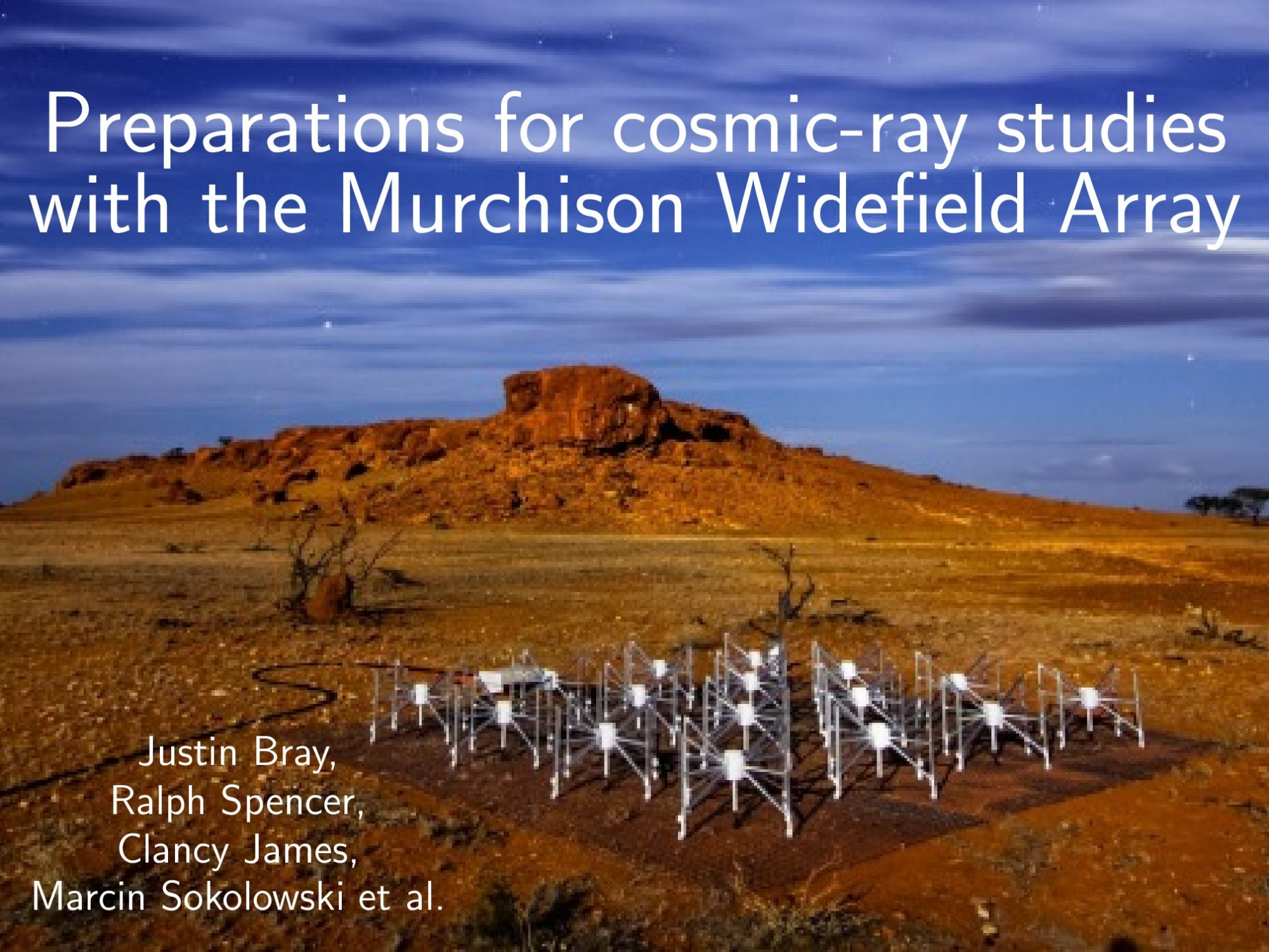
Preparations for cosmic-ray studies with the Murchison Widefield Array



Justin Bray,
Ralph Spencer,
Clancy James,
Marcin Sokolowski et al.

Core idea: use an existing radio telescope

Pros:

- The array already exists, so you don't have to build it.
- Other people are developing it.

Cons:

- The array wasn't built to do what you want to do.
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- LOFAR; other talks
- MWA; this talk
- LWA; Munroe et al. (in prep.)

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Contents:

- the MWA in context
- where we're up to

The MWA as a radio telescope

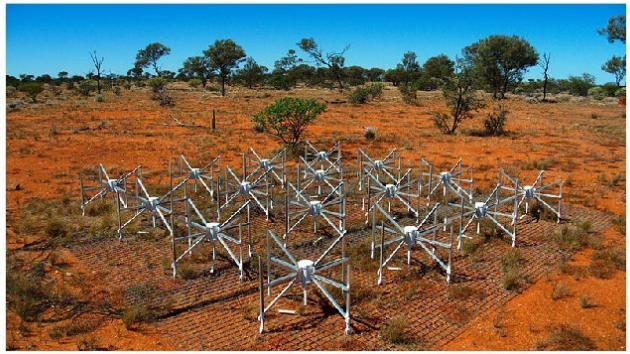
Precursor instrument for the Square Kilometre Array, at the same site.

Closest southern equivalent to LOFAR.

Targets EOR, radio galaxies, transients, heliosphere, ionosphere

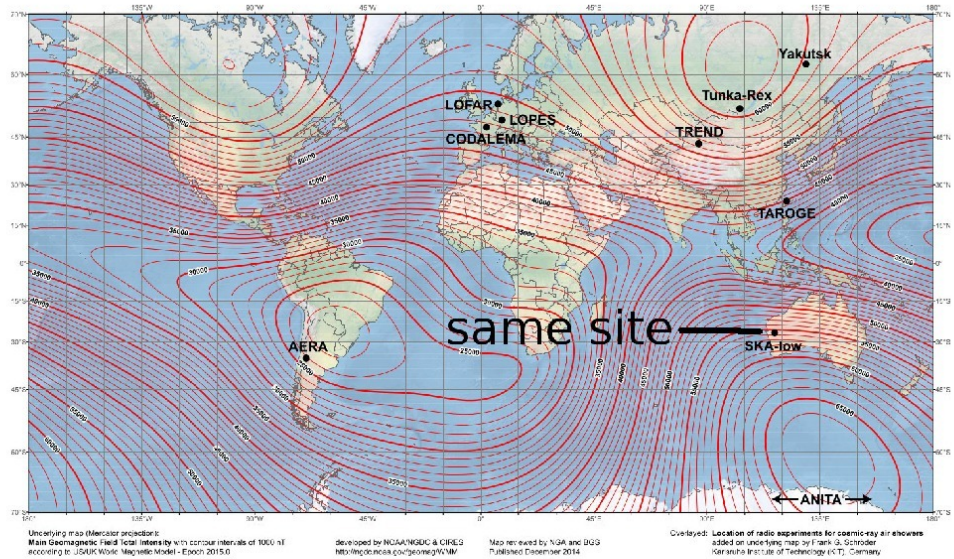
...

- analogue tile beamforming
- coarse filterbank
- return selected channels
- correlate all active tiles



MWA
70–300 MHz
256 tiles

SKA
50–350 MHz
131,072 antennas



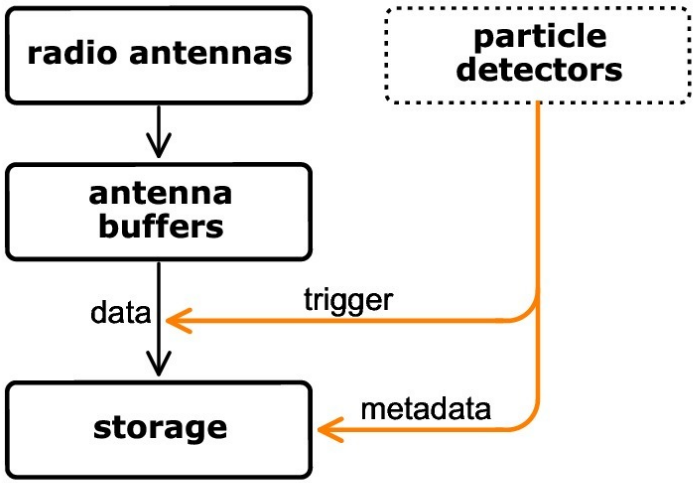
The MWA as a cosmic-ray instrument

Problem #1: analogue beamforming.

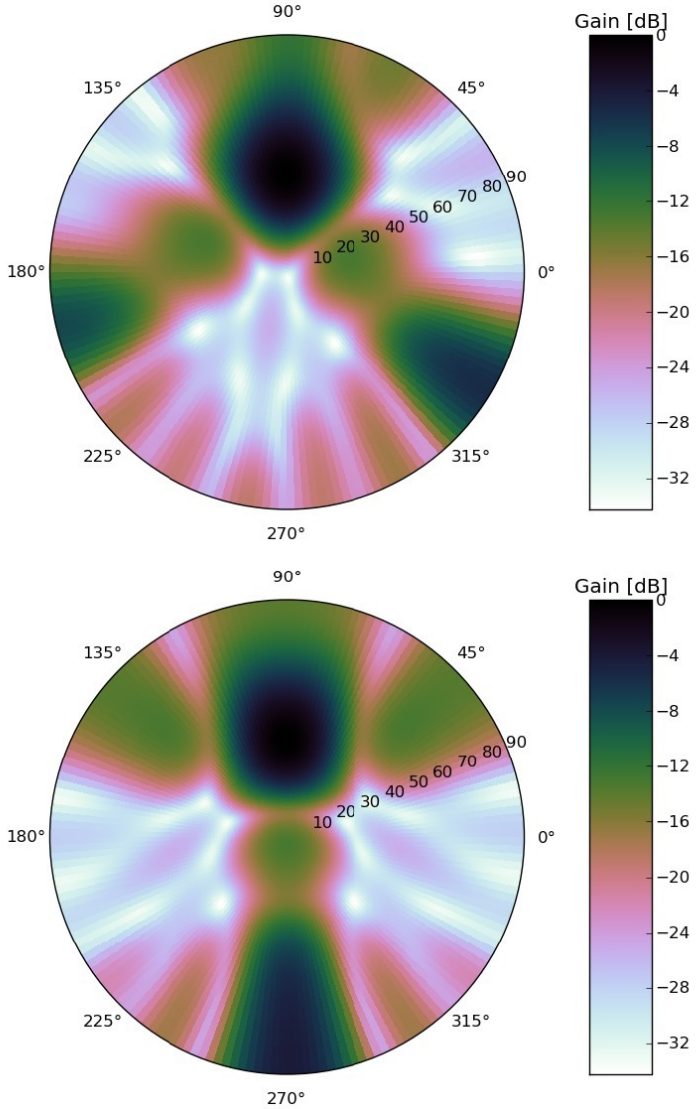
Solution #1: use non-commensal single-antenna feed-through mode.

Problem #2: radio triggering impractical.

Solution #2: particle-detector trigger.



LOFAR-HBA analogue beam



figures: A. Nelles

Array layout & scale

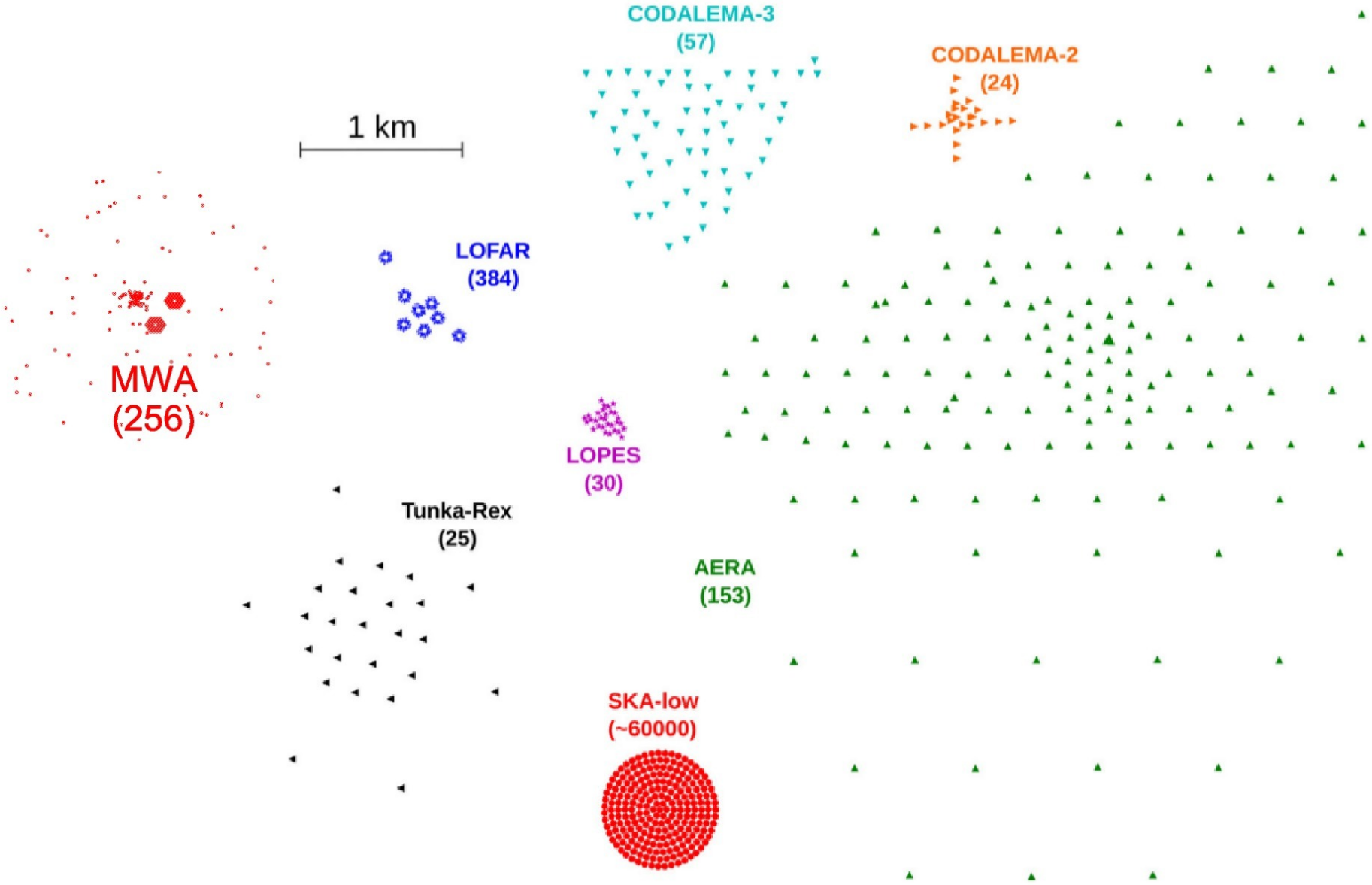
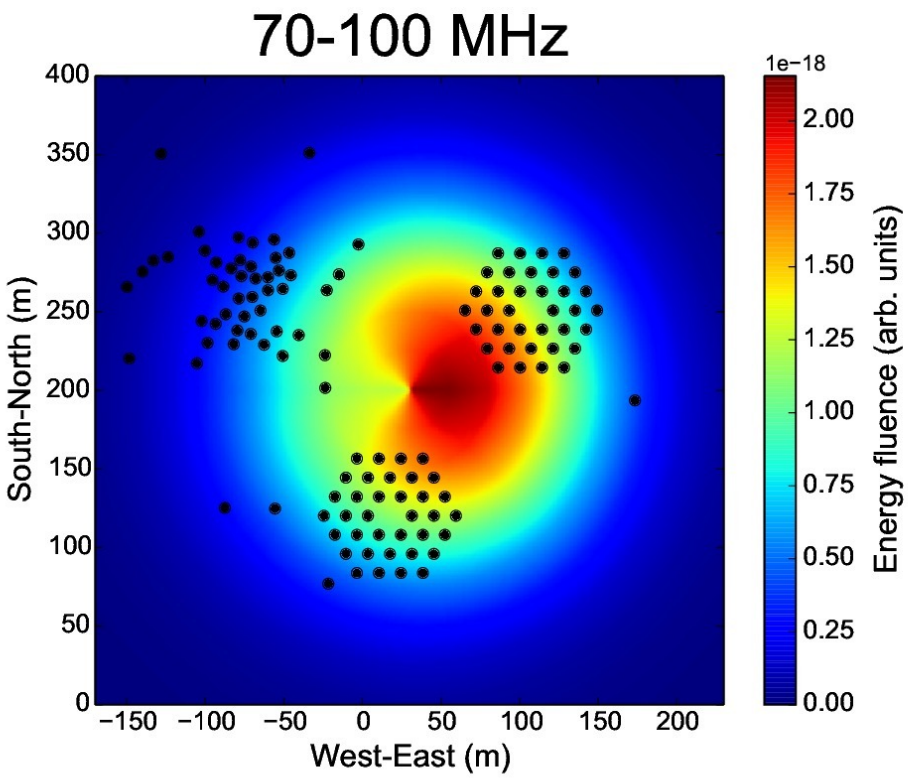
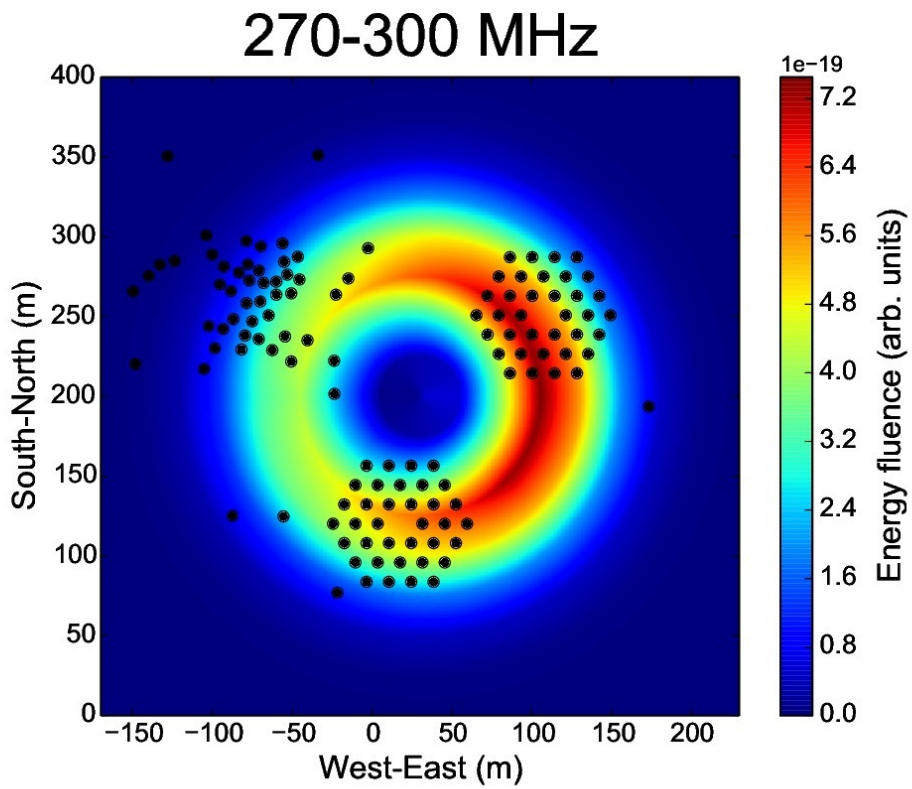


figure: A. Zilles

Array layout versus shower footprint





Shown: vertical shower (smallest footprint)

Simulations from A. Zilles.

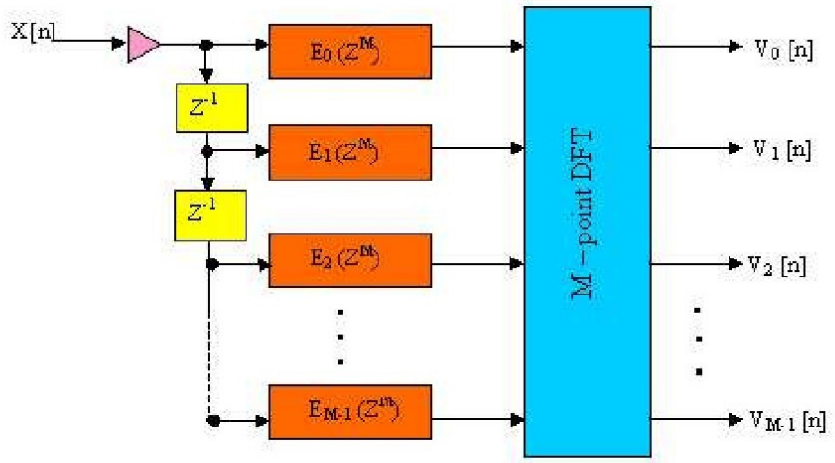
Note: optimal SNR at $\sim$ 100–200 MHz (Balagopal et al., 2018)

Operation modes

1. Tests thus far.
   - two antennas
   - full baseband data
   - radio-triggered
2. Planned operation.
   - all core tiles
   - 24×1.28 MHz channels
   - particle-triggered
3. Future development.
   - all core tiles
   - full baseband data
   - particle-triggered

polyphase filterbank

figure: Singh (2010)

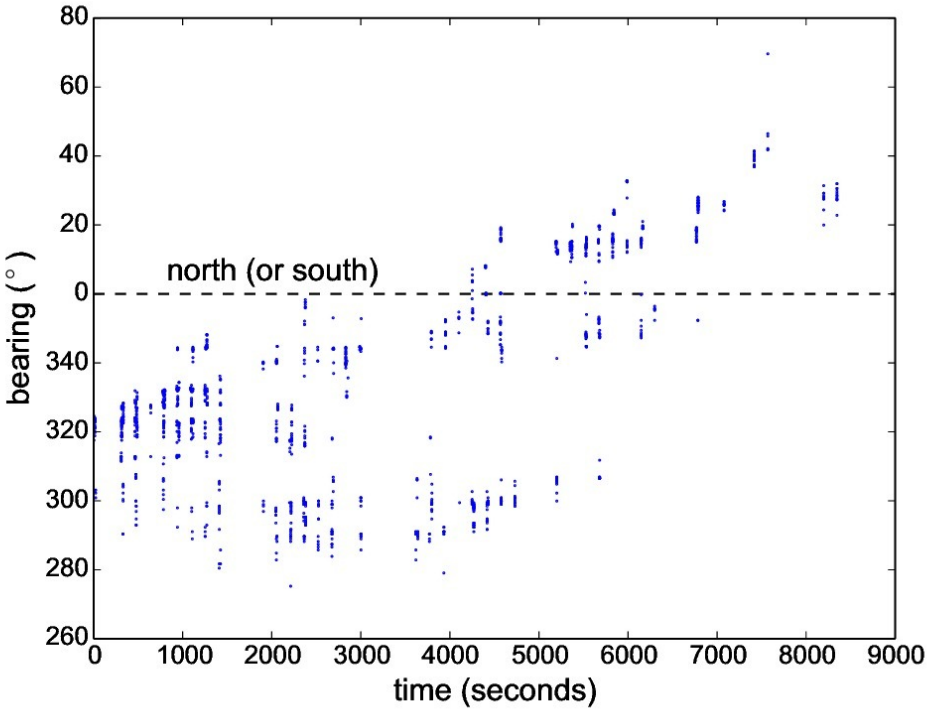


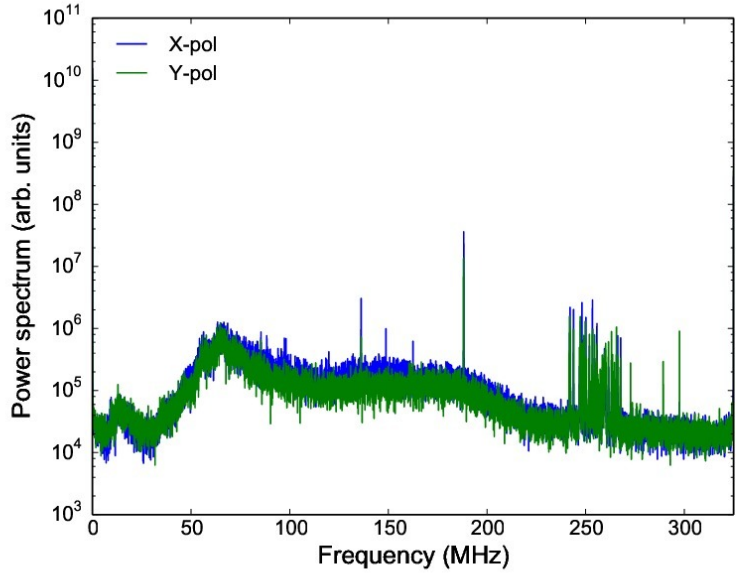
invertible: see Tobias Winchen's talk

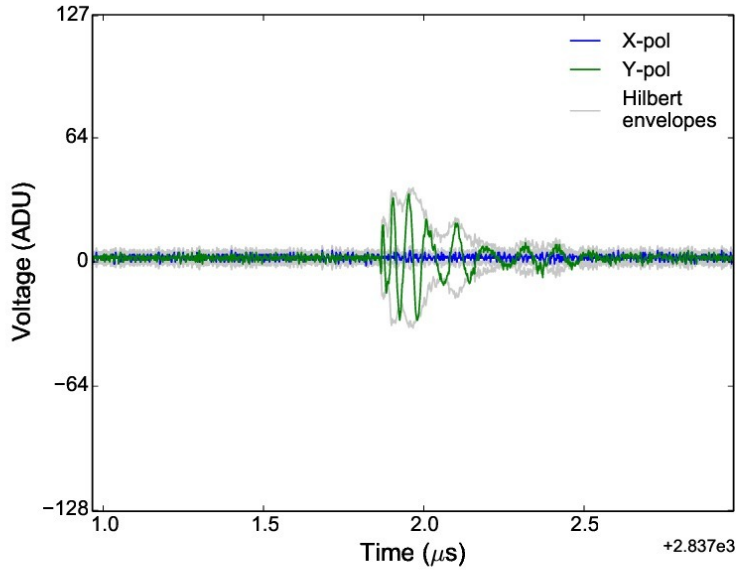
Radio-triggered two-antenna tests

A few hours of radio-triggered data on two antennas.

Enough to sample the noise and RFI environment.







Particle-detector design constraints

SKA regulations on RFI:

- no switched-mode power supplies
- no RF signal cables
- no digital electronics

Also, for MWA:

- 300 m to nearest power
- 6000 m to signal backend

SKA EMI/EMC STANDARDS AND PROCEDURES

Document number	SKA-TEL-SKO-0000202
Context	AG-RFI
Revision	01
Author	Peter Dewdney and Gie Han Tan
Date	2015-01-10
Document Classification	UNRESTRICTED
Status	Released

Name	Designation	Affiliation	Signature
Owned by:			
P. Dewdney	SKA Deputy Architect	SKAO	Peter Dewdney (Jan 22, 2015) Jan 22, 2015
Approved by:			
T. Cornwell	SKA Architect	SKAO	Jan 22, 2015
Released by:			
A. McPherson	Head of Project	SKAO	Jan 23, 2015

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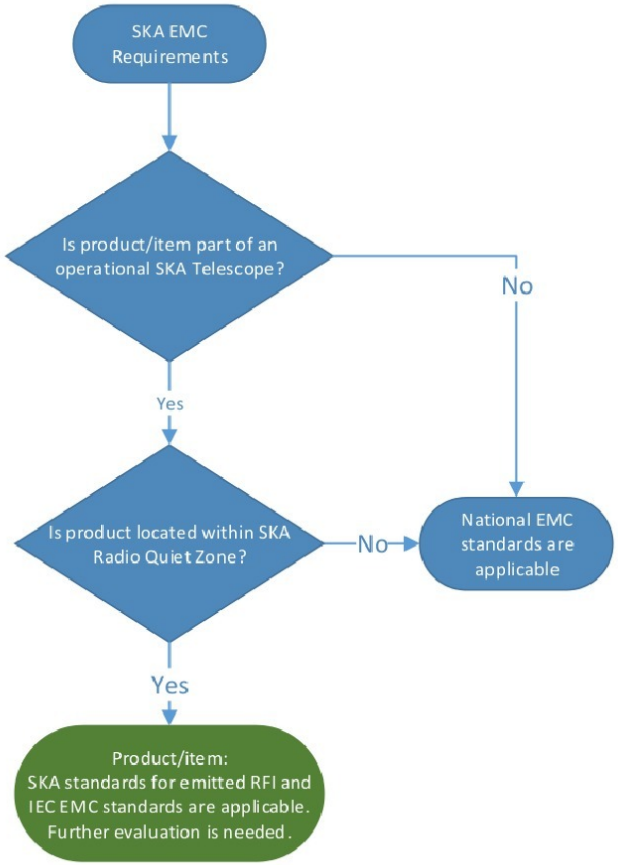

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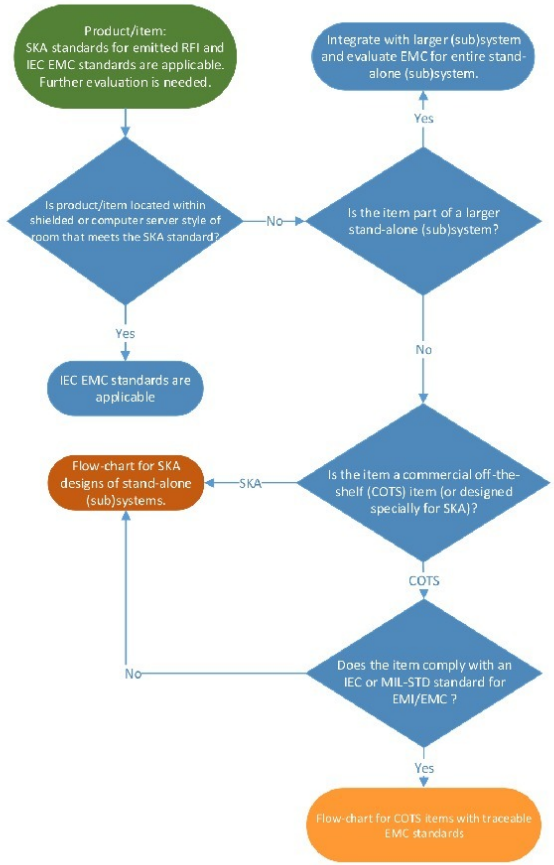

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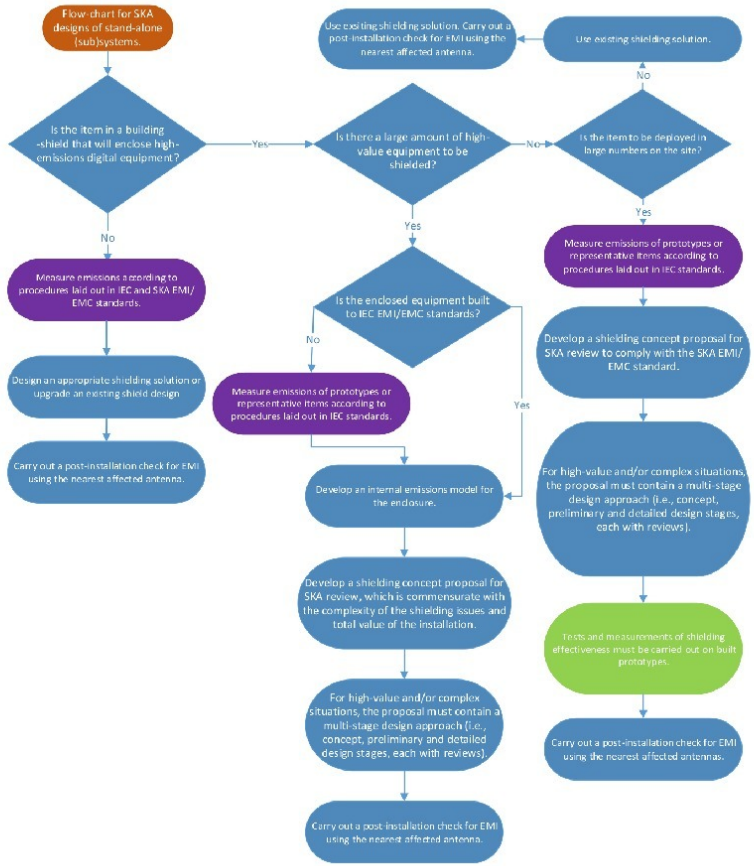

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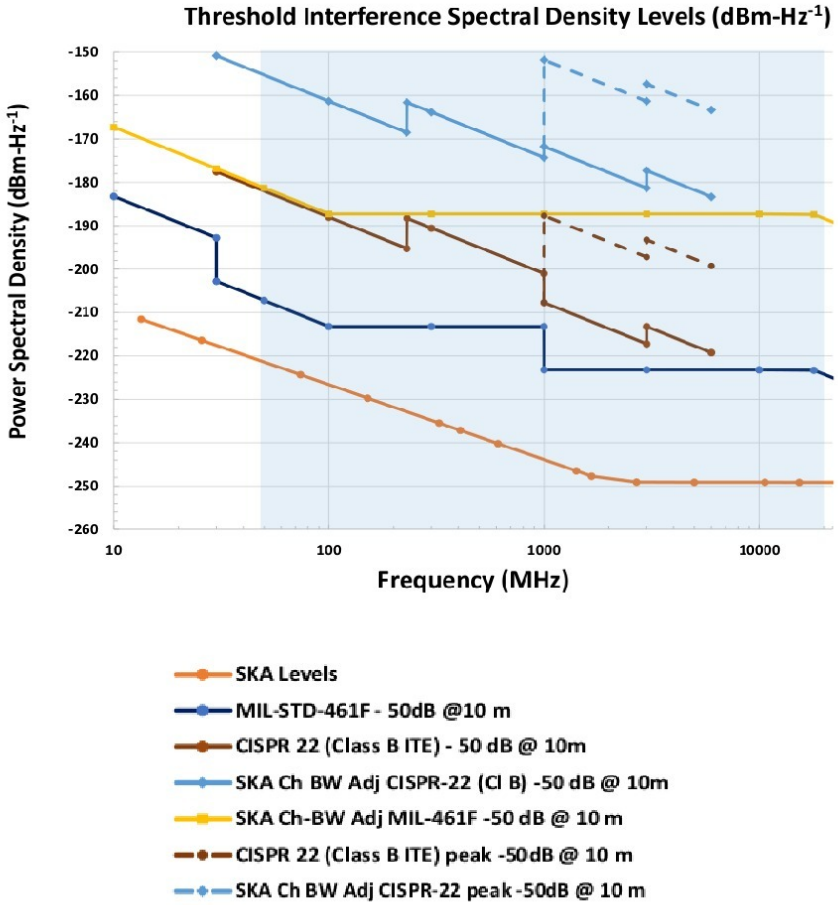
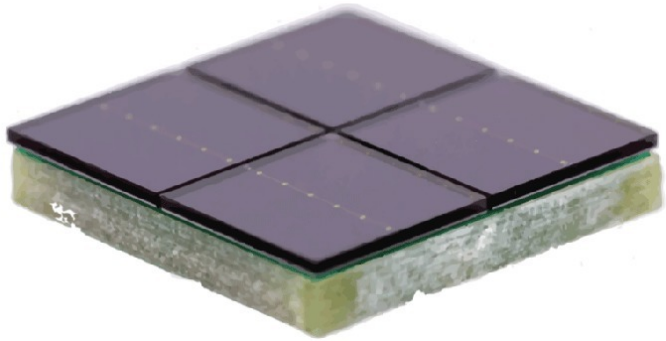


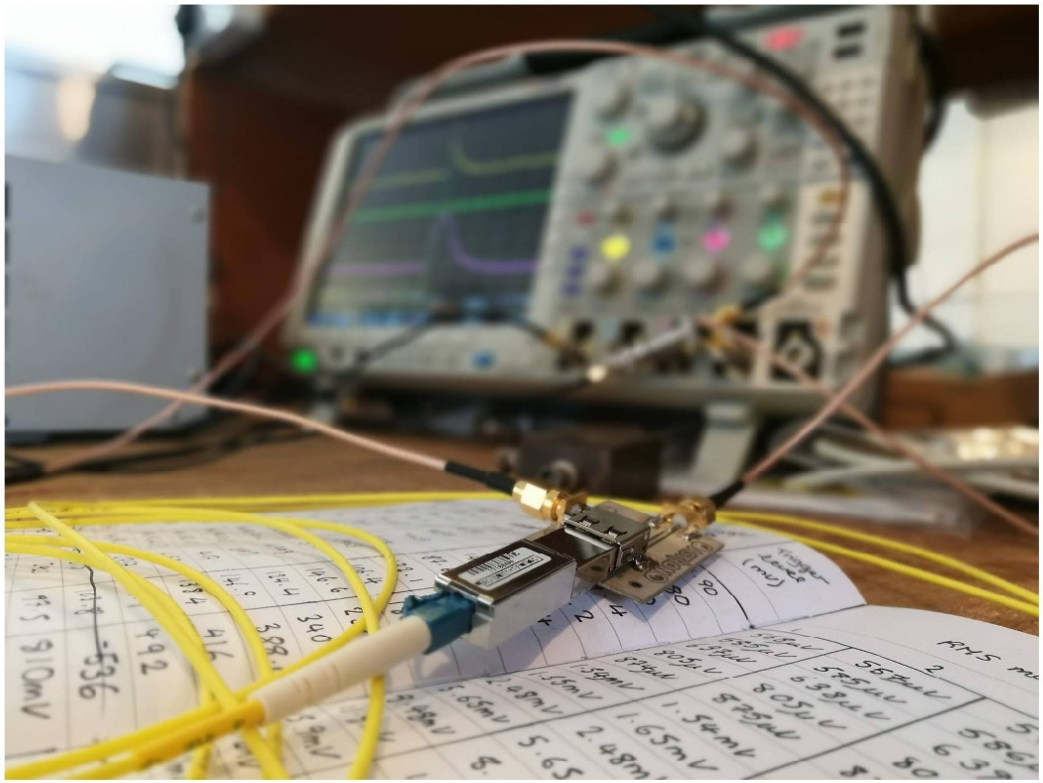
Technologies

Silicon photomultiplier (SiPM) for optic pulse detection (low power, robust).

RF-over-fibre signal (long range, no RFI).

DC power from remote supply; feedback loop to control gain.





Histogram of output amplitude:

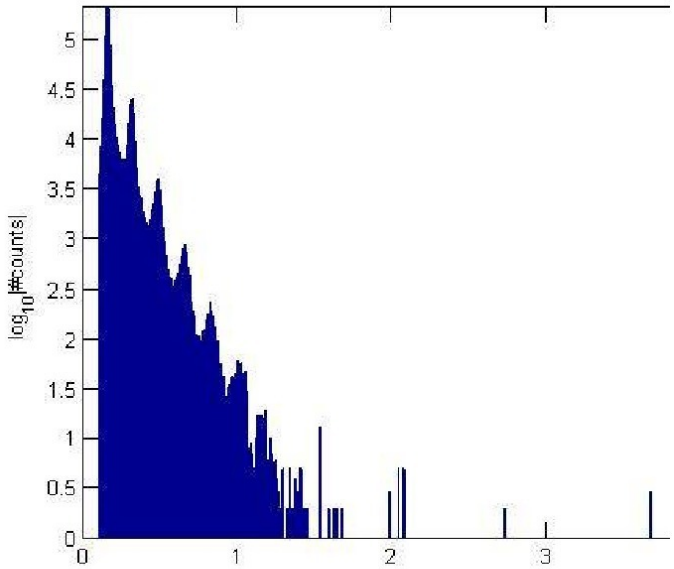
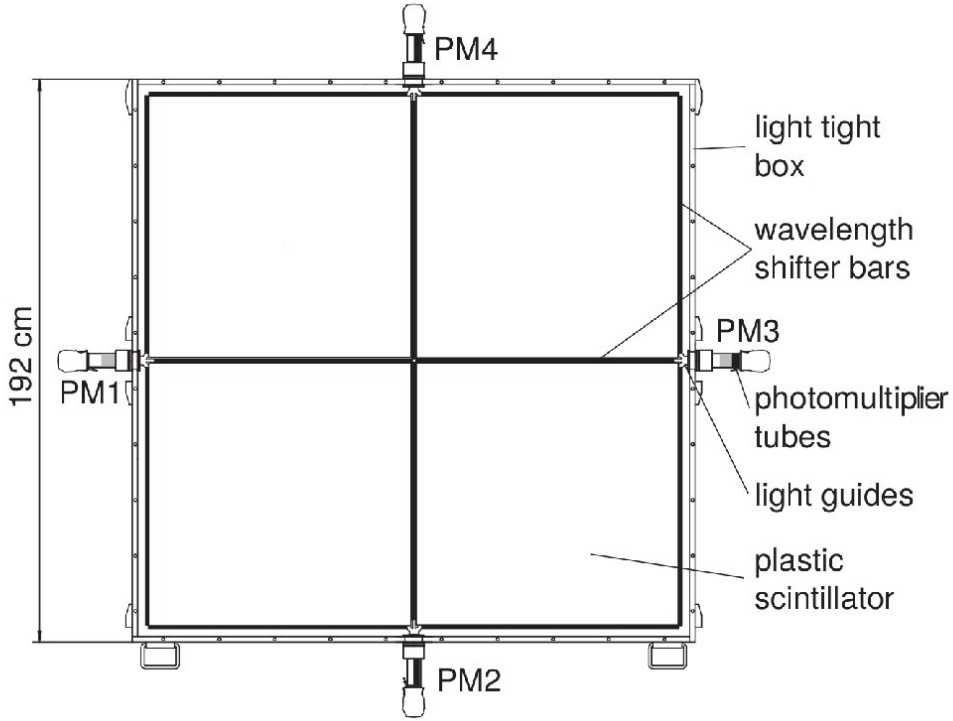


figure: B. Cropper & T. Howland

Our starting point



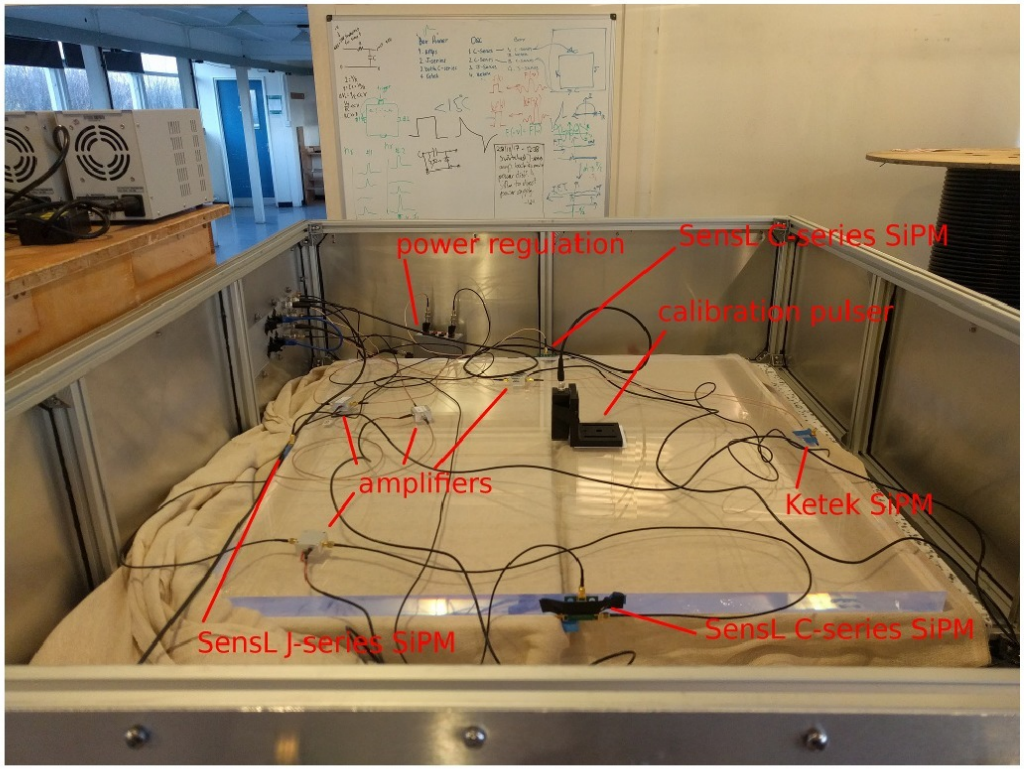
Antoni et al., NIMA 513 (2003), 490

Scintillator module.

One of $\sim$ 200 from KASCADE experiment.

Kindly provided by A. Haungs et al., Karlsruhe.

Our current prototype



benchtop prototype
(field prototype under construction;
deployment later this year)

Working:

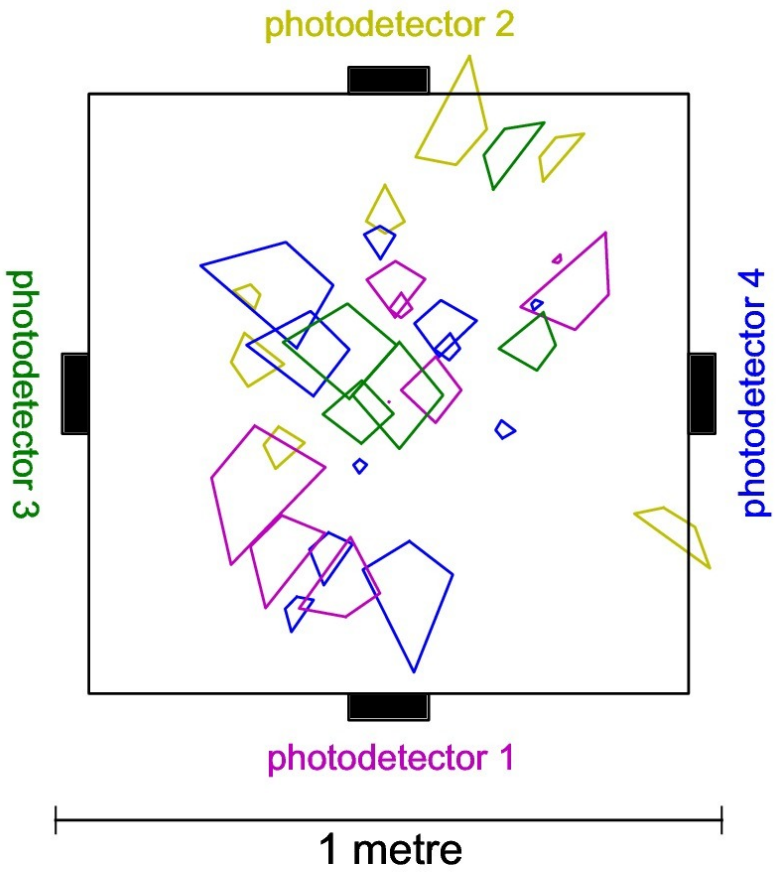
- power-regulation board
- photodetector board
- event reconstruction

In progress:

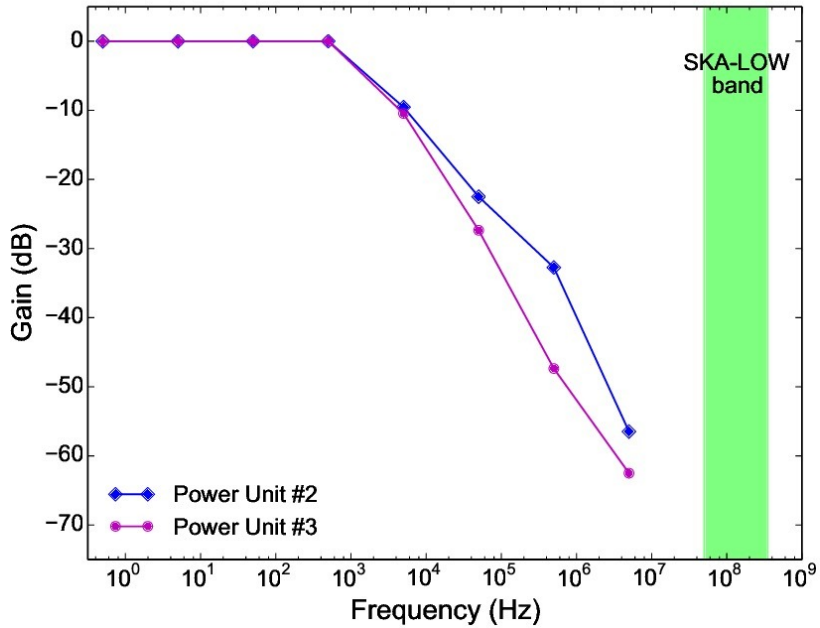
- amplifier feedback loop
- delay multiplexing
- improving sensitivity

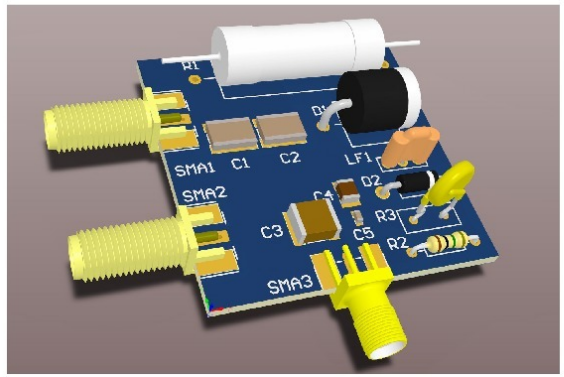
Recent results

positional reconstruction of events



RFI isolation of power-regulation board





Conclusions

The MWA is a potential radio cosmic-ray instrument with a dense antenna array and broad frequency coverage.

Much work is required to properly exploit it, but this has begun.

Pathfinder for the SKA: shares location & infrastructure.

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Thank you for your attention.