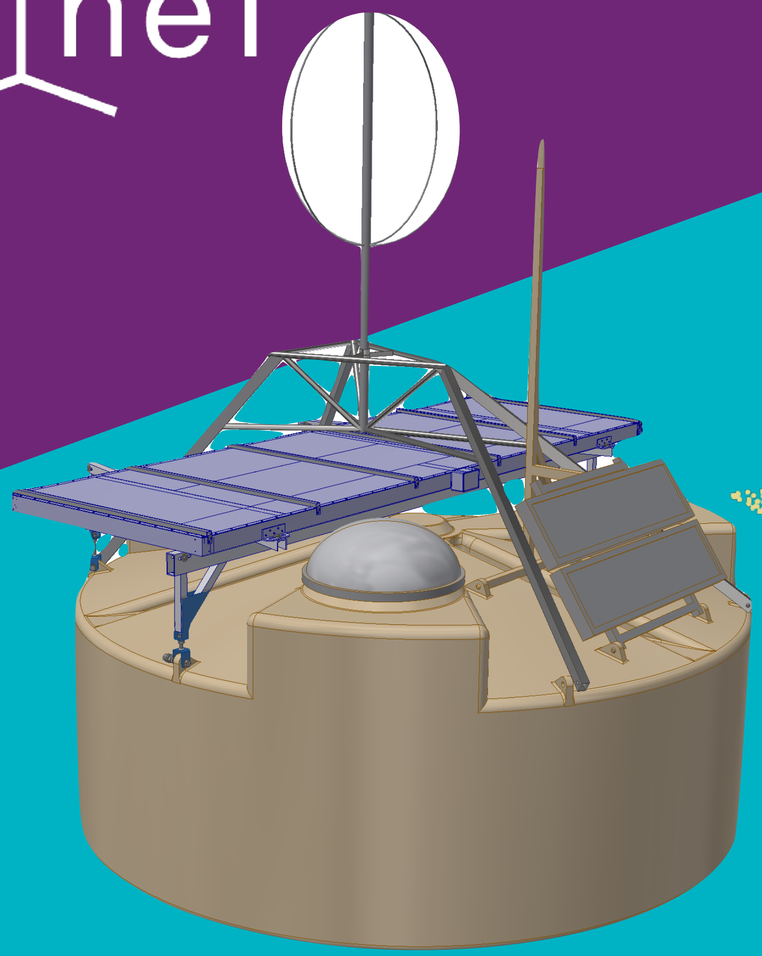
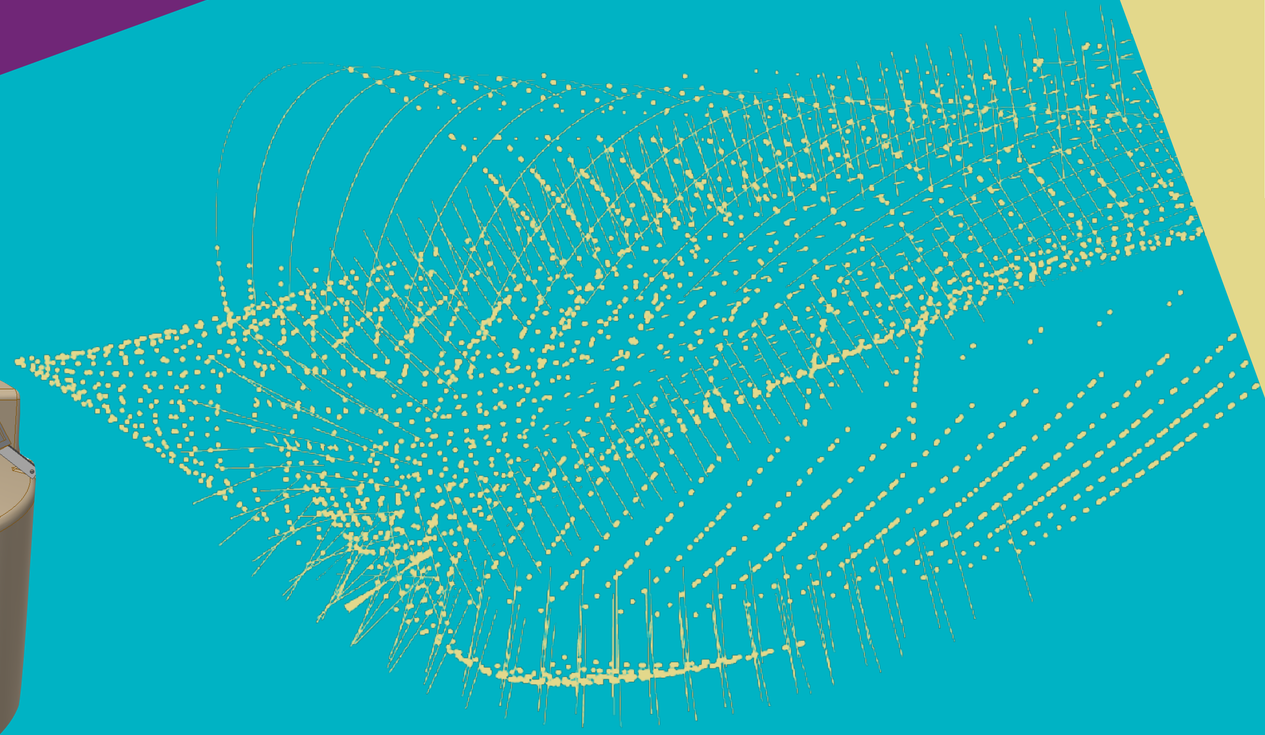
Nikhef





PIERRE AUGER OBSERVATORY

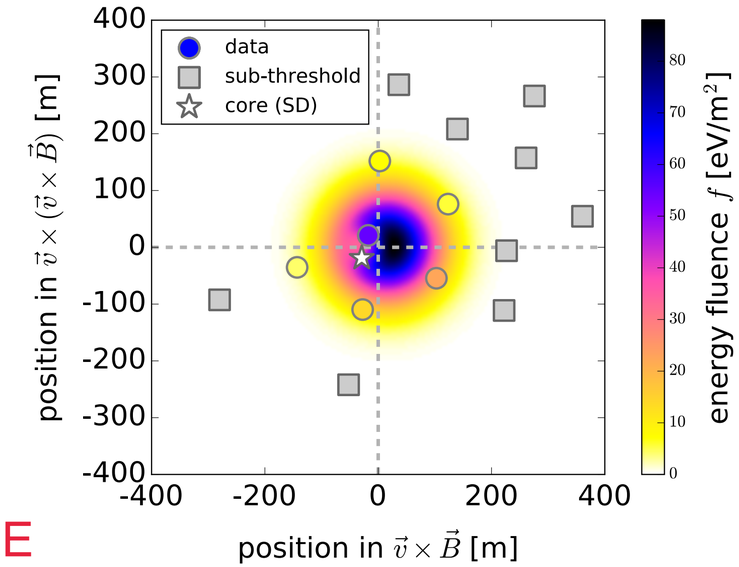
PIERRE AUGER OBSERVATORY RADIO UPGRADE

Jörg R. Hörandel
taskleader radio at Auger
Radboud Universiteit Nijmegen
Nikhef, Vrije Universiteit Brussel

jamboree 2018

MEASURING AIR SHOWERS WITH MULTIPLE TECHNIQUES

PIERRE AUGER OBSERVATORY



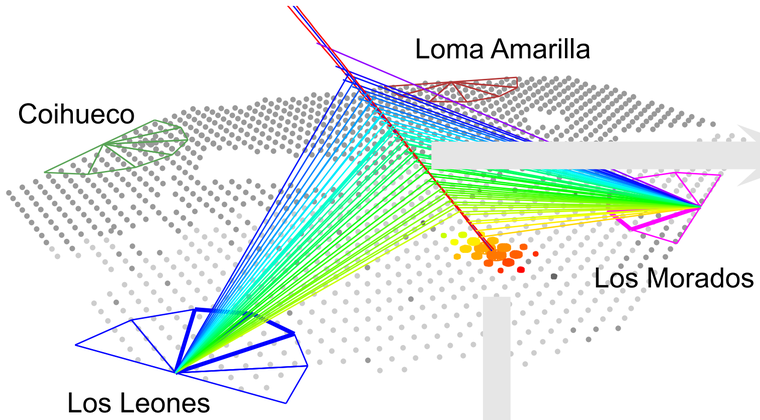
EXPOSURE

Auger 9.0*10⁴ km² sr yr

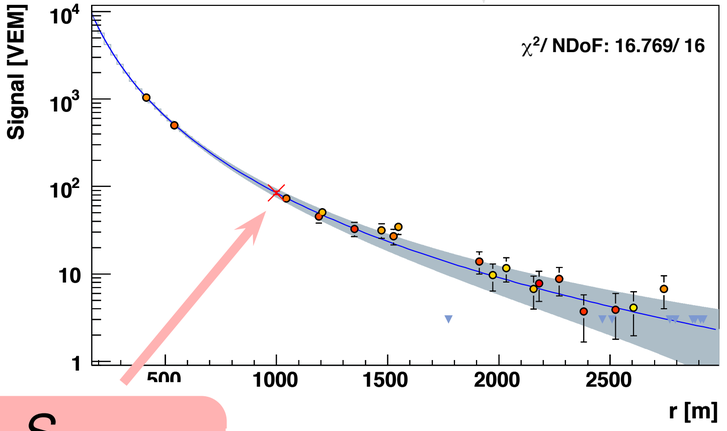
TA 0.8*10⁴ km² sr yr

RADIO DETECTOR

X_{max}, E_{cal}

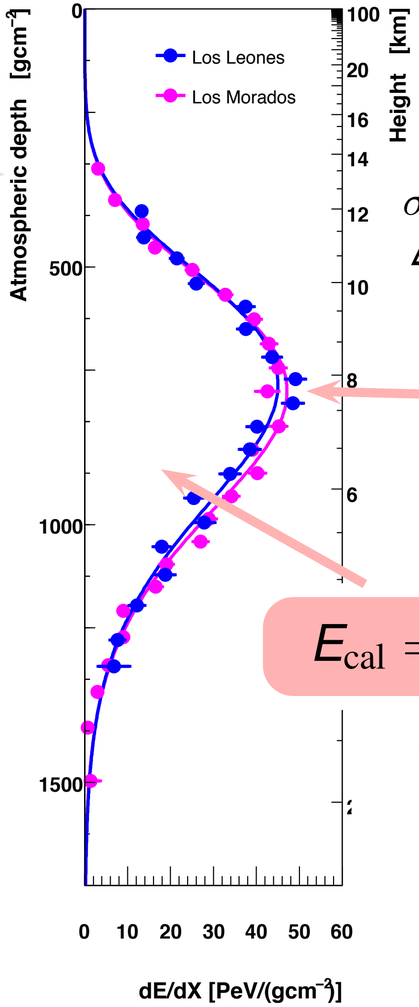


SURFACE DETECTOR



S_{1000}

$E_{surface} = f(S_{1000}, \theta)$



$\sigma_{X_{max}} \leq 20\,\mathrm{g/cm^2}$

$\Delta_{sys} \leq 10\,\mathrm{g/cm^2}$

X_{max}

$E_{cal} = \int \frac{dE}{dX}\, dX$

$\sigma_E/E \sim 8\,\%$

$\Delta_{sys} \approx 15\,\%$

FLUORESCENCE DETECTOR

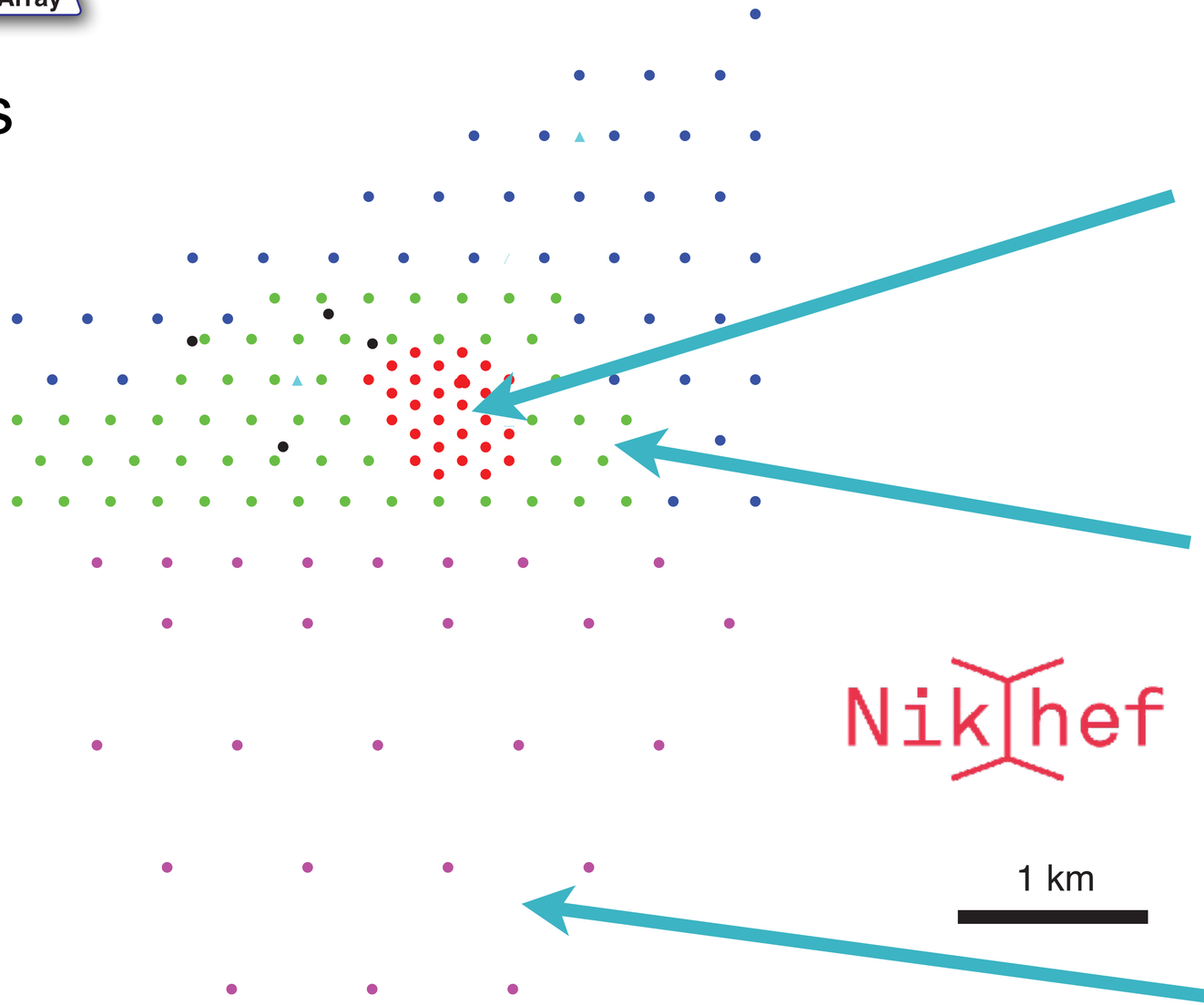
PIERRE AUGER OBSERVATORY

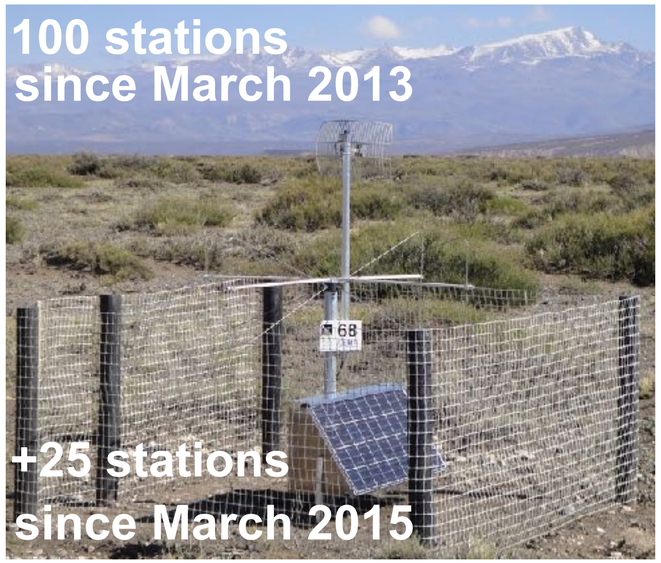
AERA
Auger Engineering Radio Array

~150 antennas

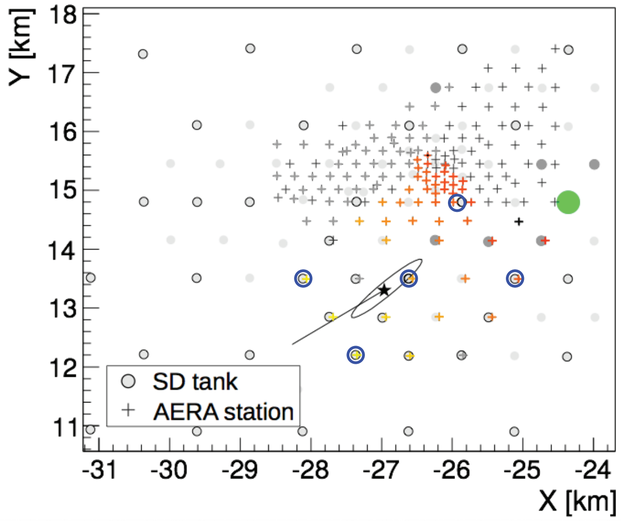
~17 km^2

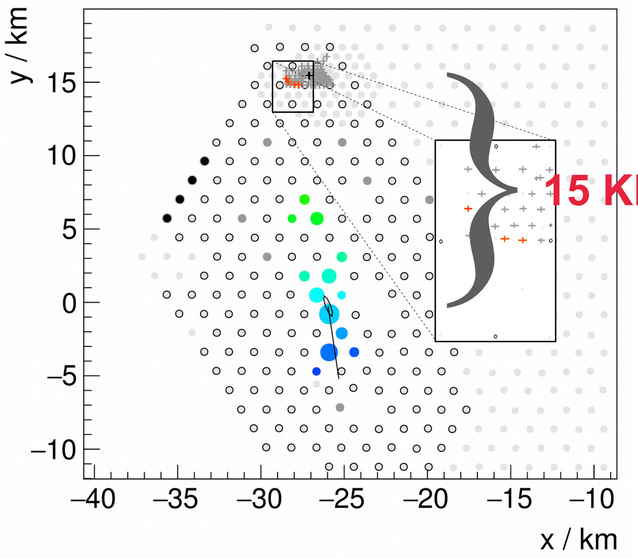
30-80 MHz





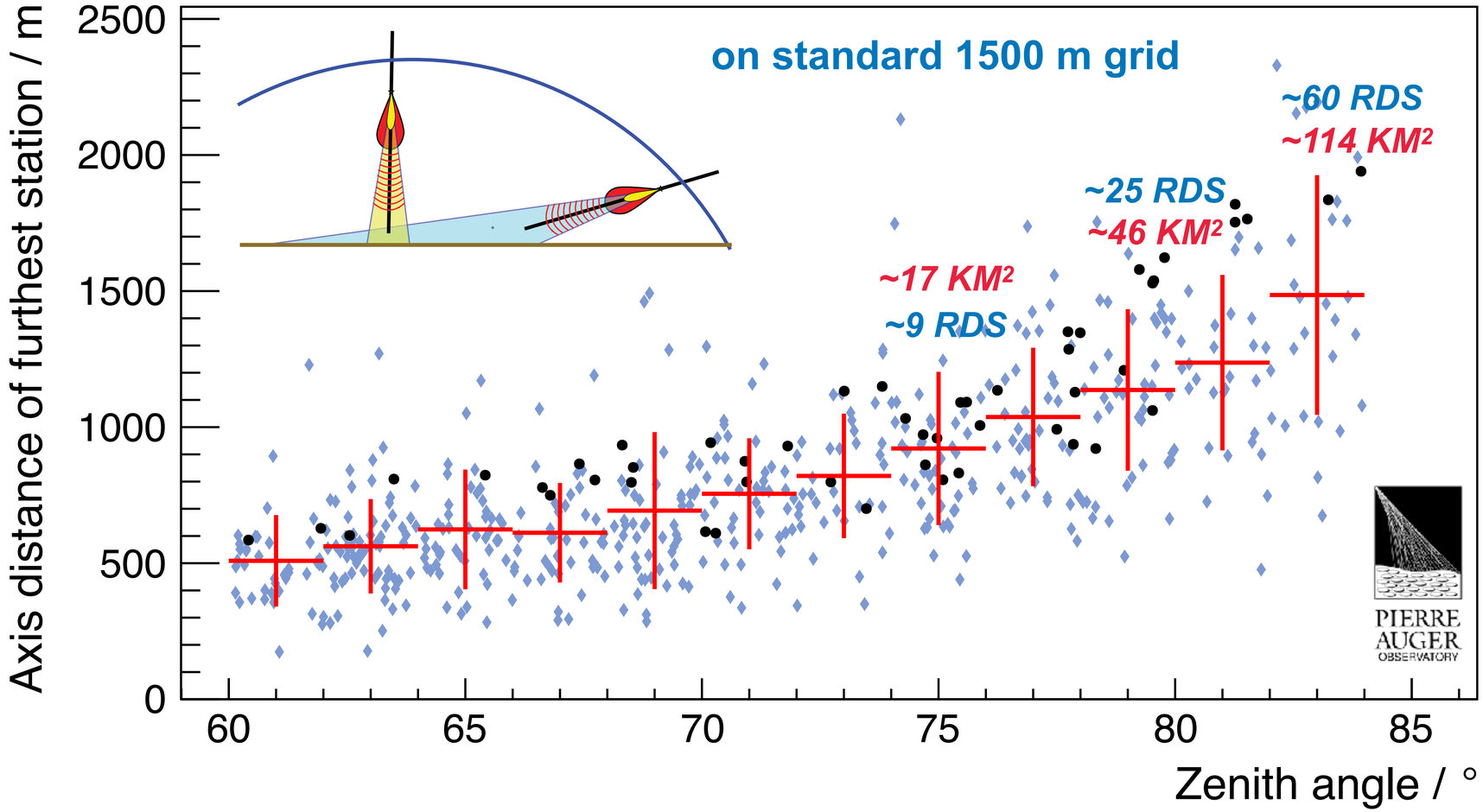
HORIZONTAL AIR SHOWERS MEASURED WITH AERA





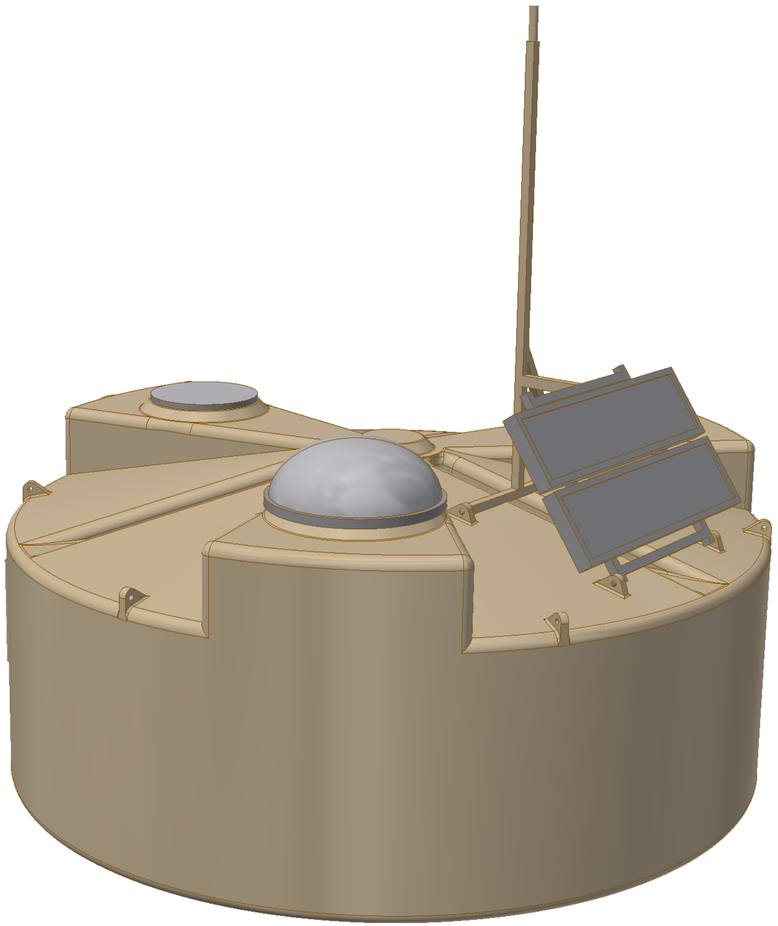
A. Aab et al., JCAP 10 (2018) 026

large footprints -> measure showers on 1500 m grid



UPGRADE OF THE PIERRE AUGER OBSERVATORY

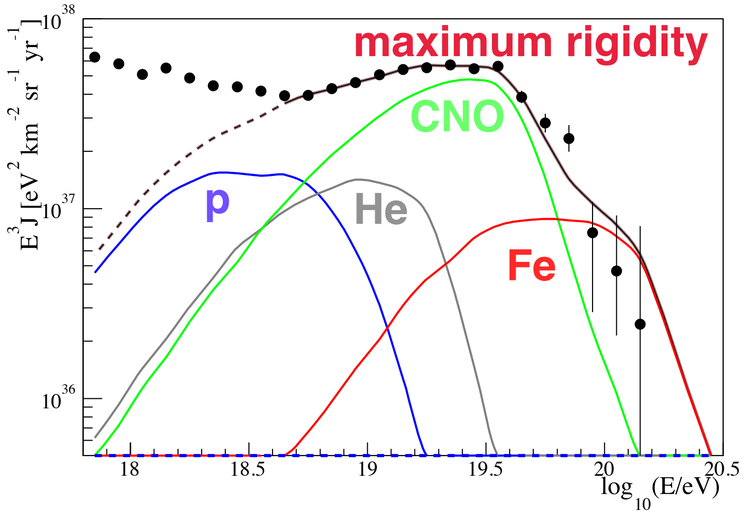
-electronics
-scintillator

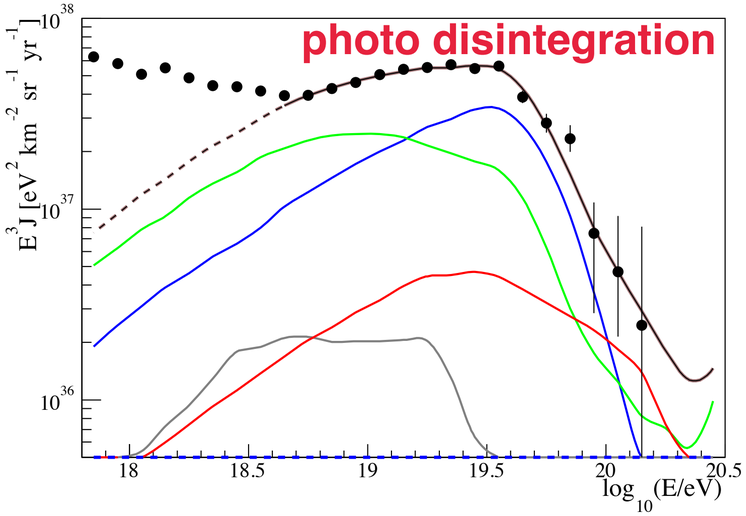


Nikhef

Key science questions

- What are the sources and acceleration mechanisms of ultra-high-energy cosmic rays (UHECRs)?
- Do we understand particle acceleration and physics at energies well beyond the LHC (Large Hadron Collider) scale?
- What is the fraction of protons, photons, and neutrinos in cosmic rays at the highest energies?





UPGRADE OF THE PIERRE AUGER OBSERVATORY

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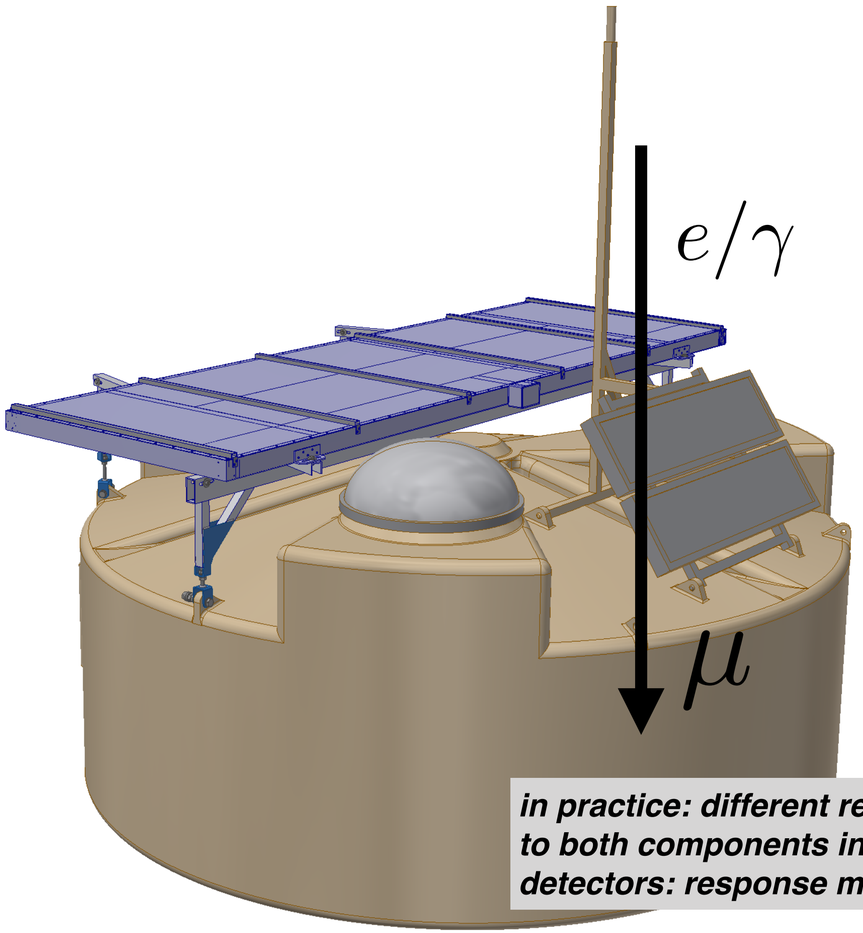

in practice: different response to both components in both detectors: response matrix

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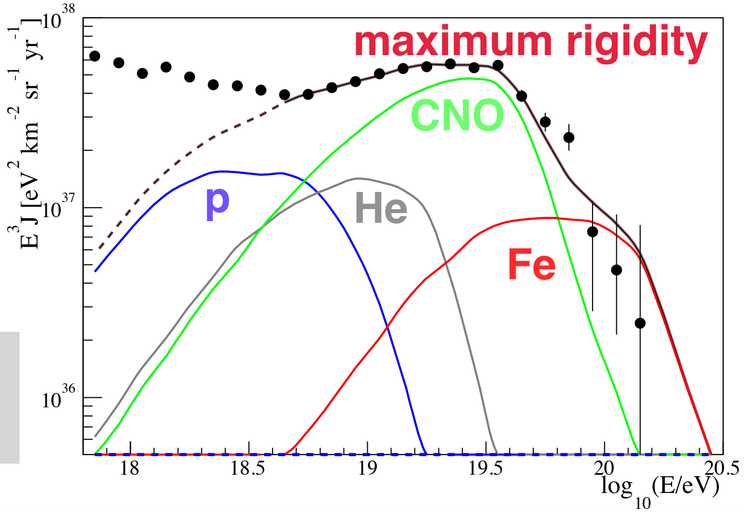

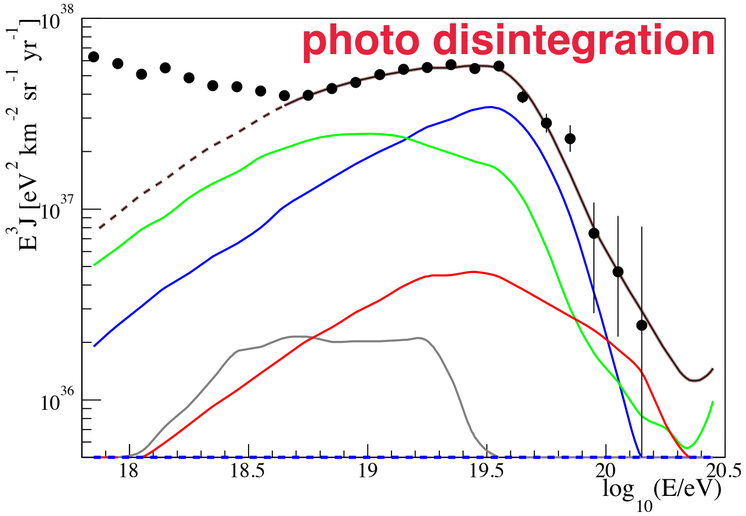

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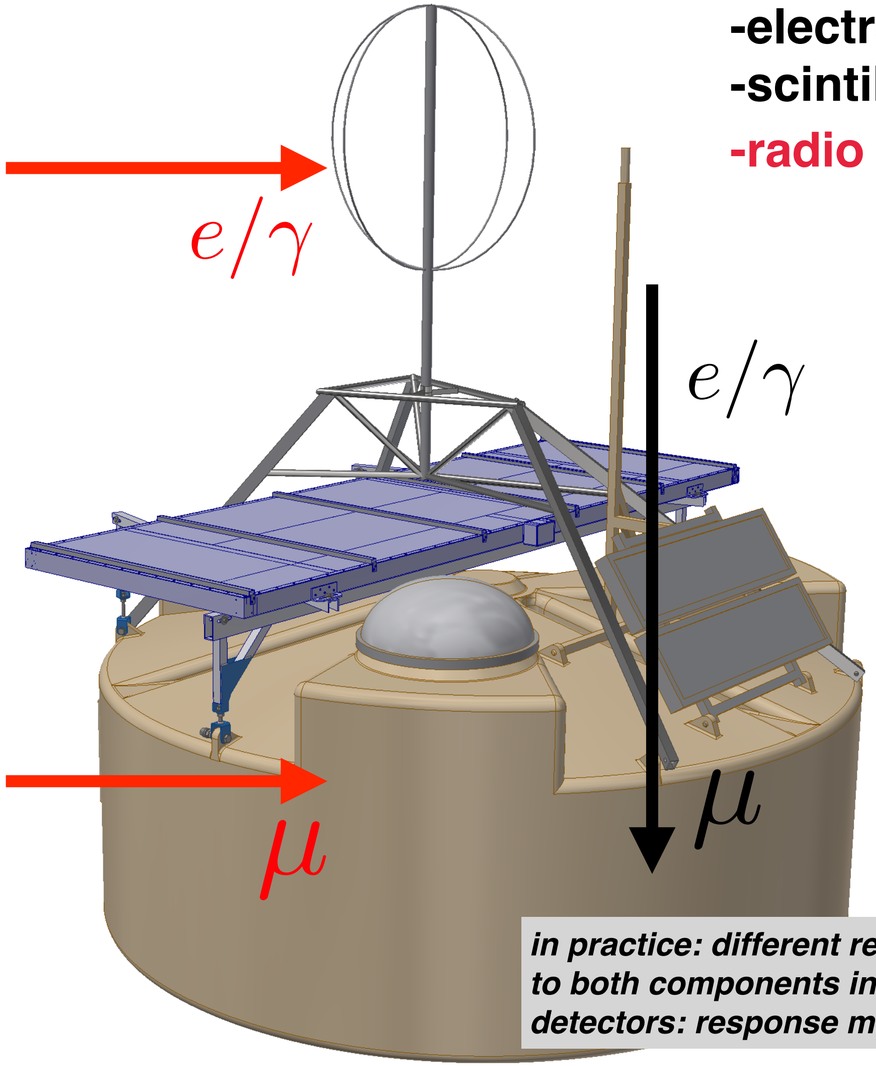

-electronics
-scintillator
-radio detector

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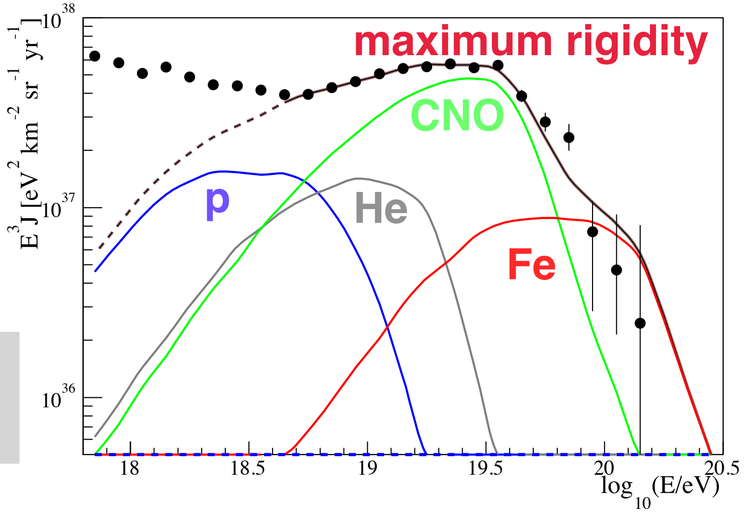

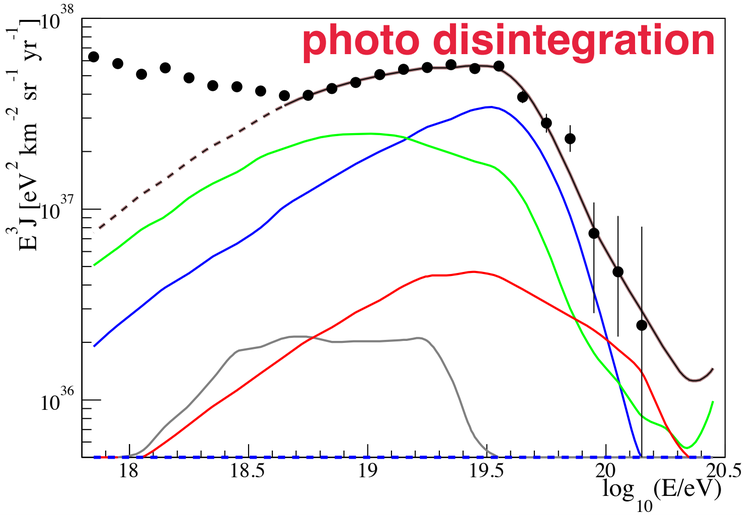

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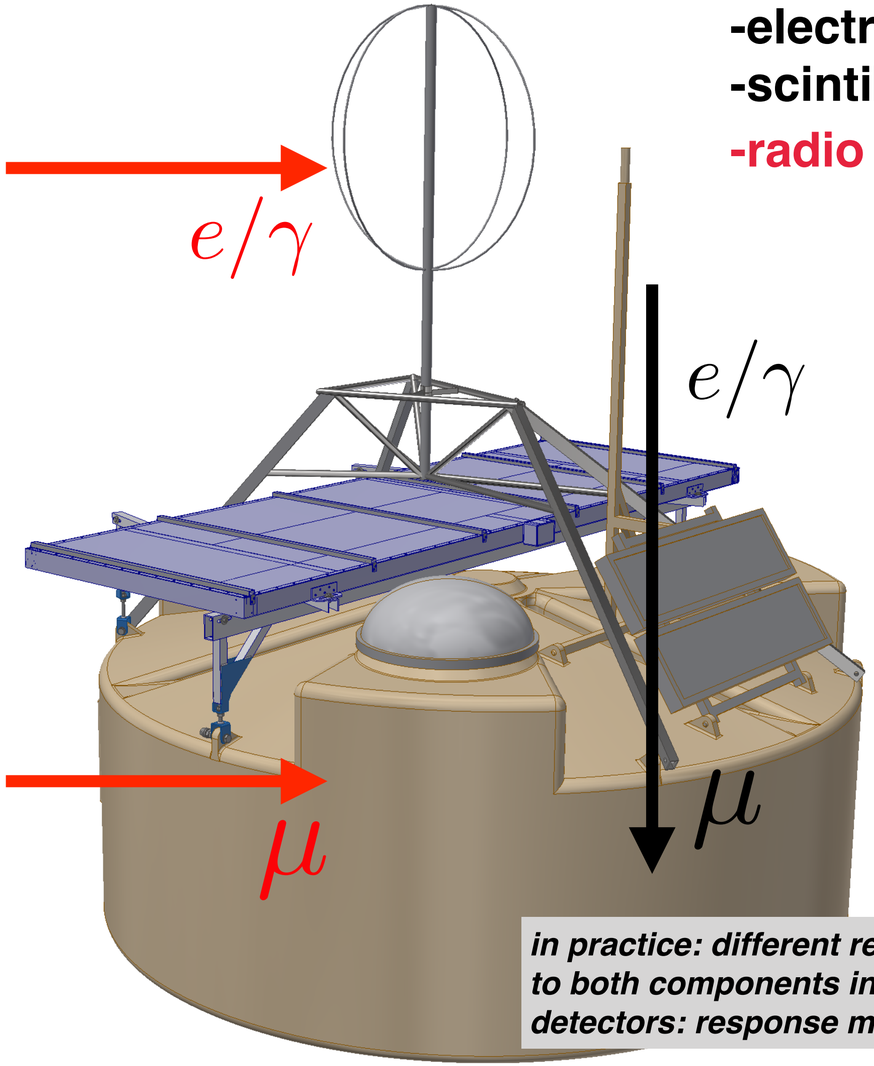


-electronics
-scintillator
-radio detector

in practice: different response to both components in both detectors: response matrix

European Research Council

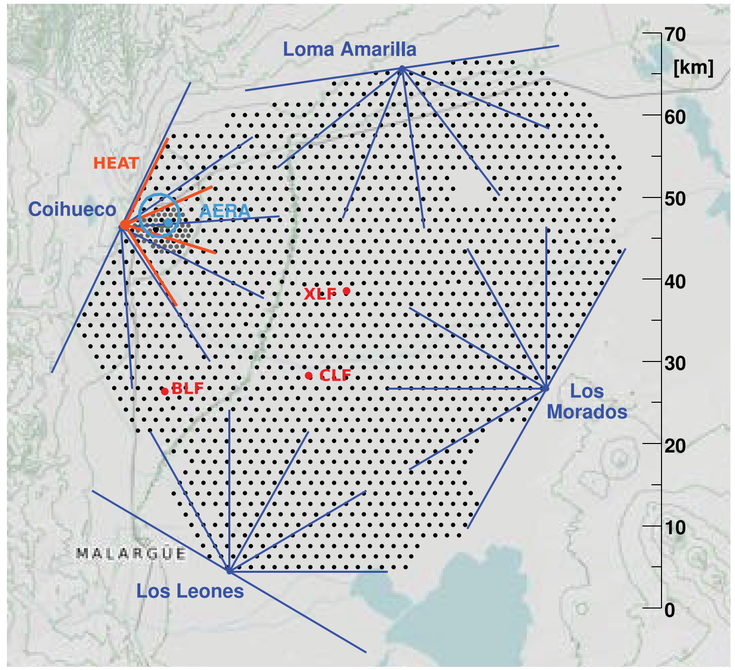
3.5 M€ ERC Advanced Grant Hörandel

Netherlands Organisation for Scientific Research

2.5 M€ NWO-Groot

1661 detector stations, covering 3000 km^2

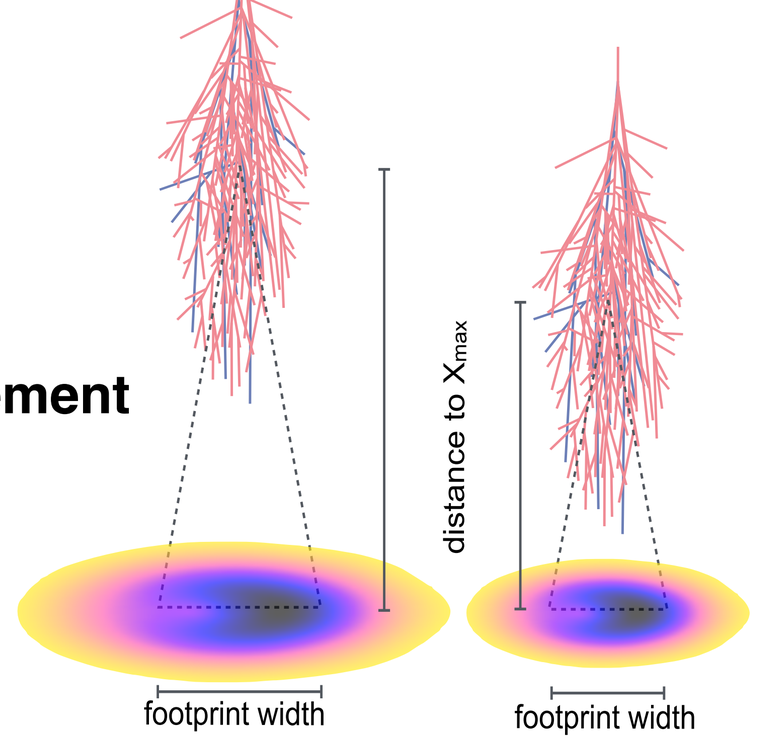
project implementation in progress



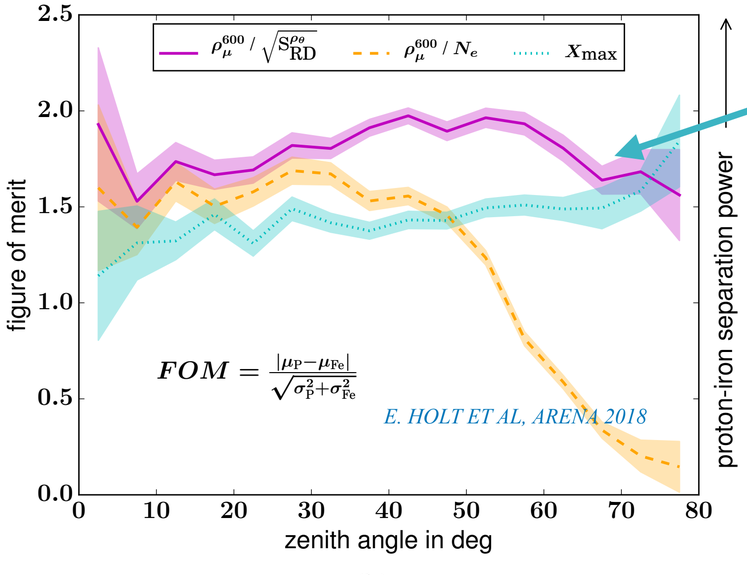
MEASUREMENT OF PARTICLE TYPE

***attention*:**
type of particle determined

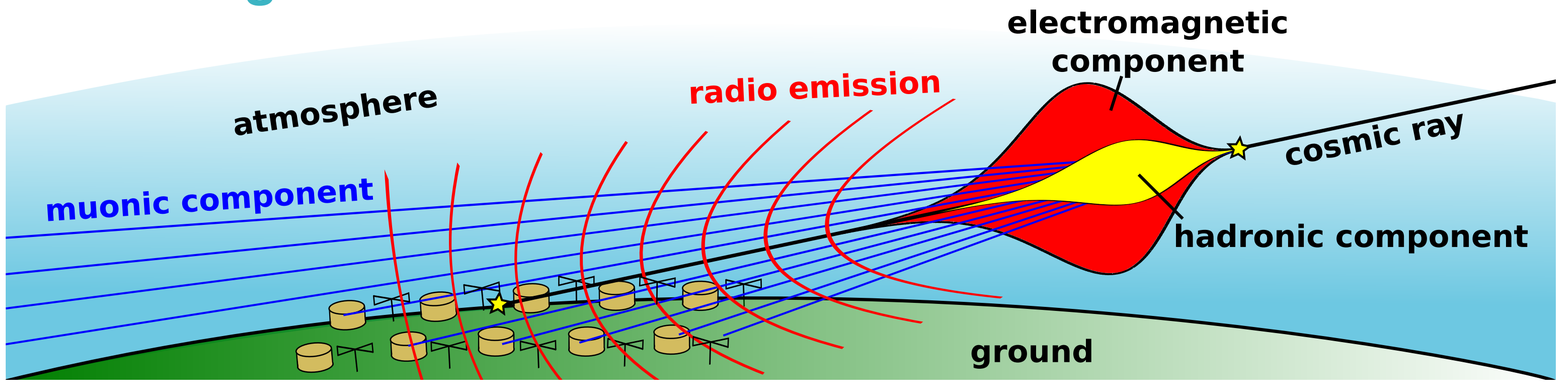
for vertical showers:
size of footprint
geometrical measurement



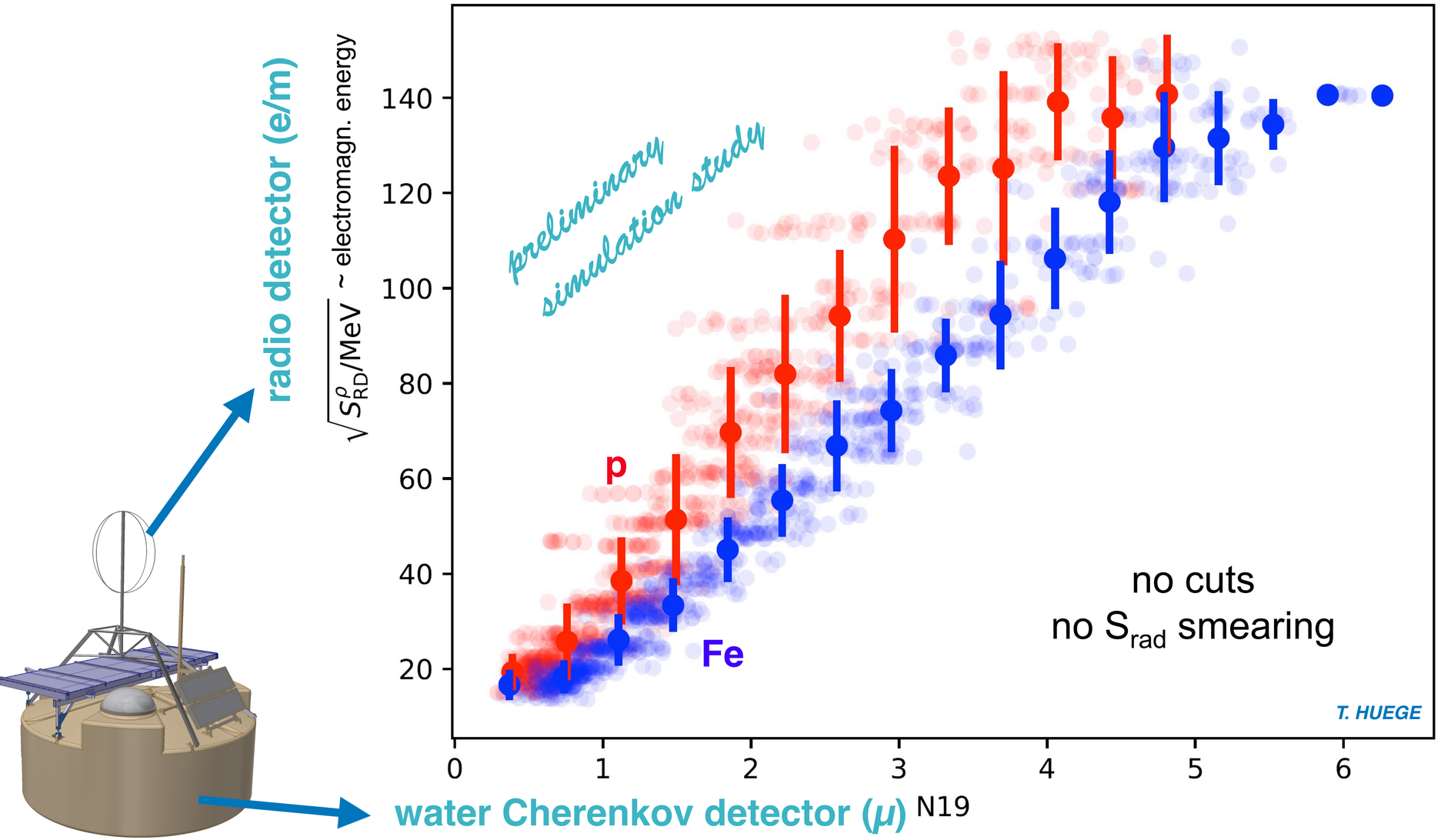
for horizontal showers:
electron/muon ratio
important: radio emission not absorbed in atmosphere



good separation power up to high zenith angles

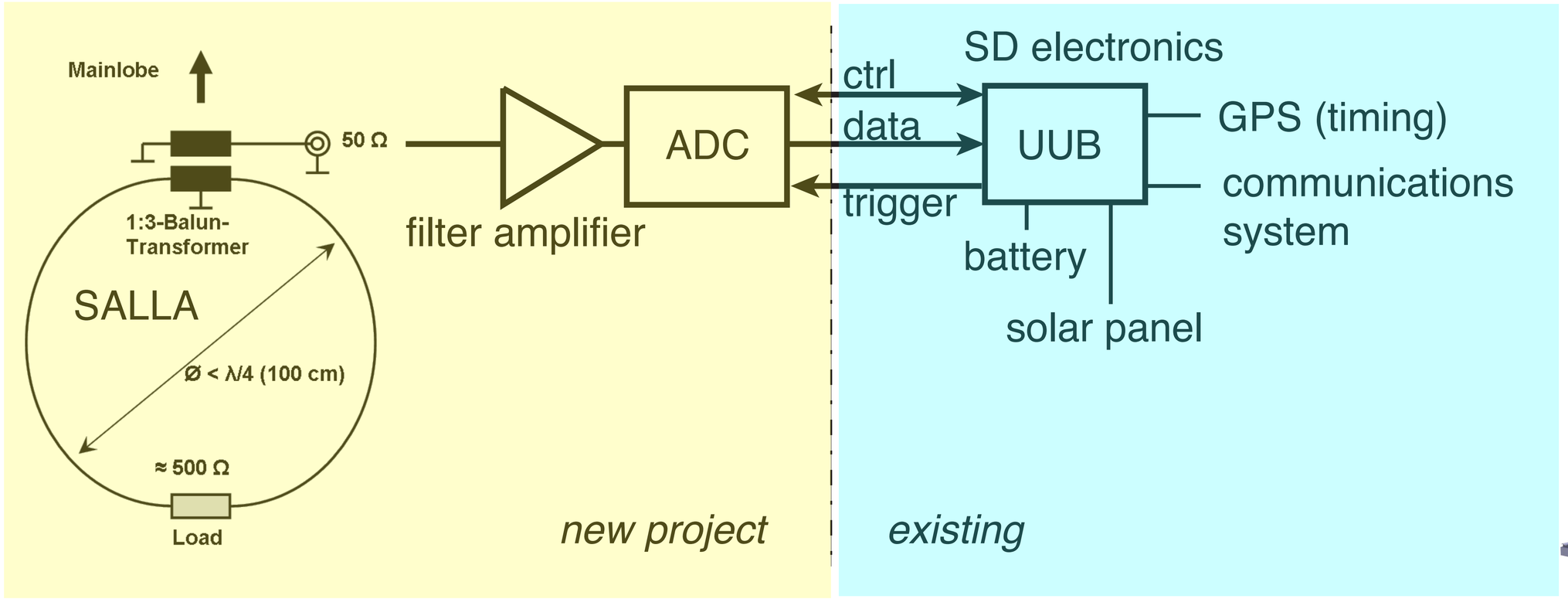


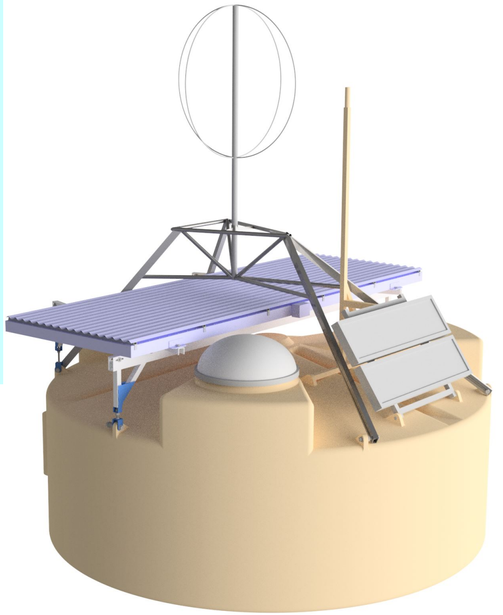
RADIO-WCD PROVIDES GOOD MASS SEPARATION



- **can separate species with S_{rad} and N_{19}**
- **separation increases with energy**
- **saturation at highest energies is an artifact of the maximum simulated energy**

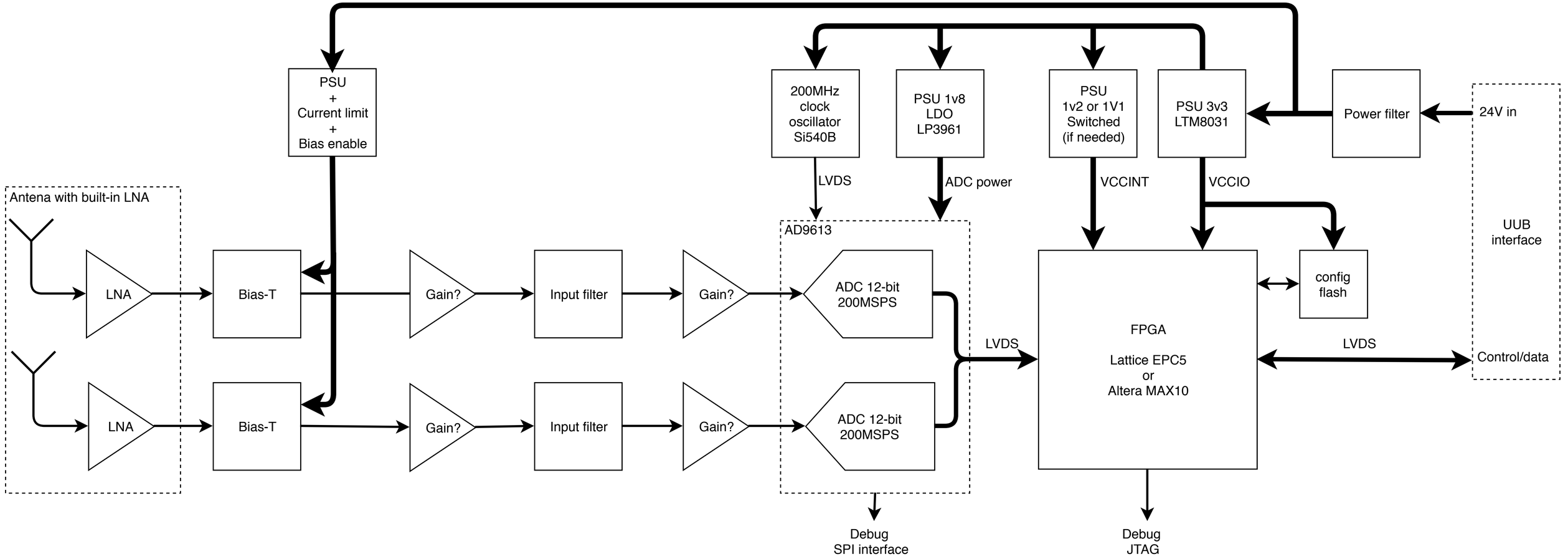
INTEGRATION OF RADIO UPGRADE (RD), SCINTILLATOR UPGRADE (SSD), AND WATER CHERENKOV DETECTOR IN *ONE* UNIT



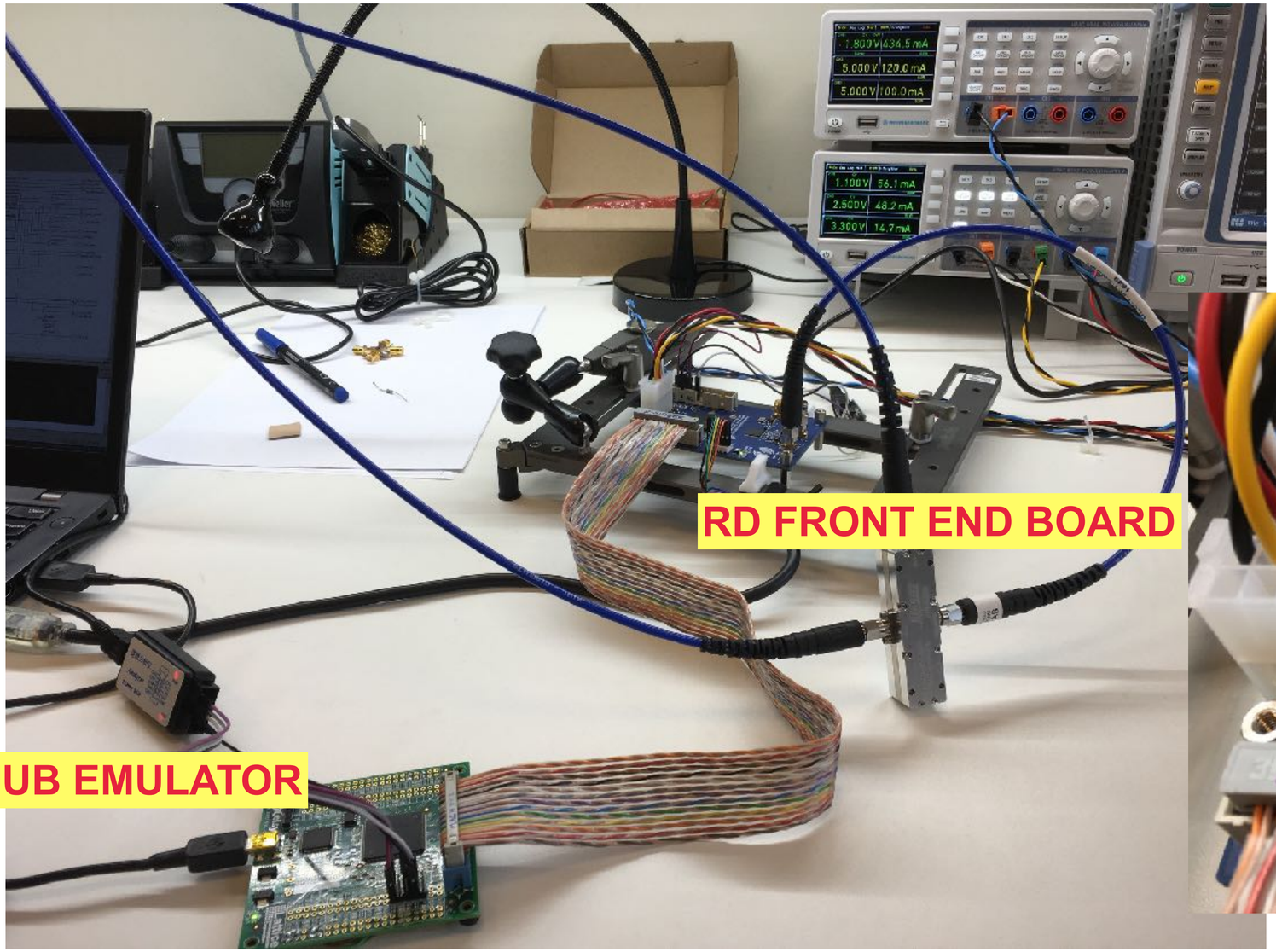


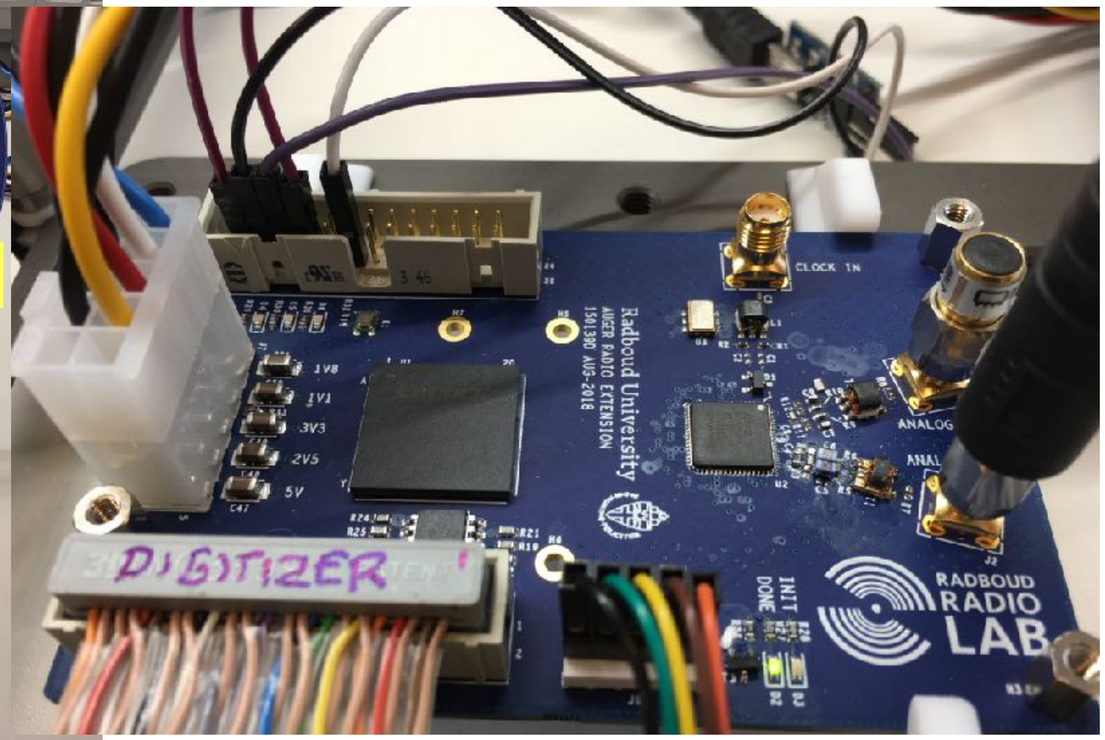
Shared infrastructure **(solar power, battery, GPS timing, communications system) and integrated data acquisition**

RD FRONT END BOARD

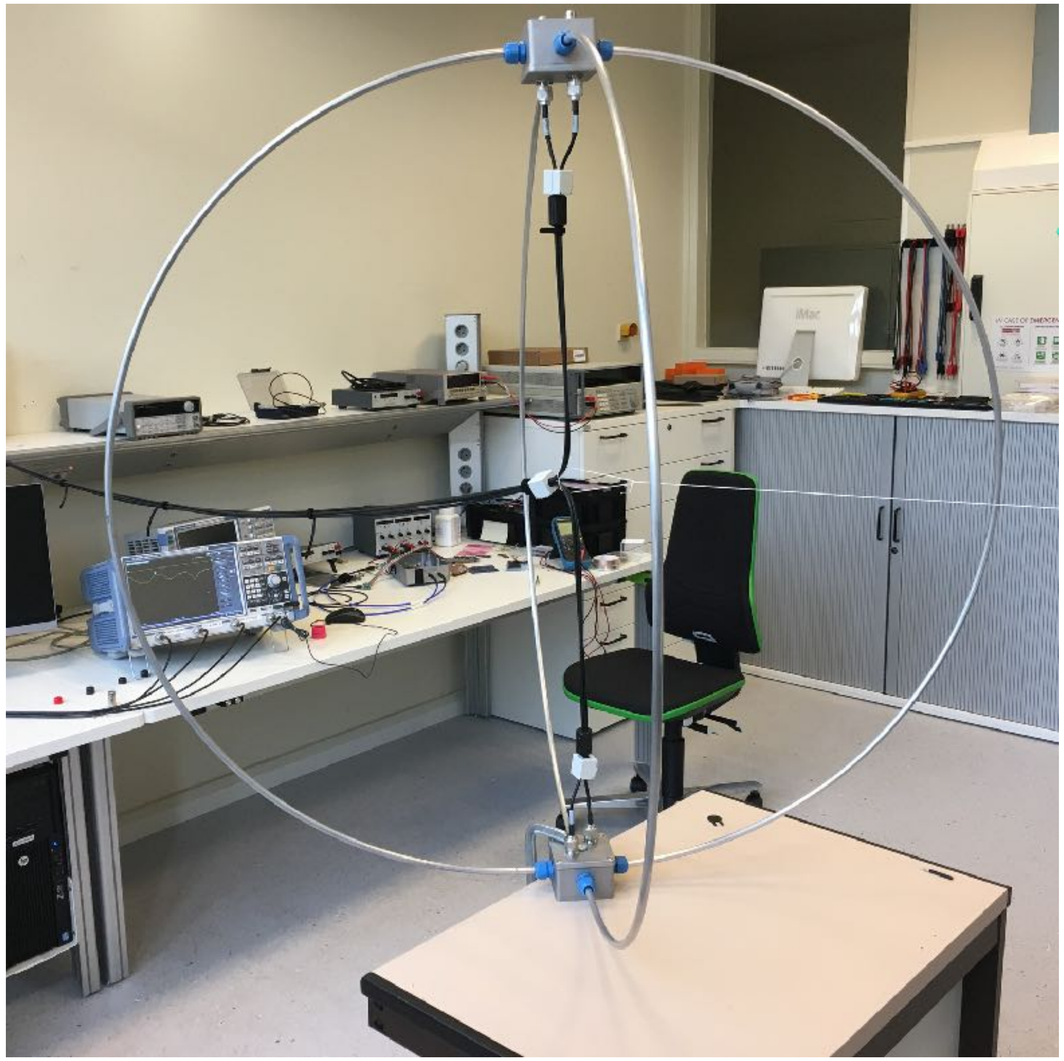


PROTOTYPE RD FRONT-END BOARD





ANTENNA CHARACTERIZATION



COMPLETE READ-OUT CHAIN IN PLACE:

- **SALLA ANTENNA**
- **LNA**
- **RDFRONT END BOARD**
- **UUB EMULATOR**
- **PC**

TIME LINE

Jan 2019: *RU Nijmegen CvB visiting Auger observatory*

antenna prototype on wcd and SSD station

Mar 2019: RD Fornt end board with interface to wcd electronics (UUB) installed in field

Mar 2019: preliminary design review

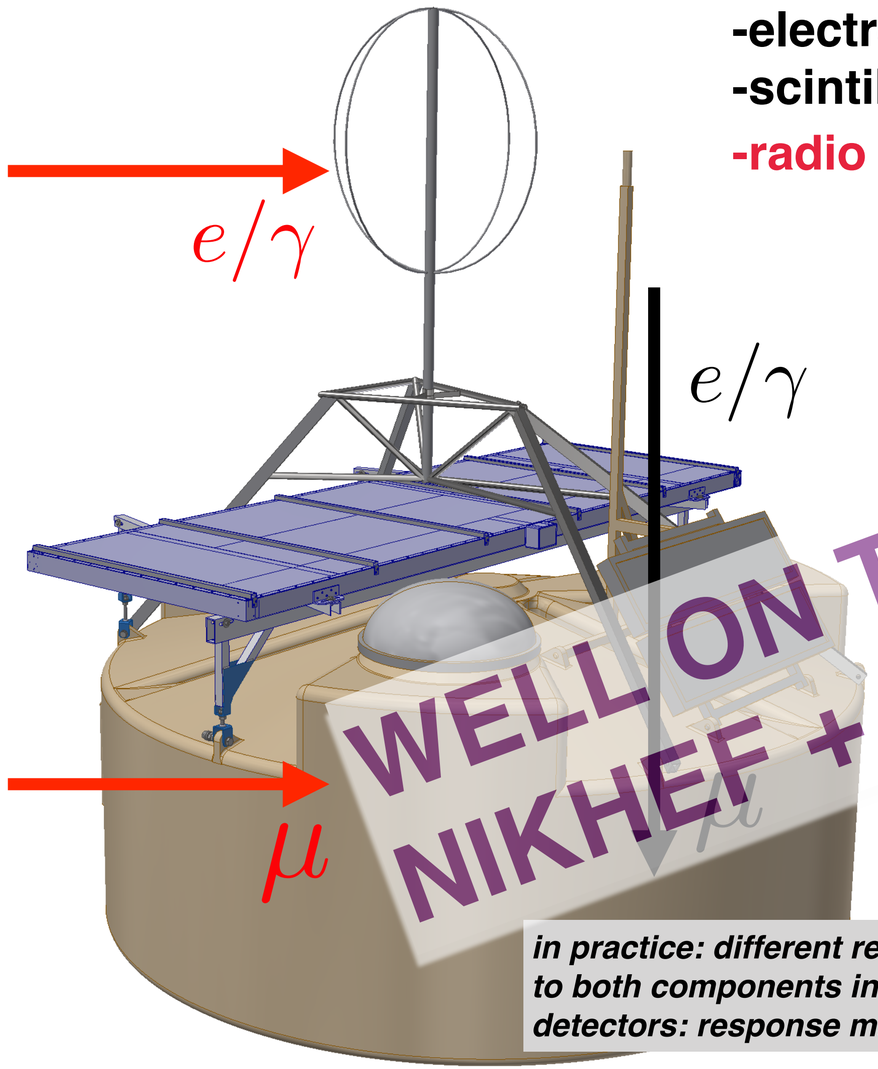
June 2019: *collaboration meeting in Nijmegen*

critical design review

summer 2019 get ready for mass production

2020 install RD upgrade in field

UPGRADE OF THE PIERRE AUGER OBSERVATORY



-electronics
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-radio detector

European Research Council

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WELL ON TRACK
NIKHEF + NL PLAY LEADING ROLE

in practice: different response to both components in both detectors: response matrix