Karlsruhe Institute of Technology

VRIJE UNIVERSITEIT BRUSSEL

PIERRE AUGER OBSERVATORY

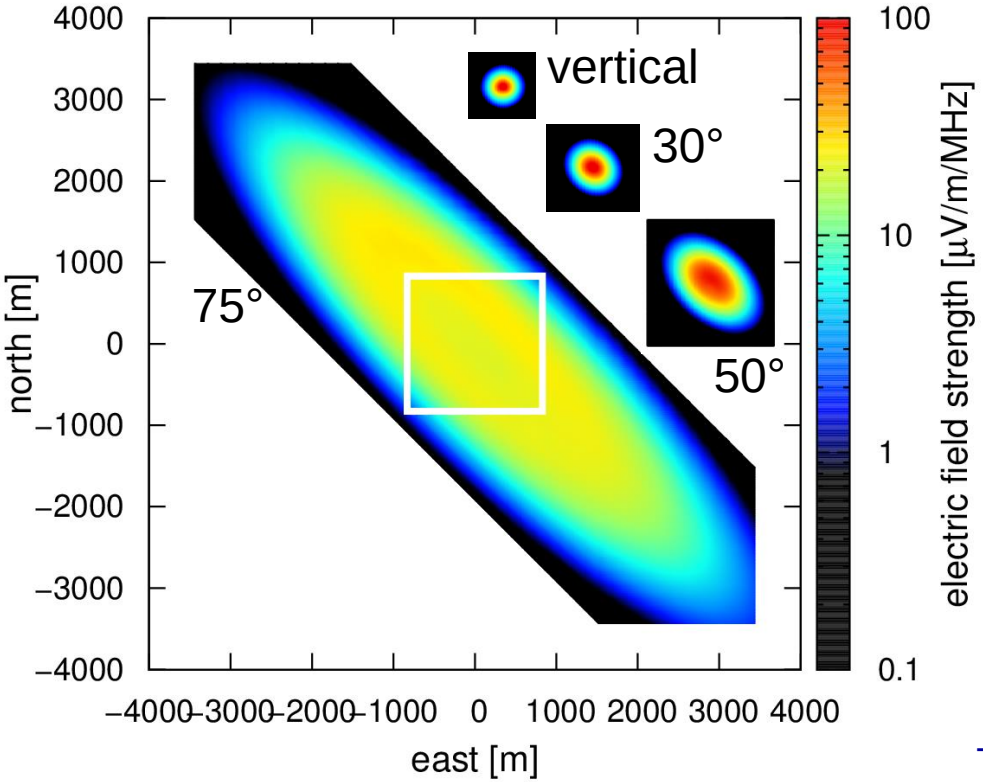
Radio Technique and GCOS

Tim Huege

Most important points

- Radio detection is mature and delivers valuable information
  - Independent calibration of absolute energy scale
  - „Electromagnetic energy“ within 10%
  - Xmax for vertical showers (AERA), for inclined requires interferometry
- Larger antenna spacing -> higher zenith angles -> smaller solid angle
  - 1.5 km grid for AugerPrime RD will work
  - 2.0 km grid seems like stretching it
  - Potentially „clusters“ with broad-band antennas?

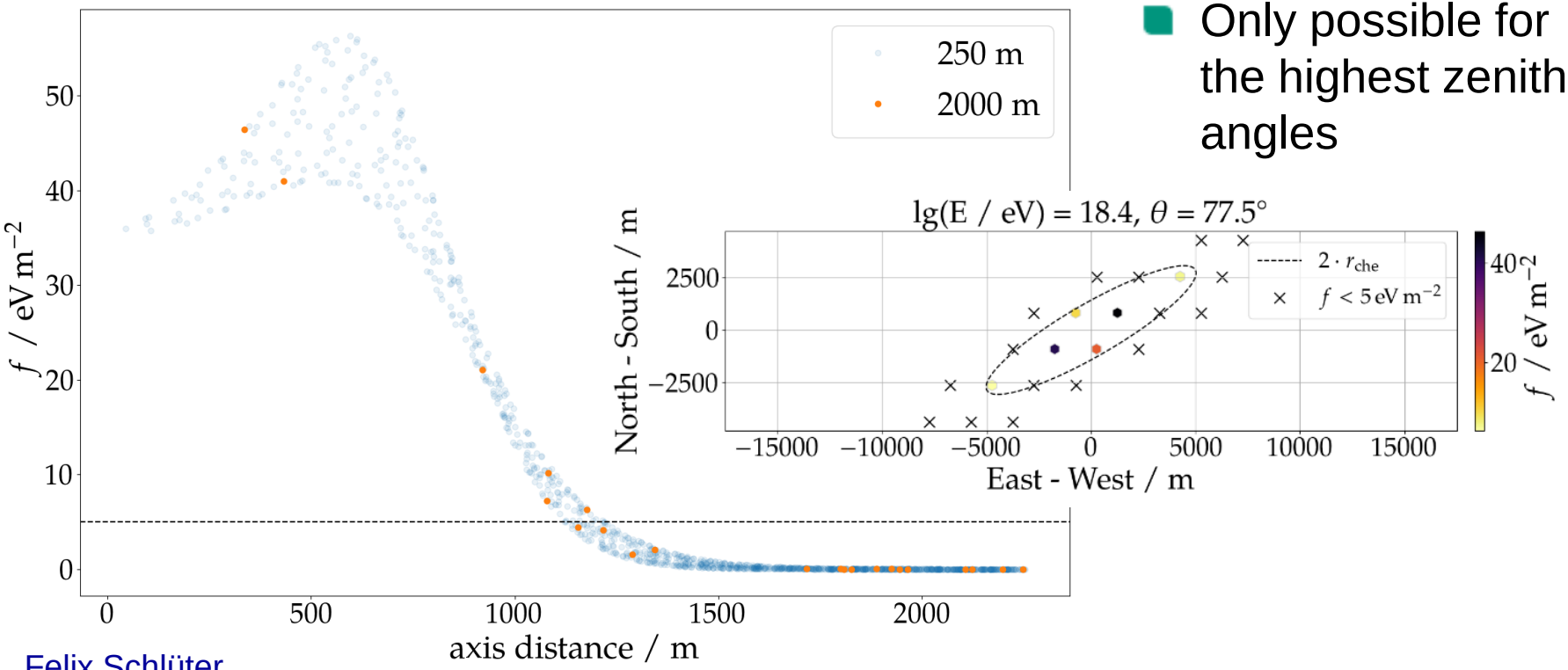
Required detector spacing – inclined showers



- Vertical showers make small footprint with strong signal
- Inclined showers make large footprint with weak signal („emission source far away“)
- Accessible CR energy is directly coupled to zenith angle
  - Low zenith angle, low energy
  - High zenith angle, high energy

TH, A. Haungs, UHECR2014, arXiv:1507.07769.

An air shower at 30-80 MHz on a 2 km grid



- Only possible for the highest zenith angles

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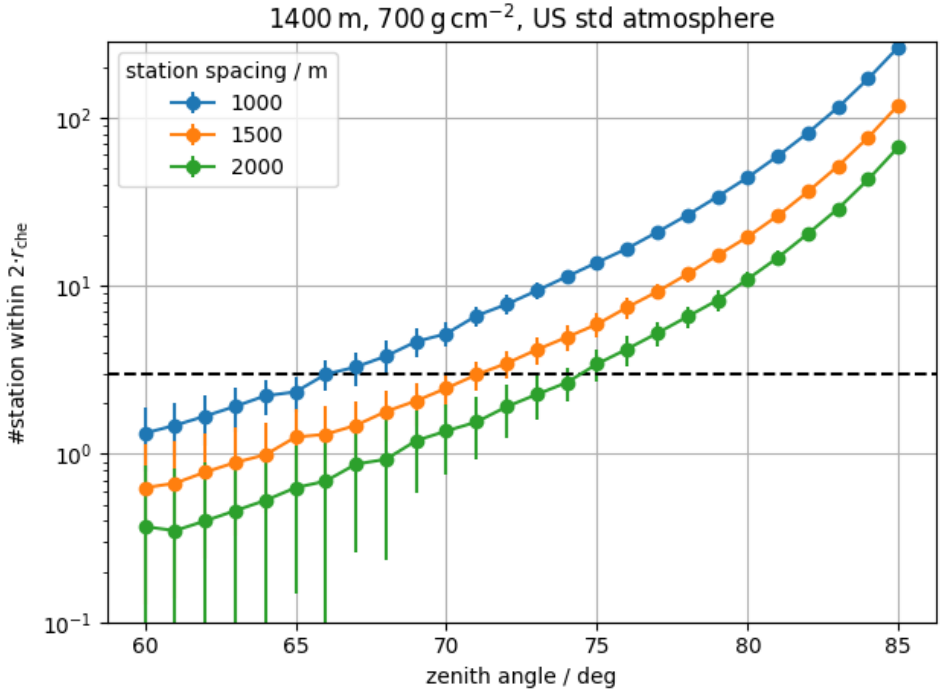
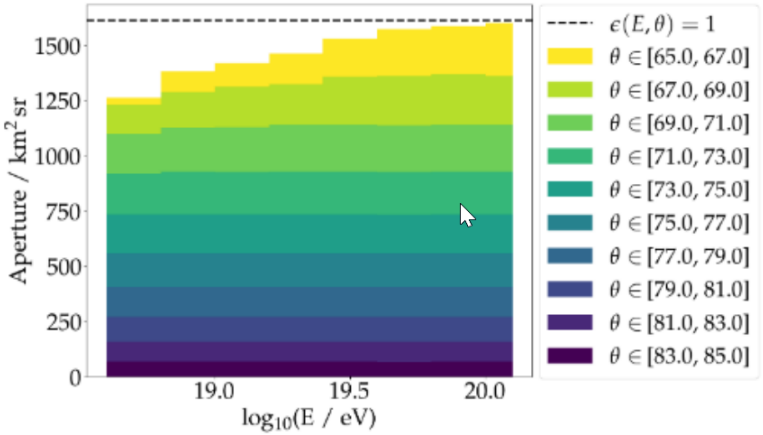
Radio array grid size and zenith angle



- The larger the grid, the higher the needed zenith angle – mind cos(θ)!



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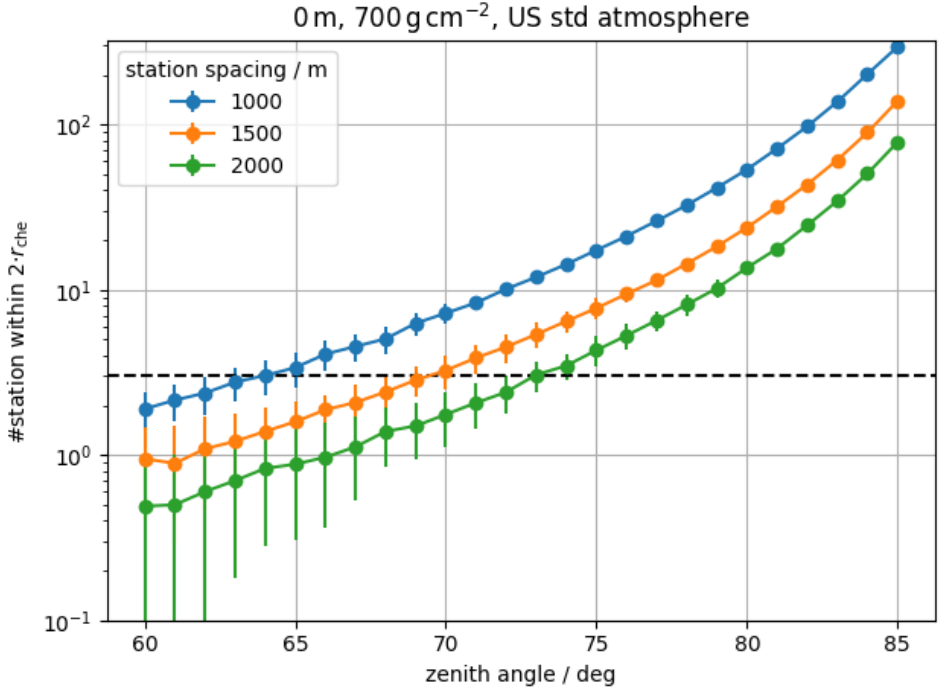
Radio array grid size and zenith angle



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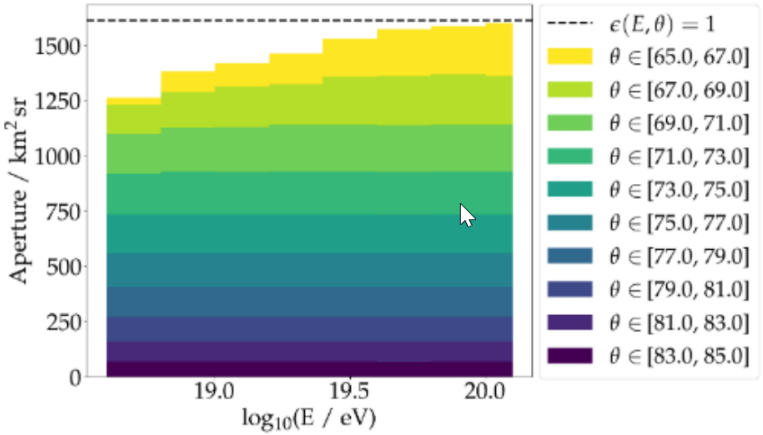

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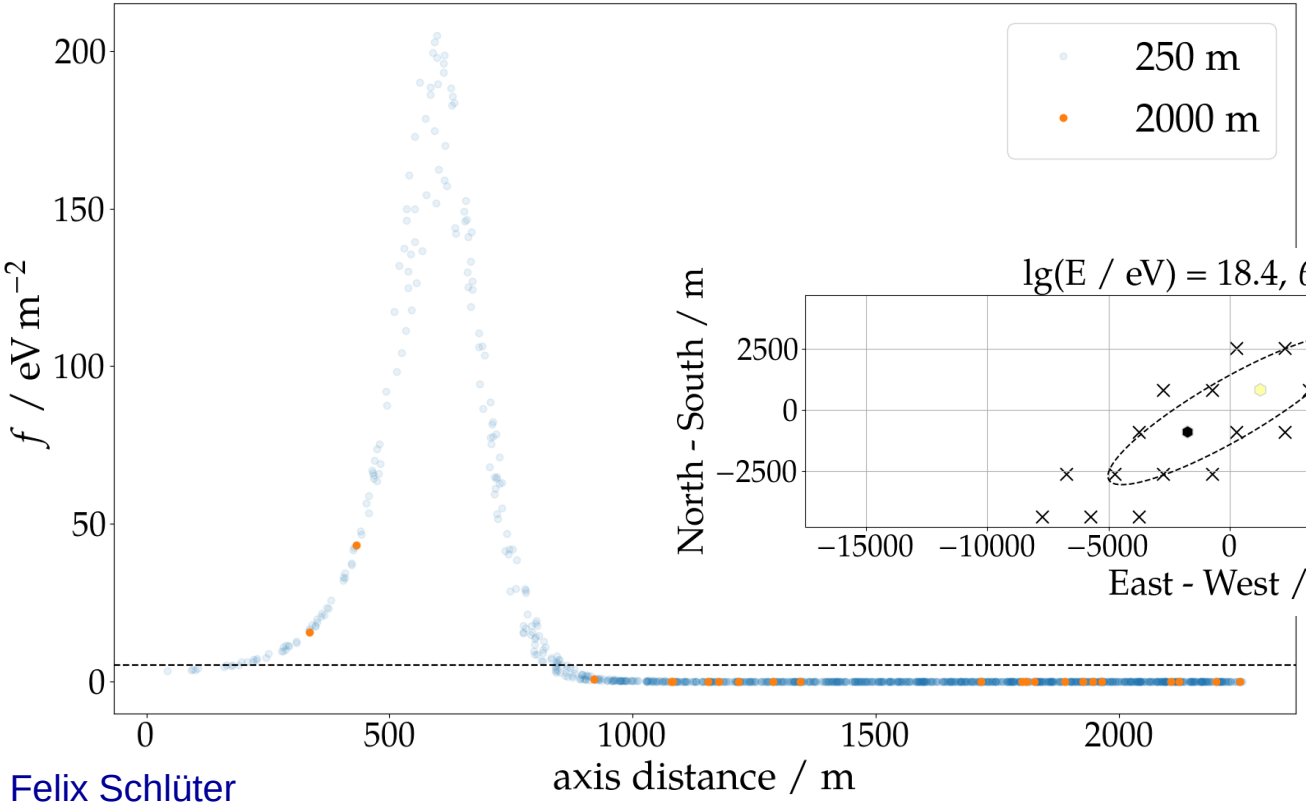
Air shower at 150-350 MHz



- Cherenkov ring becomes very narrow

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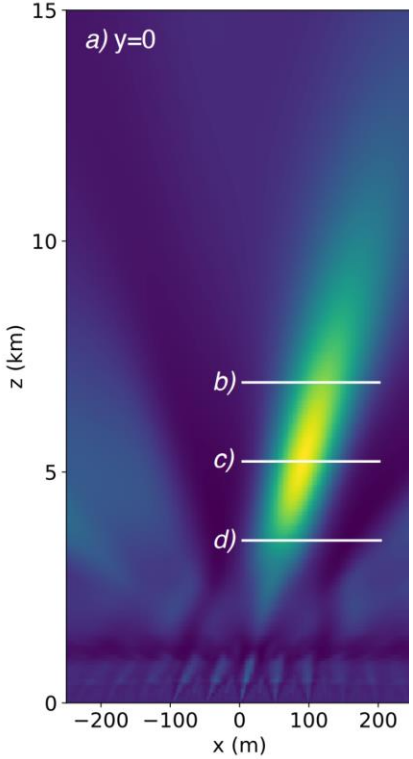
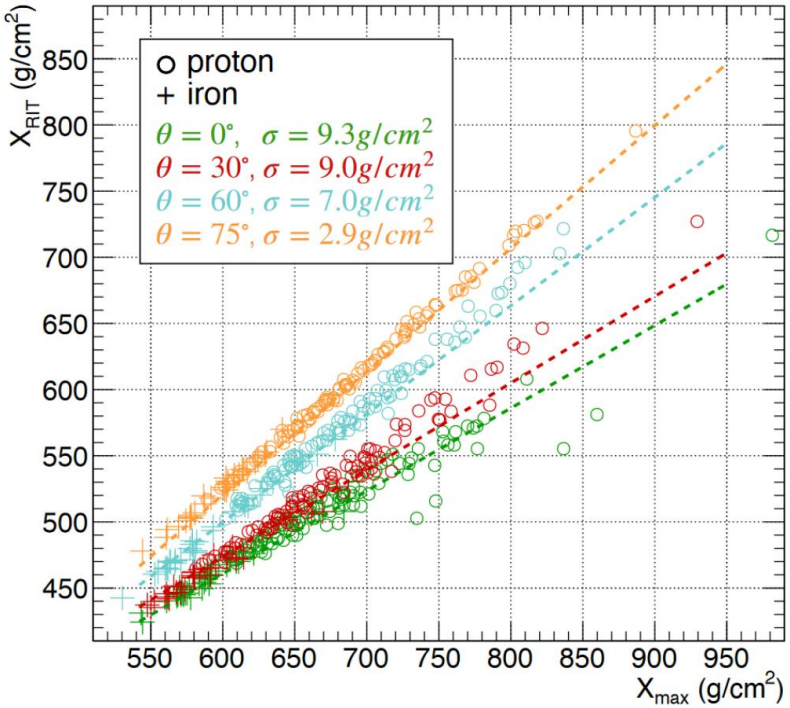
Radio-interferometric technique

Radio-interferometric reconstruction

Interferometric map



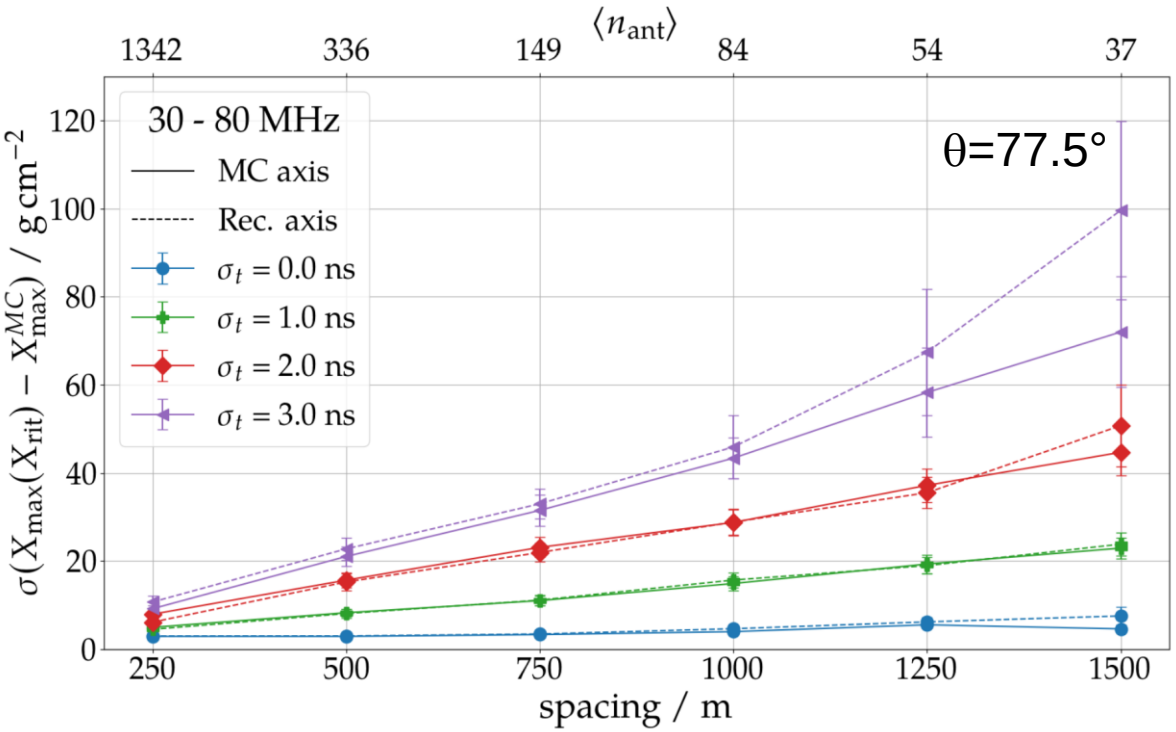
Xmax determination



- Radio pulses contain phase information
- LOPES successfully used interferometry
- Recent simulation study finds superb Xmax resolution for inclined showers
  - We would have N_e, N_μ and Xmax

H. Schoorlemmer, W. de Carvalho, arXiv:2006.10348

RIT under more realistic experimental conditions



- Achievable resolution depends on antenna spacing
- Accurate time synchronization is essential
  - GPS timing (~5 ns) is insufficient
  - Differential GPS good enough?

Felix Schlüter, TH, JINST

What to do in a next-generation experiment?

- „Layered particle detector“ plus Radio antenna
  - Extra cost for Radio is small, likely well below 1000 EUR per station
  - Provides data for mass composition studies, energy scale calibration
  - Tracking of particle detector aging
- If possible, go to frequencies of several 100 MHz, for potential „single-station analysis“ à la ANITA, ARIANNA, lowering thresholds
- If possible, try time synchronization on 1 ns scale (differential GPS, …?)
- Grid beyond 1.5 km seems unfavorable, usefulness of local clusters needs to be properly investigated