

Science Update from the Cosmic Ray Key Science Project

LOFAR Cosmic Ray Key Science Project:

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S. Thoudam, P. Schellart, O. Scholten, S. ter Veen,
M. Van de Akker

Anna Nelles

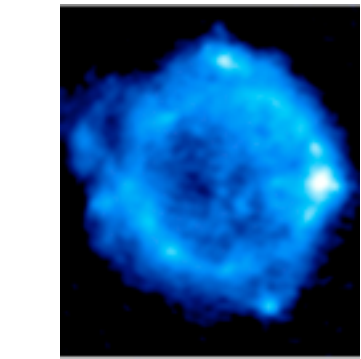
Radboud University Nijmegen



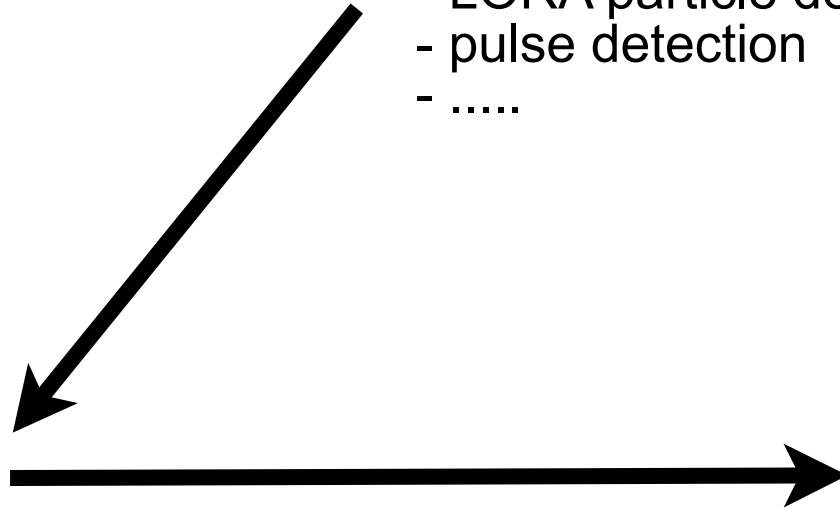
TBB data taking

Trigger

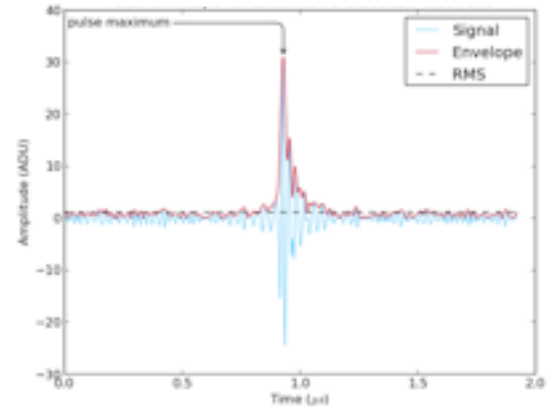
- LORA particle detector
- pulse detection
-



Ongoing observation



Read-out
Buffers (TBBs)



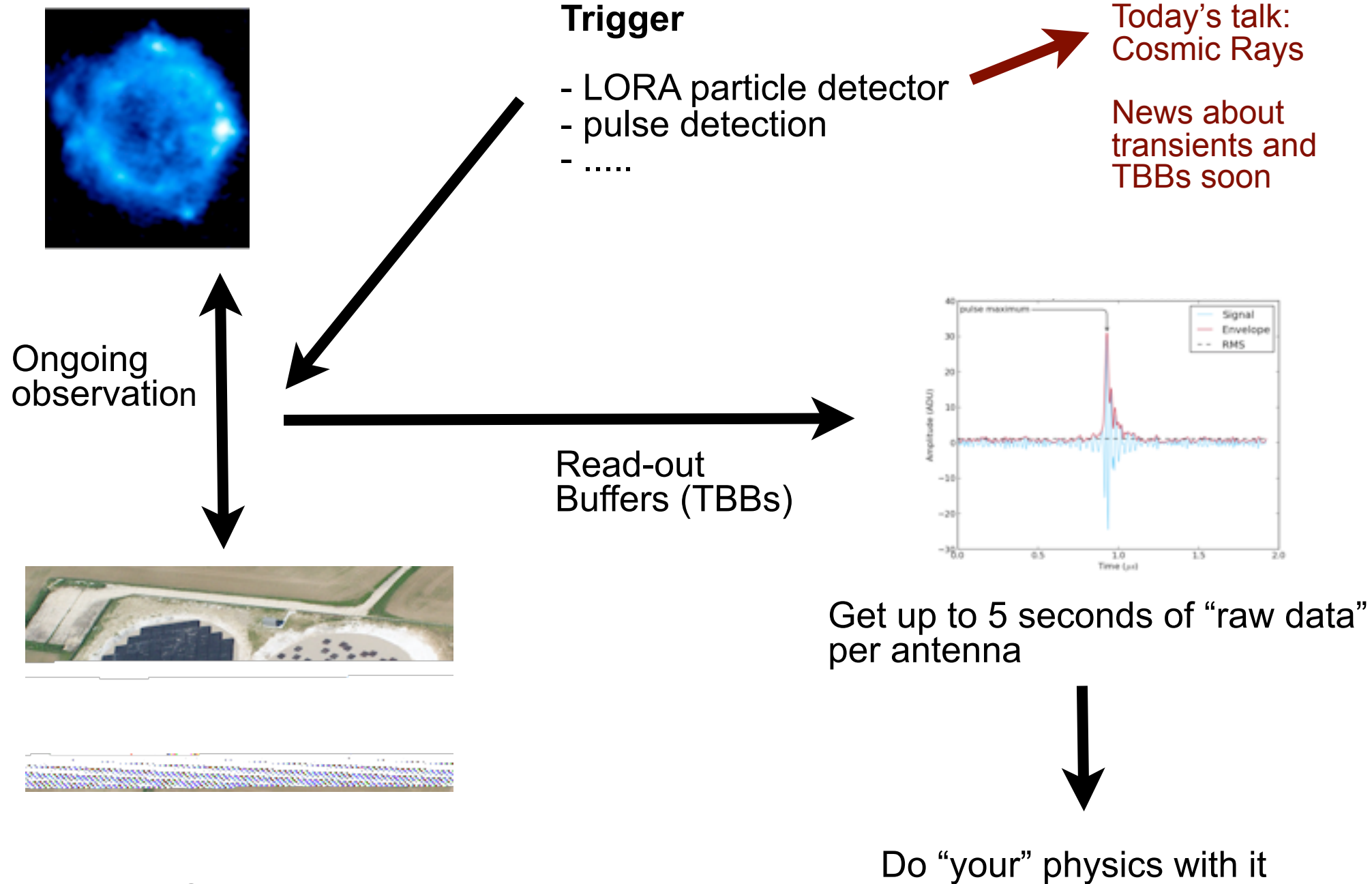
Get up to 5 seconds of “raw data”
per antenna



Do “your” physics with it

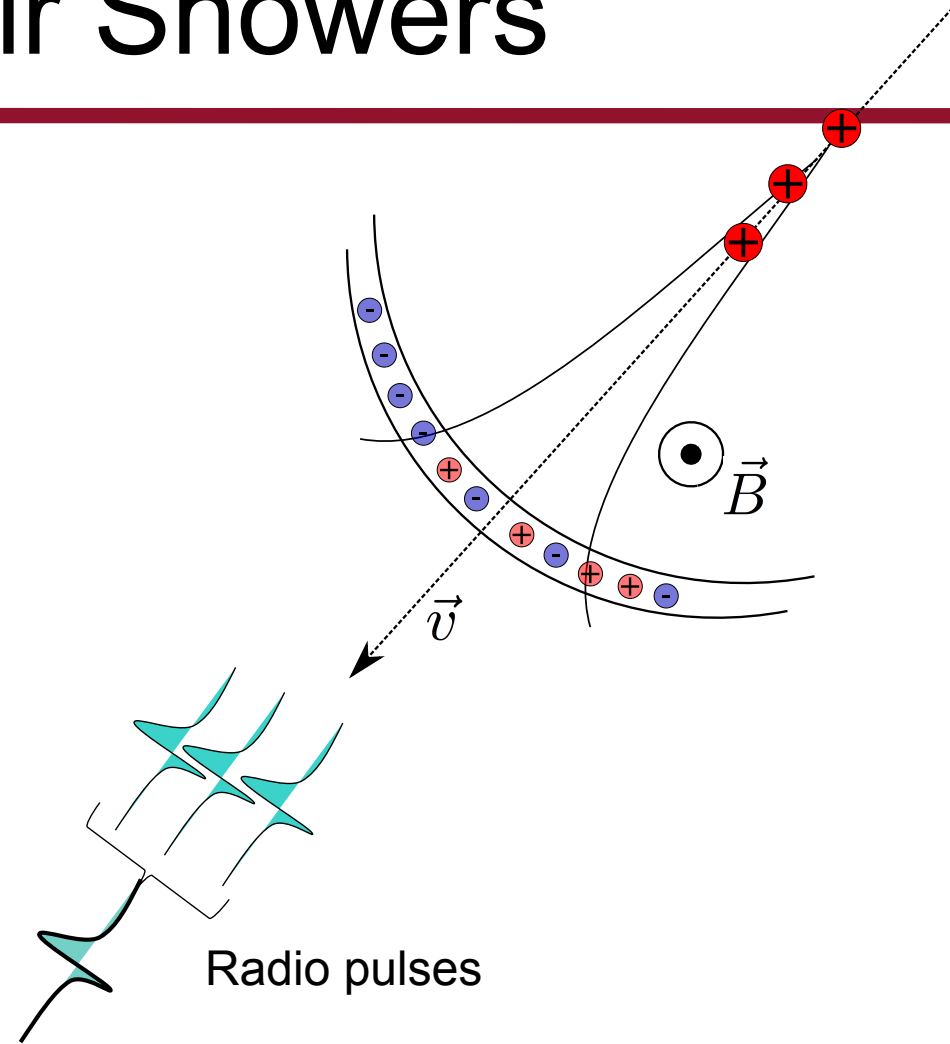
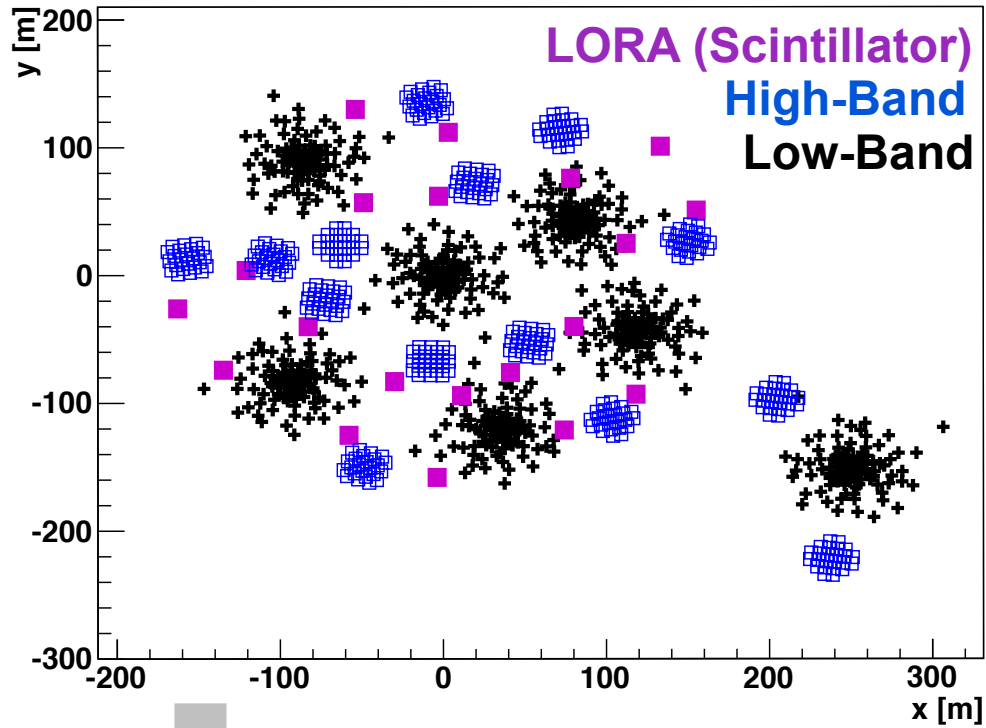


TBB data taking



Measuring Air Showers

Central Core of LOFAR



Using the LBAs

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**Astronomy
&
Astrophysics**

Detecting cosmic rays with the LOFAR radio telescope

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ABSTRACT

The low frequency array (LOFAR), is the first radio telescope designed with the capability to measure radio emission from cosmic-ray induced air showers in parallel with interferometric observations. In the first ~ 2 years of observing, 405 cosmic-ray events in the energy range of 10^{16} – 10^{18} eV have been detected in the band from 30–80 MHz. Each of these air showers is registered with up to ~ 1000 independent antennas resulting in measurements of the radio emission with unprecedented detail. This article describes the detect, as well as the analysis pipeline, and names of

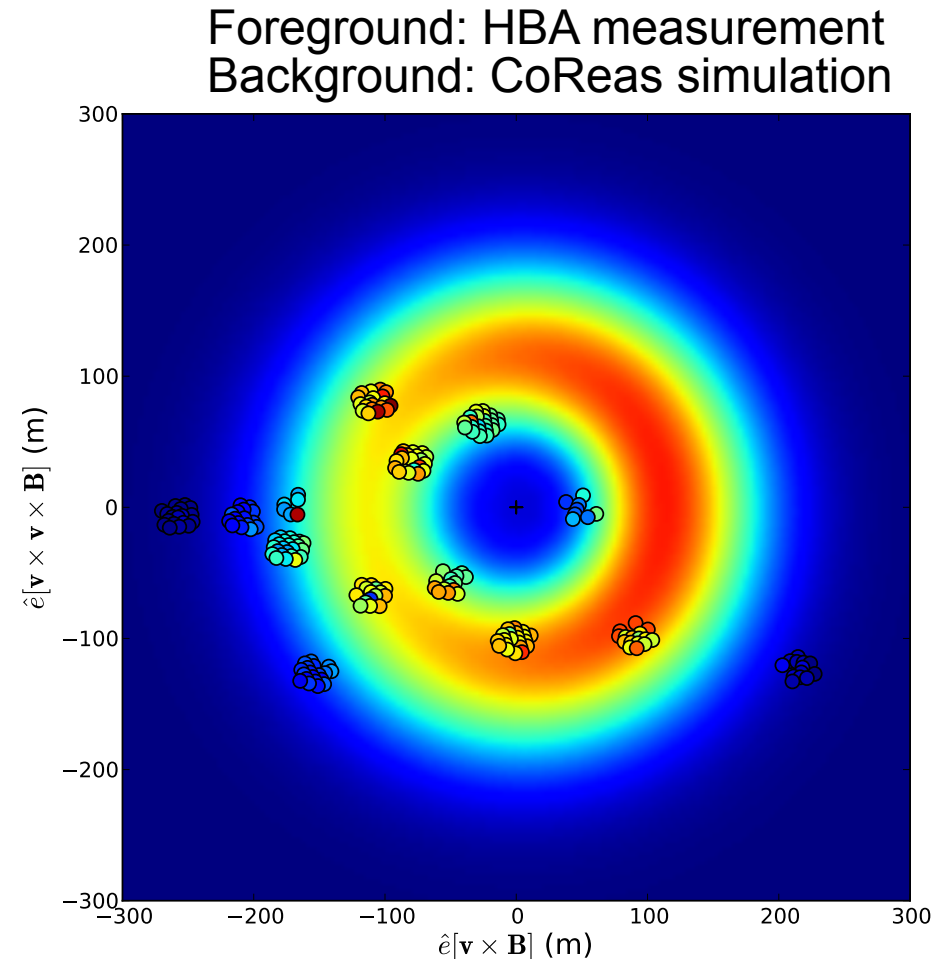
Using the HBAs

- Article currently under review at LOFAR publications committee

Main result:

- Cherenkov ring (enhanced emission, due to refractive index of air) measured
 - **First experiment to do so**
- Cherenkov ring probably sensitive to type of particle

(A. Nelles, P. Schellart et al, Measuring a Cherenkov ring in the radio emission from air showers at 110-230 MHz with LOFAR, to be submitted to Astroparticle Physics)

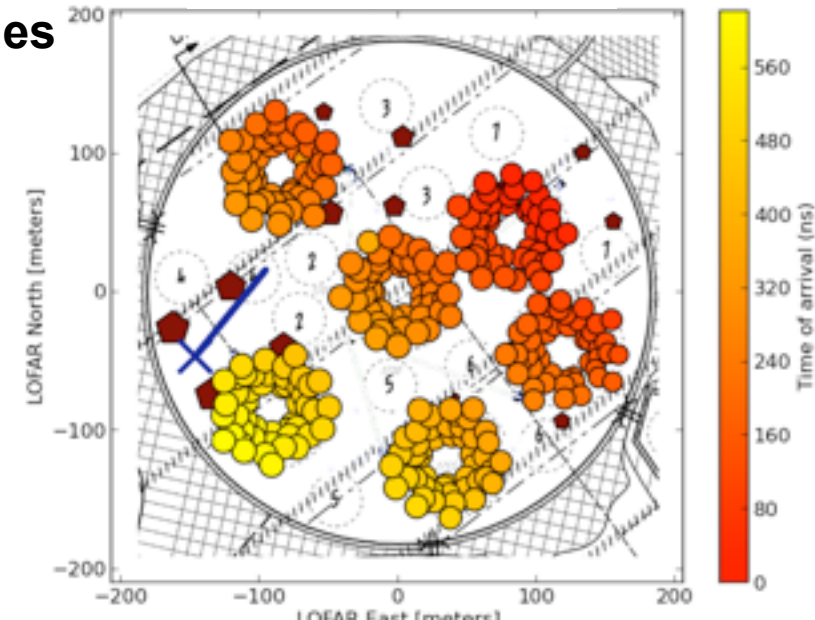


Wavefront Curvature

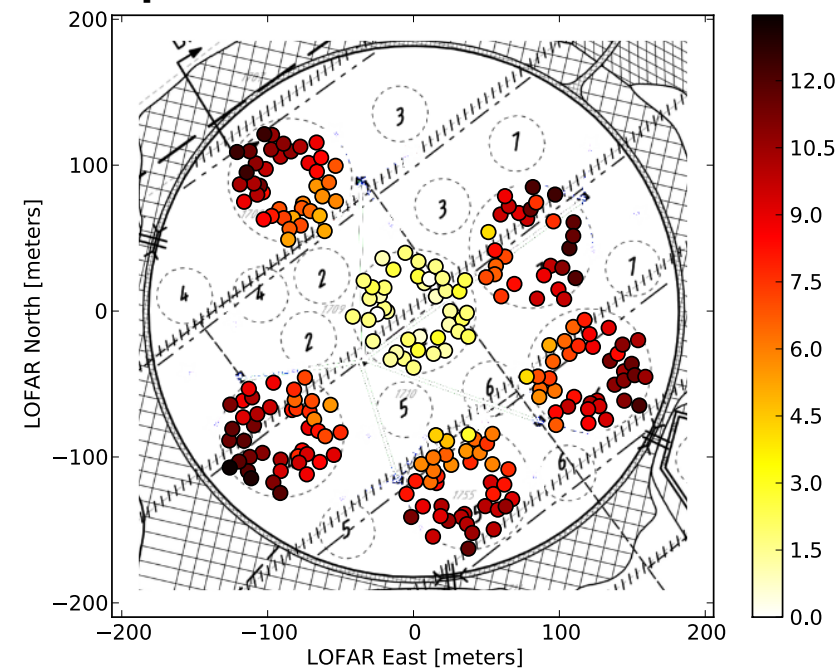
What is the shape of the wavefront?

- subtracting the plane wavefront solution
- treating curvature as a perturbation gives ~ 6 ns delays at edge of the array
- this can be directly measured with LOFAR
- result: wavefront hyperbolic
- Shape might be measure of X_{\max} , independent of pulse power

Arrival Times



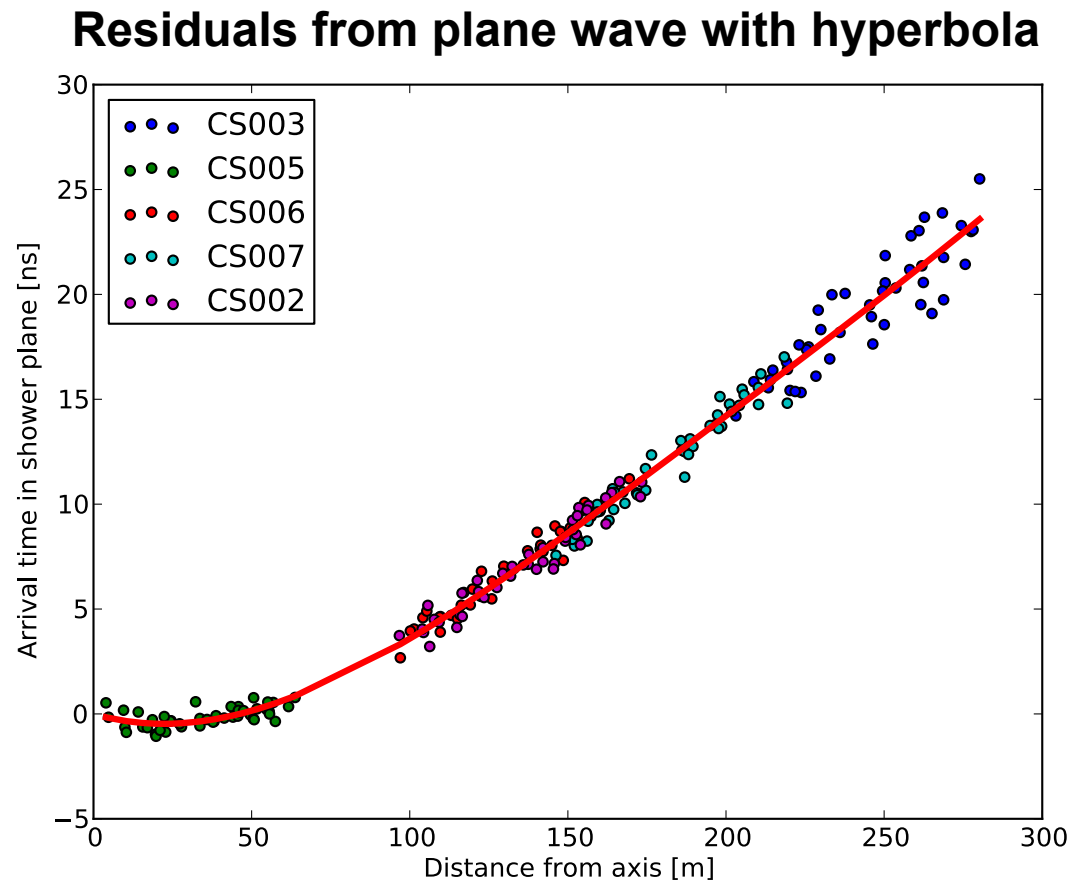
Residuals from plane wave



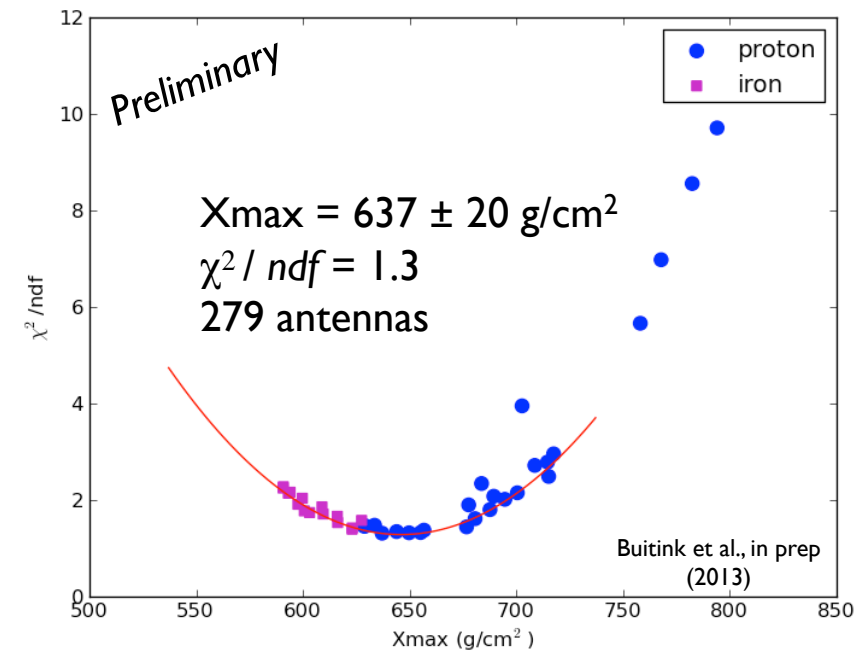
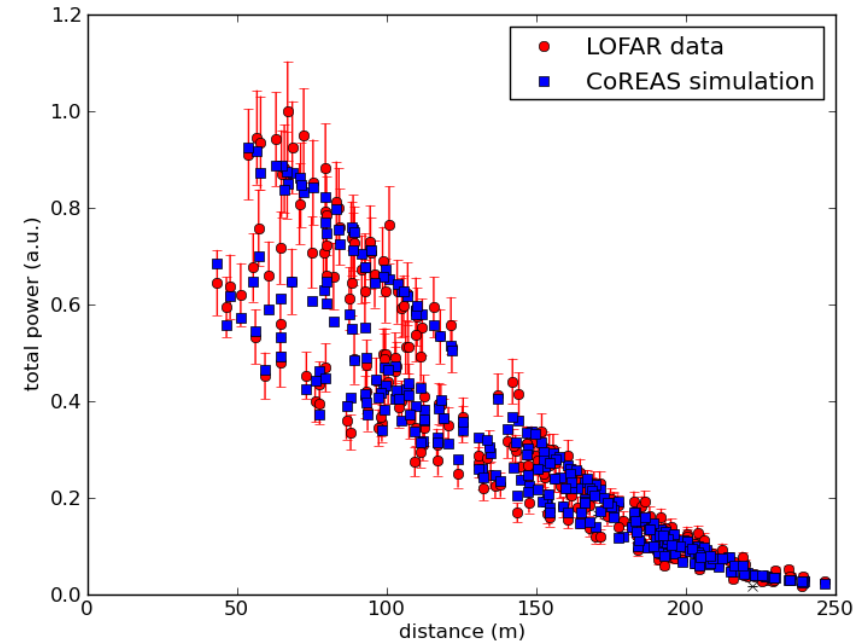
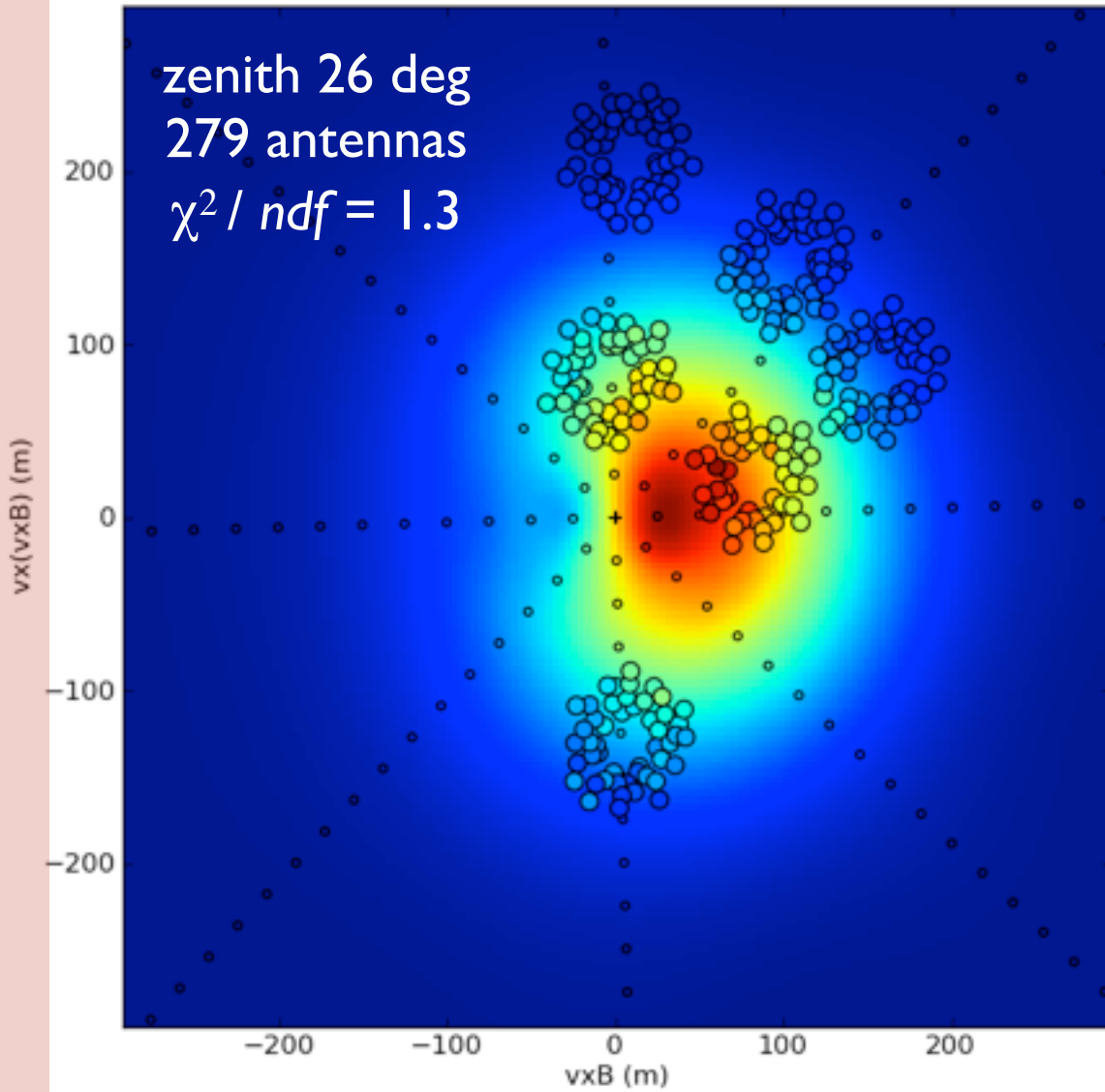
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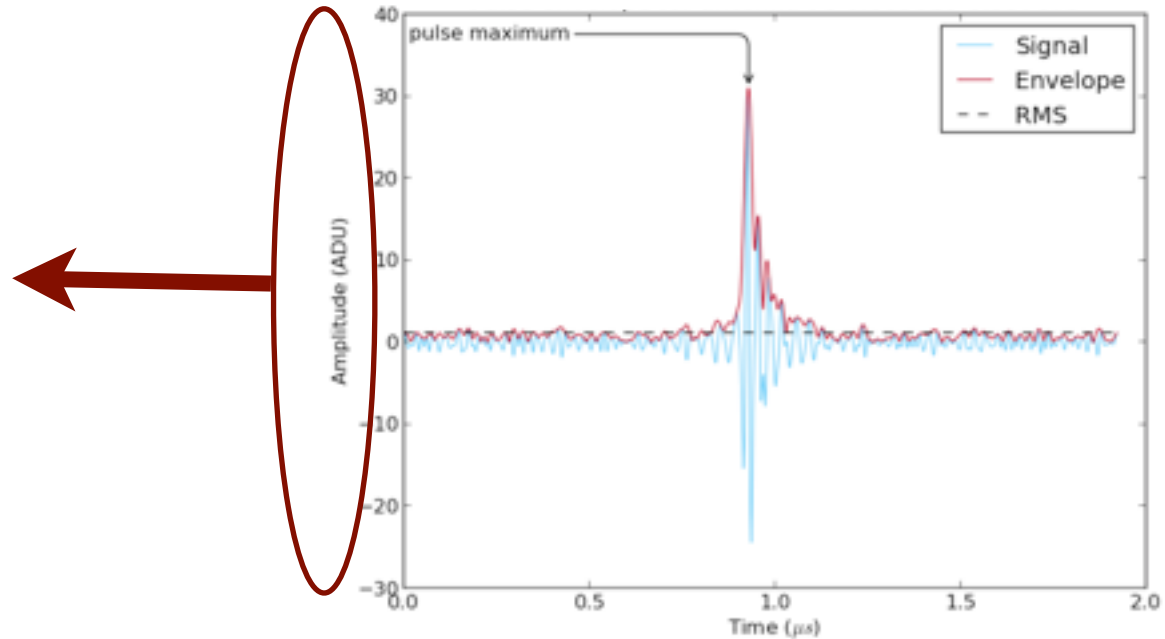
Resolving Xmax



Open Issues

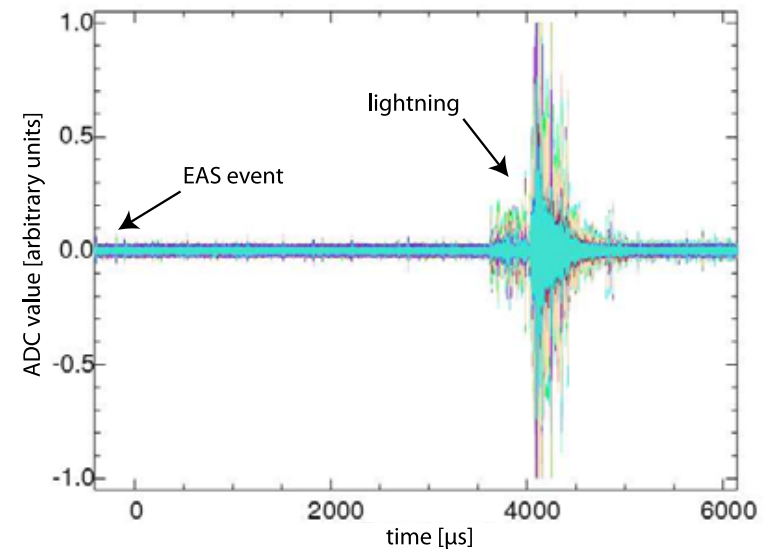
Absolute Calibration

- V/m instead of ADU
- needed for comparison to other experiments
- => cross-calibration with antenna from other experiment planned

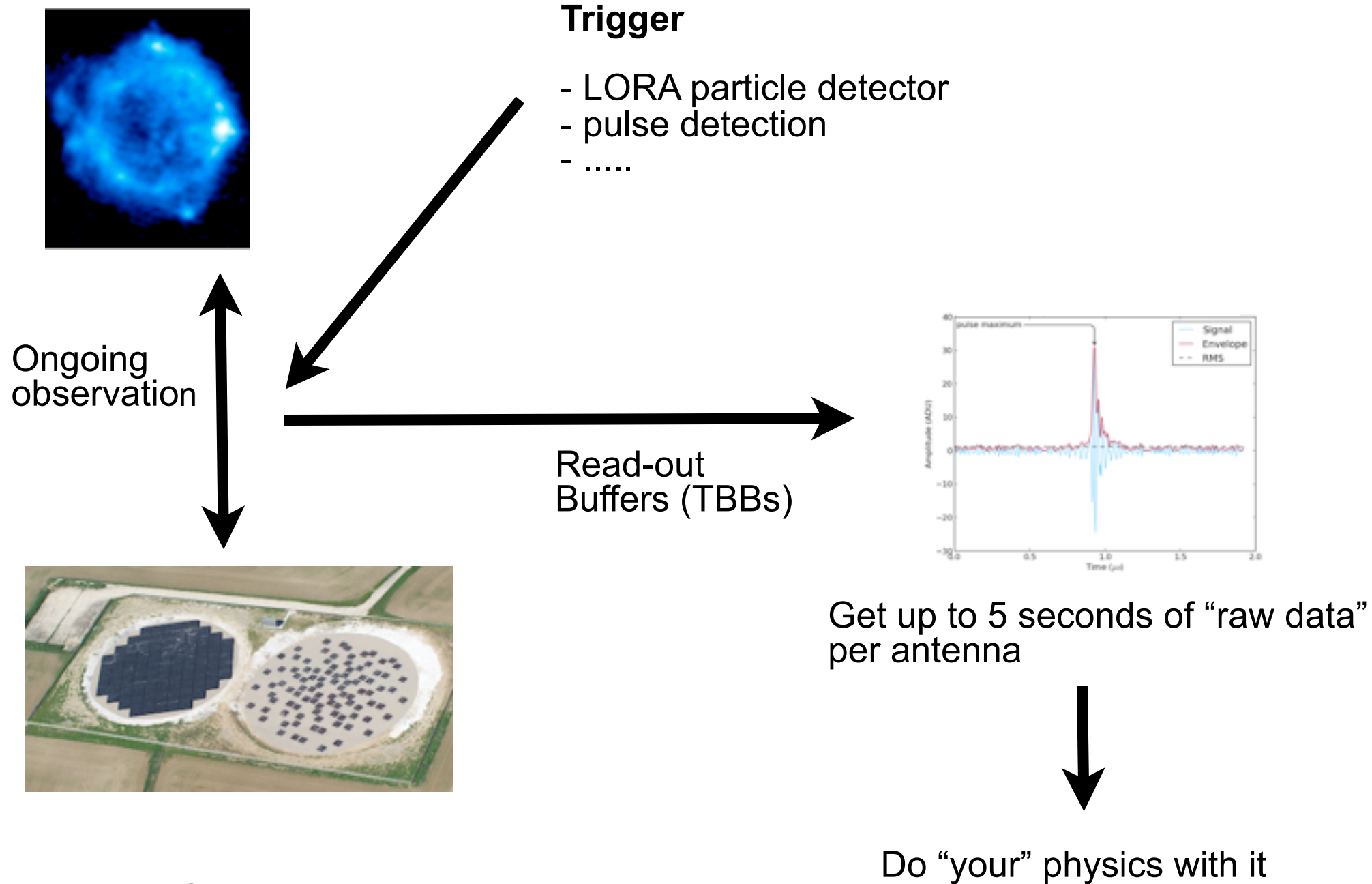


Defined observing conditions

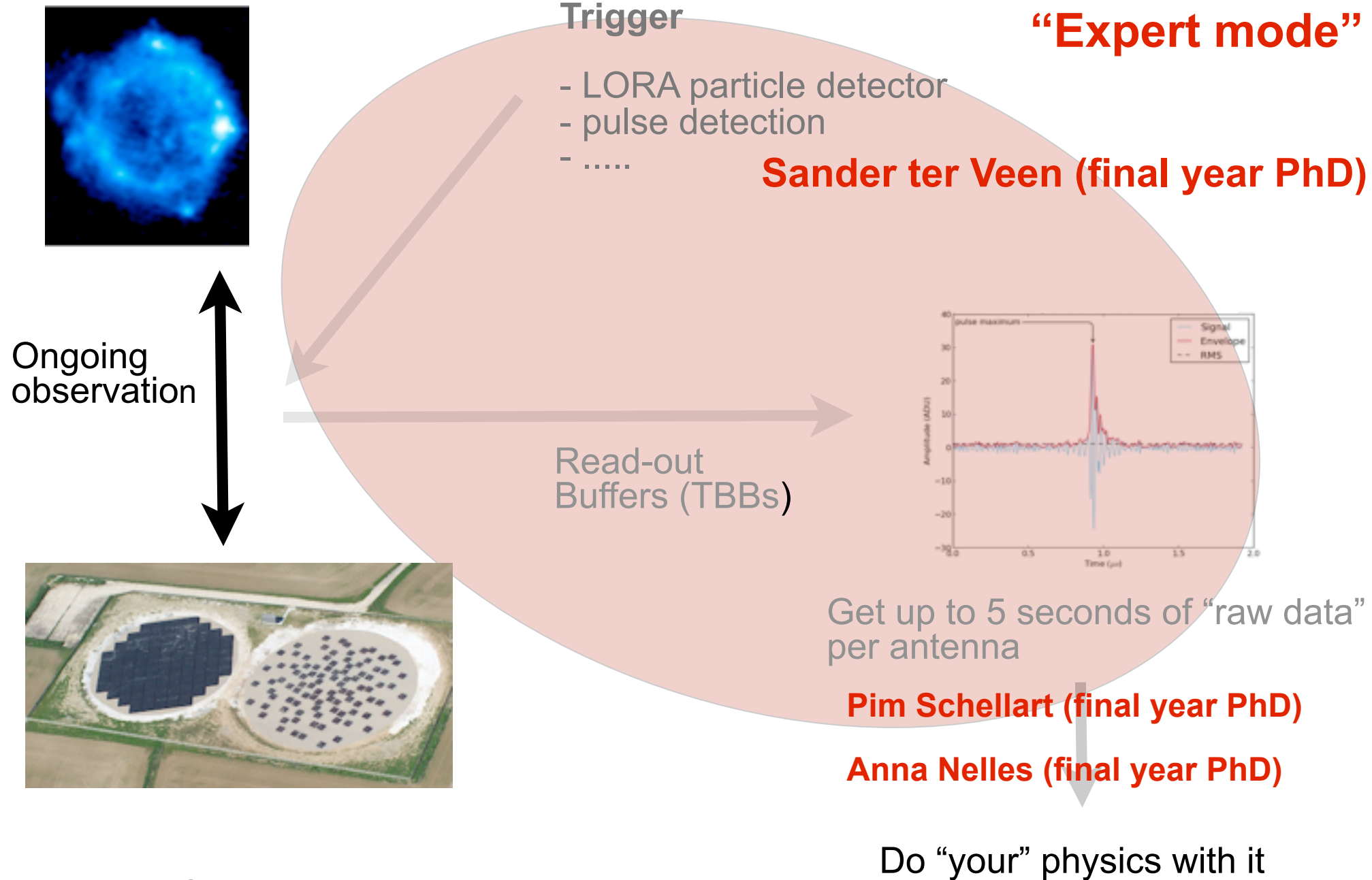
- Electric field affects air showers
- => planned to install electric field meter at superterp



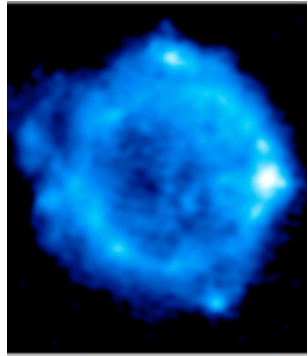
TBB data taking



TBB data taking



TBB data taking



Ongoing observation



Trigger

- LORA particle detector
- pulse detection
-

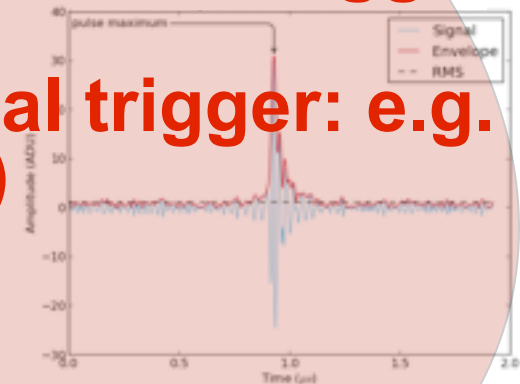
Sander ter Veen (final year PhD)

“Expert mode”

= Need general solution for triggering

(LORA, Frats, external trigger: e.g. transients, GRBs, ...)

Read-out
Buffers (TBBs)



Get up to 5 seconds of “raw data”
per antenna

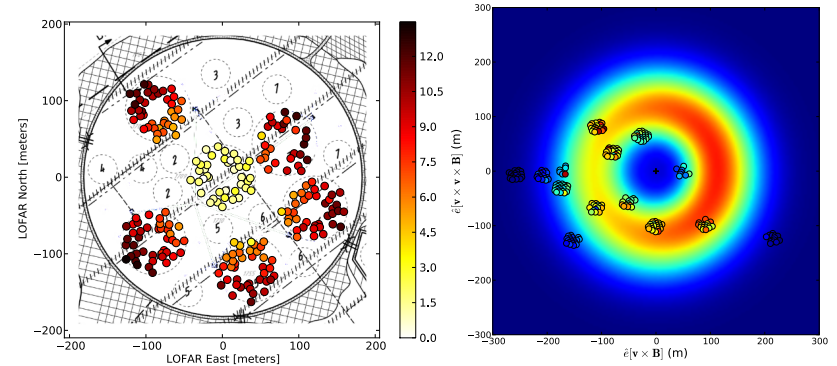
Pim Schellart (final year PhD)

Anna Nelles (final year PhD)

Do “your” physics with it

Summary of CR KSP

- Four science papers published/underway
 - LBA observations
 - HBA observations
 - Wavefront
 - Shower maximum



- Open issues: absolute calibration, local electric field
- Operations in “Expert mode” smoothly
 - “Experts” will finish PhD soon
- **General trigger solution needed that works for all possible users of the TBBs**