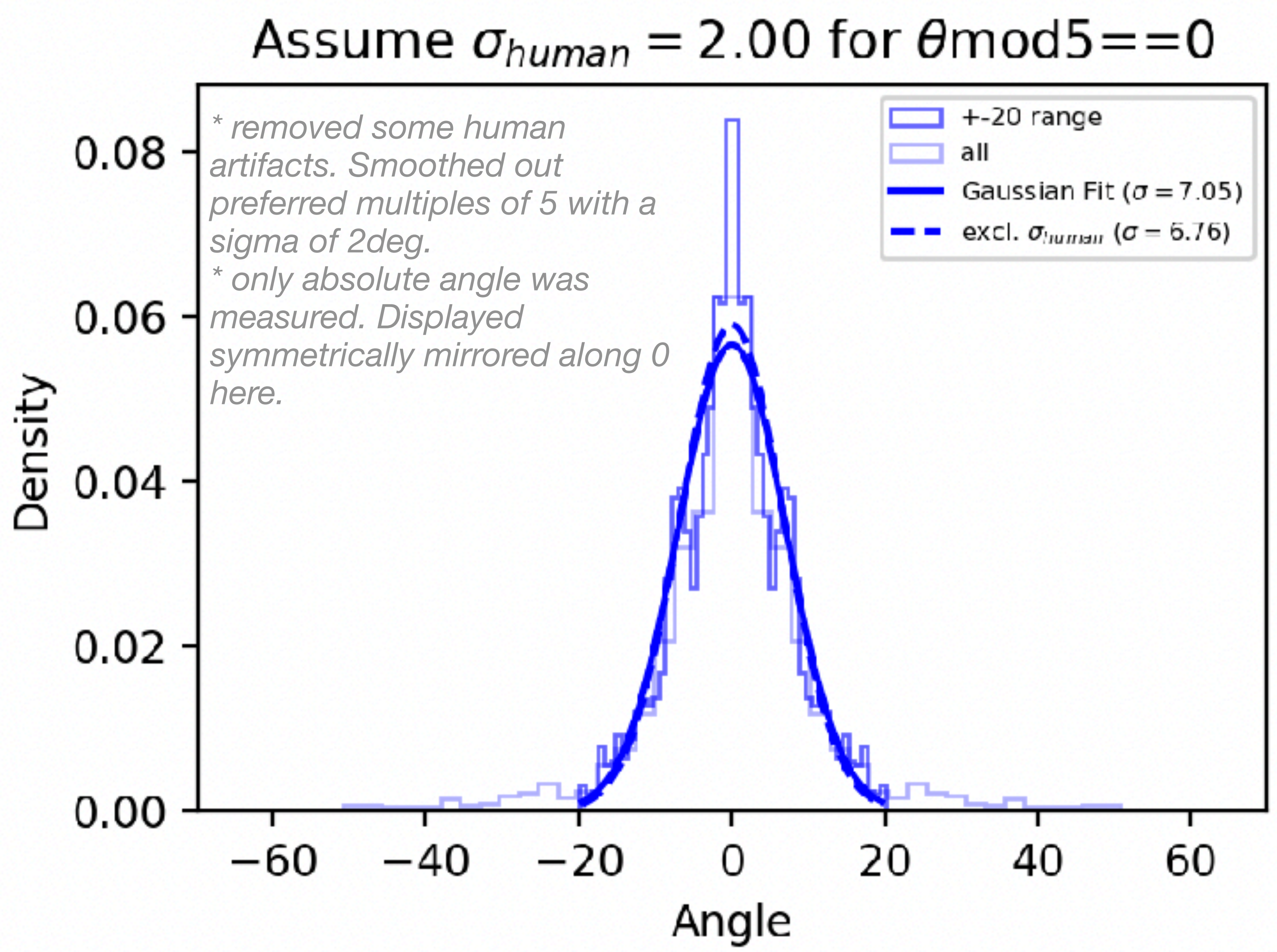
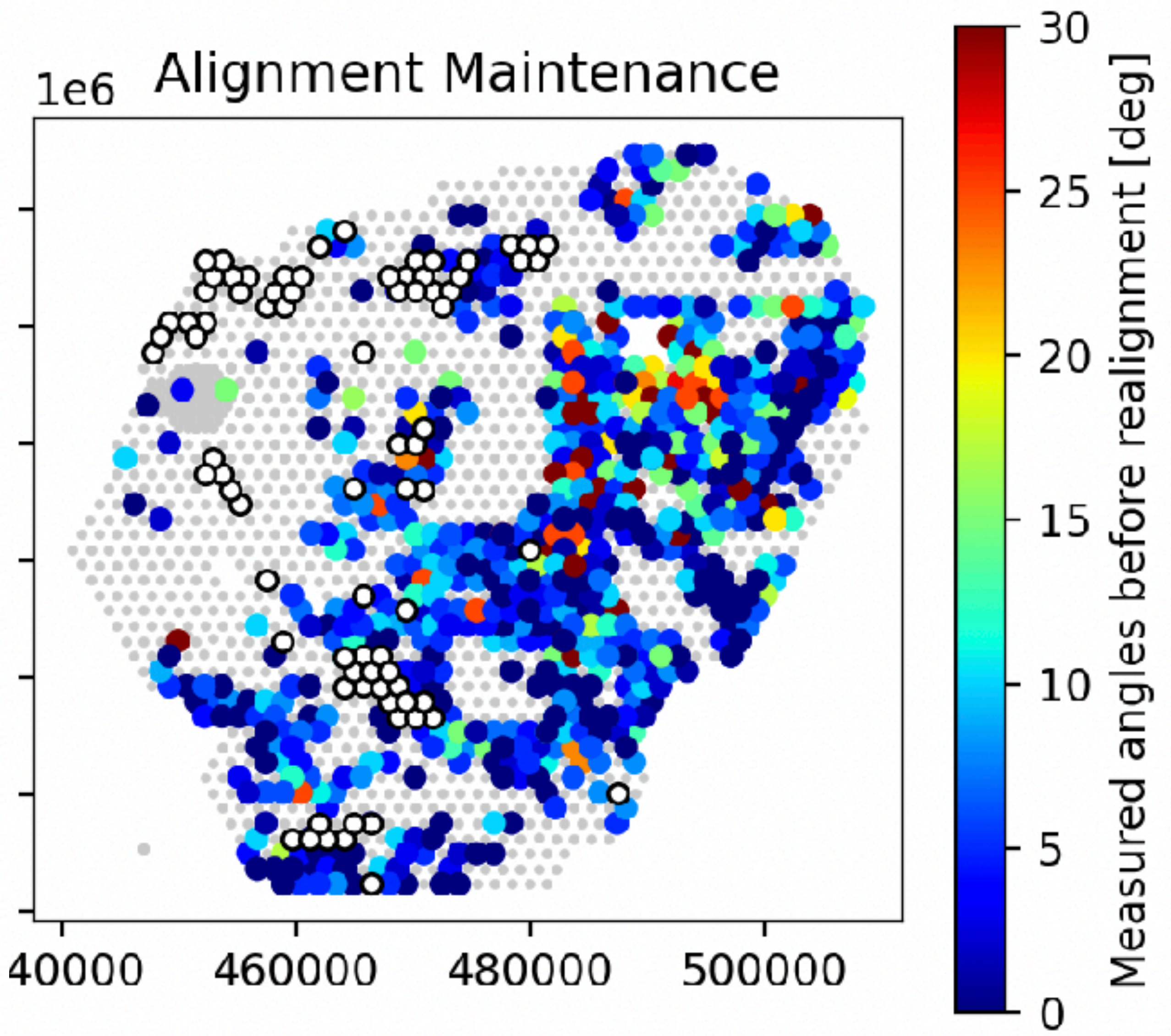
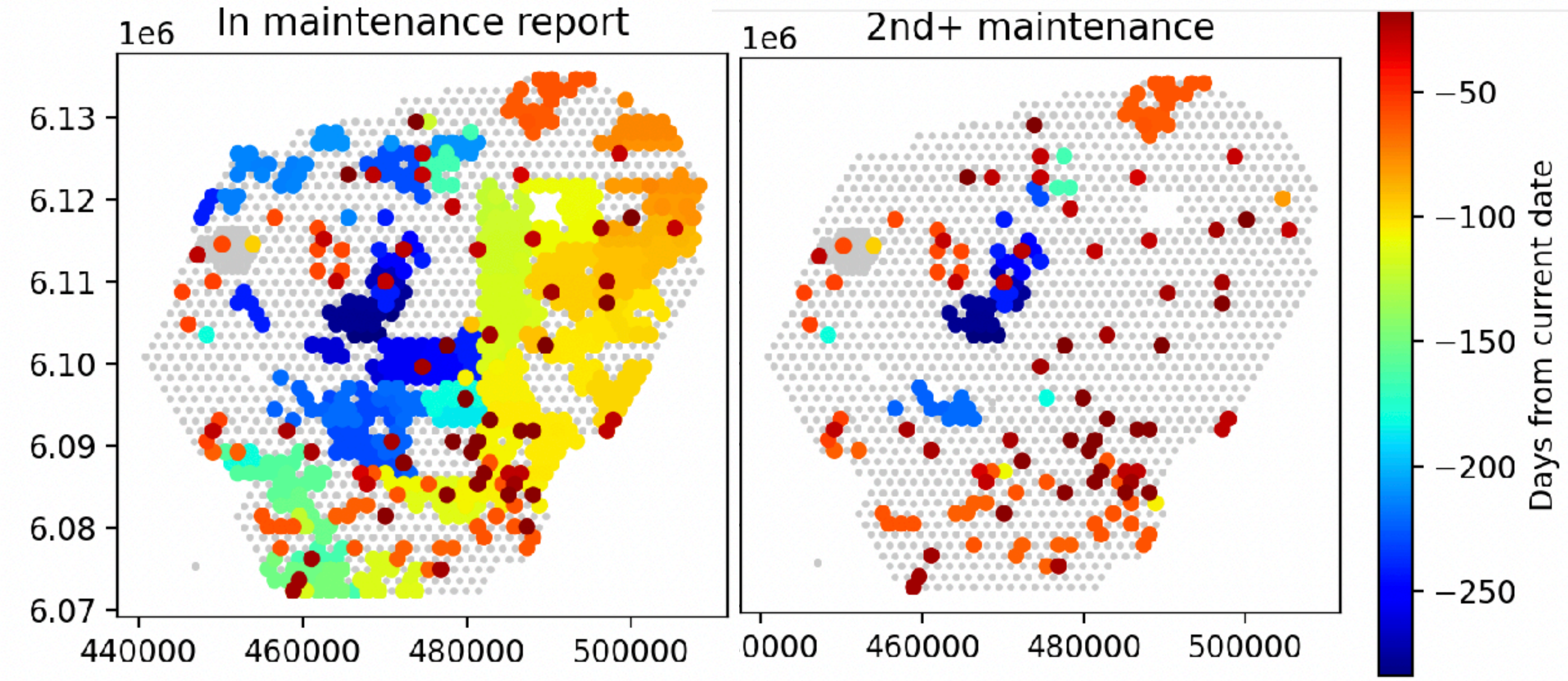
<u>Time and location of maintenance</u>

- Digitized maintenance reports from Marcos (<u>link</u>)
- Alignment was measured (incl. compass uncertainty) before most maintenance: ~6-7deg (vs 4-5 from TV)
- Filter by **First visit** (deployment) and **Second visits** (finishing deployment + maintenance)









Current/upcoming maintenance

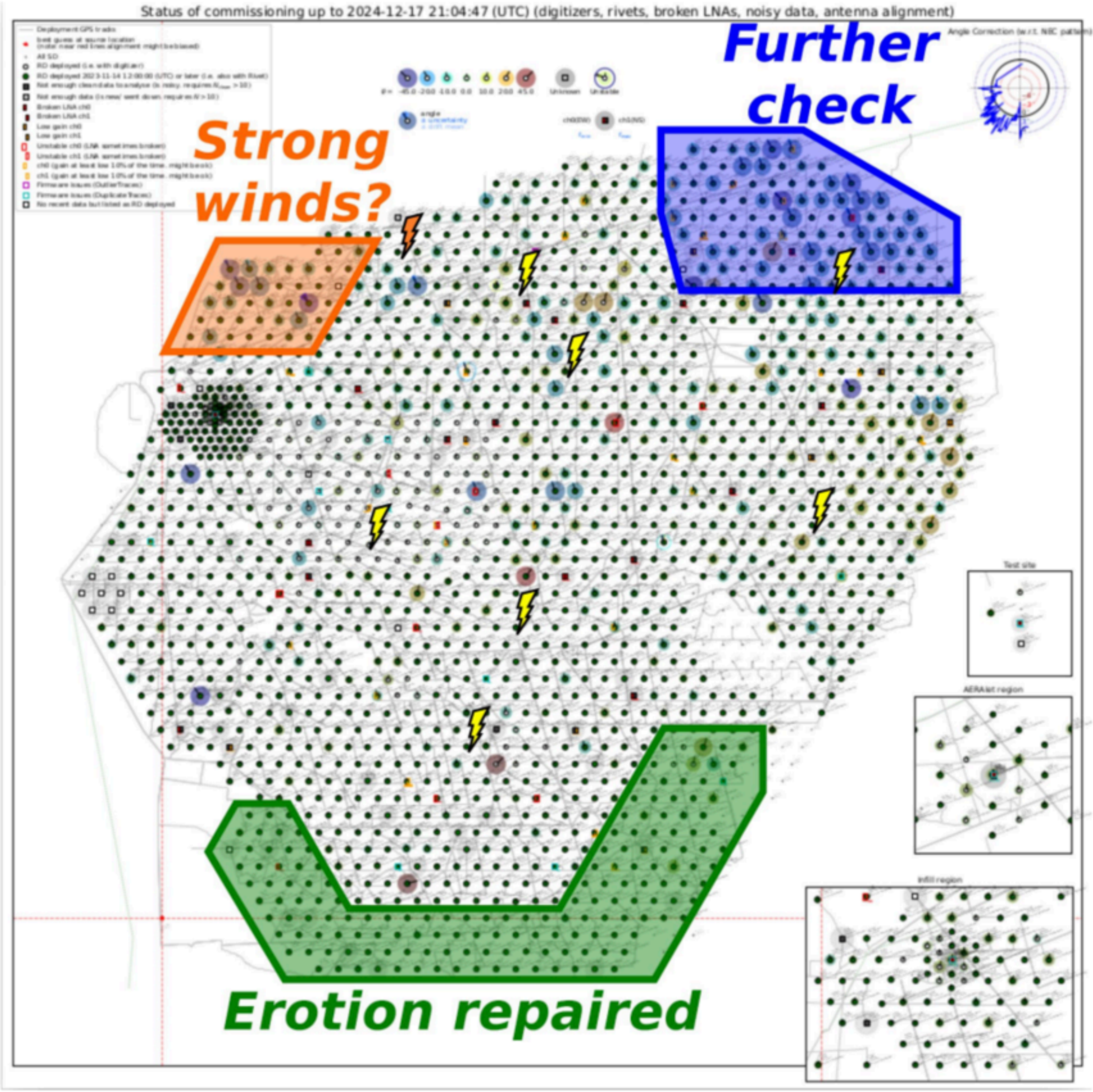
Issues being addressed

- North-West: some **broken rivets**
  —> investigating soon. Can implement stronger fix if needed

- North-East: **high rotations & gain issues**
  - Region installed in two phases (antenna & electronics)
  - Extreme thunderstorms in Dec/Jan especially in NE
  - Dust in LNA housing from initial deployment —> affecting gain
  - Broken LNA channels —> affecting gain
    —> Investigation ongoing. Can be a combination of these

- South: **Erosion** due to terrain (SD issue affecting RD tilt)
  —> repaired over past months

- Misc:
  - A few misaligned antennas/ swapped channels/ broken LNAs spread all ov
  - Theft of cable tensioners (10) & signal cable (2) —> Ingo is on it.
  - **Lighting impacts**
    - 7 stations directly hit by lightning (2 only damaged RD)
    - 1 exploded the RD mast.
    - Ricardo notes every year this happens a few times (Numbers TBD)



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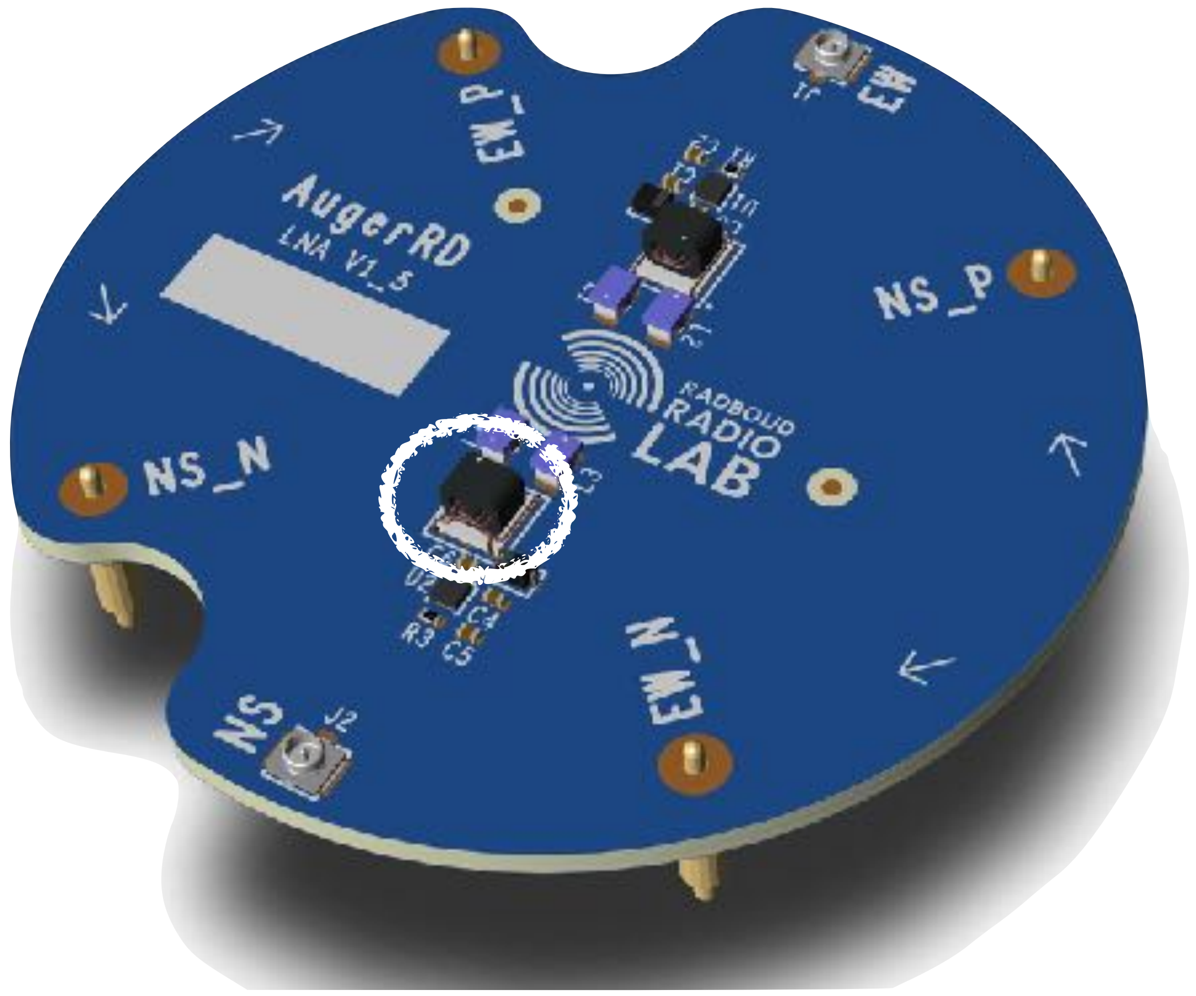
} LNAs

vendor info in EDMS

Radboud is working on a calibration tool for Malargüe



LNA: amplifier chips are in Malargüe
—> Mauro successfully repairs LNAs

RD components

- solar panels - 2000 units
- antenna arms - 6800 parts
- ropes (6 km) and tensioners for the mast
- Al tubes for frame - 13600 parts
- Al plates and antenna foot - 8500 parts
- small parts, u-bolts, nuts, screws, … ~400000 pieces
- housings for digitizers - 2000
- pigtail cables for the LNA - 4000
- housings for LNAs and bottom loads - 12000 parts
- glass fiber antenna masts - 1700
- ferrites - 8500
- mounting brackets for solar panels - 3400 pieces
- L-ground bracket inside the dome - 1700 pieces
- signal cables inside mast - 3400 cables
- fixtures to assemble ferrites - 24 units
- signal cables from LNA to digitizer - 6800 units
- digital cable from digitizer to UUB - 1700 units
- bottom load PCBs - 2000 units
- Low Noise Amplifiers (LNAs) - 2000 units
- Digitizers (RD frontend) - 2000 units

spare parts in Malargüe

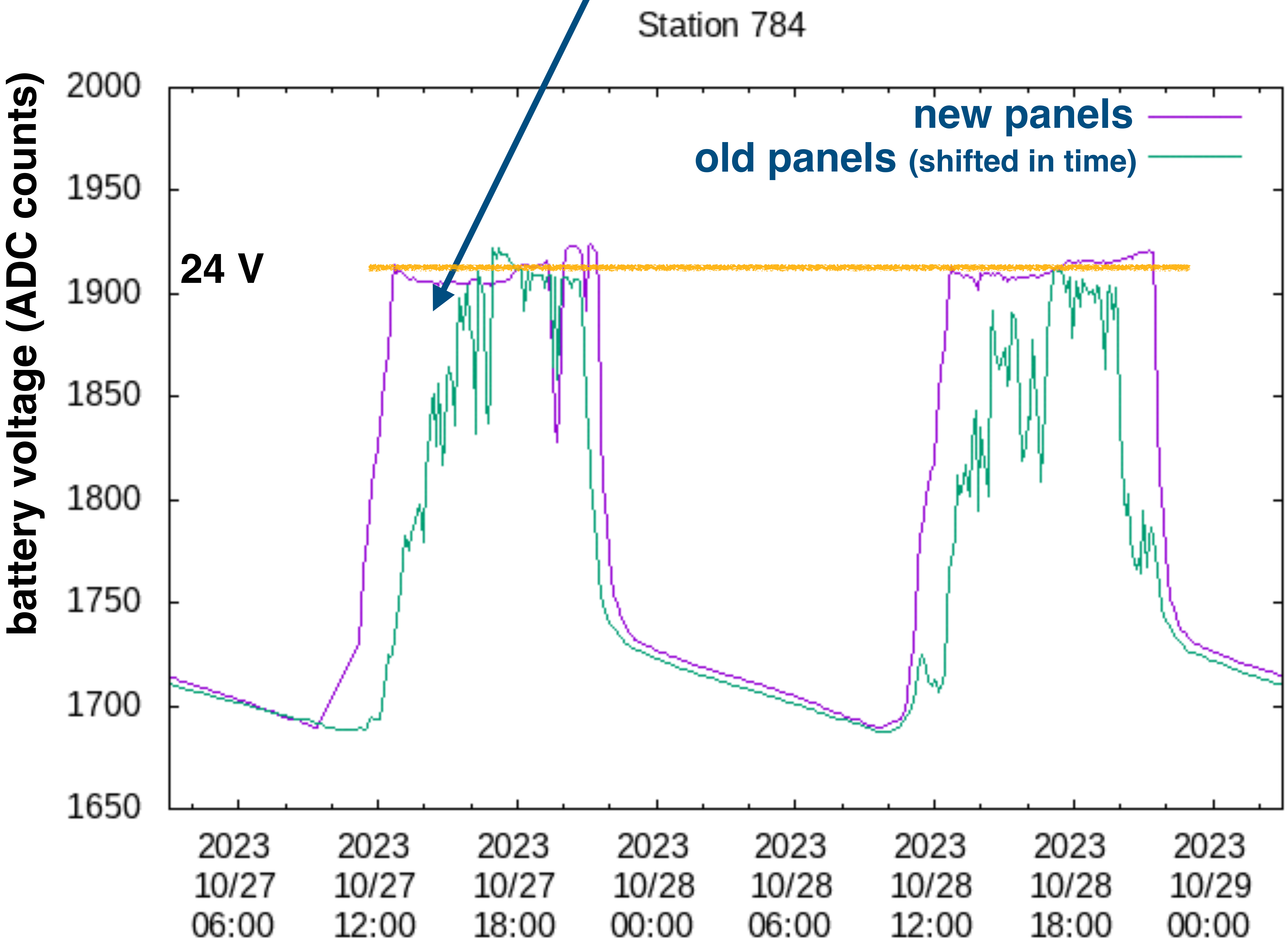
installed 1660 positions

produced
1700 components
(40 spares mechanics)
2000 units
(340 spares electronics)

—> 6 sea containers, 75 m³ each + several (~8) air freights

Solar panels

more solar power available —> quicker recharging of batteries
—> stable operation

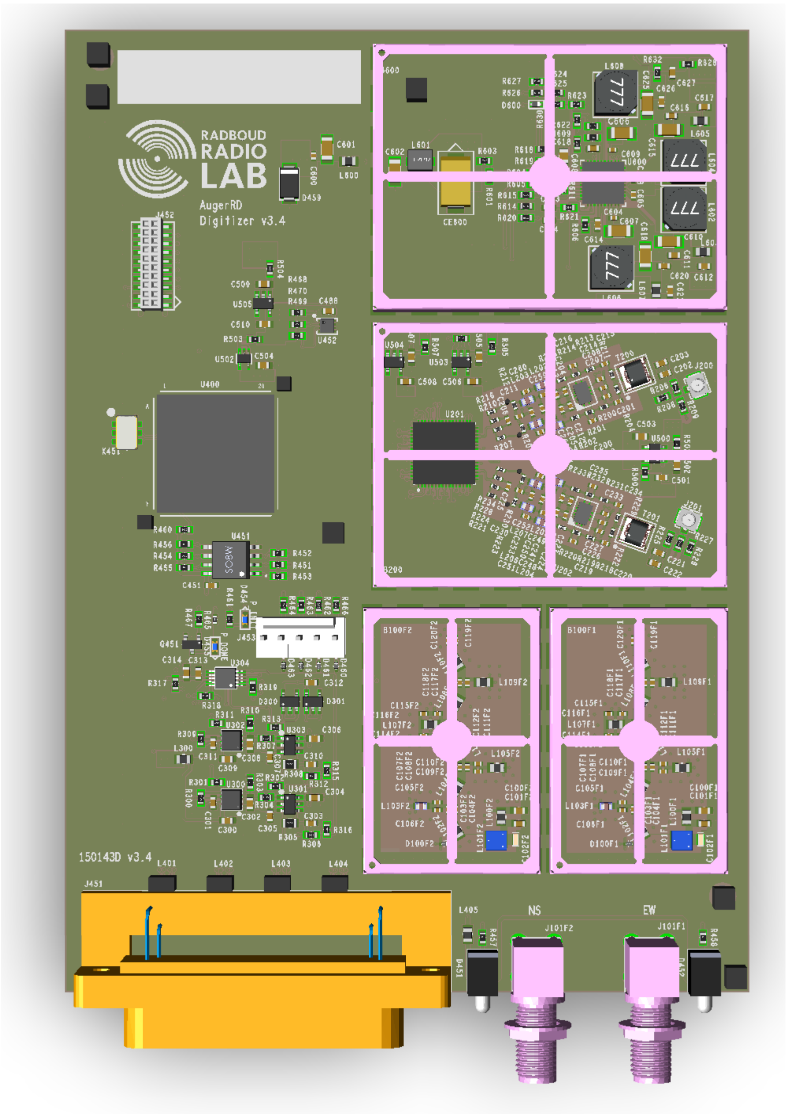


replacing 20 yr old 2x53 W panels with

Luxor ECO Line 200 Wp

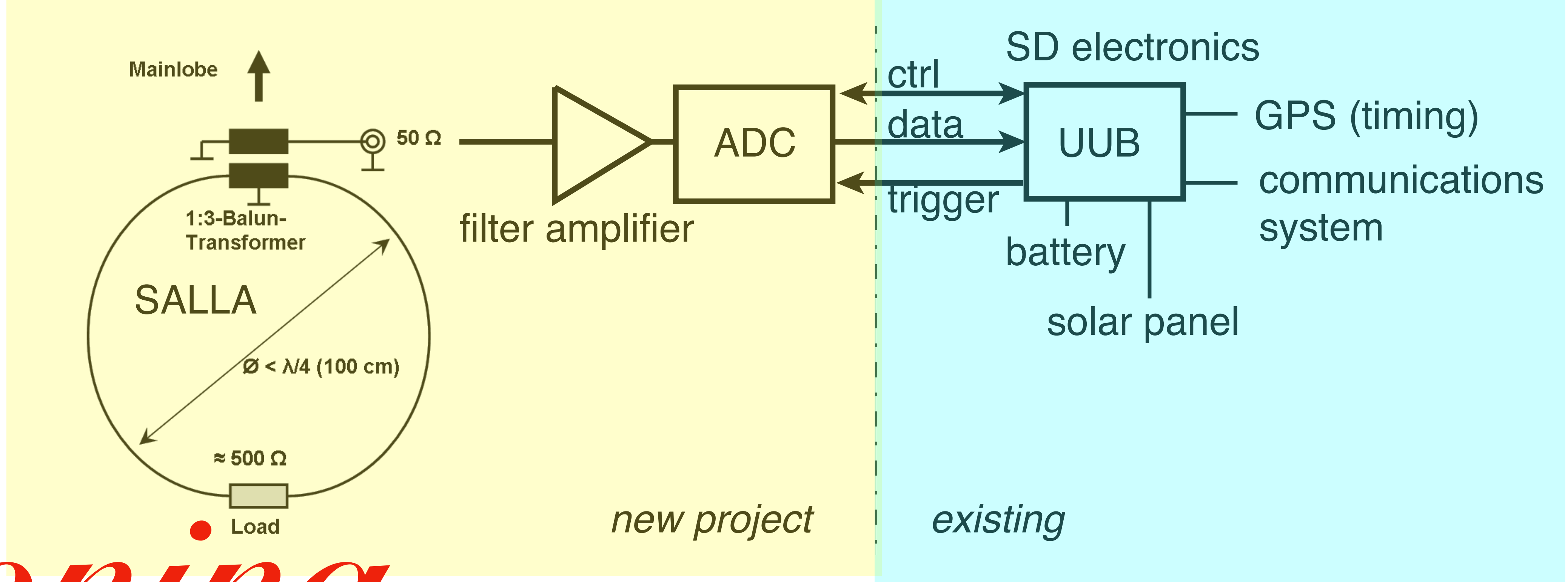
RD Digitizer

power consumption: 2,4 W



2010 produced

2009 fully functioning



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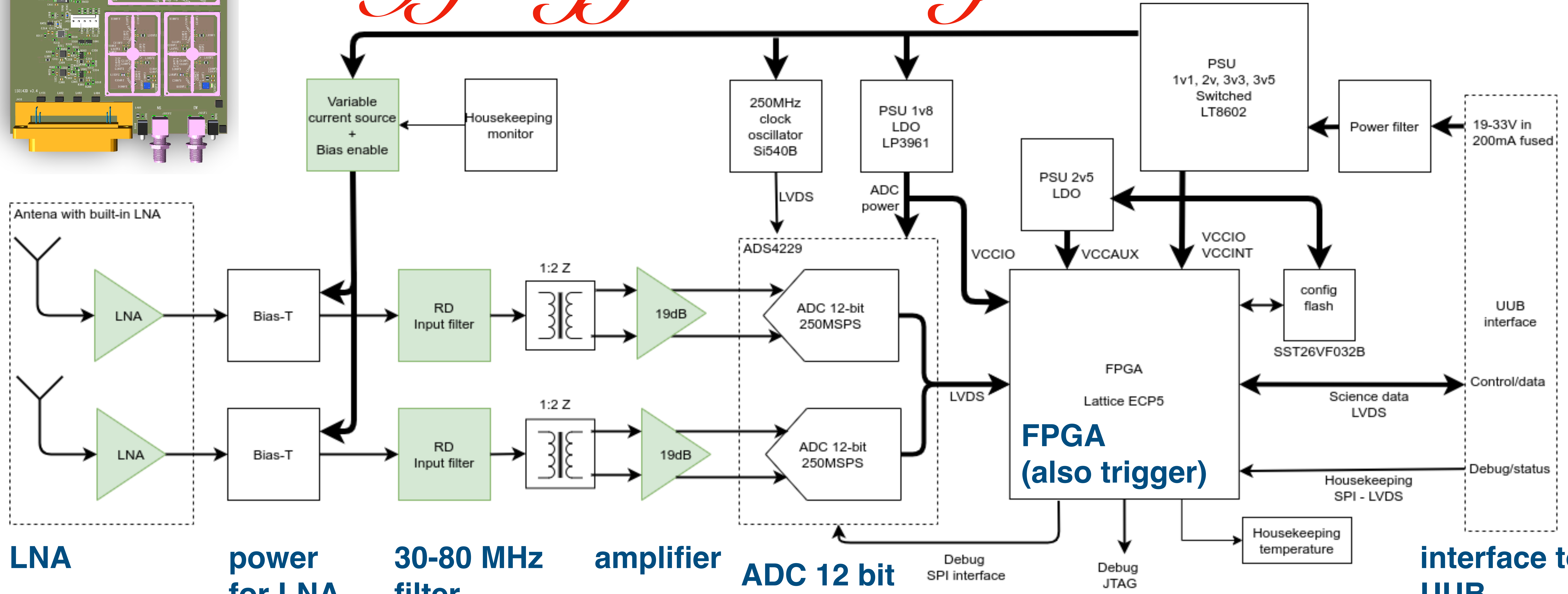


FPGA (also trigger)

LNA

power for LNA

30-80 MHz filter

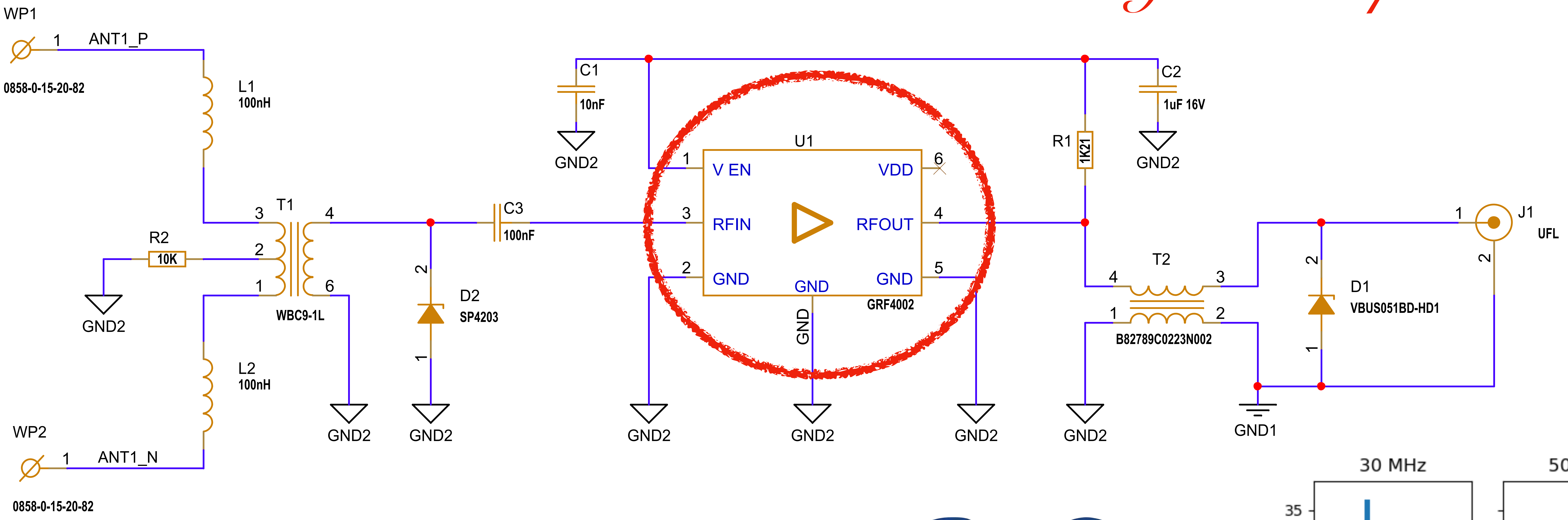
amplifier

ADC 12 bit 250 MHz

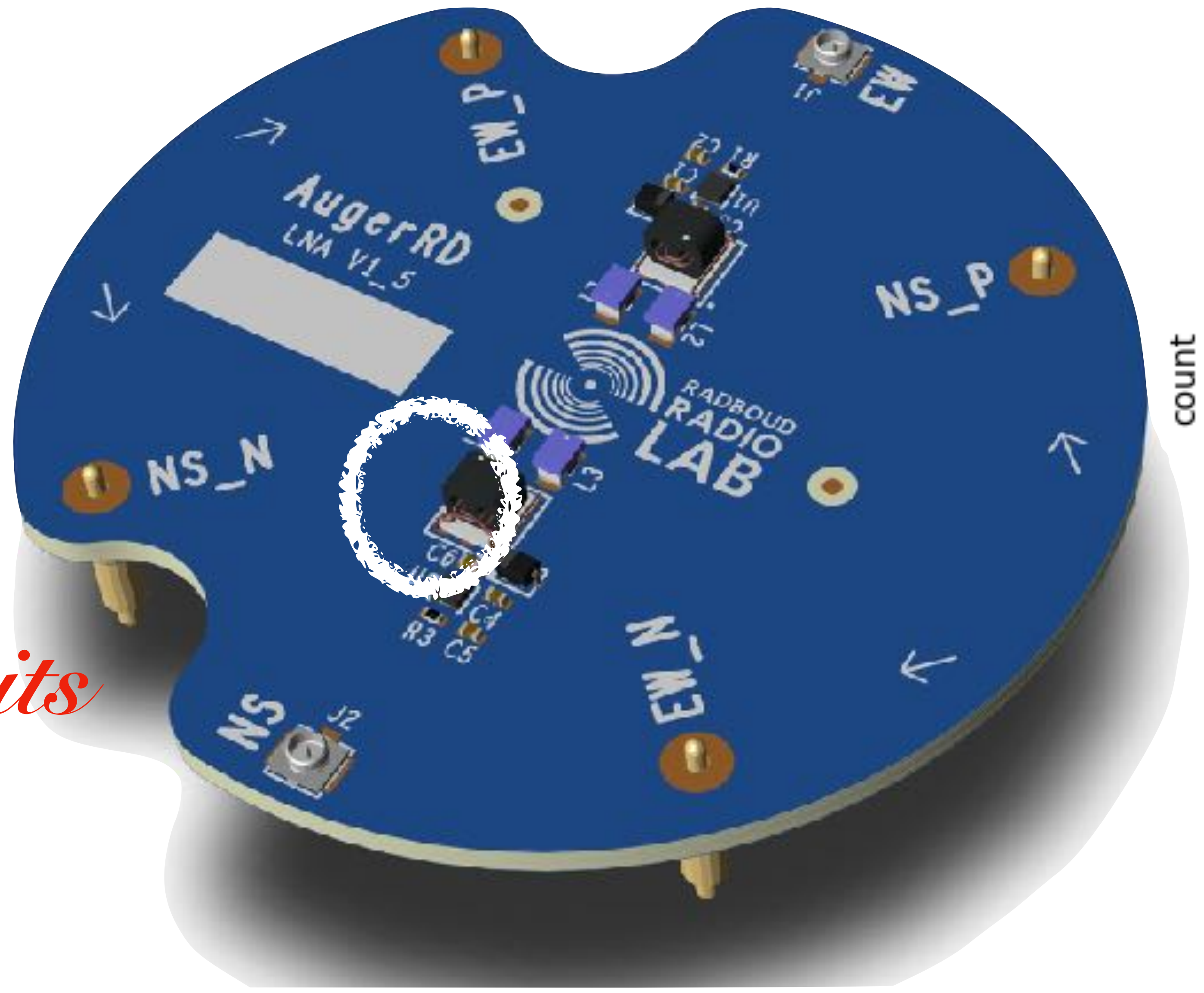
interface to UUB

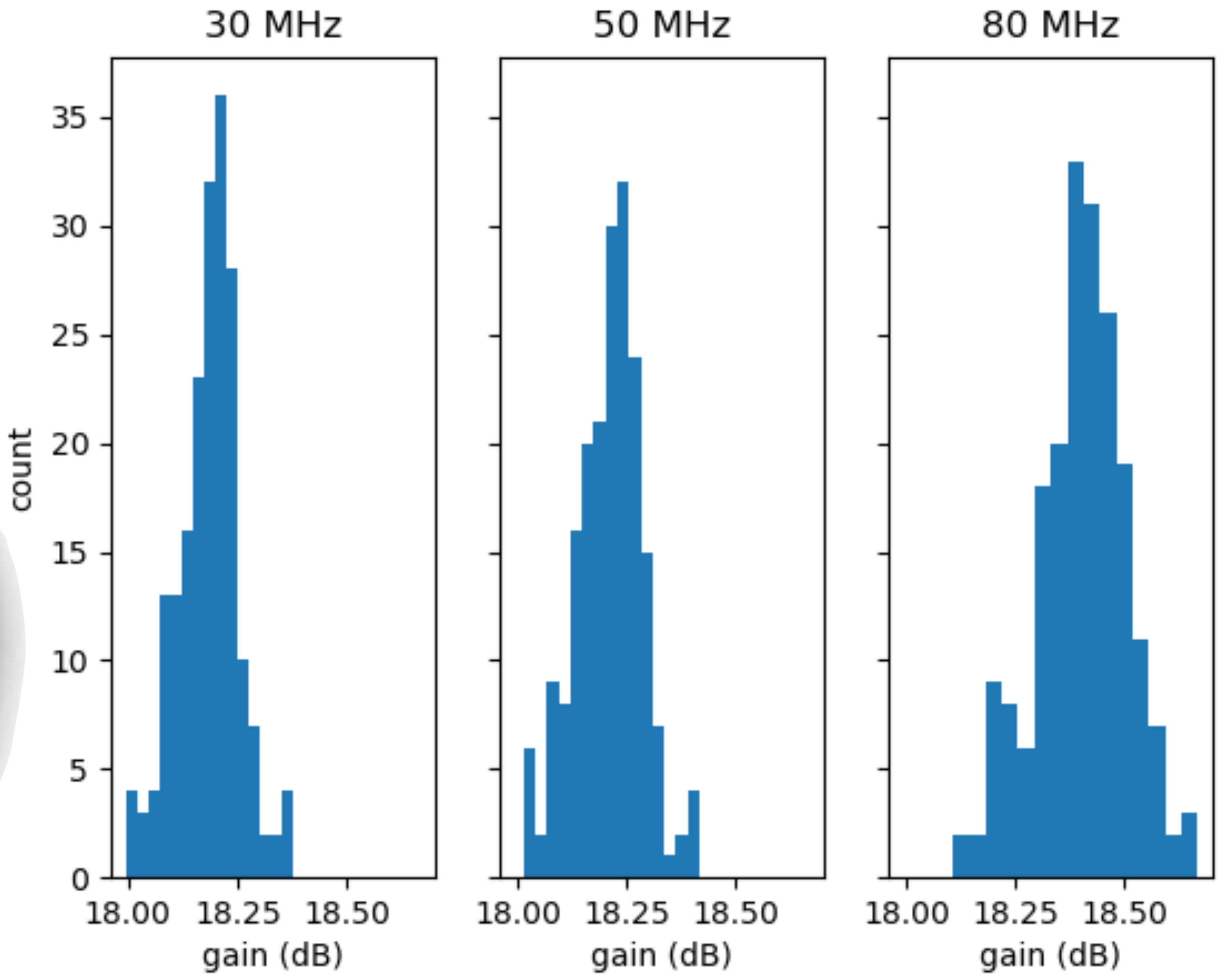
Low Noise Amplifier

some amplifier chips destroyed during transport/ installation & some in field —> repair in Malargüe



~1% in voltage





we have 1000 spare chips in Malargüe
Mauro has successfully repaired 115 units

power consumption: 0,2 W

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Data Management

- Is RD data well integrated into the data stream? ✓
- Is the RD data consistent and reliable ?
- Is the communication interface with UUB stable? ✓
- Can CDAS handle the volume of data produced by RD? ✓
- Is the monitoring of RD in place and well understood?

yes, RD data are integrated on UUB into standard SD data stream

we have some dead time, working on solution

yes, stable operation - no issues known

yes, we are routinely taking data - no problems known

2 branches
- from „Lyon data“ —> MORD tool available
- real time data

Data transfer from RD to UUB

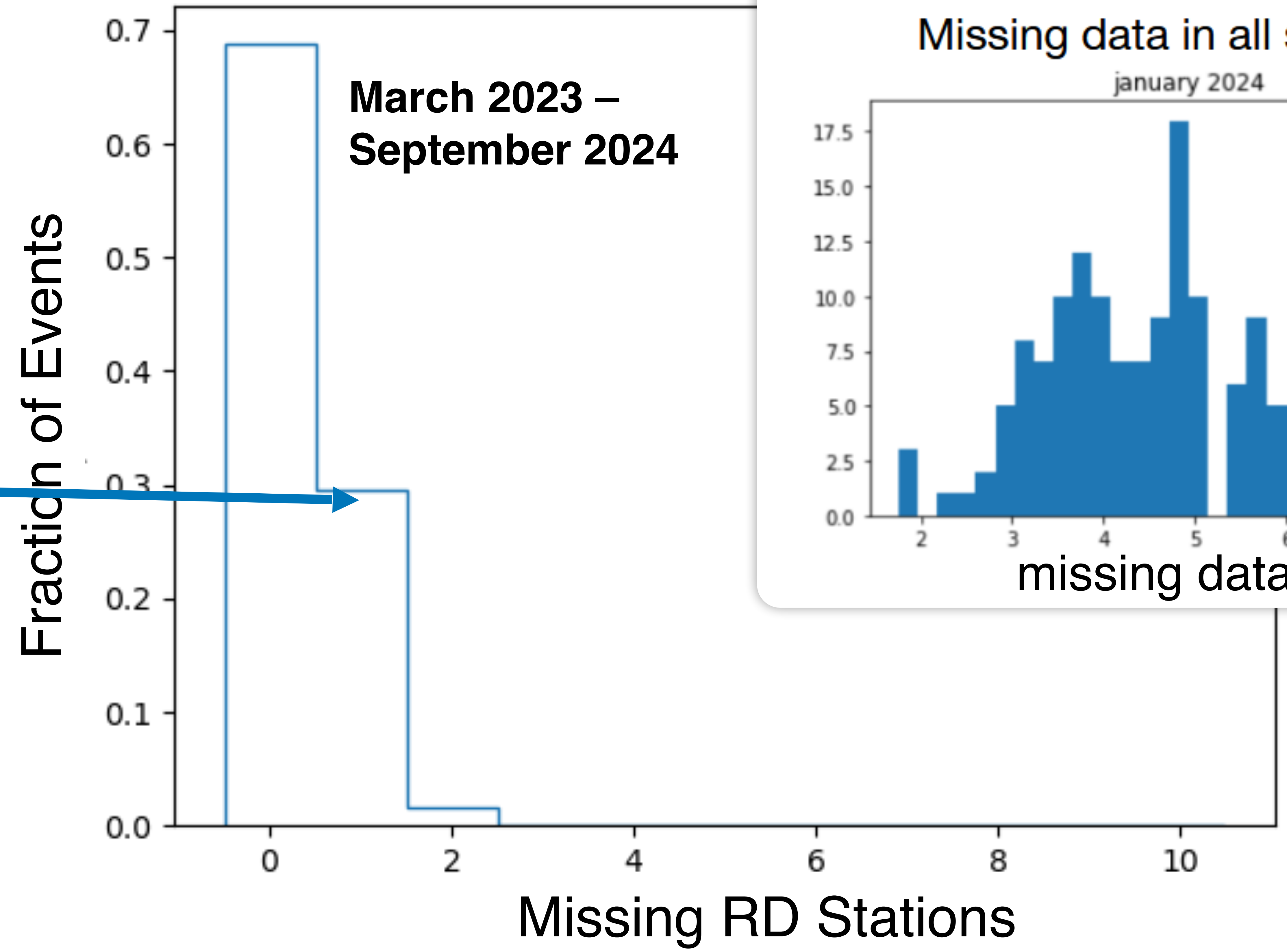
Sjoerd Timmer

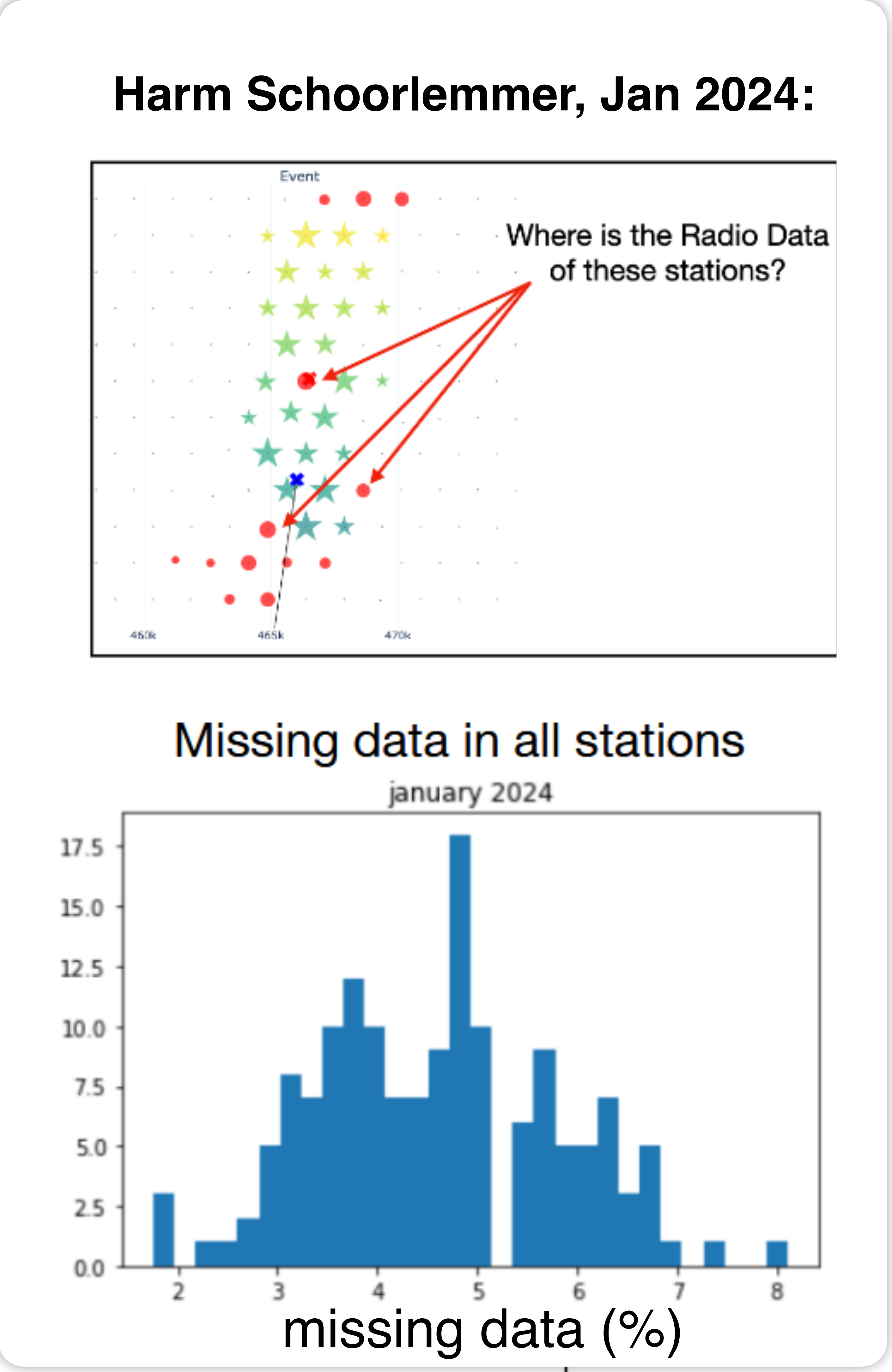
The Dead time feature

- Read out of RD data takes ~0.45ms
- During that time no additional triggers can be processed

➔ Loss of ~5% of traces

30% of events are missing 1 or more stations!



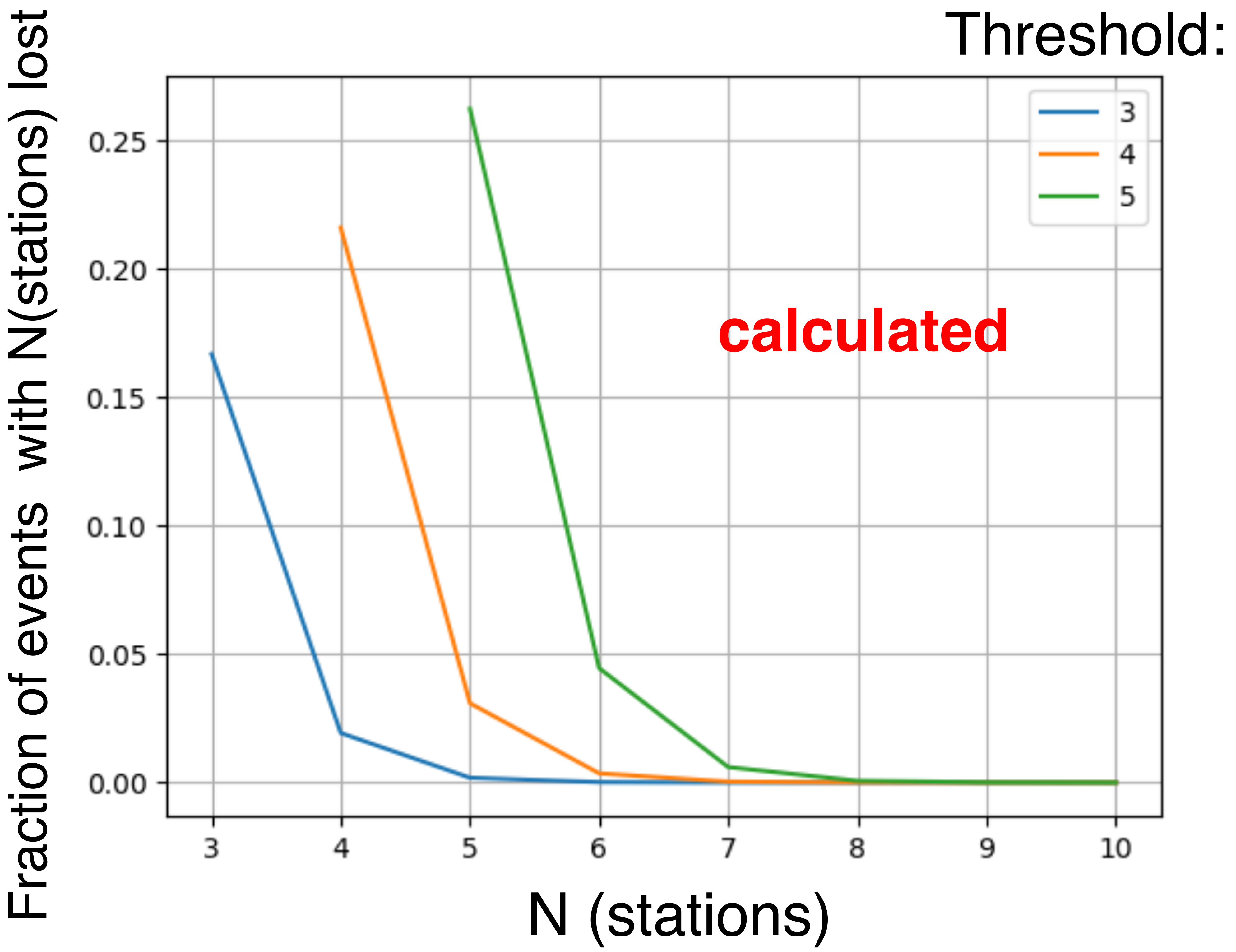


this is only relevant for events at threshold (i.e. lowest energies)

Simon Strähnz

The dead time feature:
Theoretical extend

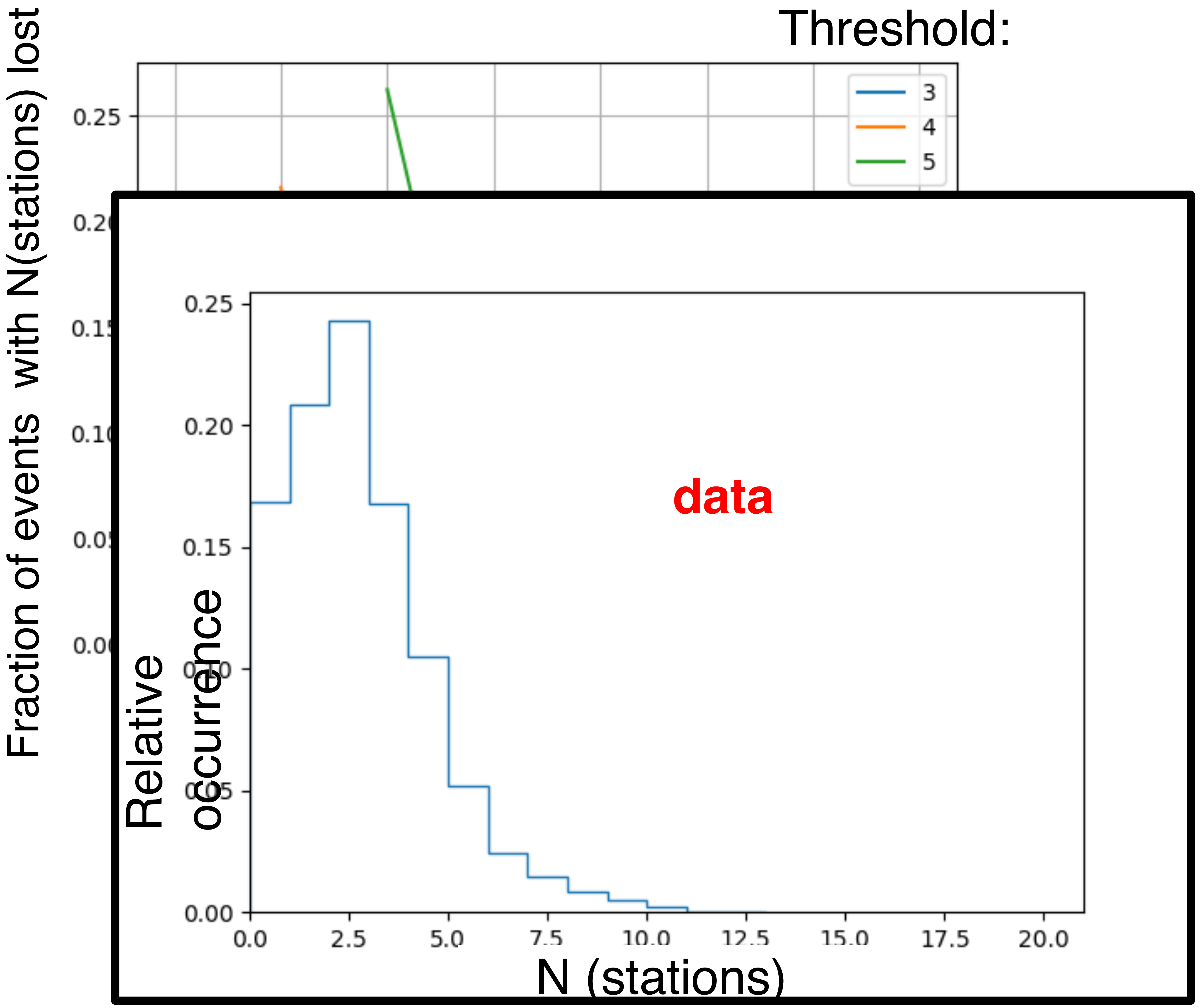
- Assume binomial distribution *worst case*
- Find the probability that event is lost as function of N(stations)



Simon Strähnz

The dead time feature:
Theoretical extend

- Assume binomial distribution *worst case*
- Find the probability that event is lost as function of N(stations)
- Weight by relative occurrence of N(stations)



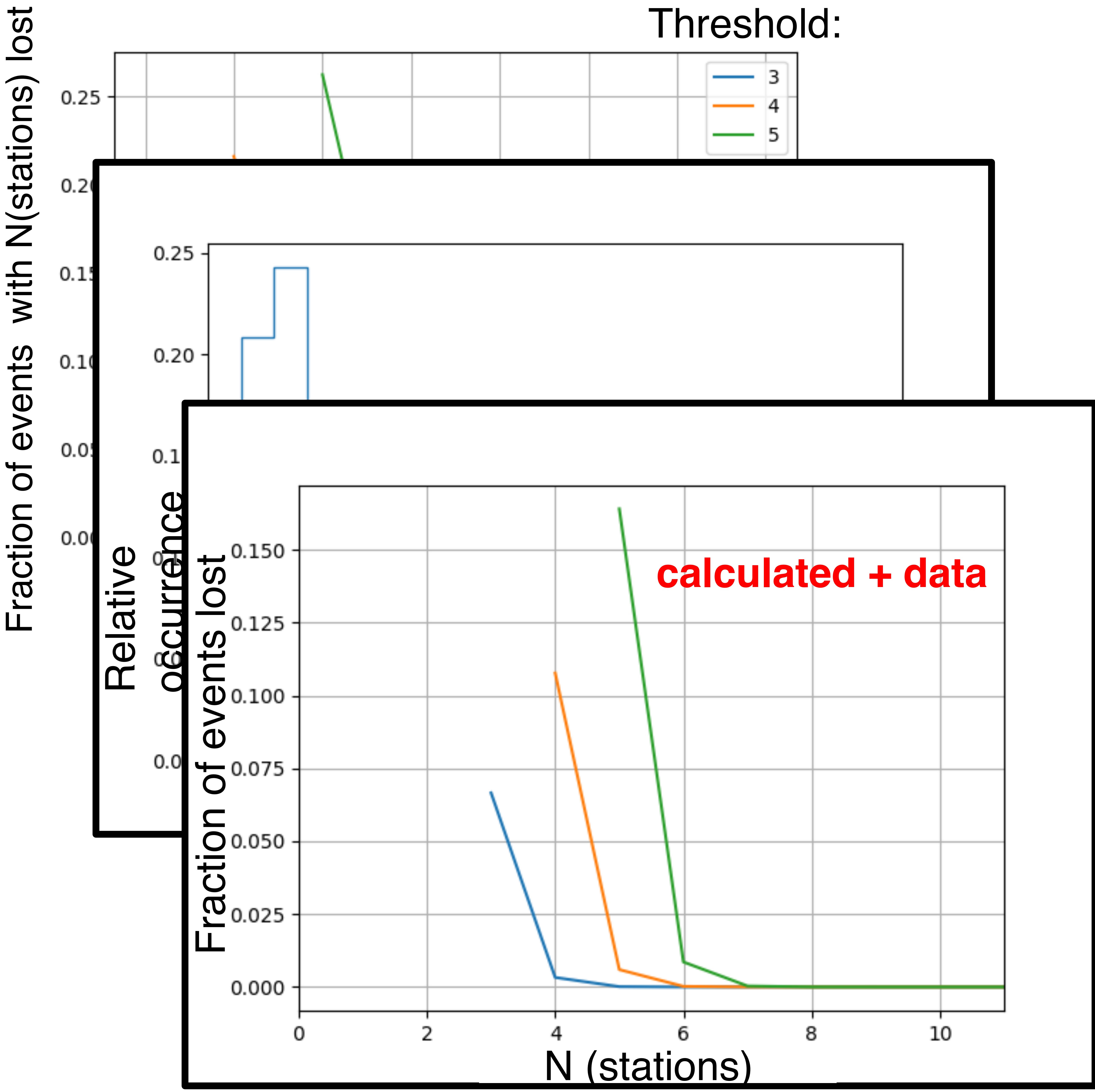
Simon Strähnz

The dead time feature:
Theoretical extend

- Assume binomial distribution *worst case*
- Find the probability that event is lost as function of N(stations)
- Weight by relative occurrence of N(stations)
- With threshold of 5 stations:

➔ **17.3% of events lost**

this is only relevant for events at threshold (i.e. lowest energies)



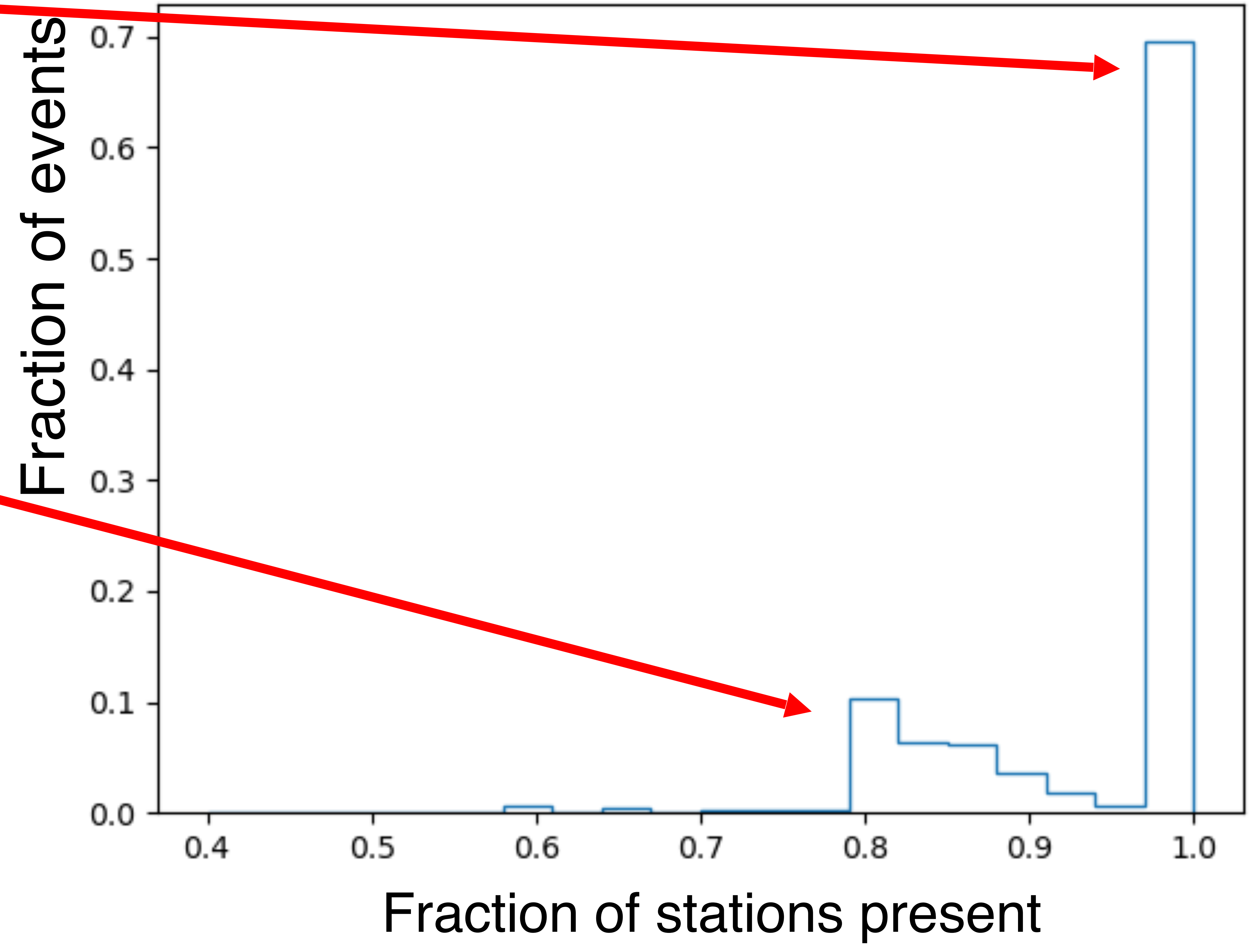
Simon Strähnz

The Dead time feature:
In early data (Mar 2023 – Sep 2024)

- In Data: Only 70% of events ($N \geq 5$) have all stations present

- Peak at 0.8: 5 → 4 stations

→ ~12% of all events (N = 5) lost



this is only relevant for events at threshold (i.e. lowest energies)

Simon Strähnz

Possible solutions

- **compression of data**
  (not too effective)

- **do not transfer „uninteresting“ data**
  (do quick check on RD, like max value below a threshold)

- **multiple buffers**
  (keep recording while data transfer,
  requires modification of FPGA code,
  read-out noise seen by RD, could lower transfer speed to below science band,
  needs book keeping on RD and UUB side - we cannot mix events&triggers
  —> work for Dave & Sjoerd)

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- real time data

RD monitoring - offline Lyon data

MoRd: Monitoring Auger's RD

Longterm monitoring overview

The plots are interactive: there is a toolbox on the right side providing zoom/save options.
As you see, we are growing. So, if you are looking for a certain station in a page -> just use ctrl+F as normal search
You can Zoom part of the plot, choose to show station(s) by double click on their names in the legend, or hide a station(s) by single click on legend
Pages content Pages Summary. Check the User Guide. The source code for these webpages can be found here at gitlab.

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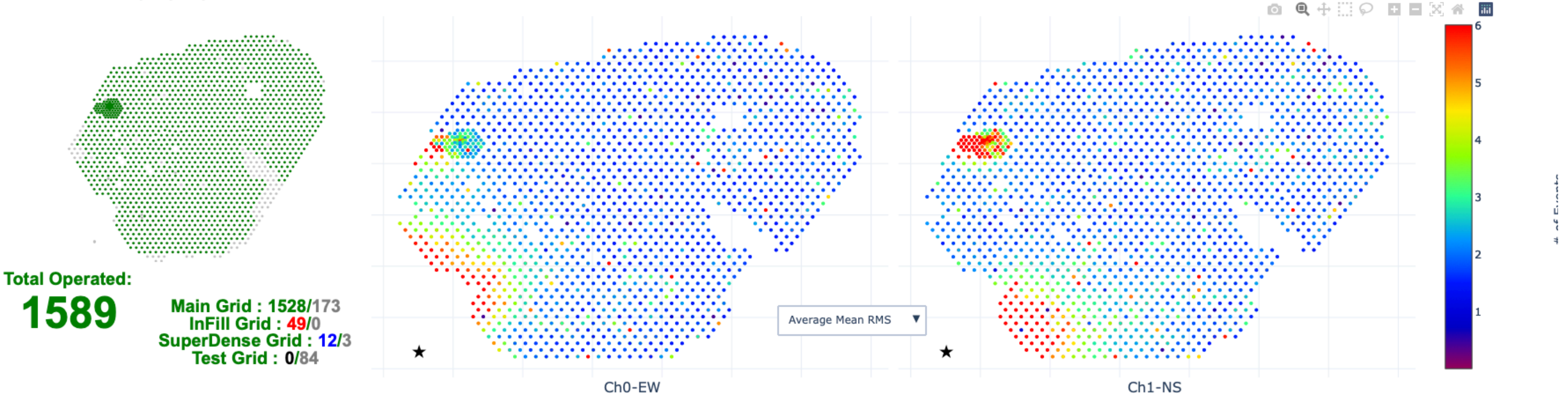
Current Status (01/03/2025 at 06h59) from sd_2025_03_01_06h59



https://hef.ru.nl/mord (usual Auger password)

RD Monitoring

- Block with variables defined and implemented in RD-FE firmware
- First test was running, Tomas had quick look to confirm data validity
- For long time not included in RD-FE firmware running in the field
- RD-FE and UUB firmware upgraded in the field on 19th Sep'24
- Sending of RD-Mon not enabled at all stations
- Not yet implemented in CDAS LS and central version

RD-Monitoring data

- Block defined
- Monitoring sent every 400 sec
- But Mon-message not prioritized
  lost in case of high leeds-load
- For galactic calibration ok up to about 1h
- In addition RD-trigger info required:
  - cumulative T1
  - cumulative RD-traces
  - Cumulative seconds RD-T1 vetoed

```
Metadata from RD:
* hardware id: 2(?) bytes
* firmware version: 2(?) byte
* LNA feedback:
  * current NS: 1.5 bytes
  * voltage NS: 1.5 bytes
  * current EW: 1.5 bytes
  * voltage EW: 1.5 bytes
* temperature:
  * 2 bytes
* calibration: (suggested cadance)
  * 30-80MHz in 5 bands of 10 MHz
  * every ~14 minutes (800 s)
  * 2 channels (alternate, one channels each 400s)
  * 64 bits per bin: 40 bytes total -> here is a potential
  * number of fft's: 4 bytes
  * used threshold: 2 bytes
  * time spent accumulating: 4 bytes
```

RD-Monitoring data

- CDAS writed un-handled RD-Mon part to file
- Test file and code made available by Ricardo

```
========== found header ... ========
StId=0664 Pack=2 reg_time=0.000000000 276
==== Monit start time(GPSSec)=1423266439 =========
monit: temp=772 ... curr/volt(ADC)=418/734; 419/766
fft: nffts=8192;dt(ms)=3194;th=30;streach=100;offset=123;nsum=4;nvals=52;
f(MHz)  N/S         E/W
 30.03  5.4563e+13  5.8686e+13
 31.01  5.9236e+13   5.903e+13
 31.98  1.1531e+14  1.5641e+14
 32.96  6.8926e+13  6.8651e+13
 33.94  6.0954e+13  6.4047e+13
 34.91  6.0611e+13  6.8307e+13
 35.89  6.1985e+13  7.1743e+13
 36.87  6.3703e+13  6.8376e+13
 37.84  6.4802e+13   6.975e+13
 38.82  5.9649e+13  6.8857e+13
 39.79  6.0473e+13  6.9888e+13
 40.77  6.1435e+13  7.1193e+13
 41.75  7.1056e+13   7.779e+13
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  * time spent accum

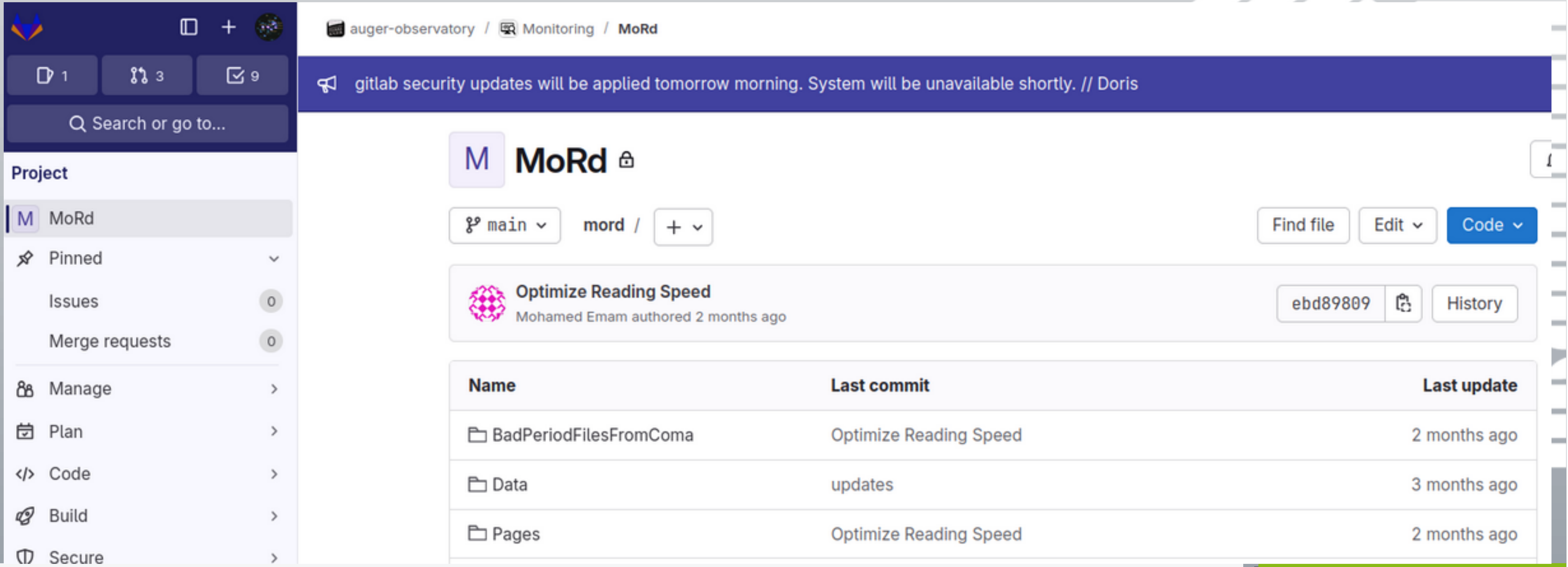
```
SdId 906 occurs 216
SdId 1747 occurs 216
SdId 904 occurs 216
SdId 1729 occurs 216
SdId 1743 occurs 216
SdId 635 occurs 214
SdId 1741 occurs 216
SdId 863 occurs 216
SdId 1738 occurs 216
SdId 663 occurs 216
SdId 665 occurs 216
SdId 1740 occurs 216
SdId 920 occurs 206
SdId 902 occurs 216
SdId 1735 occurs 213
SdId 1737 occurs 215
SdId 657 occurs 220
SdId 865 occurs 215
SdId 664 occurs 215
```

RD-Monitoring

- Block to be implemented in MonitCalib and LongTermMonitCalib
- Requires modification in CDAS-Mr, definitioin of tables in mondb
- Spectrum in MonitCalib, or also directly in other format?
  What is the input for the Galactic-Calibration analysis?

RD DQM

- Processing of daily sd-files
- Tool in gitlab: https://gitlab.iap.kit.edu/auger-observatory/monitoring/mord



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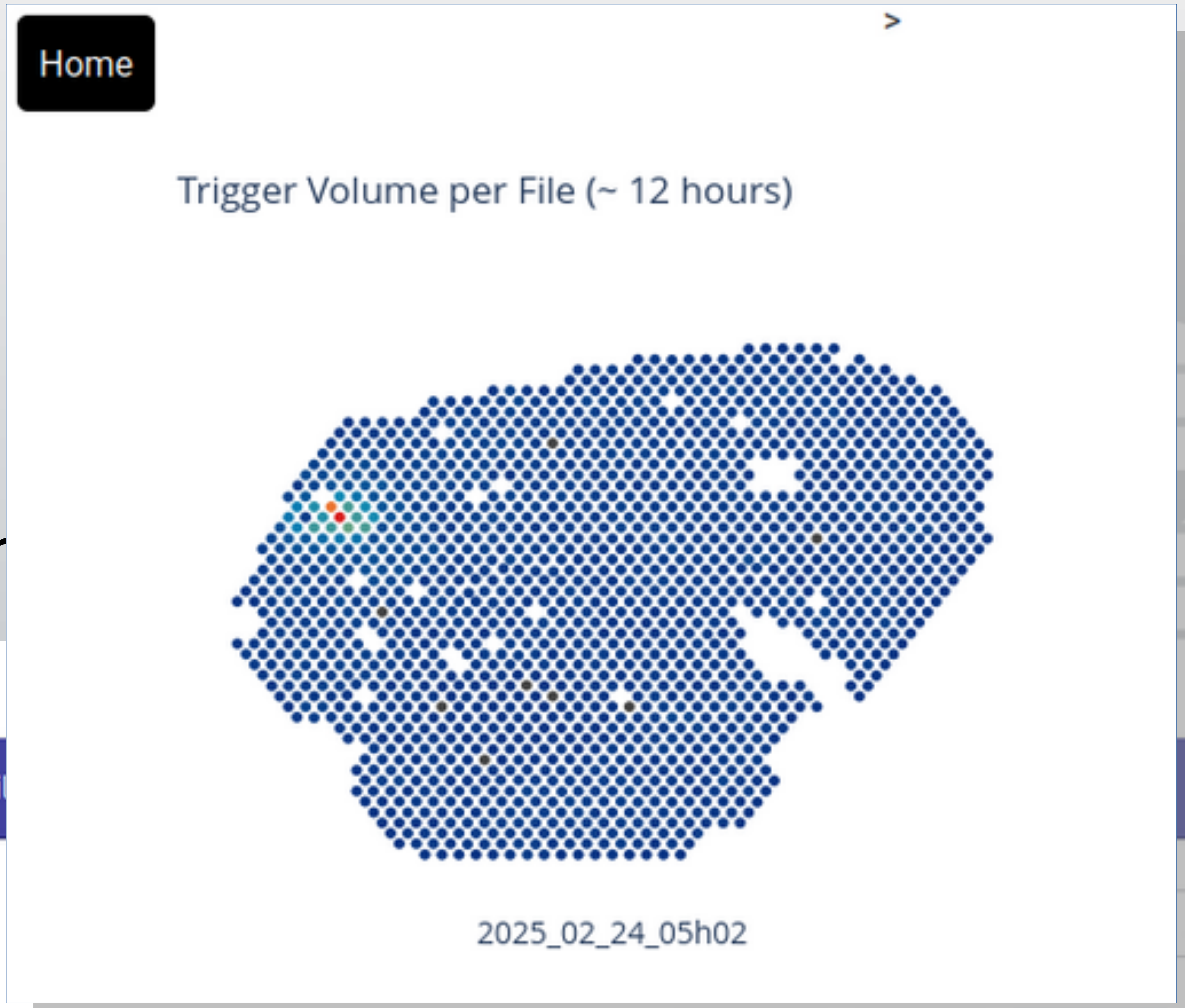

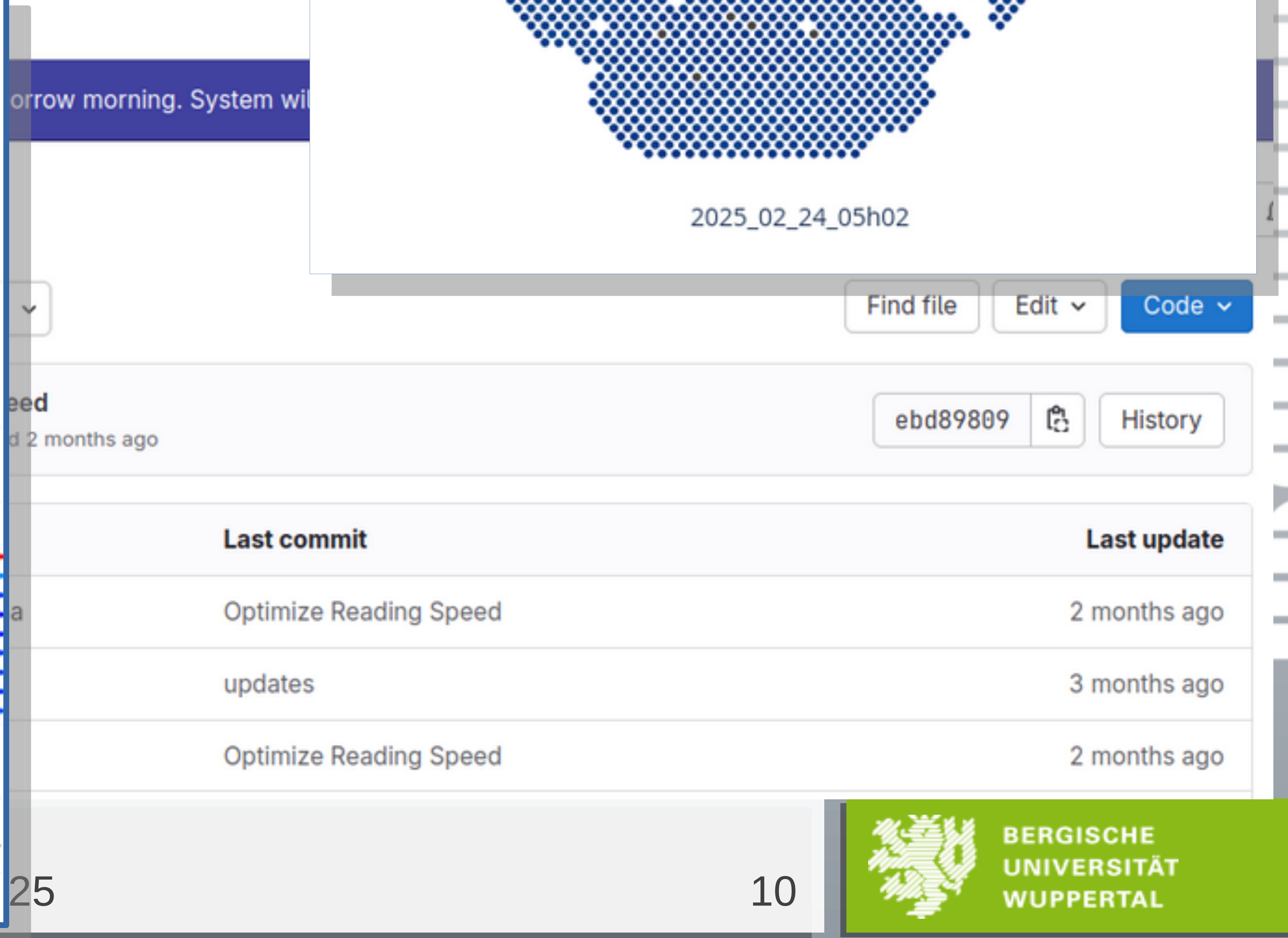

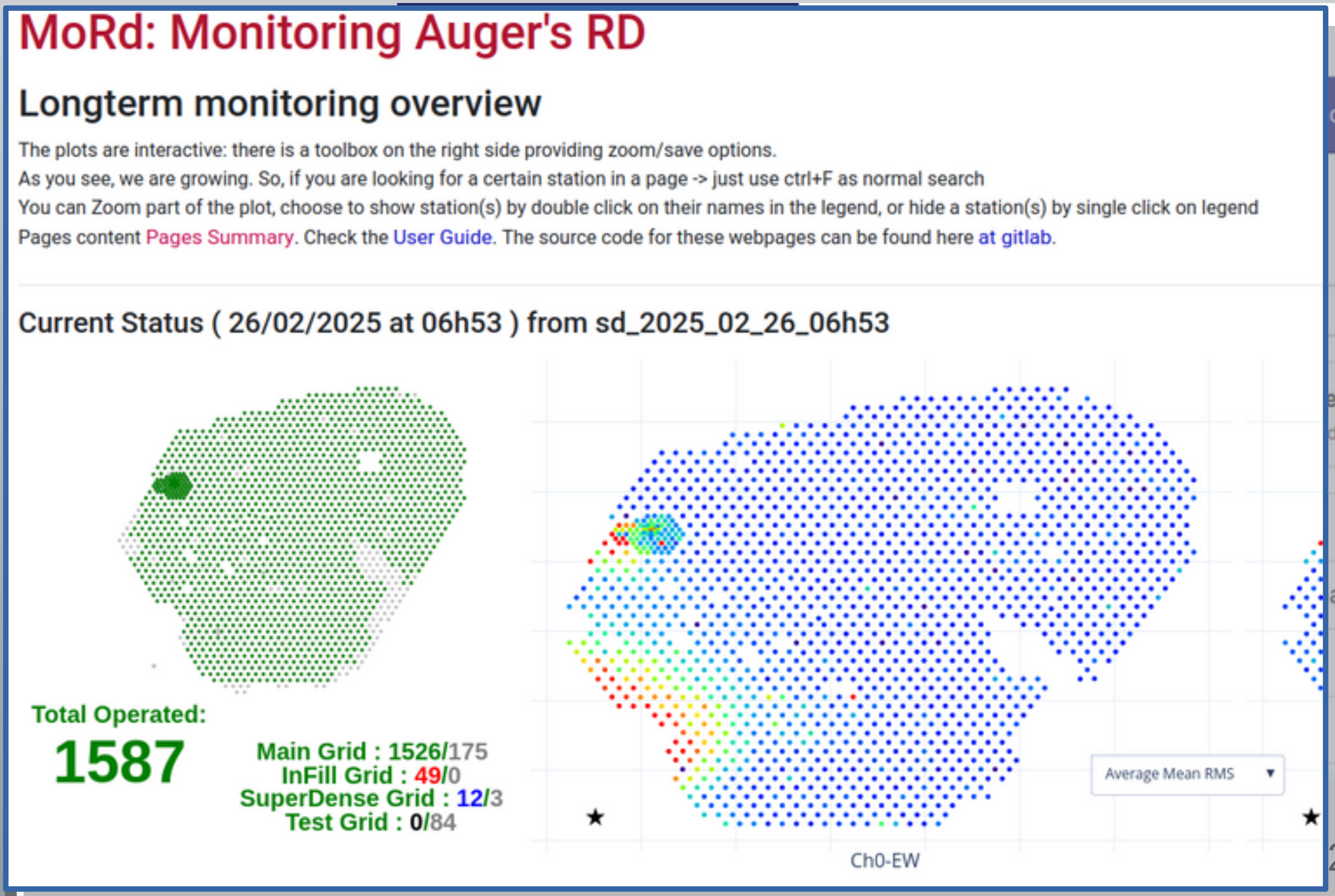

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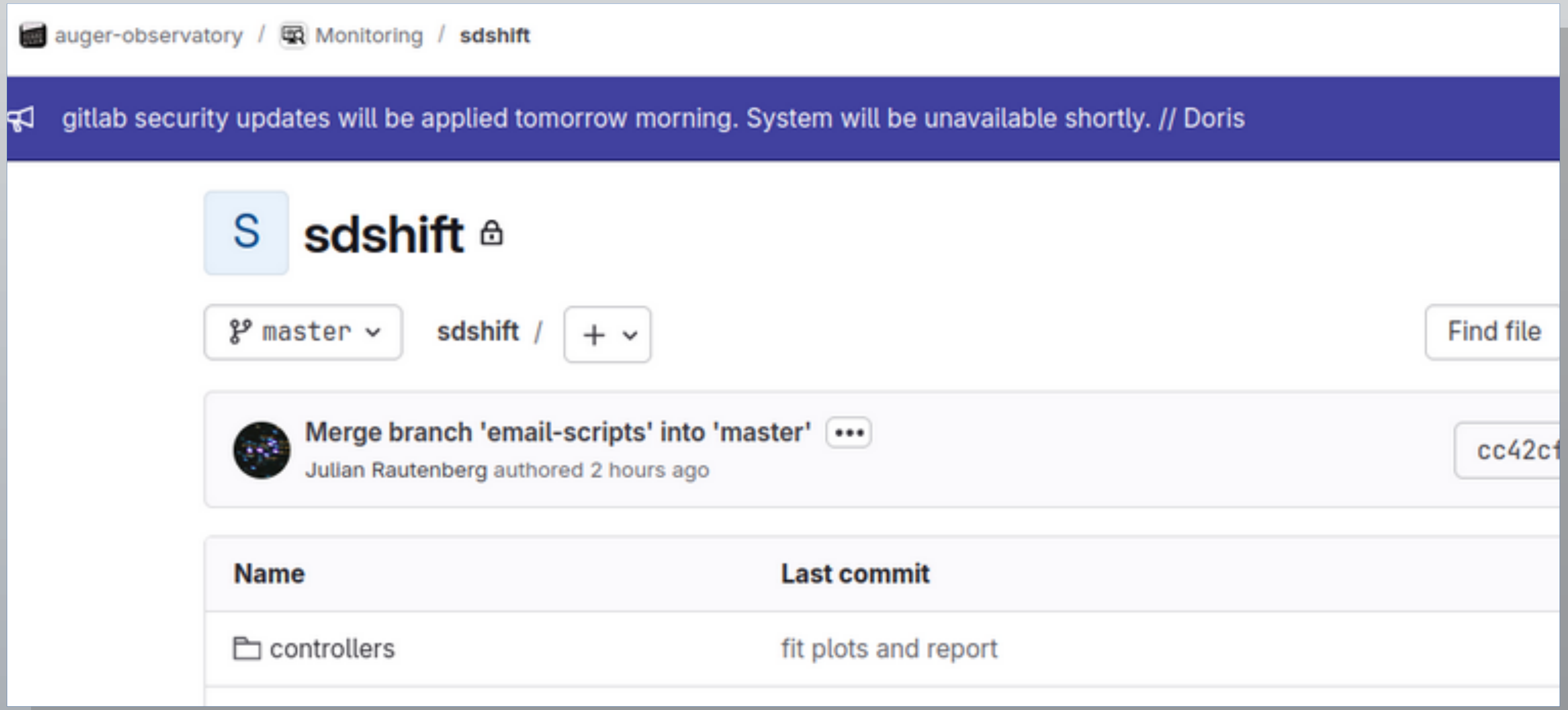
RD-Shift

- RD-SQM provides plots that can be implemented in the SD shift
- SD-Shift transistion still ongoing, then open for additional components



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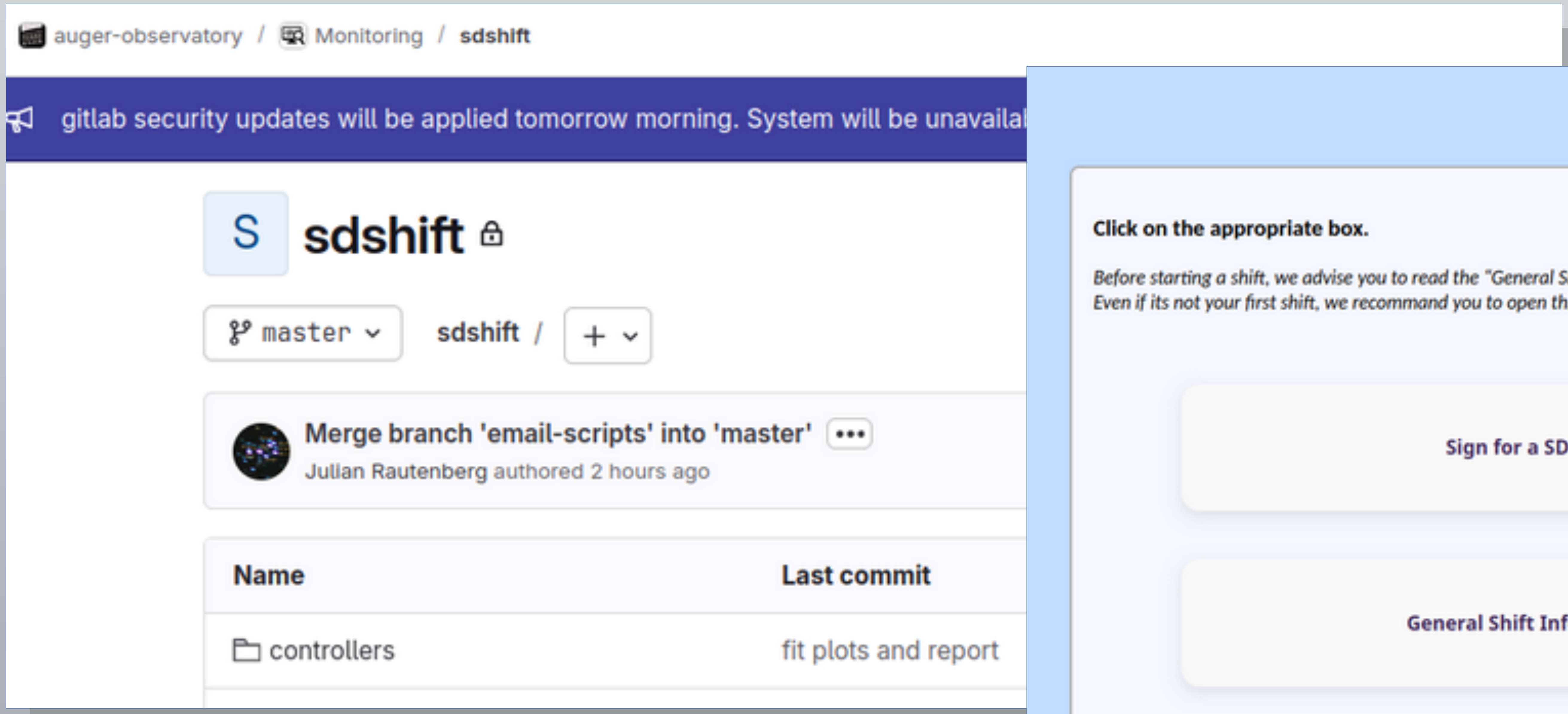

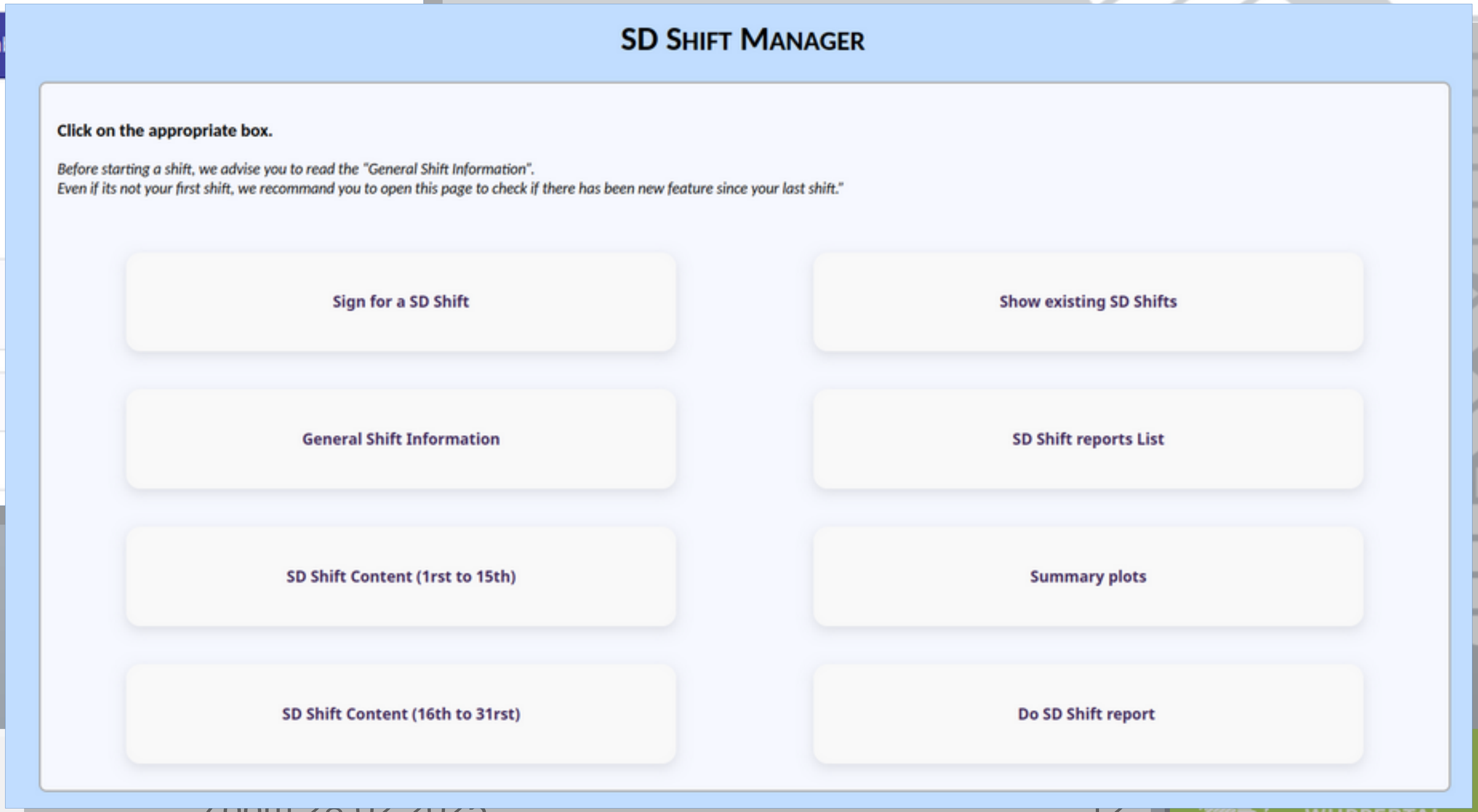

yes, drawings collected by Jörg and put to EDMS by Patrick

Technical Documentation

- Are drawings, schematics, and any other relevant documents complete and posted to CERN EDMS and/or PMS? ✓
- Are instructions for operating and maintaining software code, as well as the code itself, available and organized? ✓
- Is a complete list of equipment and components including part numbers and vendor contact information available? ✓

yes, code from Dave (UUB) and Sjoerd (RD) is on KIT GitLab

yes, information collected by Jörg and put to EDMS by Patrick

Procedures. The following procedures must be complete:

- General operation. ✓
- Hardware and software troubleshooting and maintenance. ✓
- Process for handling major repairs.
- Inclusion of safety considerations in all procedures. ✓

Ricardo Sato knows how to run software and update RD firmware

<u>Marcos</u>, Mauro, Andrés trained to do maintenance

Radboud will provide a (simplified) tool for lab calibration (needed after e.g. components have been exchanged)

Training.

- Has an appropriate number of observatory personnel been trained to operate and provide routine maintenance?

training for Marcos, Anrdés, Mauro ongoing

Mauro has already successfully repaired 115 LNAs (replaced amplifier chip)

WORK IN PROGRESS! List of LNA failures and supply

- **From reports by Marcos:**
  - **2000 : original supply**
  - ~1624 **: in the field** *(number of unique station IDs that have appeared in MoRD. Maybe 5 or so are moved stations so are duplicates)*
  - **>120 : new ones not yet used** (at least 120 from the last shipment + all others [value to be confirmed])
  - ~80 **: needed to finished the current maintenance**
  - 28**: needed to fill in final landowner region**
  - ~175 : **broken, brought back from the field** (128 are already repaired and nearly all redeployed; all w/o/ further issues).
    - 115 : LNA amplifier chip repaired (From PMS).
    - 13 : 'pig-tail' repaired (From PMS)
    - 60 : to be repaired (likely 10% pigtail, 90% chip, a few misc. issue)
    - ~10? : **likely gone forever**. *(9 destroyed by lighting. Maybe a few more broken during deployment. Some still repairable.)*

- ***For context: historical lightning cases in PMS:***
  - *40 specific cases described in the history of SD. More cases where just GPS antenna was affected. PMS record is not complete.*
    ***80 over SD period** is a more likely estimate [based on Marcos asking staff]*
  - ***<10 stations / year** is what the staff finds acceptable normally.*
  - *We had **2 catastrophic failure cases with RD** in the recent thunderstorm season.*
    —> no reason to suspect a much higher rate. Maybe a little based on that our antenna is higher than the GPS antenna.

LNA failures after initial deployment

- Failures of bottom loads/ cables / ferrites / structural components is not very high. More than enough spares available.

- **Pre-note:** 'BrokenLNA flag' == Broken LNA amplifier / broken pigtail / broken cable / unplugged cable / missing self-cutting screw / …
  —> Anything that makes the gain drop.

- **<u>From MoRD data (all T3 traces)</u>:** stations that show 'BrokenLNA flag' in data (i.e., flat or nearly flag spectrum). Not all are yet repaired
  - During deployment (<30d since deployment): ~67 *(maybe 5 are firmware issues mimicking a dead channel. Only 13 with 2ch failure)*
    + *the failures that were directly replaced [see previous slide]*
  - During operation (>30d since deployment) : ~72 *(dominated by NorthEast issue since Nov'24-Jan'25. Dust/water/lighting/…)*
    ~15 up till Oct'24 (*1300 station deployed at that time. Only 2 with 2ch failure)*

* code will appear in my sandbox at some point

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WORK IN PROGRESS!

Estimation of failure rate

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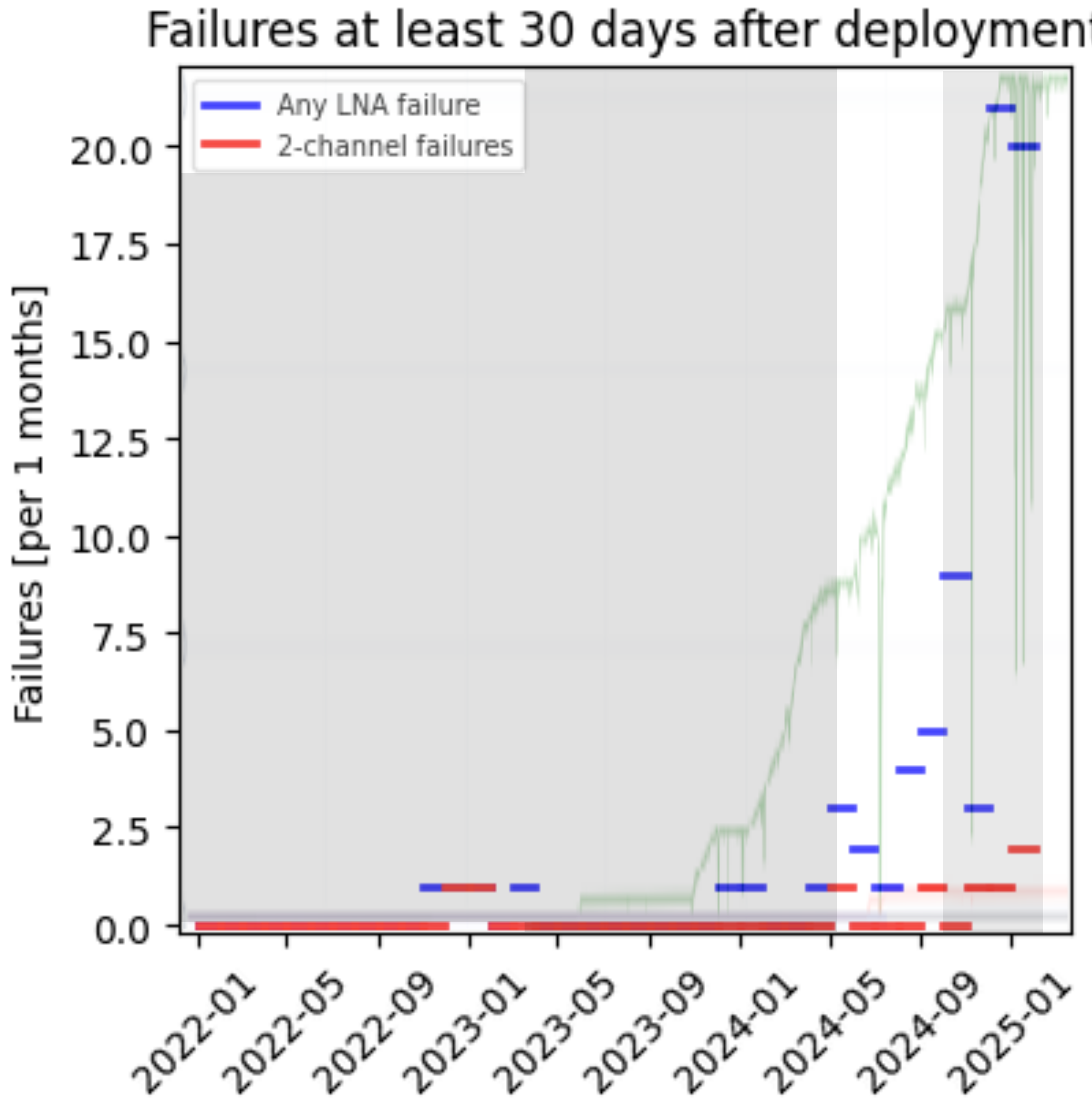
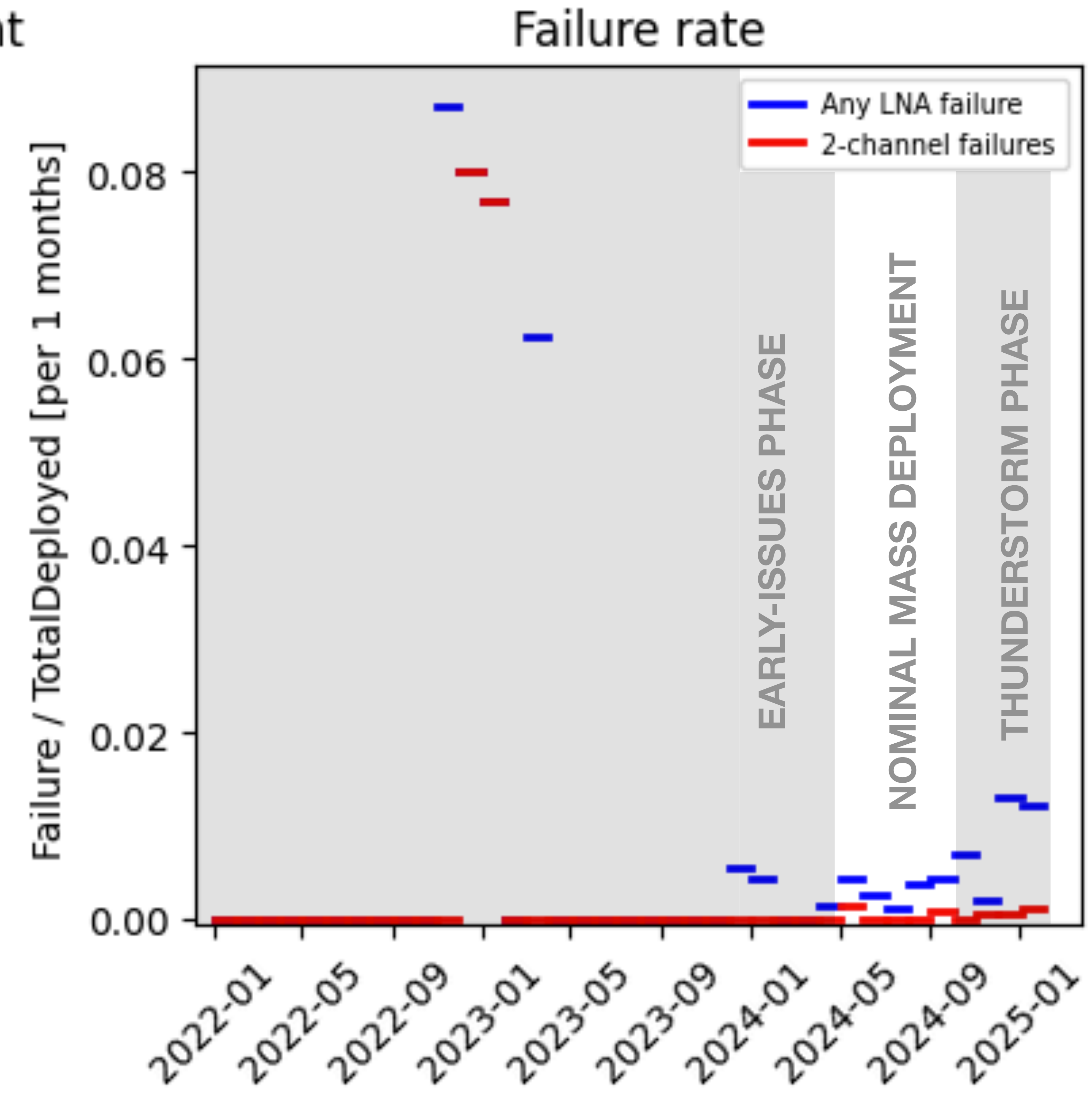
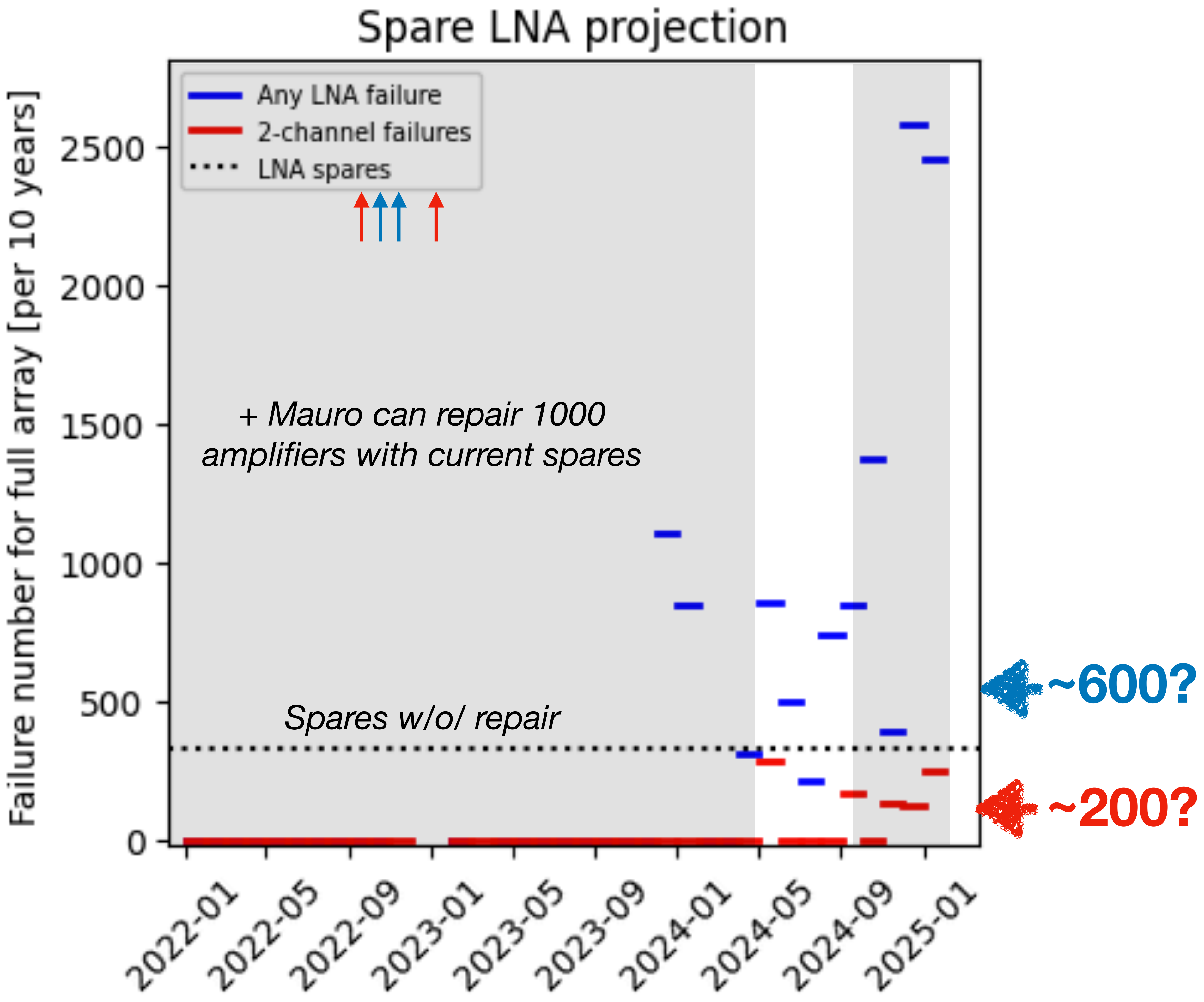
- **Note:** failure rates are complicated to estimate. Convolution of: ‘regular failures’, residual deployment issues, and thunderstorm season.
- Failures of Oct-now are focussed towards the North-East region —> Does not extrapolate to full array over 10 years!
  - 2 months of a full array in a **heavy thunderstorm season** is a big part of our uptime.
  - Only 7 stations are confirmed to be affected by lightning. ~50 others from Oct-Jan could be a mix of dust/lightning/water/etc…?
- Very rough guess on estimated spares/repairs we might need 200-600?
  —> Might be lower if part is still due to deployment issues. Might be a bit higher when including regular thunderstorm periods.

Absolute number of failures per month	% of failures per month	Rates extrapolated from 1m to 10yr







Operations costs.

- Evaluate the annual resources (person-power & costs) required for routine operation and maintenance for each subsystem, including materials and equipment. Discuss anticipated rates of failures and frequency of repairs and replacements.

main failures during operations:

- **broken LNA amplifier chips (over voltage)**
  1000 spare amplifiers are in Malargüe (1000/72 ~14 years)
- **rotated antennas (strong wind)**

—> Jörg is in discussion with Gualberto and Ingo how this translates to FTEs needed/year

Detailed frame of the Review:

- SALLA antenna and all mechanical components and supports;
- HF electronics of the antenna (LNA), signal digitizer and UUB electrical interface;

The review should assess, but not be limited to, the following issues:

Radio Detector
Operations Readiness Review

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Equipment availability and readiness

- Are components and software fully commissioned, operating reliably, and meeting performance requirements?
- Are all the hardware, power and software interfaces fully functional, compatible and operational?
- Are special tools and testing equipment required for routine maintenance present and available to the Observatory staff?
- Are the most common failures are yet known, understood and have a mitigation plan?
- Is there a long-term plan for component repairs or replacement?
- Has a reliable source for all spare parts, tools, and consumables been identified for future procurements? Are spares available on site as required?

minor open items:

working on calibration device for LNAs

Data Management

- Is RD data well integrated into the data stream?
- Is the RD data consistent and reliable ?
- Is the communication interface with UUB stable?
- Can CDAS handle the volume of data produced by RD?
- Is the monitoring of RD in place and well understood?

working on alternative read-out to reduce/eliminate dead time

working to integrate RD in SD monitoring UUB->CDAS-data base

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working to integrate RD in SD shift

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completing training of Marcos, Andrés, Mauro

Operations costs.

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estimating together with Ingo, Gualberto, Marcos efforts for LNA repairs and field work