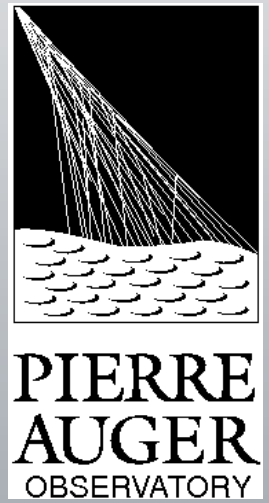
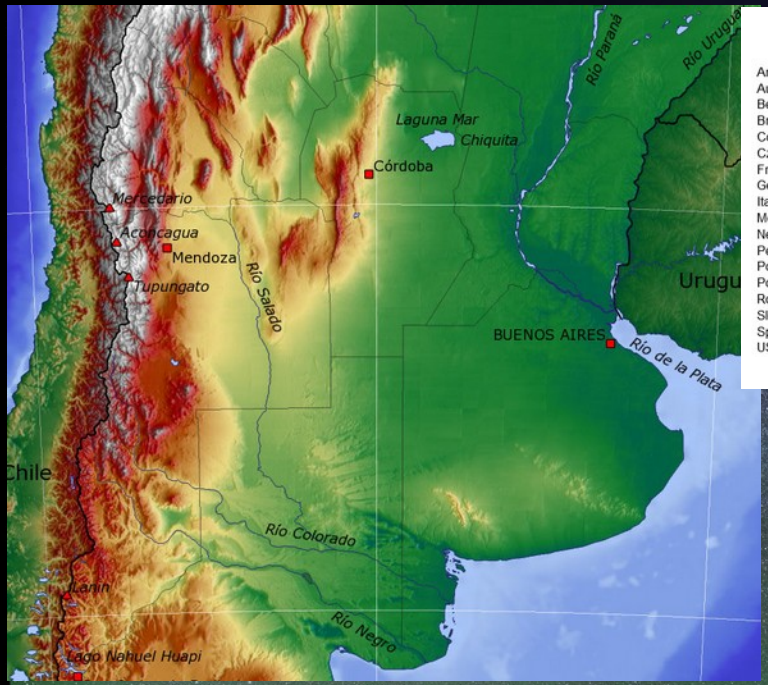
Auger Radio Detector



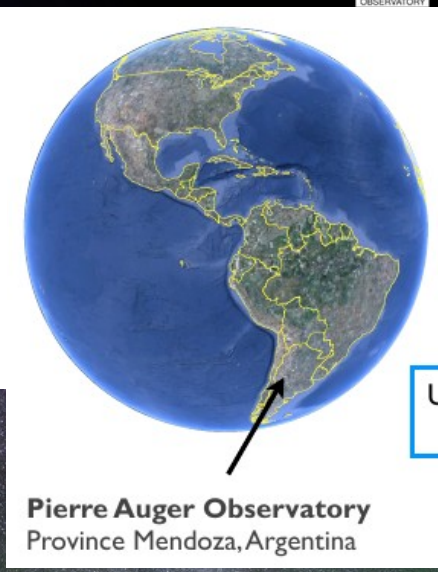
Julian Rautenberg

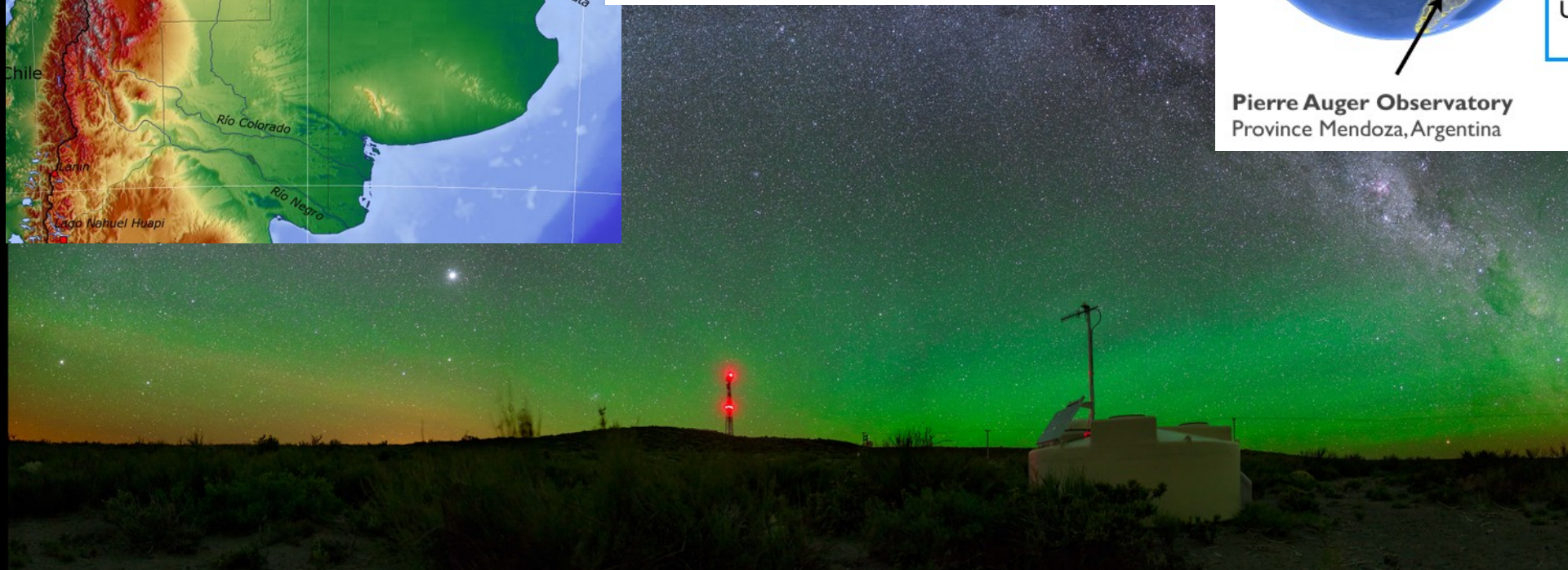
Bergische Universität Wuppertal

Das Pierre-Auger-Observatorium


Río Paraná
Río Uruguay
Laguna Mar Chiquita
Córdoba
Mercedario
Aconcagua
Mendoza
Río Salado
Tupungato
Urugu
BUENOS AIRES
Río de la Plata
Chile
Río Colorado
Lanin
Río Negro
Lago Nahuel Huapi

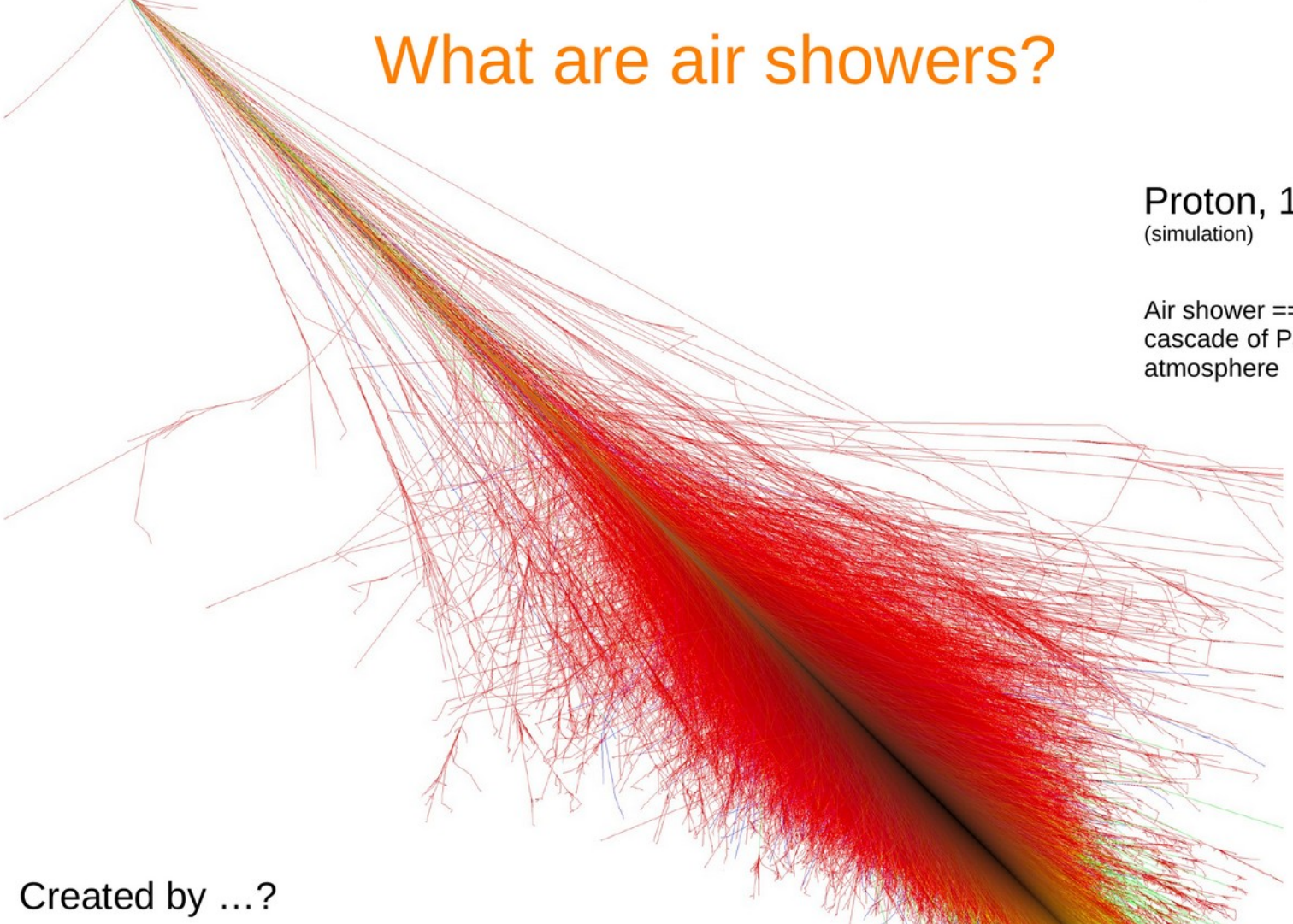

Argentina
Australia
Belgium
Brazil
Colombia
Czech Republic
France
Germany
Italy
Mexico
Netherlands
Peru
Poland
Portugal
Romania
Slovenia
Spain
USA
Pierre Auger Observatory


Pierre Auger Observatory
Province Mendoza, Argentina



What are air showers?

F/ Riehn



Proton, 100 TeV
(simulation)

Air shower ==
cascade of Particle interactions in atmosphere

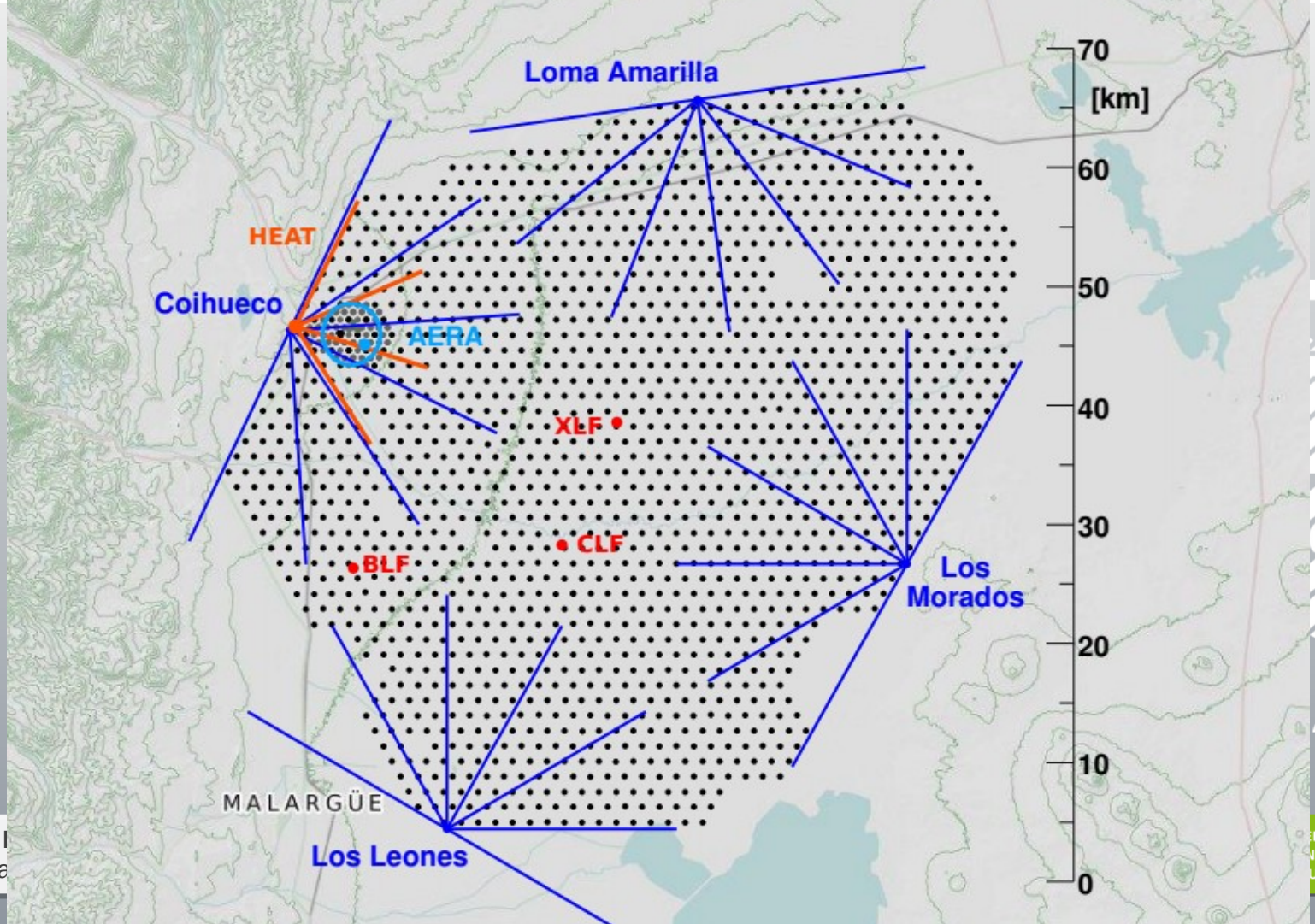
10^7 particles

$\gamma, e^{\pm}$

$\mu^{\pm}$

hadrons

Created by …?



Auger
julian.ra

RGISCHE
NIVERSITÄT
UPPERTAL

Loma Amarilla

HEAT

Coihueco

AERA

XLF

CLF

BLF

Los Morados

50

40

30

20

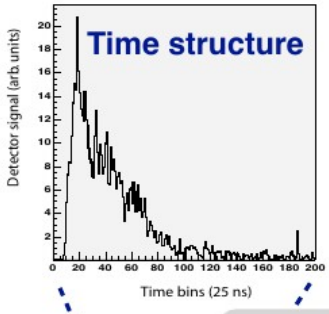
10

0

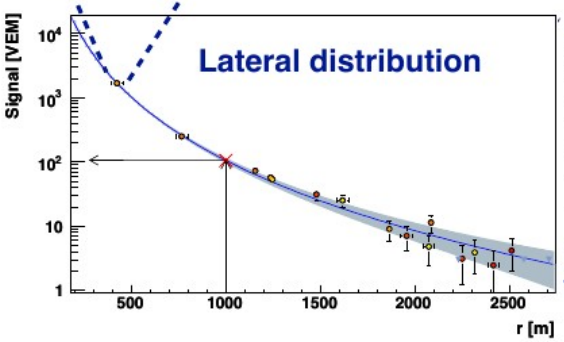
27 Fluoreszenz Teleskope
5 Gebäude
Tagsüber durch Tore geschützt
Kommuniktions-Türme

1660 Surface Detector
1.5 km Abstand
Solar-Power/Batterie
GPS (Zeit)
Proprietaere Kommunikation
3 PMT detektieren Tscherenkovlicht

R.Engel

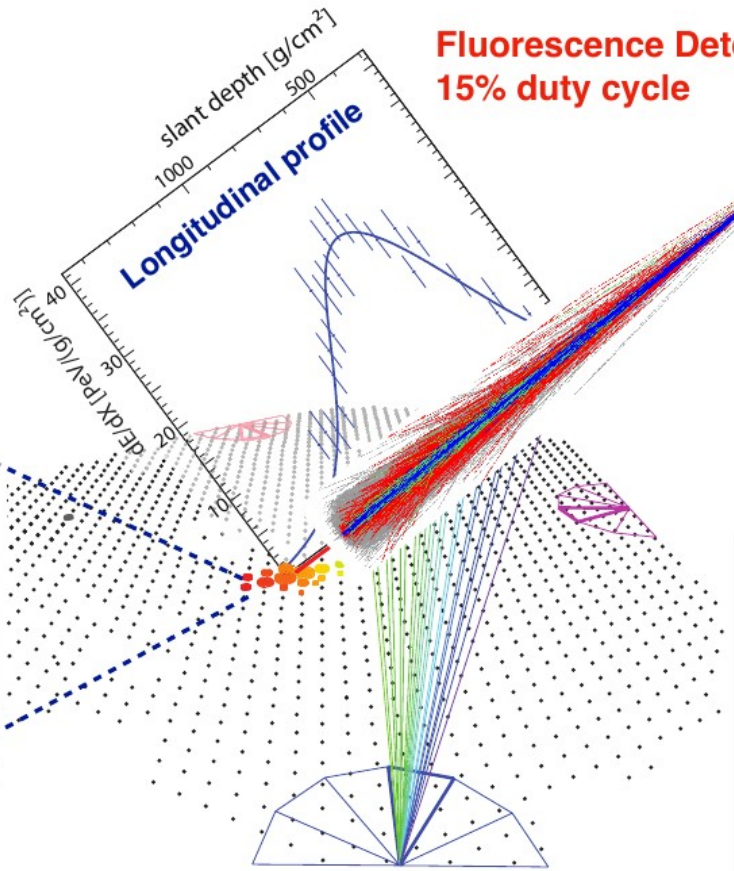


$$E_{\mathrm{rec}} = f(S_{1000}, \theta)$$



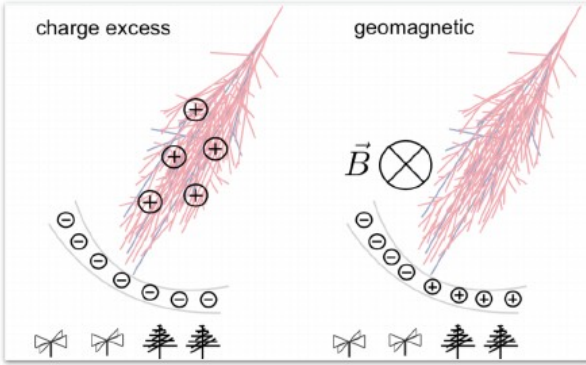
Surface Detector (SD)
100% duty cycle

Fluorescence Detector (FD):
15% duty cycle



$$E_{\mathrm{cal}} = \int_0^{\infty} \left(\frac{\mathrm{d}E}{\mathrm{d}X}\right)_{\mathrm{obs}} \mathrm{d}X$$

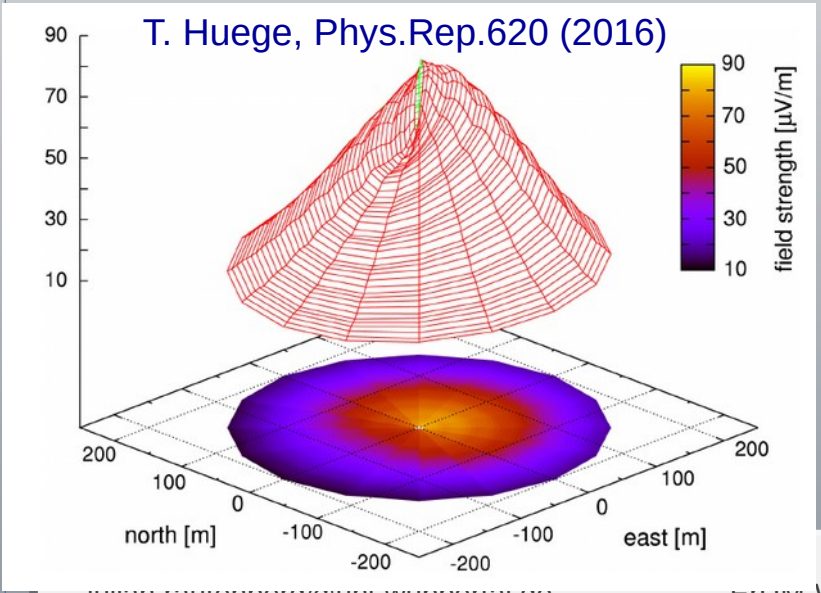
Radio Detector (RD):
100% duty cycle

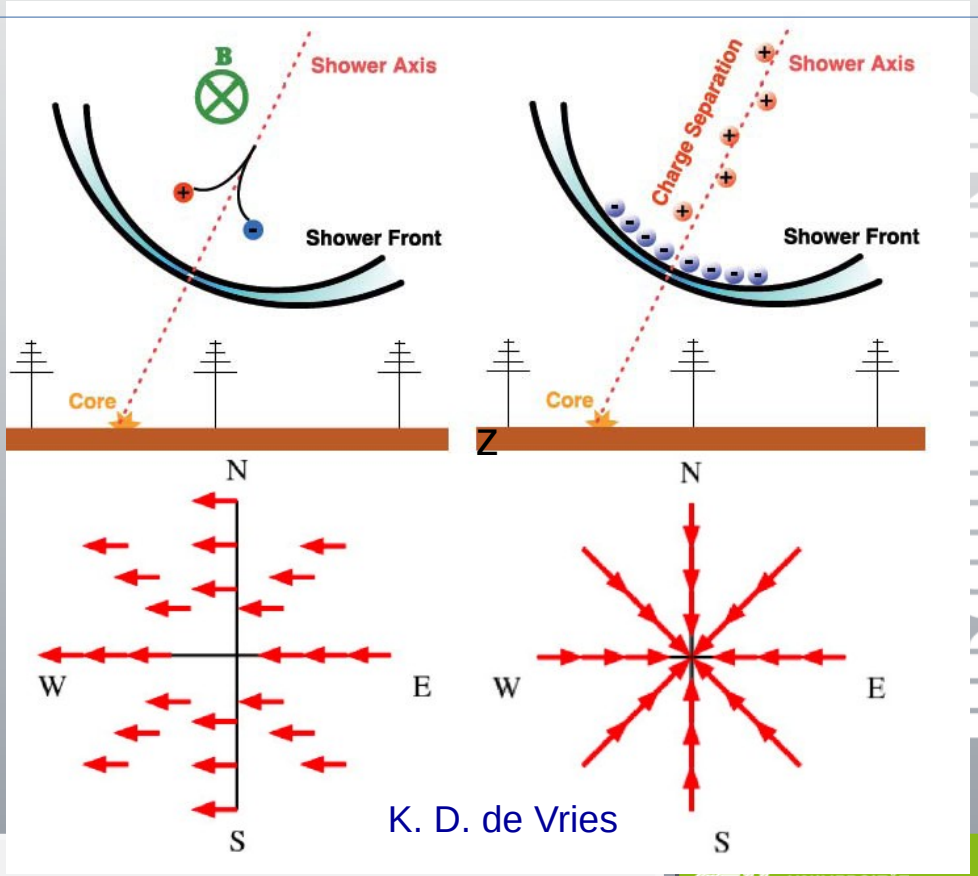


Radio-Emission of EAS:

Geomagnetic contribution:
- Time variation of transverse current

Charge-Excess contribution:
- Time variation of charge access





Radio at Pierre Auger Observatory: AERA

Deployed in three phases:

- Phase I: 24 RDS in 09/2010
- Phase II: +100 RDS in 05/2013
- Phase III: +25 RDS in 02/2015

Four grid spacings:

150, 250, 375 / 750 m

Two antenna types

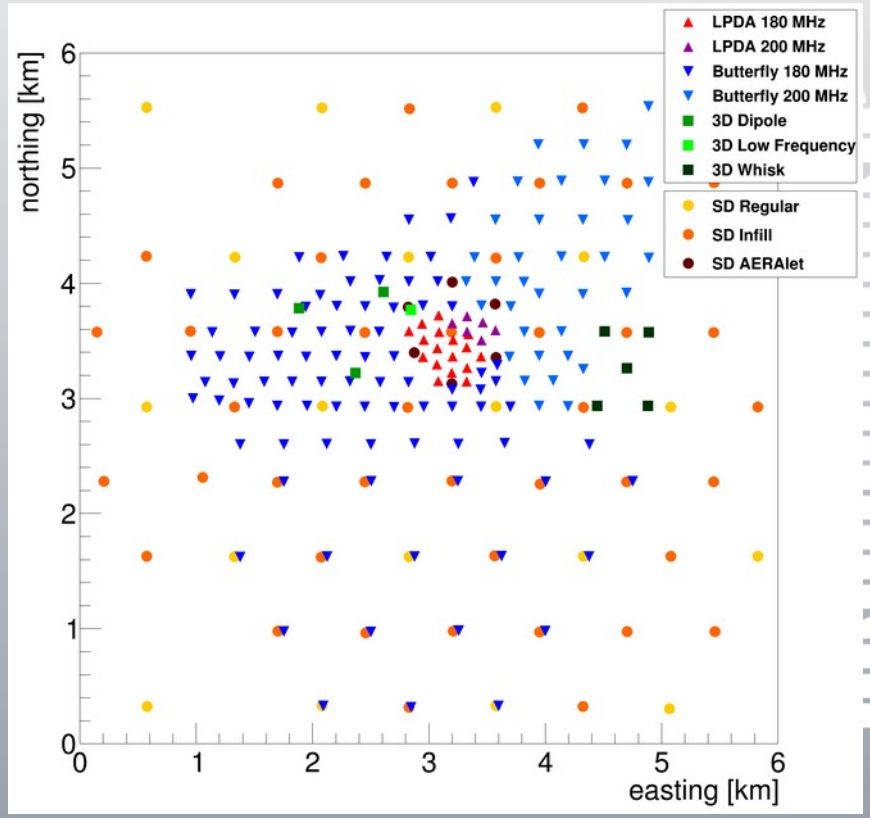
LPDA / Butterfly

Two main trigger schemes

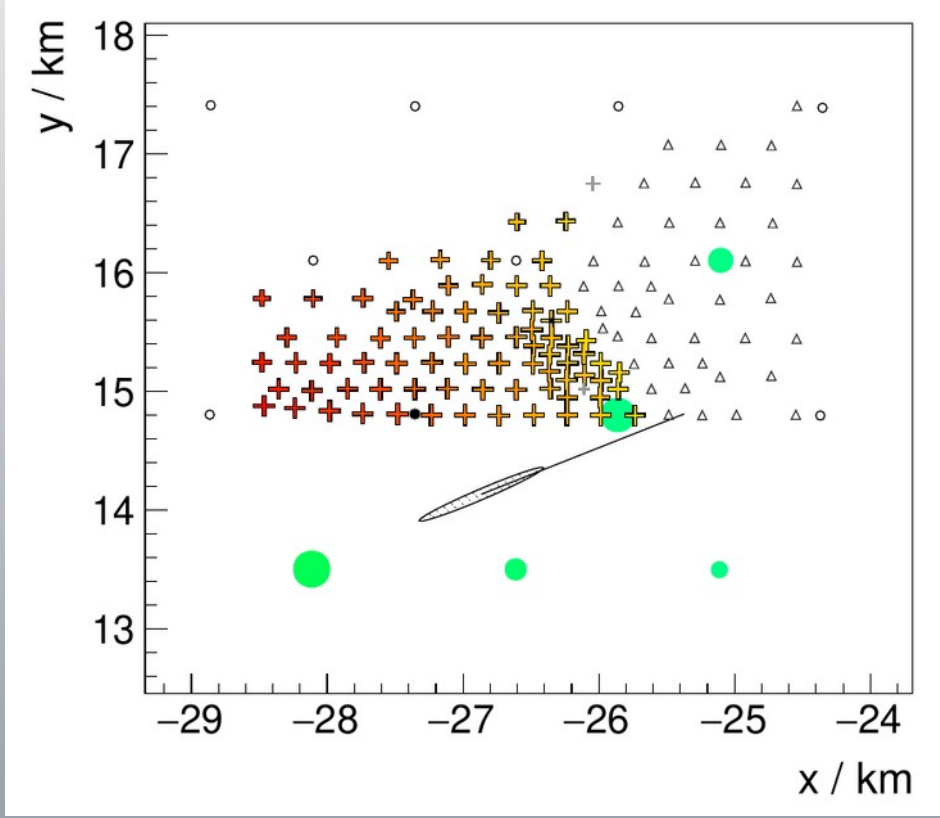
External / scintillator

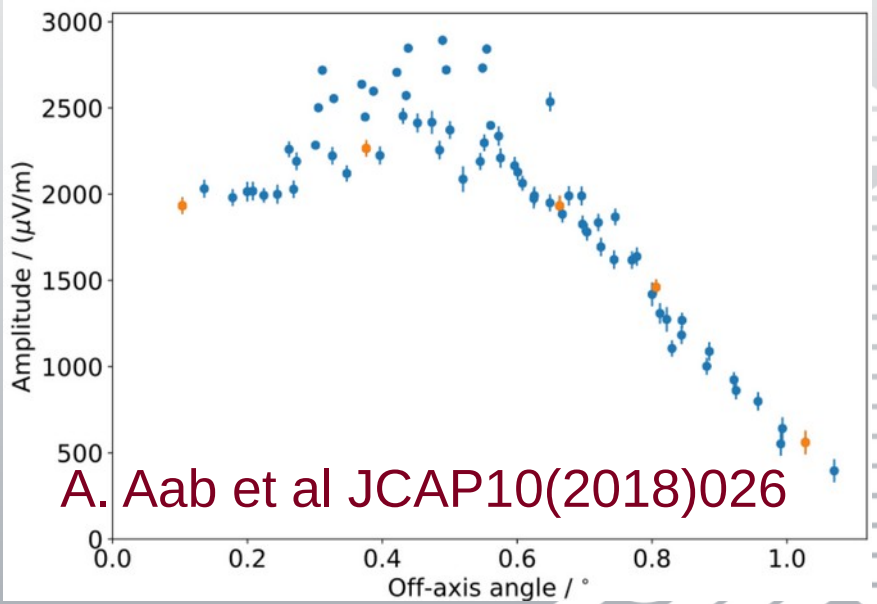
Prototype RDS (3D, lowFreq)

AERAlet (SDS on 433 m grid)



Inclined shower with AERA @ Auger

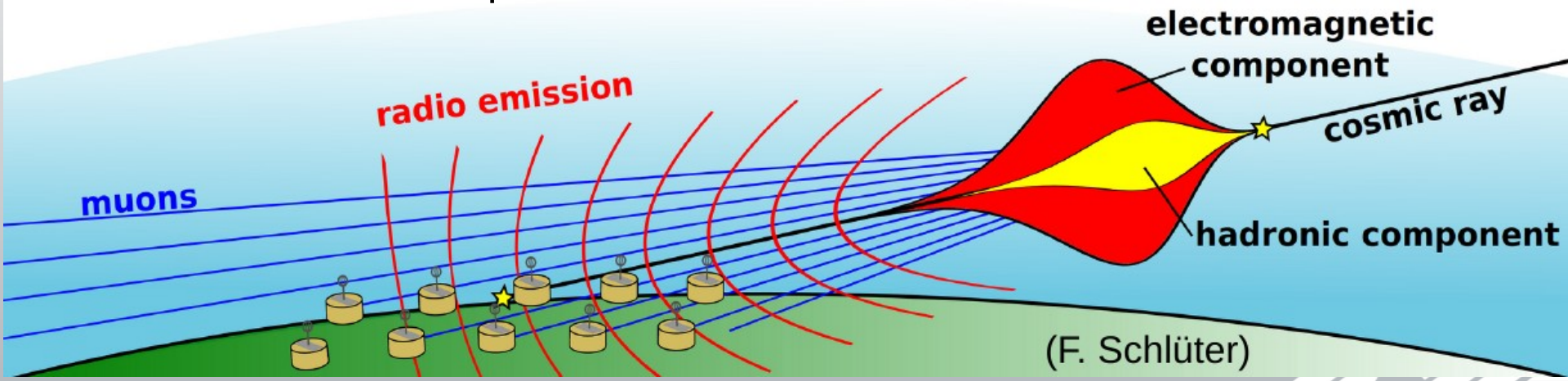




A. Aab et al JCAP10(2018)026

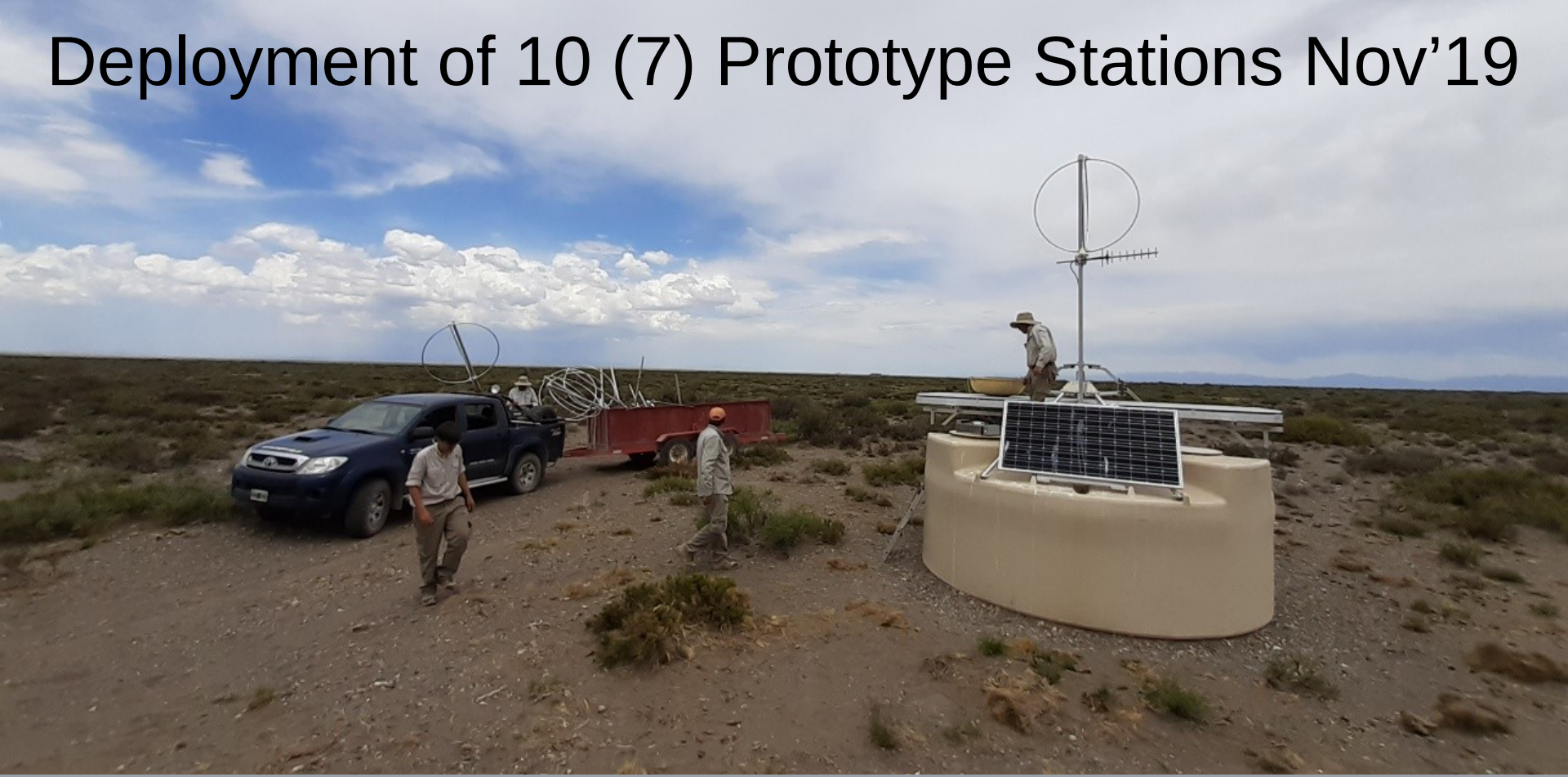
RD ideal EM Detector

No attenuation in atmosphere



Radio-Upgrade Science Case Document agreed by Collaboration Board June 2019: Radio Upgrade for all 1660 Stations

Deployment of 10 (7) Prototype Stations Nov’19



Measured event triggered by SD with RD reconstruction

Global reconstruction (LDF + axis) (5)

$E = (3.16 \pm 0.67) \times 10^{18}$ eV

$(\theta, \phi) = (83.3 \pm 0.2, 87.0 \pm 0.1)$ deg

Wavefront: (sphere)

$(\theta, \phi) = (82.2 \pm 10.93, 86.84 \pm 7.45)$ deg

geomagnetic angle $\alpha = 80.6°$

χ^2 / ndf = (< 0.01) / 1

radius = 24 ± 169 km

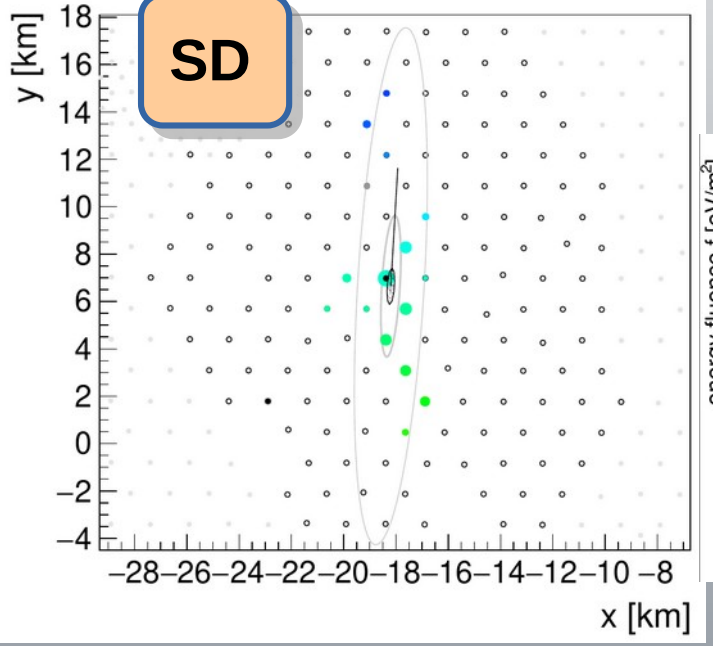
LDF: (HAS)

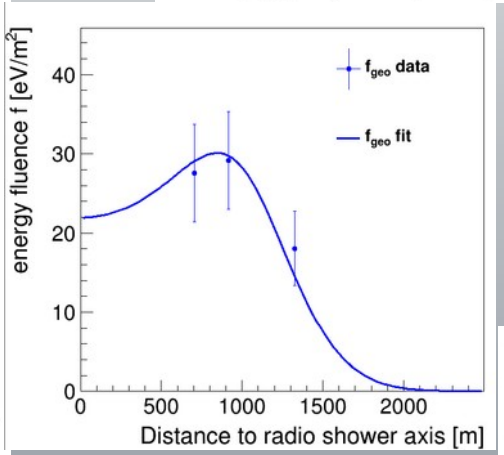
Emag energy = $(4.64 \pm 0.81) \times 10^{18}$ eV

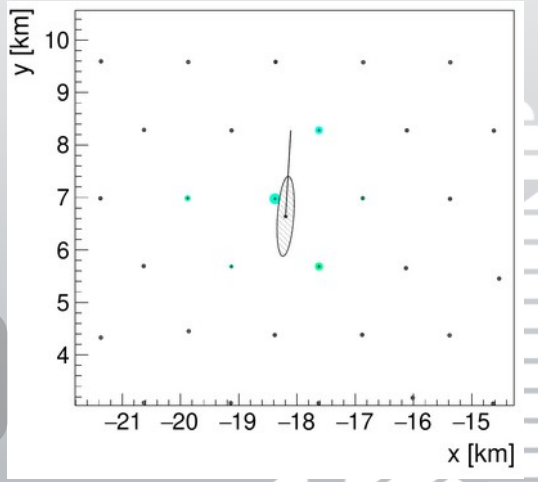
Core (x, y) = (-18.20, 6.64) km

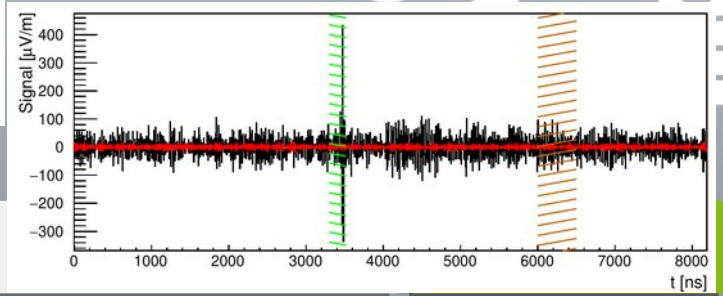
SD

RD









Auger RD
julian.rautenberg@uni-wuppertal.de

Propagtion of Waves

- EM-Emission, Pulses of few ns, propagating at speed of light
- Only small region of coherence
- Changing refractive index and reflection on ground with varying premittivity (weather)
- AERA komplex geometry (ca. 200m), but RD with regular 1.5 km grid
- Few events, O(1/day)
- Convincing but time-consuming simulation (CoREAS/CORSIKA), scaling with number of antennas to be simulated