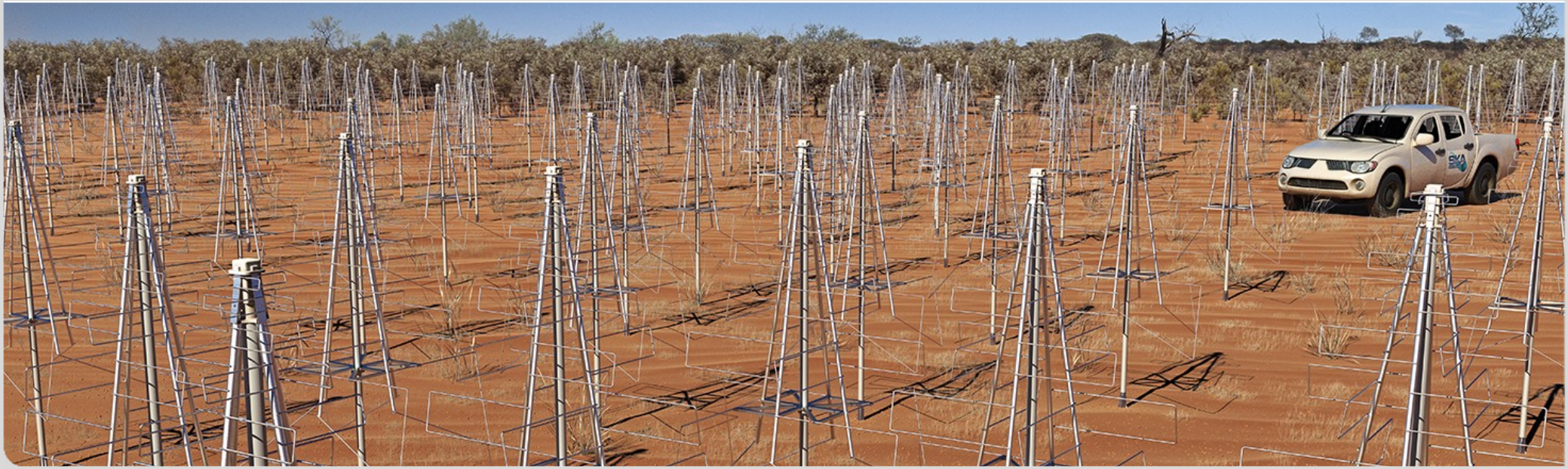
Karlsruhe Institute of Technology

Mass composition using radio detection of EAS with SKA1-low

Anne Zilles (KIT) for the SKA focus group on High-Energy Cosmic Particles



SKA1-low at site of the MWA

Altitude: 370 m, BField Inclination: -60°, Total BField: 55.5 muT

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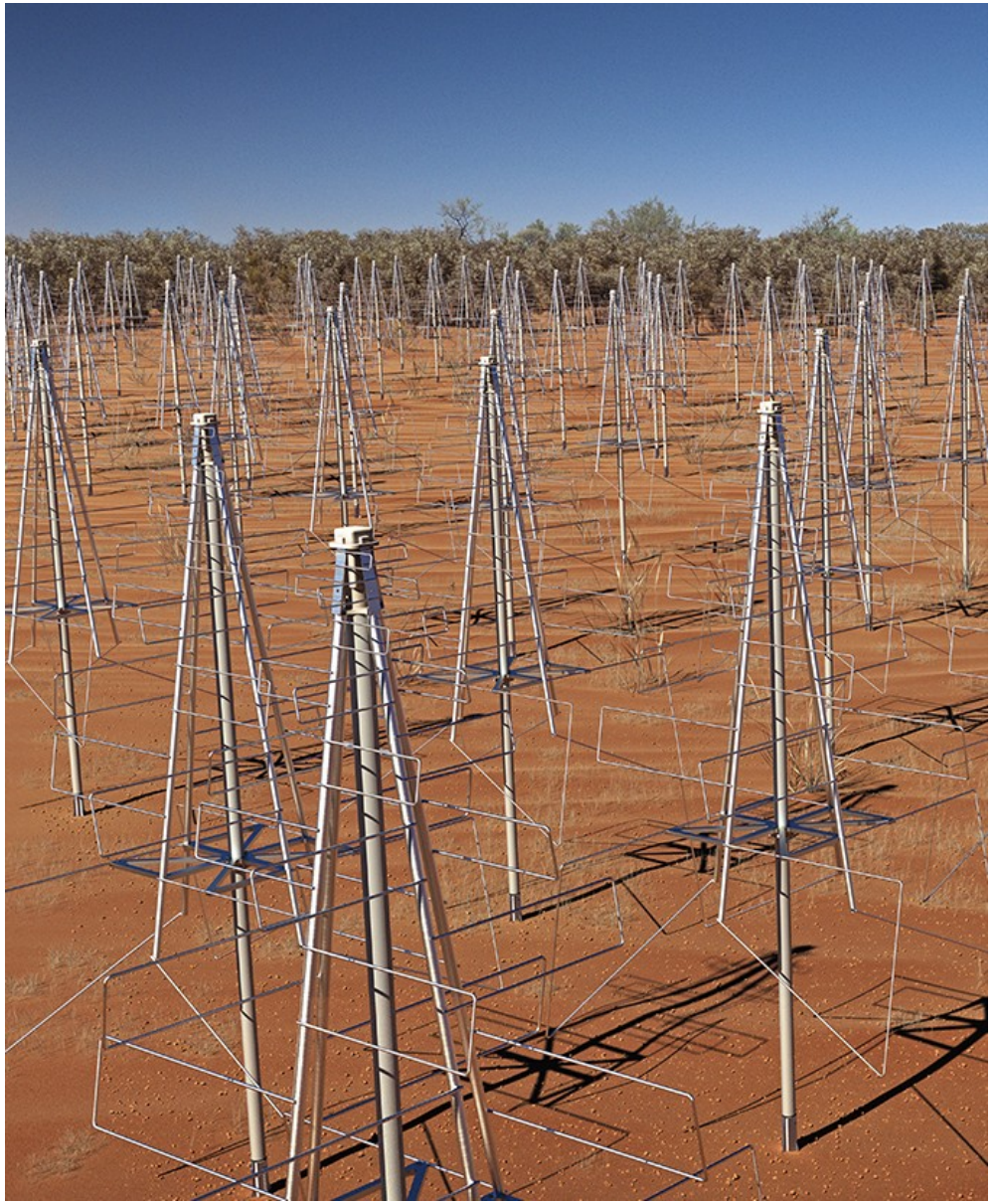
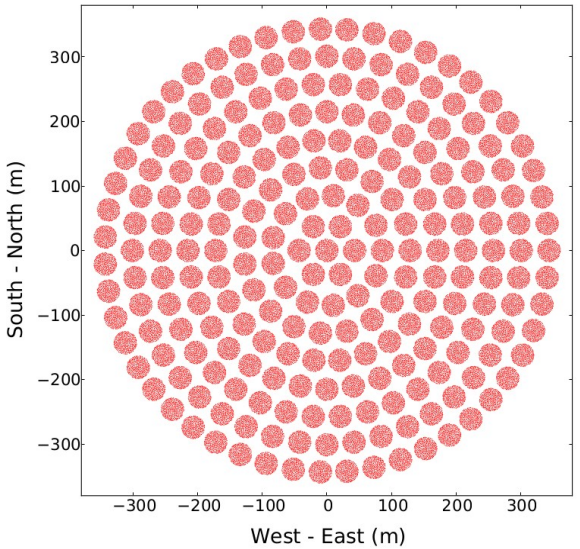
SKA1-low - low frequency array stations



- in the final design stages
- phase 1 construction 2018-2023
- first science 2020
- ~60,000 dipole antennas in a circle of 750 metre diameter
- bandwidth 50-350 MHz
- can be used for air shower detection with minor additions



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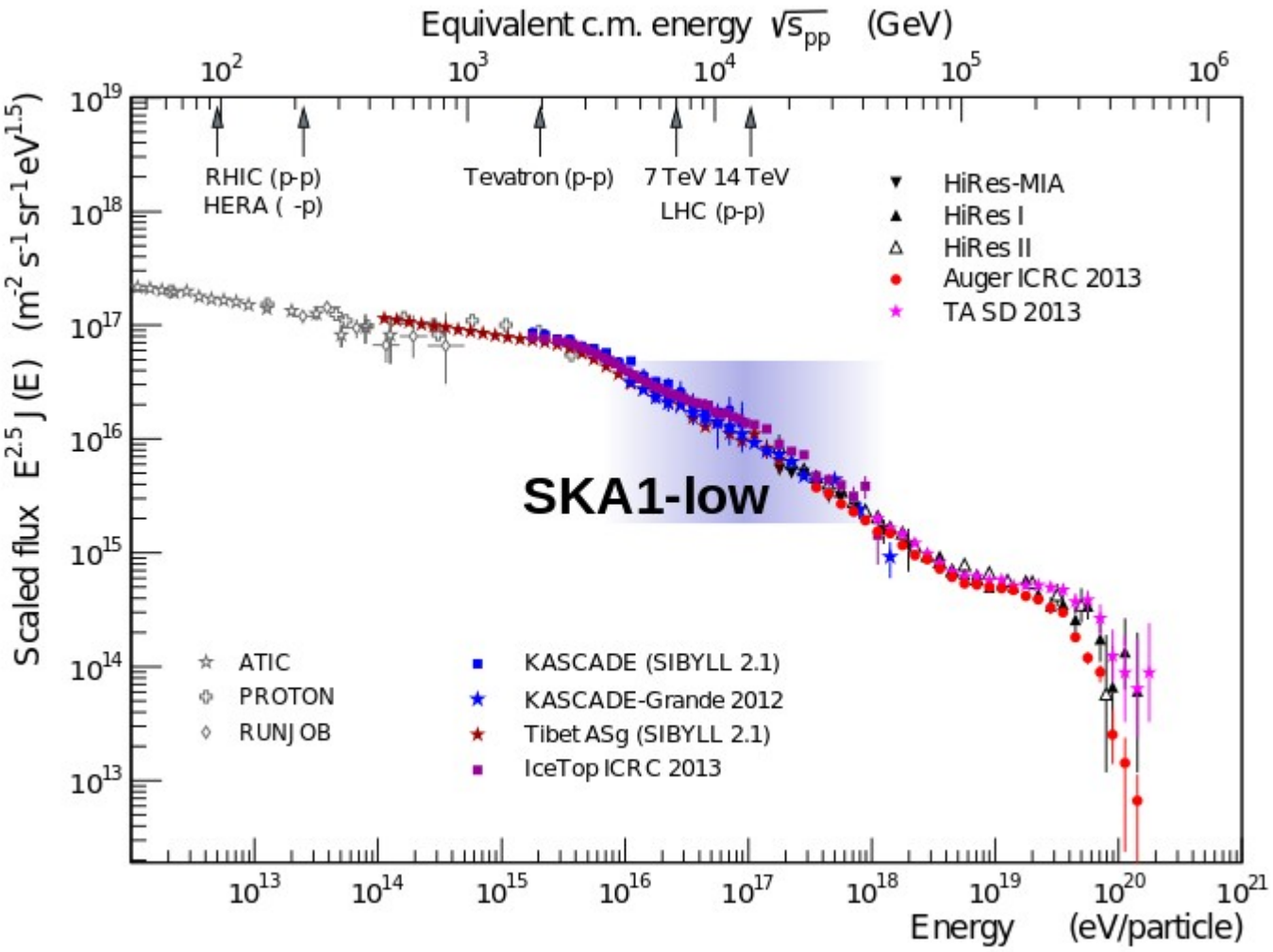
CR: transition from galactic to extra-galactic



High-precision composition measurements
→ possibly decompose in individual elements

adapted from R.Engel et al., updated by T.Huege/AZ

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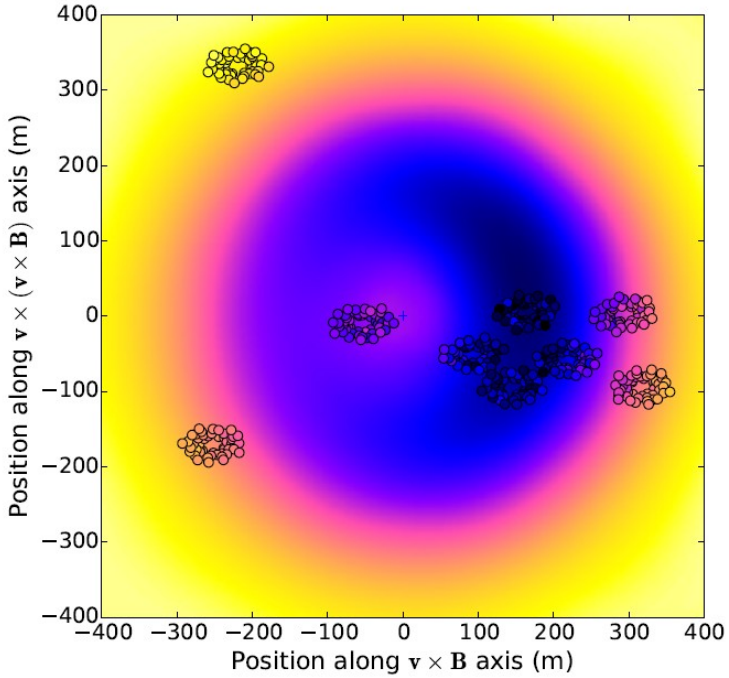
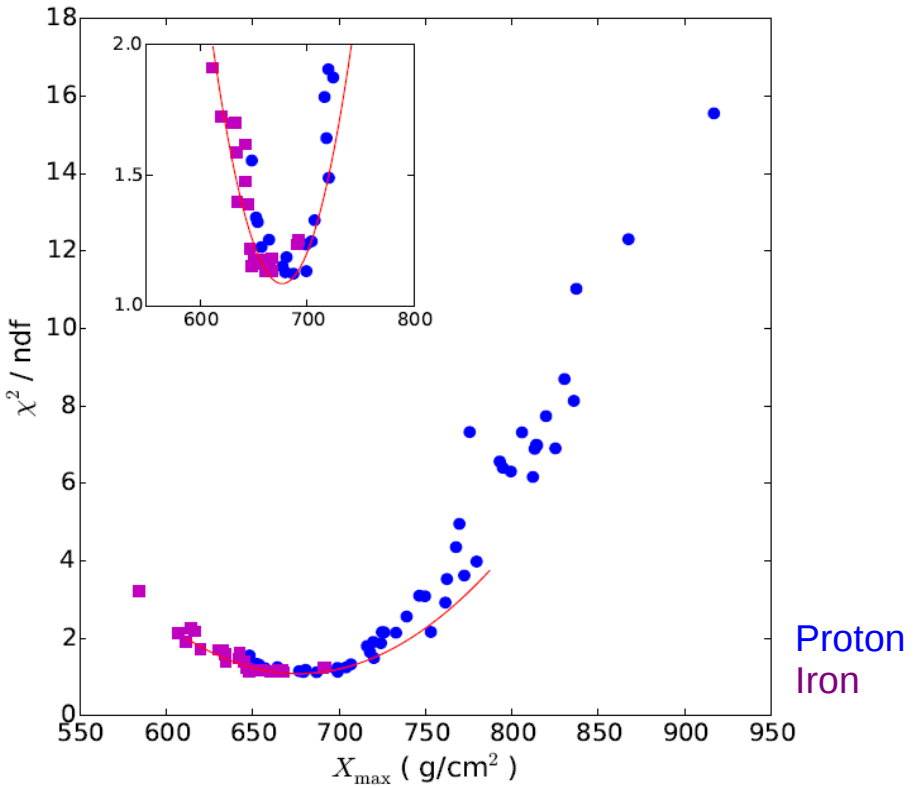
Xmax reconstruction from LDF - LOFAR

(see J. Hörandel: Radio Xmax detection with LOFAR and AERA)





2d LDF fit to CoREAS simulations yields mean Xmax to ~17 g/cm^2

S. Buitink et al., Phys Rev D (2014), arXiv:1408.7001

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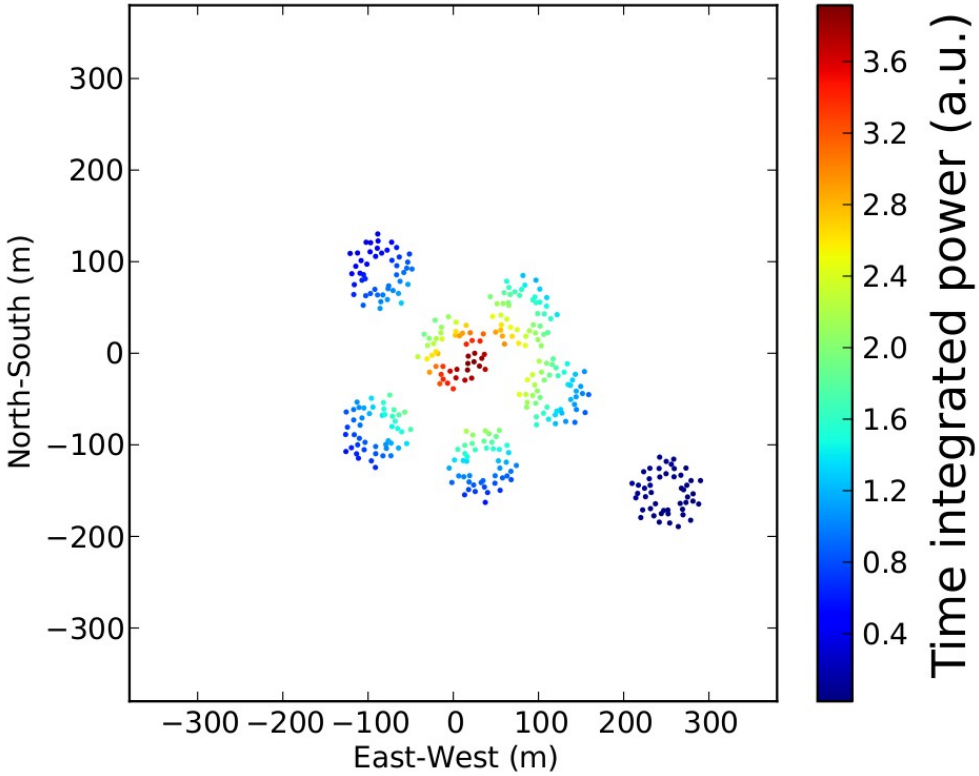
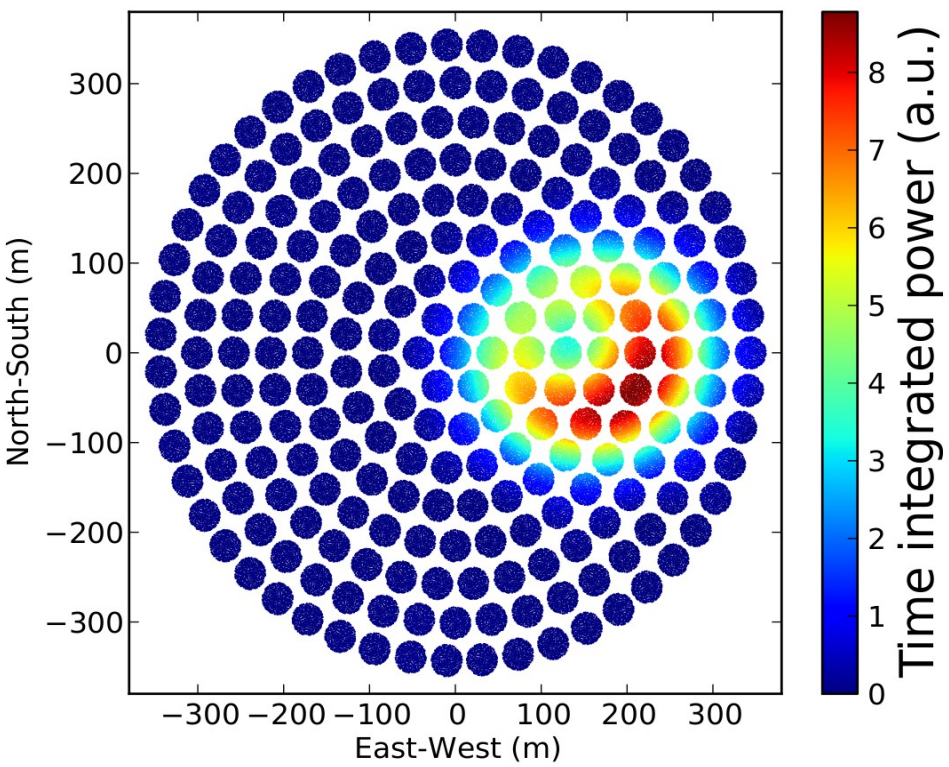
SKA will provide detailed radio footprint

Proton, 10^{18}eV, zenith = 30°

LOFAR



SKA-low



Frequency range:	**30 – 80 MHz**	**50 – 350 MHz**
Bandwidth:	**50 MHz**	**300 MHz**

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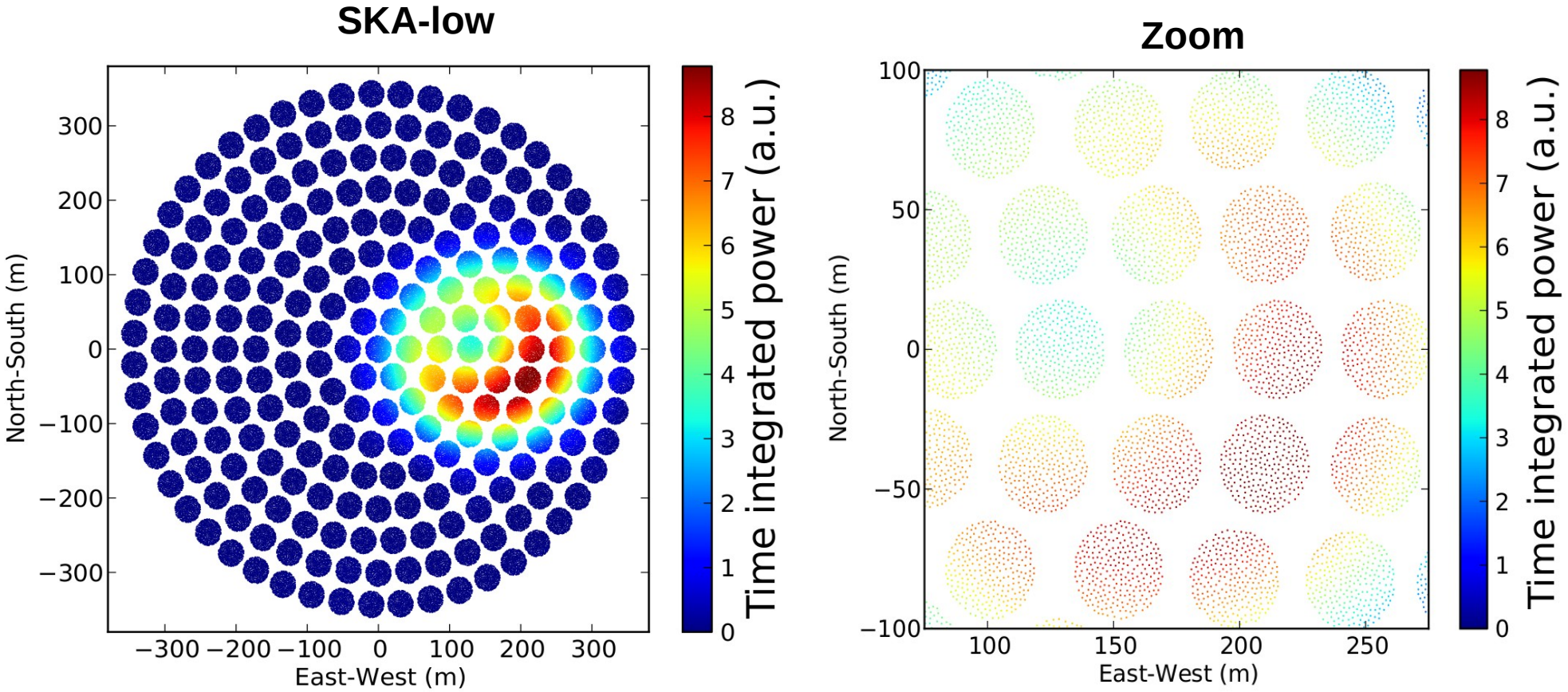
SKA will provide detailed radio footprint

SKA1-low can measure individual air showers with ***extreme*** precision



→ **Xmax determination with <= 10 g/cm² resolution seems feasible!**

Fluorescence detection technique: ~ 20 g/cm²

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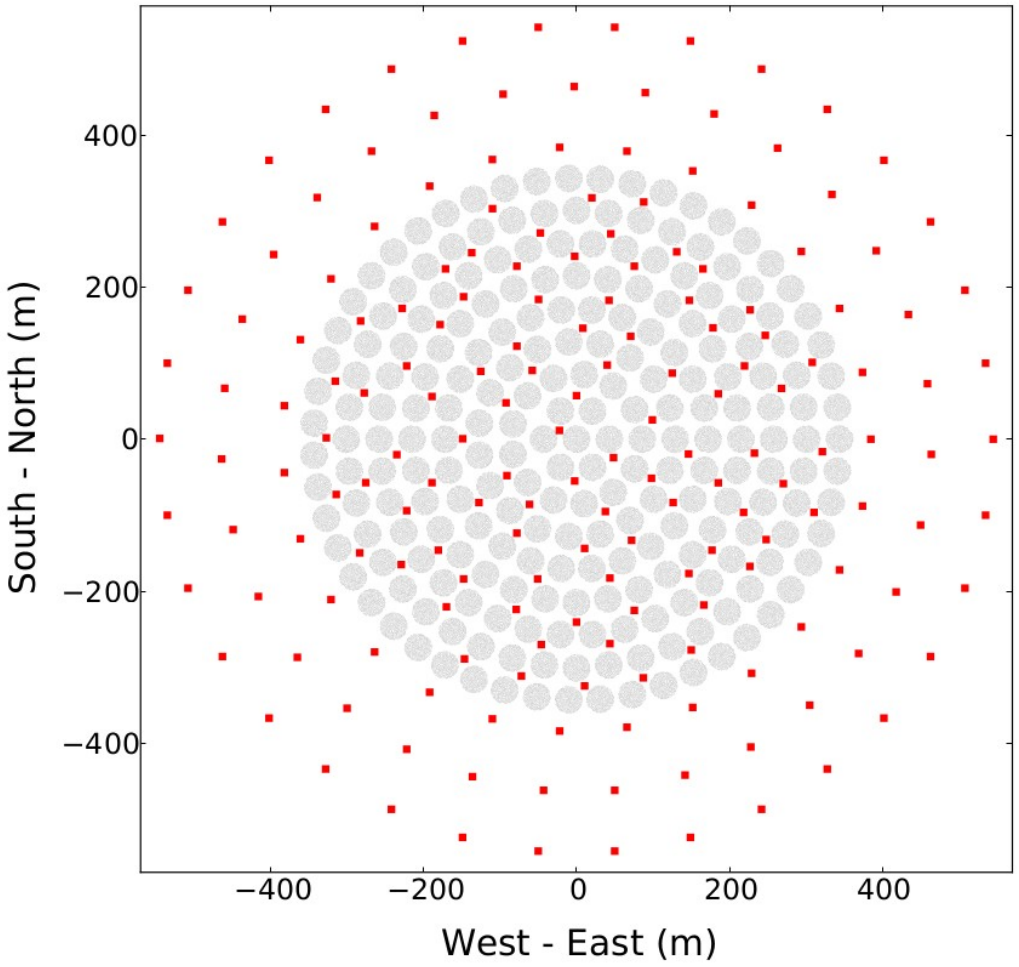
Engineering change: e.g. triggering array

- particle detector array for efficient and pure trigger
- should become efficient at ~10^{16} eV,
  average distance ~50-100 m
  - option: 180 scintillators from KASCADE array, 3.6 m^2 each
- extend fiducial area outside the SKA1-low core to area ~1 km^2



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Science potential of SKA-EAS

- precision study of transition from Galactic to extragalactic cosmic rays → Xmax determination with ~ **10 g/cm²** resolution

- precision study of interaction and air shower physics beyond LHC energies

  - proton-air cross section, ...

- precision studies of radio emission from EAS

  - „tomography“ of EAS using near-field interferometry

- study of thunderstorm physics and possible connections with EAS

See: T.Huege et al. (ICRC2015)

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High Energy Cosmic Particles

Focus group dedicated to cosmic ray science, details coming soon...

High Energy Cosmic Particles Focus Group Membership

Name	Institution	Country	Membership Type
Anne Zilles	Karlsruhe Institute of Technology	Germany	
Benoit Revenu	Nantes University	France	
Clancy James	ECAP	Germany	
Frank Schroeder	Karlsruhe Institute of Technology	Germany	
Heino Falcke	RU Nijmegan	Netherlands	
Jaime Alvarez-Muniz	Santiago Compostela	Spain	
Justin Bray	University of Manchester	UK	
Ken Gayley	University of Iowa	USA	
Lilian Martin	Nantes University	France	
Maaijke Mevius	ASTRON	Netherlands	
Olaf Sholten	University of Groningen	Netherlands	
Ralph Spencer	University of Manchester	UK	
Richard Dallier	Nantes University	France	
Robert Mutel	University of Iowa	USA	
Ron Ekers	CSIRO	Australia	
Rustam Dagkesamanskii	Pushchino Observatory	Russia	
Sander ter Veen	RU Nijmegan	Netherlands	
Stijn Buitink	Vrije Universiteit Brussel	Belgium	
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Torsten Ensslin	MPA Garching	Germany	
Katherine Mack	University of Melbourne	Australia	
Julian Rautenberg	University of Melbourne	Australia	
Nadir Hashim	Kenyatta University	Kenya	
Steven Tingay	ICRAR, Curtin	Australia	
Evan Keane	SKA Organisation	UK	Office Contact

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State of the project

- we have become an „SKA focus group“ since May 2015
- we have submitted a detailed „Engineering Change Proposal“ and entered phase 2 out of 6 (recommend)
- there is still a lot to be done before first data in 2020
- if you are interested, contact us!

http://astronomers.skatelescope.org/home/focus-groups/

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SUMMARY

- SKA1-low can be upgraded for cosmic ray detection
- it would be a unique radio detector („ultimate detail in measurements“)
- the science potential lies in precision measurements
  - mass composition in the transition region
  - particle interactions and air shower physics
  - air showers and thunderstorms
- an engineering change proposal is under consideration

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Appendix

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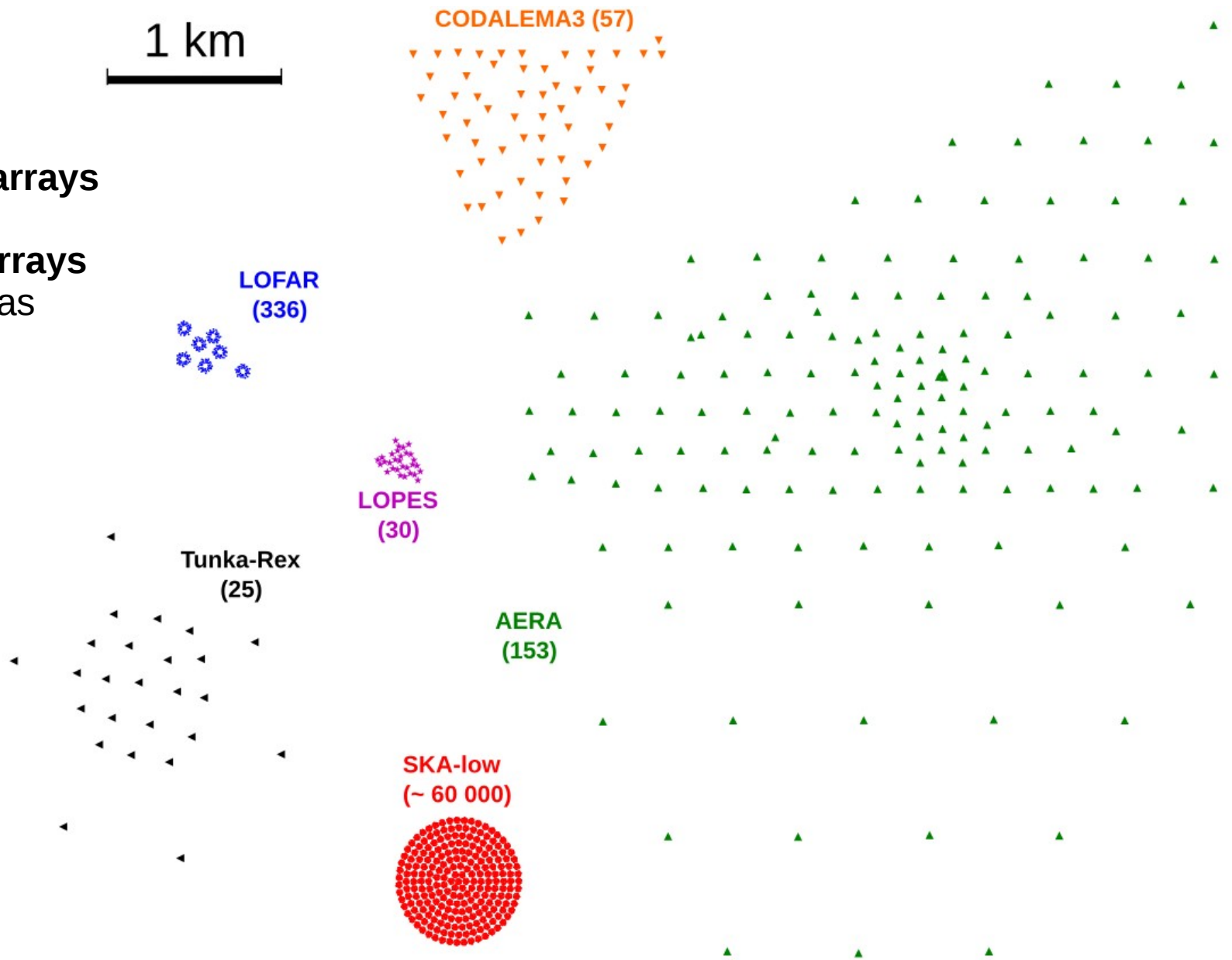
Comparison of radio arrays

Two diff. Concepts:

- **sparse antenna arrays** cover large areas
- **dense antenna arrays** on fairly small areas



SKA1-low area is roughly 0.5 km²

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Engineering change: antenna buffering

- in SKA1-low, antenna data are beam-formed on-the-fly
- air shower detection needs individual-antenna signals
  - continuously buffer individual-antenna raw-data
    - 800 MHz sampling
    - at least 8 bit, preferably 12 bit dynamic range
    - buffer depth determined by trigger latency (10 ms)
    - 1.3 TeraBytes of buffer for 60,000 antennas
  - read out 50 microseconds upon an external air shower trigger
    - estimated rate of 1 trigger per minute
    - read out in bursts of 2.2 GigaBytes/s over 3 seconds after each trigger

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