New Electric Field Mills for the Auger Radio Upgrade...

…and what I‘ve learned so far

Max Büsken

HIRSAP Meeting

3rd November 2021

Preparations for a New Experimental Setup

1) Research requirements on the measurement

- Determine boundary conditions (runtime, deployment schedule, costs, etc.)
- In our case: Study conditions for a calibrated setup

2) Design and configure the experimental stations

- Layout of the experimental stations → Necessary parts (Plan A + Alternatives)
- Compare products, get offers, consider quality/costs

3) Discussions with responsible people → Face reality

- Collect experiences from colleagues
- Determine further boundary conditions (legal issues, practical/logistical limitations)

  ↳ Discuss best solutions (for example: Setup locations)

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Karlsruhe Institute of Technology

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  ↳ Discuss best solutions (for example: Setup locations) focus

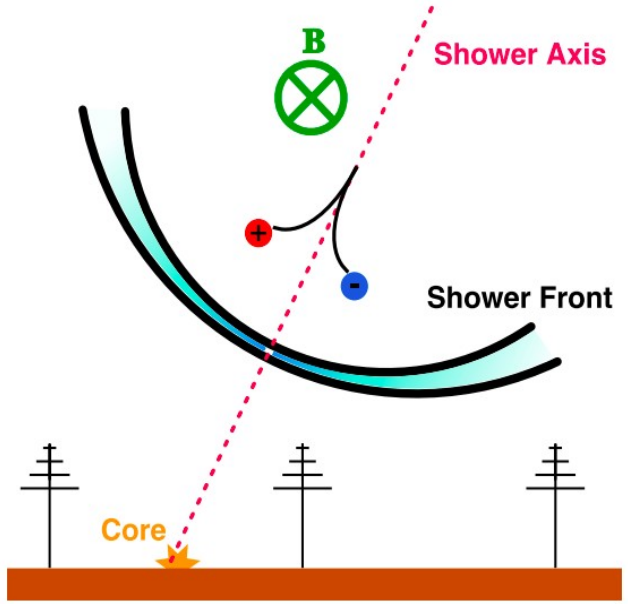
Why do we need E-field mills?

Main mechanism for the production of radio emission from cosmic ray air showers:

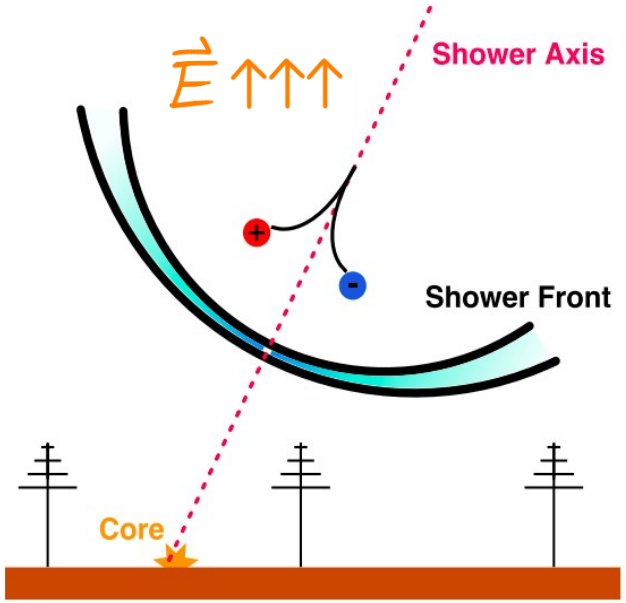
Deflection of charged shower particles in the Earth‘s magnetic field

analog

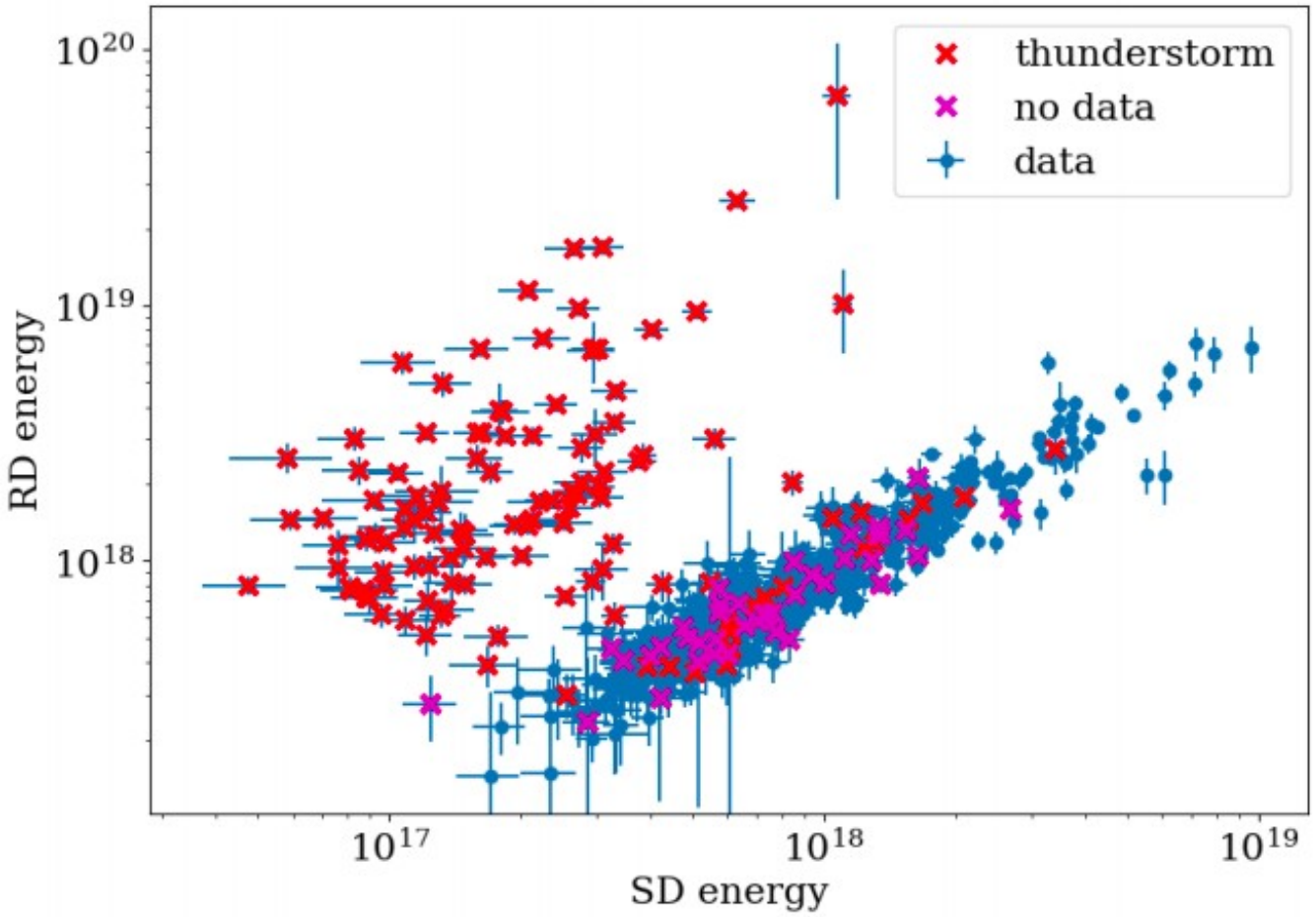
Deflection of charged shower particles in the atmospheric electric field



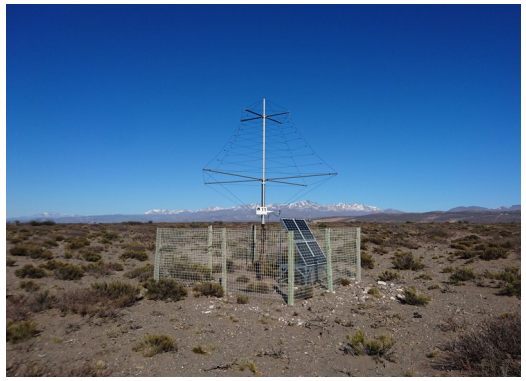
by H. Schoorlemmer



Why do we need E-field mills?

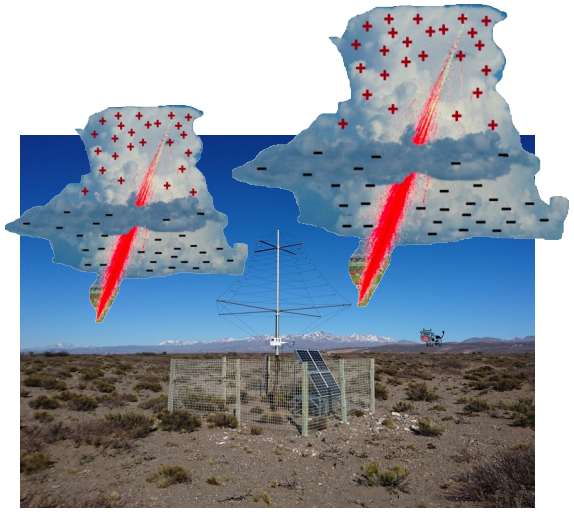


by M. Gottowik



Fair weather:
E ≈ 100 V/m

→ unproblematic ✓

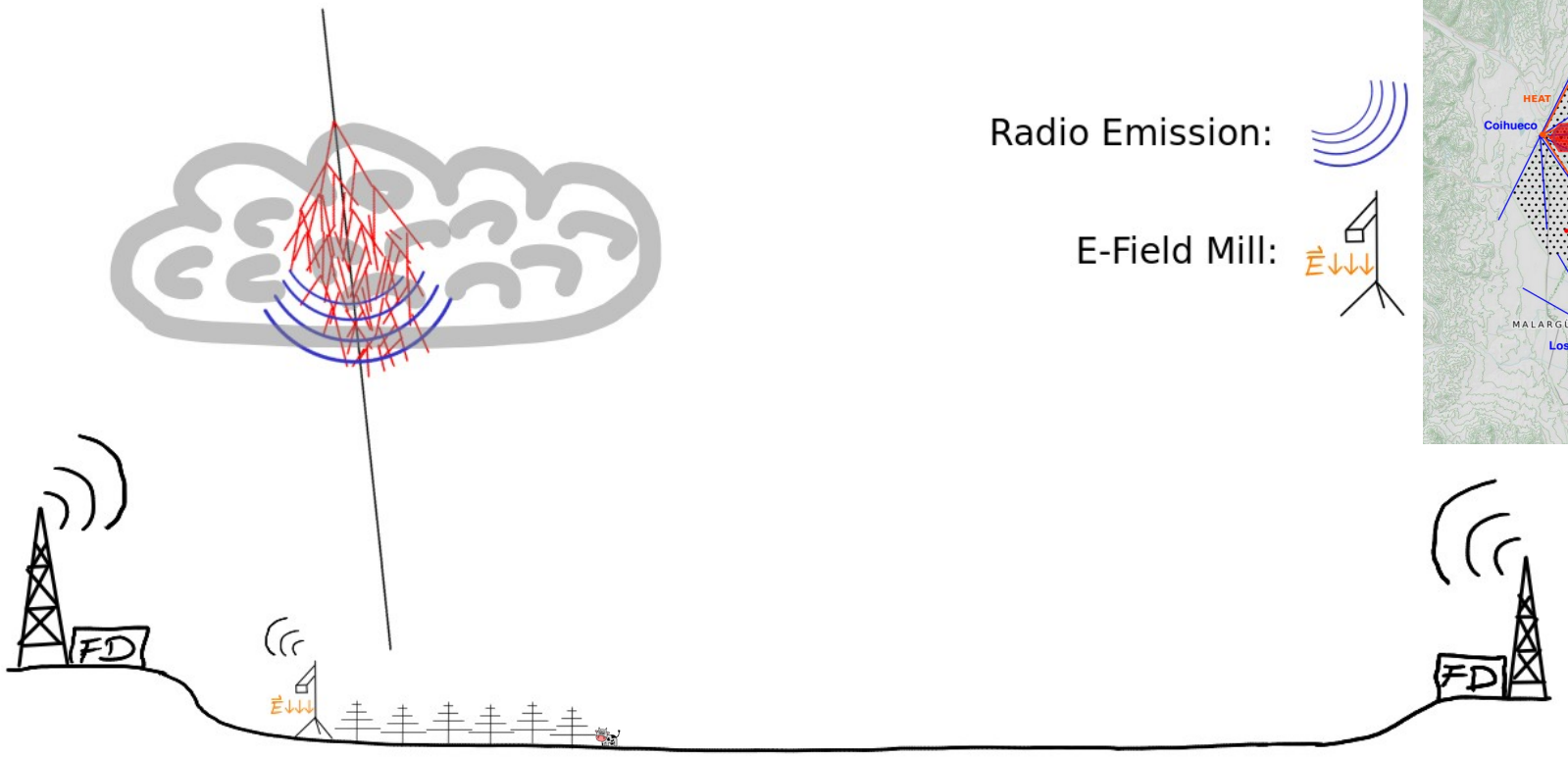


Thunderstorm conditions:
E ≈ 10.000 V/m

→ problematic !

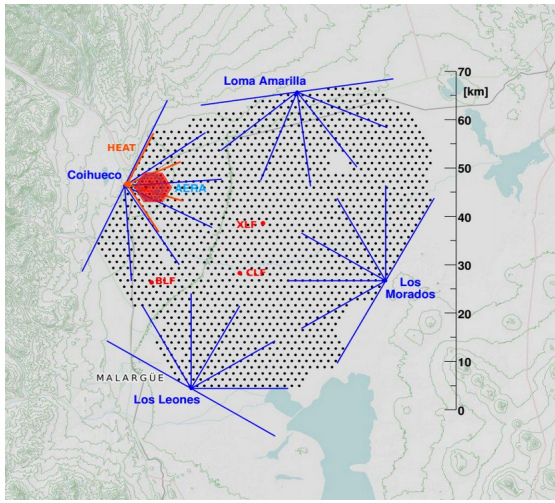
CR Air Showers & Thunderstorms

Vertical air showers: Thundercloud influencing the shower core is overhead
→ directly detect with an E-Field mill + simple algorithm (done at AERA)



Radio Emission:

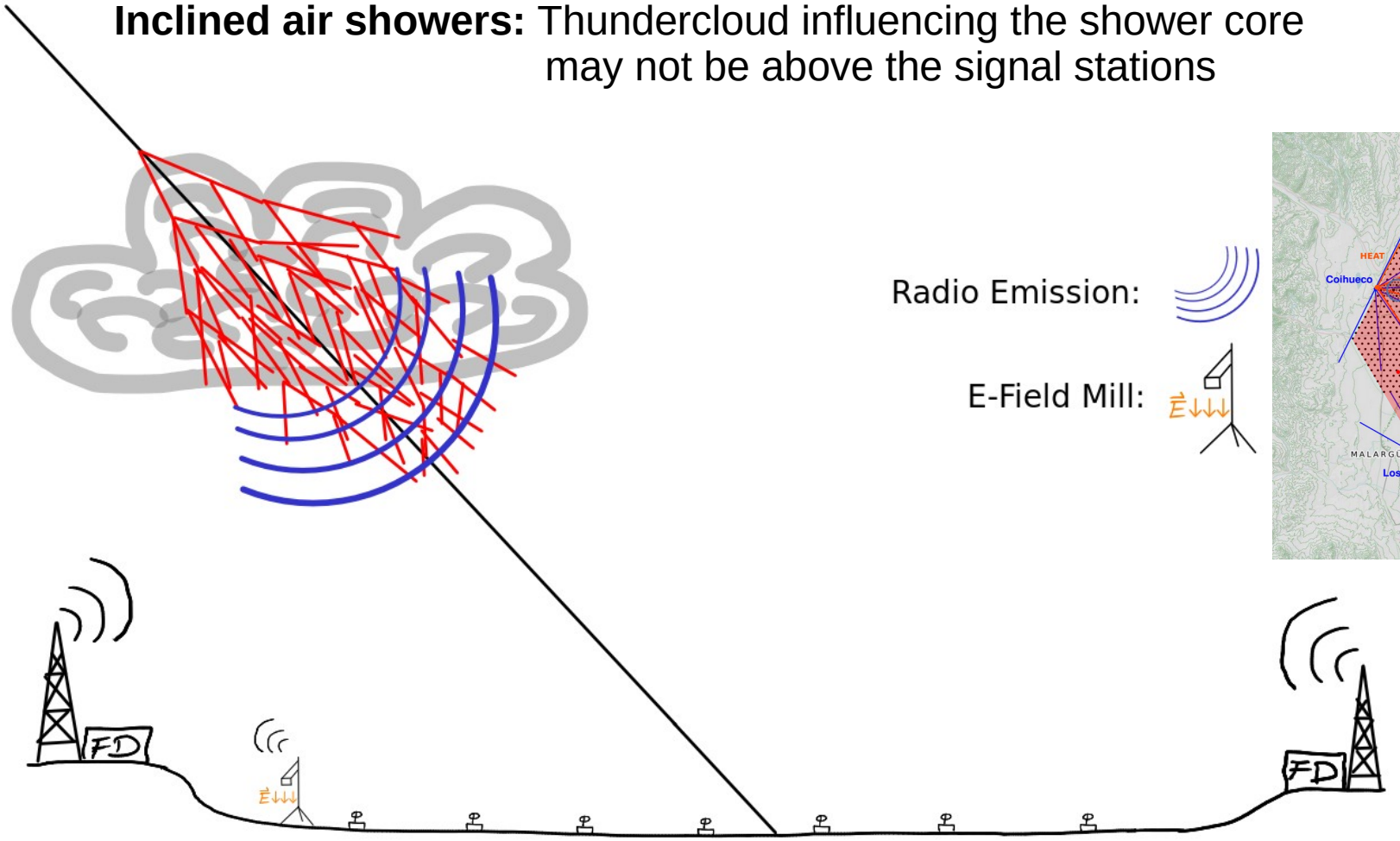
E-Field Mill:

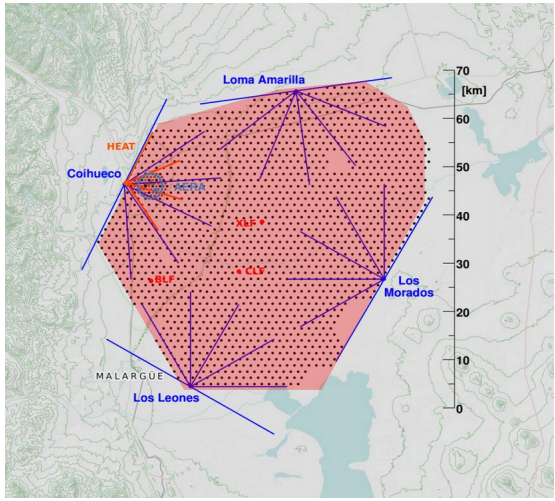


17 km²

CR Air Showers & Thunderstorms

Inclined air showers: Thundercloud influencing the shower core may not be above the signal stations

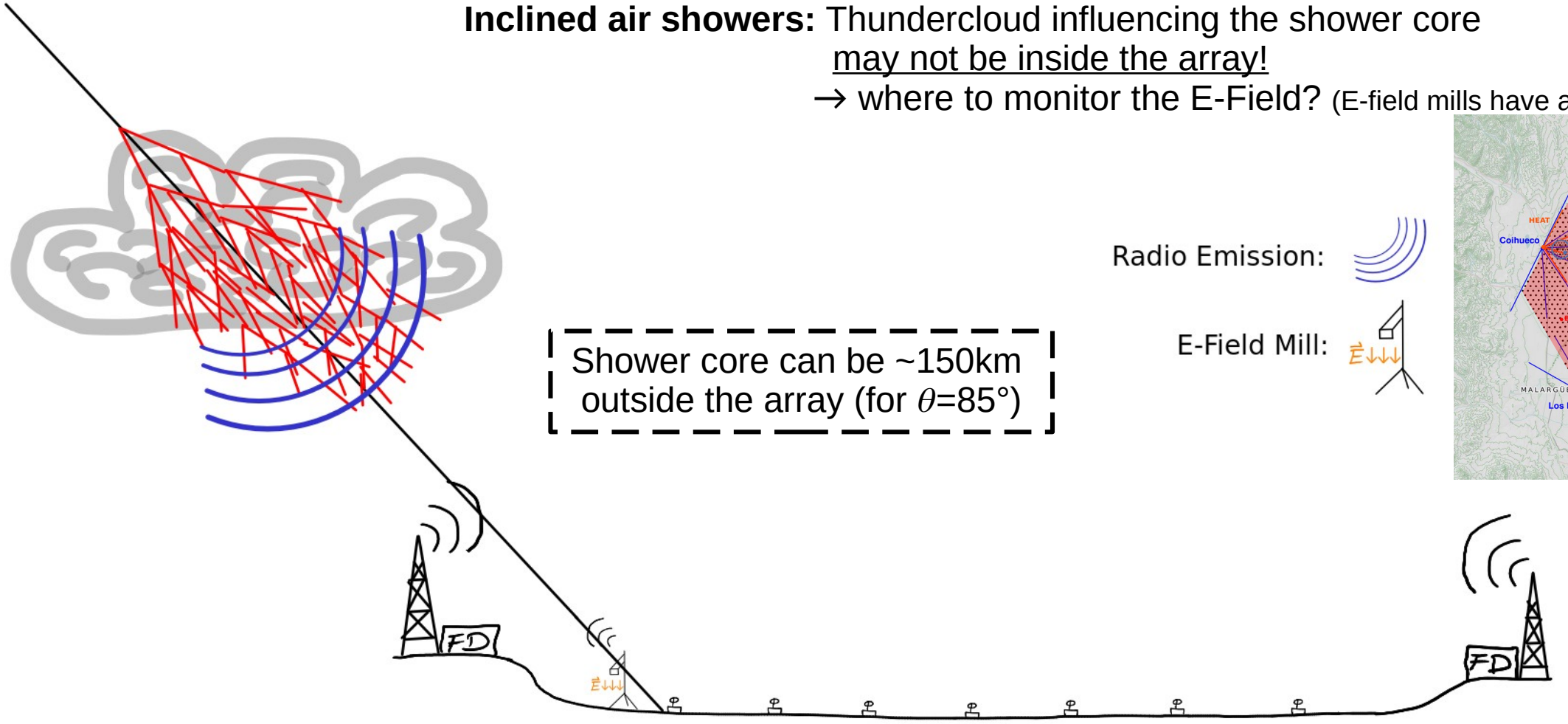




3000 km²

CR Air Showers & Thunderstorms

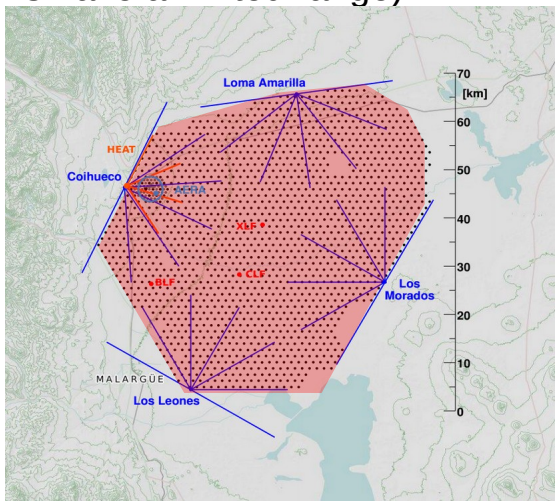
Inclined air showers: Thundercloud influencing the shower core
may not be inside the array!
→ where to monitor the E-Field? (E-field mills have a limited range)



Shower core can be ~150km outside the array (for θ=85°)

Radio Emission:

E-Field Mill:

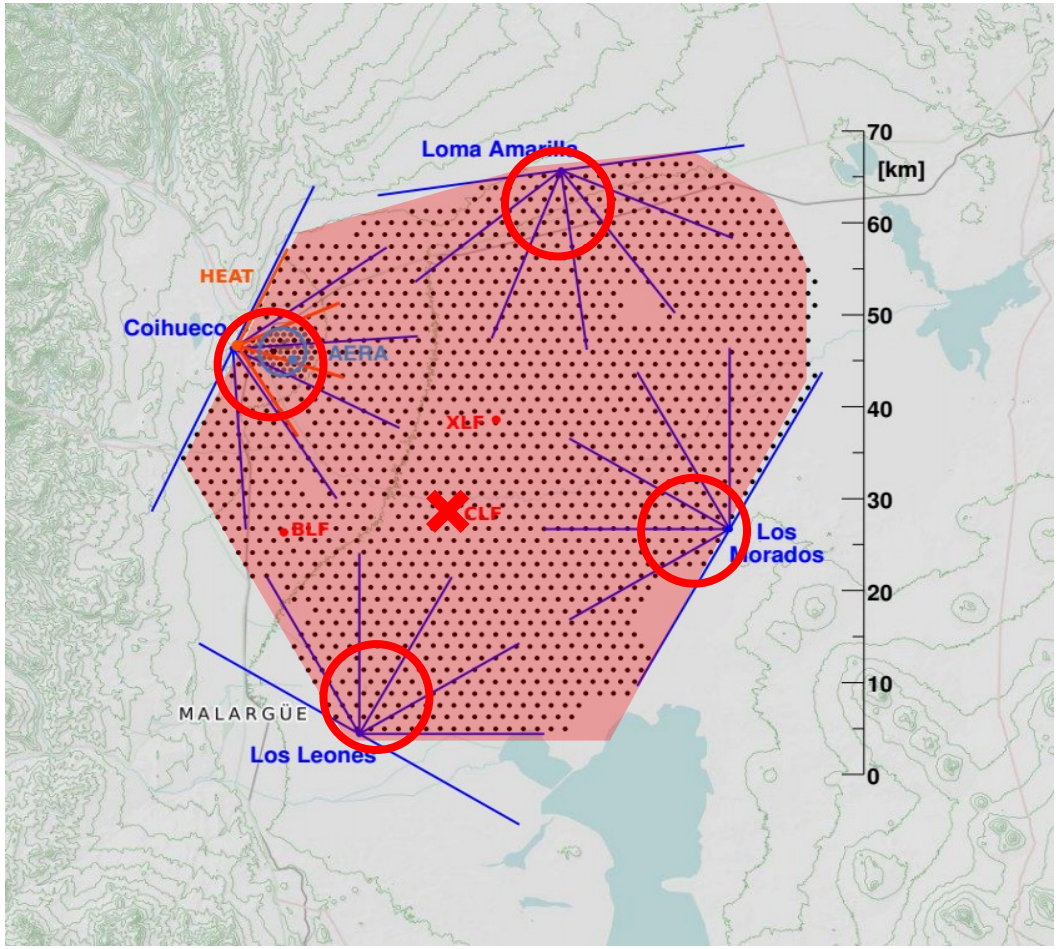


3000 km²

New E-field mills for AugerPrime RD

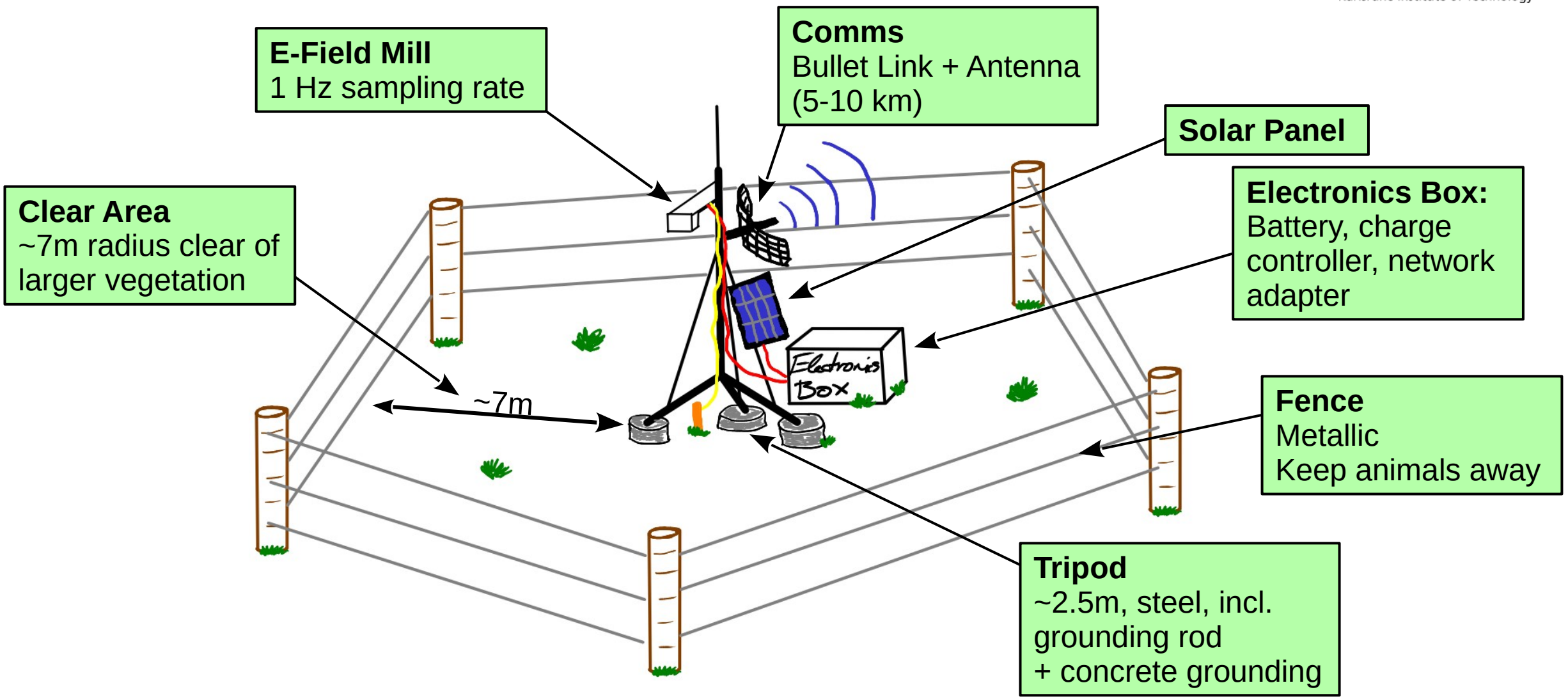
- "**Whole array**" thunderstorm monitoring → 3000 km²
- Plan of **5 new** E-field mills
  - **Autarkic** stand-alone stations (wireless connection)
    → 1 associated to each 4 FD site (a few km)
    → 1 central (CLF/XLF) with more powerful comms

  → Cover the array **as homogeneously as possible**
  → **Smart TS-flagging** of events needs more thoughts
  (Include Lightning Detection Systems by AERA
  and Colombian colleagues, etc.)



- "**Face Reality**": Permission by landowners required
  for the installation → searching for locations right now

E-Field Mill Station Design



Conlusion (so far): What have I done & learned?

- Monitoring of the **atmospheric electric field** for the radio detection of cosmic rays
- 5 new **E-Field mill** stations → Plan and design for **calibrated measurements**
- Determine best **station locations** + remote connection

I have learned that …

… in order to bring simple ideas („Let‘s monitor this.“) to life, one has to **face reality**

… one has to **prepare** for everything in advance when doing an installation in the Pampa

… such an endeavor concerns a lot of people (with a lot of opinions)

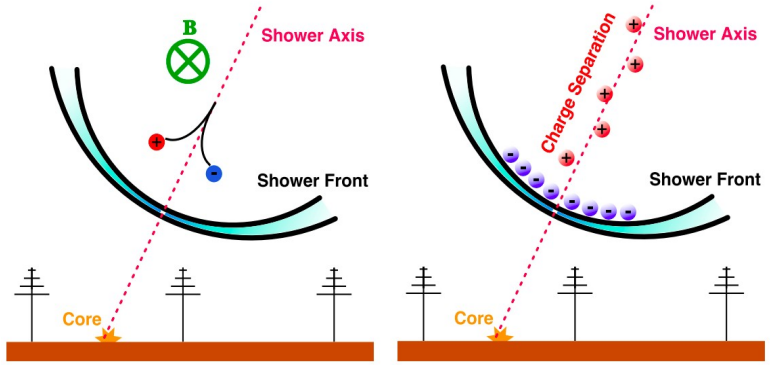
… the Auger collaboration + KIT has a lot of **very nice and helpful people!**

Thanks! Gracias! Danke!

Why do we need E-field mills?

Radio signal production:

by H. Schoorlemmer

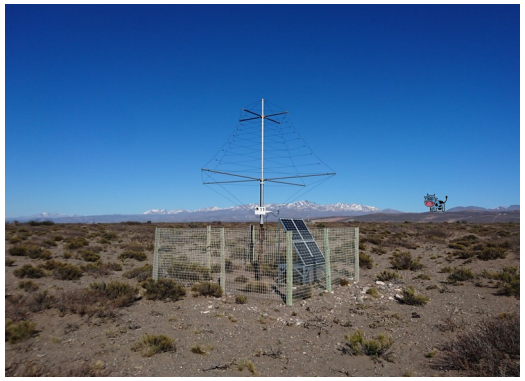


Geomagnetic excess

Charge

\+

Charged particles in the **atmospheric E-field** also produce radio signals →



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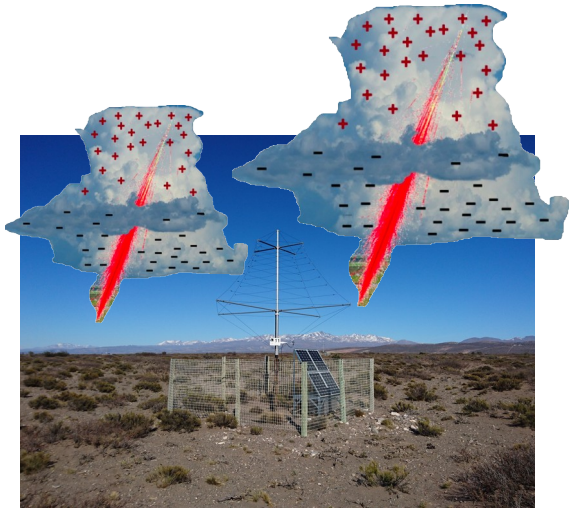

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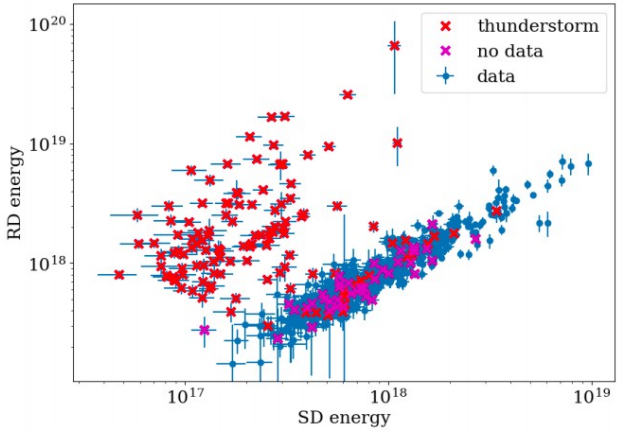
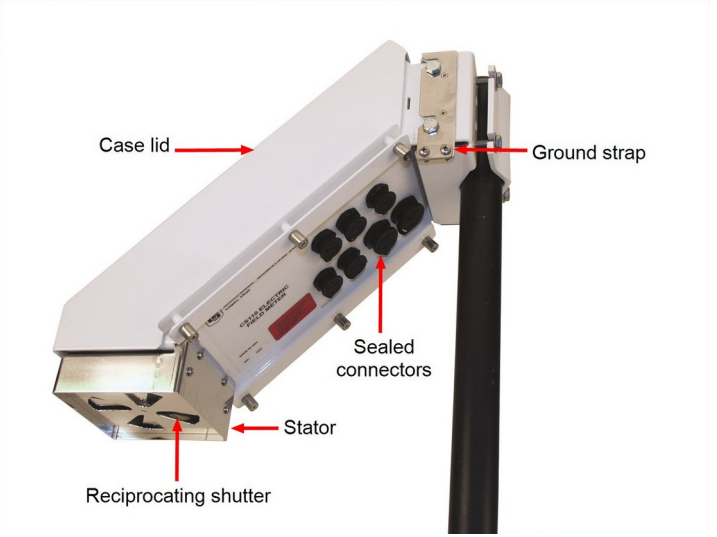


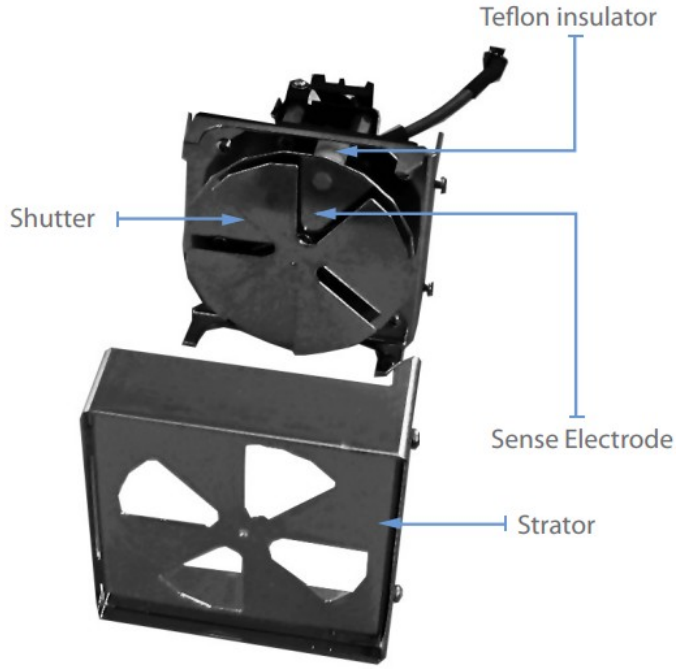
by M. Gottowik

The CS110 E-field mill

Campbell Scientific CS110

- Sense electrode periodically covered and exposed to the atmospheric E-Field by reciprocating shutter
- modulation of the induced electrical charge
  → amplified & converted into AC voltage
  → translated into electric field
  $E = M_{\text{Field Mill}} \cdot V$ ($M_{\text{Field Mill}}$ from factory calibration)
- Sample rate up to 5 Hz
- Internal Datalogger

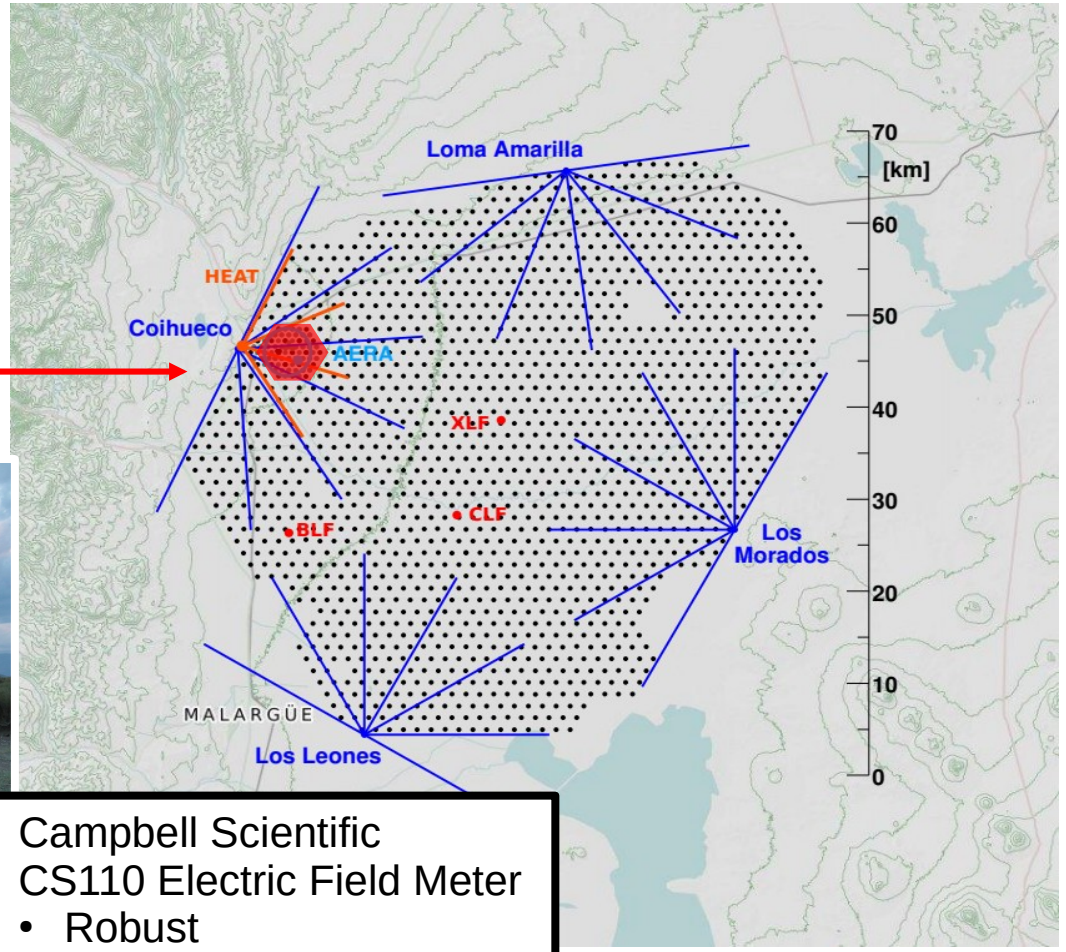


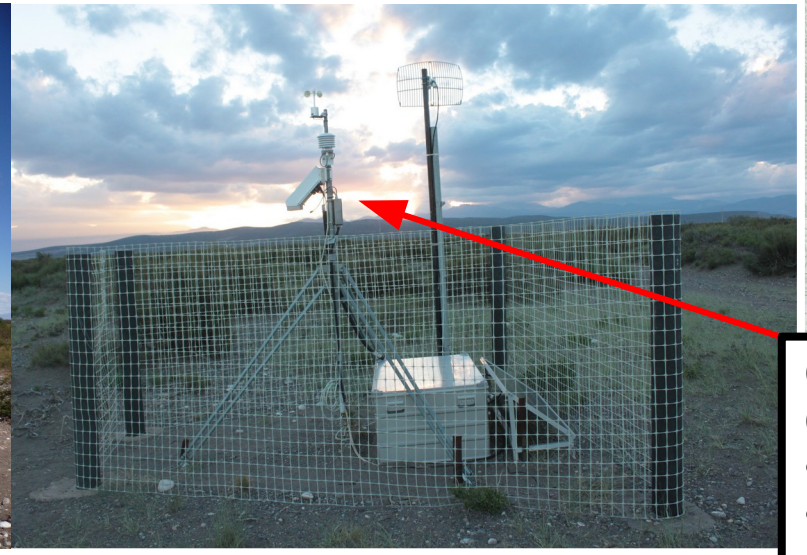


E-field measurements at AERA

- At AERA 2 E-field mills are installed
- Uncalibrated data → **Qualitative TS flagging**
- Covering 17 km²

2 E-field mills here

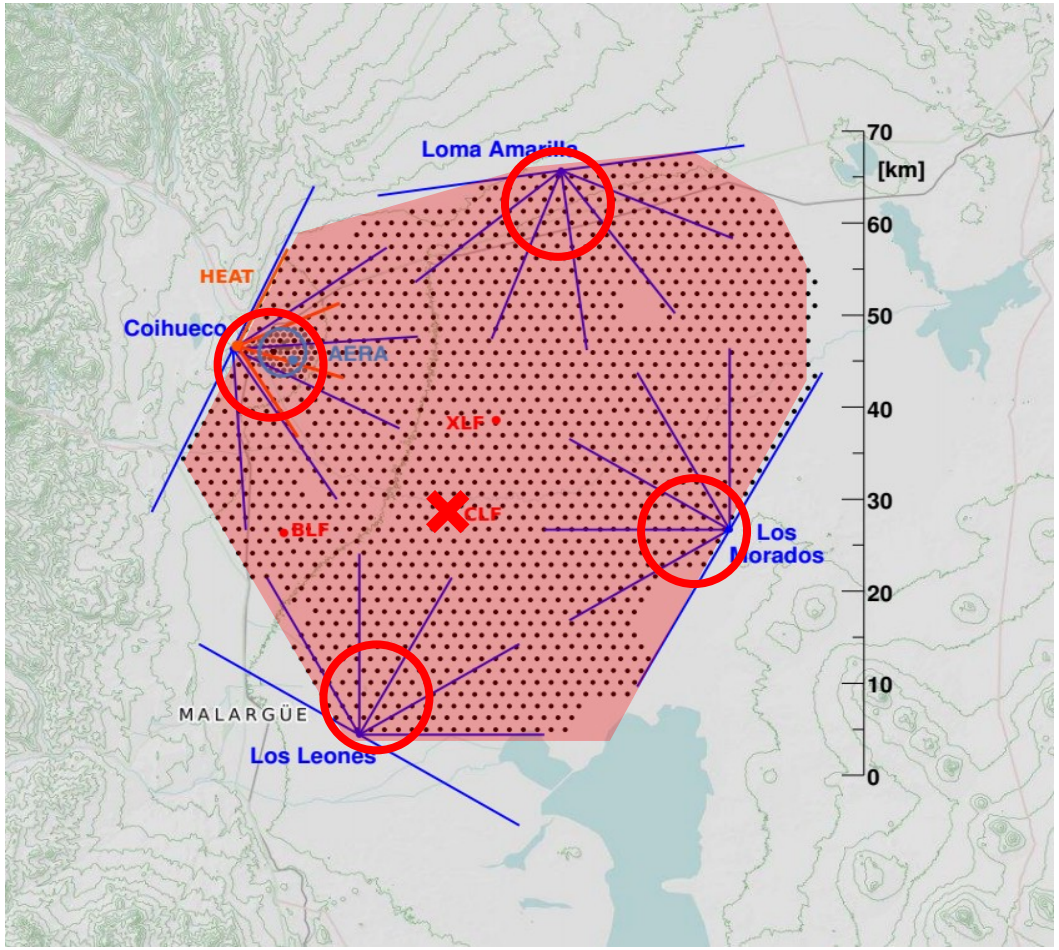




Campbell Scientific
CS110 Electric Field Meter
- Robust
- Reliable
- Technical support

New E-field mills for AugerPrime RD

- **Large scale** TS monitoring → ~3000 km²
- Plan of **5 new** E-field mills
  - → Cover the array as best as possible
  - → Near the 4 FD sites (a few km) + 1 central (BLS)
- 2/5 mills bought and tested at KIT
  - → 3 more mills on the way
- **Plan:**
  - Now: Designing/Configuring the setups
    + answering open questions
  - November meeting: Presentation at the TB
  - Early/Mid 2022: Deployment (on time with RD)



Proposed Setup: Calibrated measurement

- **Absolute calibrated** data could be useful for analysis of TS conditions + Cosmo-Geophysics

- Easiest way: „rebuild“ a **calibrated setup** from the manufacturer

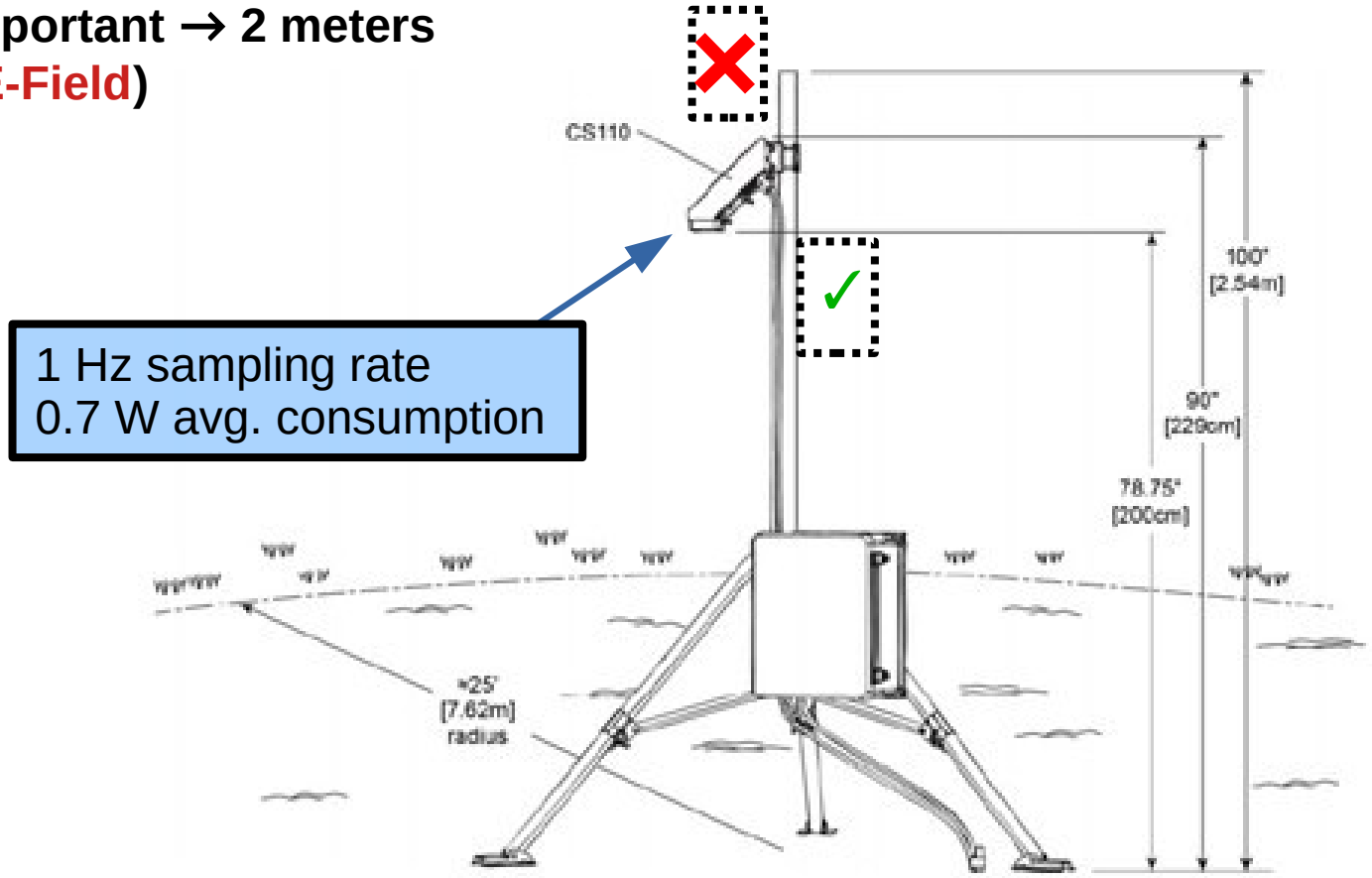
  → Data automatically calibrated

- **Effort:** Create proper site conditions and fulfill some requirements

Tripod Design

- **Mounting height of the E-Field mill is very important → 2 meters (larger height → larger enhancement of the E-Field)**
- Good grounding for the measurement is easy, but could be hard for proper lightning protection
- **Additional weather sensors?**
  → Install on opposite side and below the E-field mill
  → Antenna for wireless communications
- **Power:** Solar panel / battery / charge controller

  → autarkic stations
- Anchor to the ground with concrete foundations



**Comments by Campbell Scientific expert*

Influences: Vegetation + Fence

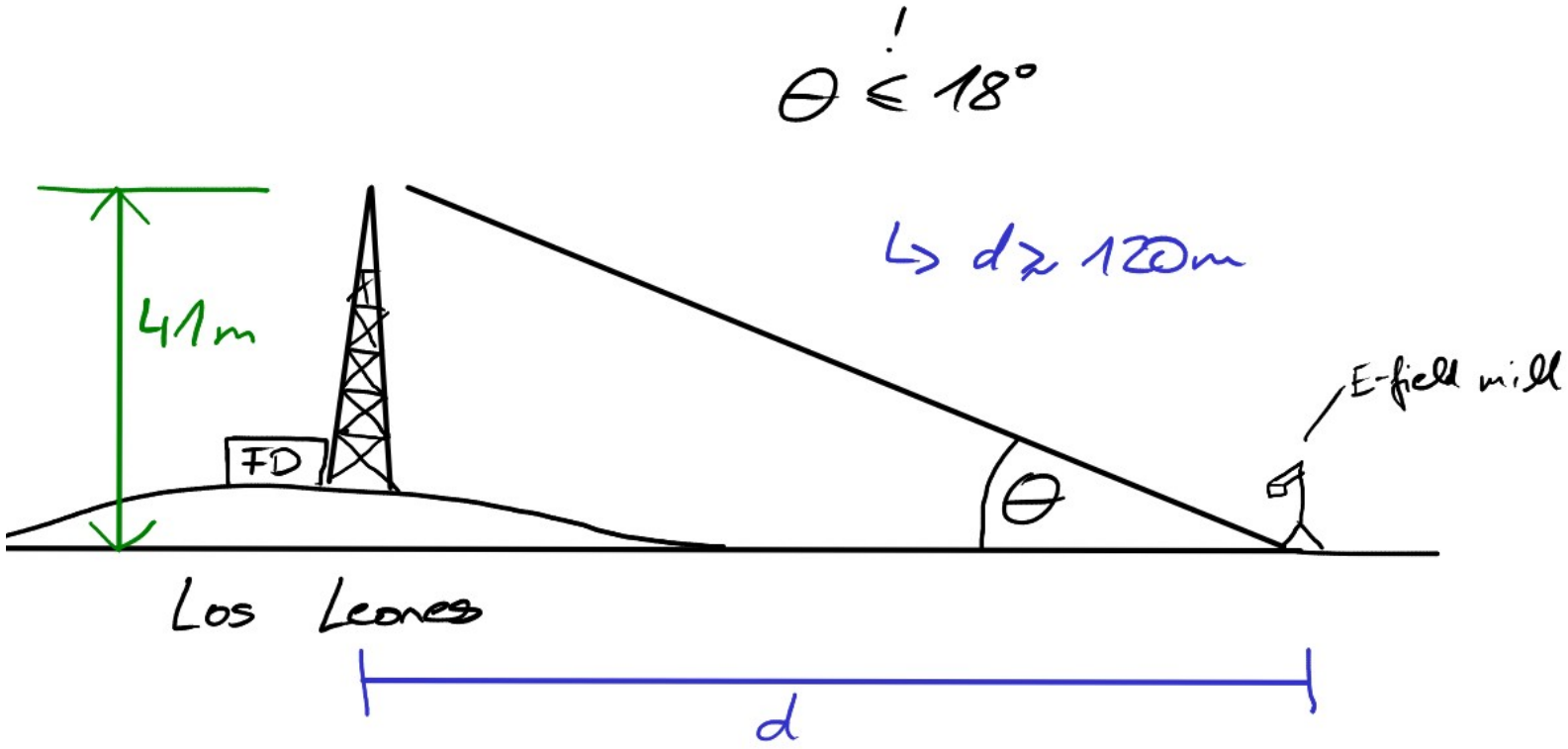
- **Vegetation growth** can reduce the effective instrument height
- Removing larger bushes should be enough at our sites

- Fence should be further away and at smaller height
  → at best no plastic, but metal (Corona discharge)
- Require a free area of
  15m x 15m

**Comments by Campbell Scientific expert*

Influences: Tall objects

- **Tall nearby objects/buildings can induce corona currents and E-field distortions**
- The comms tower (FD sites) *“cast a shadow on the electric field”*
- Campbell Scientific follows NASA’s recommendations:
  → No objects higher than 18° from the horizon
  → 120m distance for LL (41m Tower)



**Comments by Campbell Scientific expert*

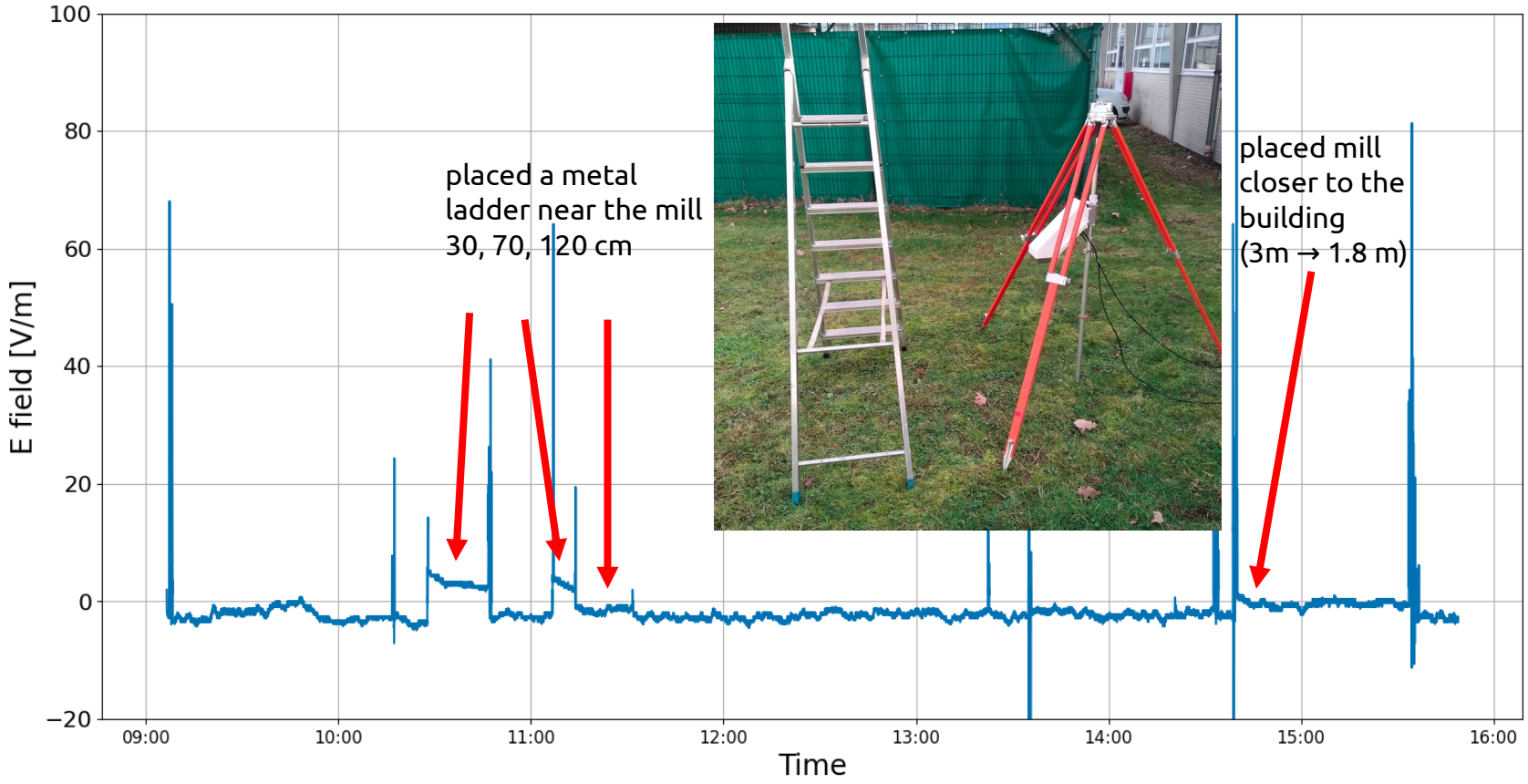
Technical Stuff & Logistics

- Autarkic power supply via solar panel & battery (as used for AERA stations)
- Readout: Serial-to-Fiber connector → FD network → CDAS ?
- Possibly need to bury fiber cables to be lightning-proof
- Regular readout and synchronisation should be prone to power outages

- CLF/XLF station will need extra considerations (unstable internet connection)

Test measurements @ KIT

- Test with a simple setup
- Fair weather conditions
- Tested some variations of the site
  → nearby metal object
  → distance to building
- Distortions look small (relative to TS E-Fields)
- <u>But</u>: Influences can scale with the E-Field



Next Steps

- Clarify **tasks in the field** (concrete foundation, laying cables, fence, etc.)
- Determine our **proposed installation plan** (setup, locations, etc.)

  + alternatives to debate, where reasonable
- Clarify **required resources** (remote connection, bandwidth, DAQ PC)

→ prepare to make best use of time at the **TB** (10-15 min)

- Test the **3 other E-Field** mills once they arrive
- Preparing everything at KIT → ready to ship