The Cosmic Ray Key Science Project

Status Report, LSM 14-10-15

Jörg P. Rachen / Sander ter Veen for the

LOFAR Cosmic Ray Key Science Project:

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Radboud University

ASTRON

university of groningen

Vrije Universiteit Brussel

Journal papers published (by May 2015, LOFAR users meeting):

Schellart+, **A&A 560, A98 (2013): Detecting cosmic rays with the LOFAR radio telescope**

Schellart+, **NIMPA 742, 115 (2014): Recent results** from cosmic-ray measurements with LOFAR

Schellart+, **JCAP 10, 014 (2014): Polarized radio emission** from extensive air showers measured with LOFAR

Buitink+, **PRD 90, 082003 (2014):** Method for **high precision reconstruction of air shower X_{max}** using two-dimensional radio intensity profiles

Thoudam+, **NIMPA 767, 339 (2014): LORA** – A **scintillator array for LOFAR** to measure extensive air showers

Nelles+, **APh 60, 13 (2015):** A parameterization for the radio emission of air showers as predicted by **CoREAS simulations** and **applied to LOFAR measurements**

Corstanje+, **APh 61, 22 (2015):** The **shape of the radio wavefront** of extensive air showers as measured with LOFAR

Schellart+, **PRL 114, 165001 (2015): Probing Atmospheric Electric Fields in Thunderstorms** through Radio Emission from Cosmic-Ray-Induced Air Showers

Nelles+, **APh 65, 11 (2015):** Measuring a **Cherenkov ring in the radio emission** from air showers **at 110-190 MHz** with LOFAR

Nelles+, **JCAP 5, 018 (2015):** The **radio emission pattern of air showers** as measured with LOFAR – a tool for the reconstruction of the energy and the shower maximum

….. plus about 10 conference presentations!

Papers recent and coming up:

Thoudam+: **Measurement of the cosmic-ray energy spectrum** above 10^{16} eV **with the LOFAR Radboud Air Shower Array**. ← **published APh 73, 34 (Jan 2016)**

Nelles+: **Calibrating the absolute amplitude scale** for air showers measured at LOFAR. ← **Submitted to JINST, referee report received (2015arXiv150708932N)**

Corstanje+: **Timing calibration** and spectral cleaning of LOFAR time series data. ← **Group internal review**

Buitink+: Radio detections of cosmic rays reveal a **strong light mass component at 10^{17} – $10^{17.5}$ eV**. ← **2nd resubmission to Nature, new systematics analysis added**
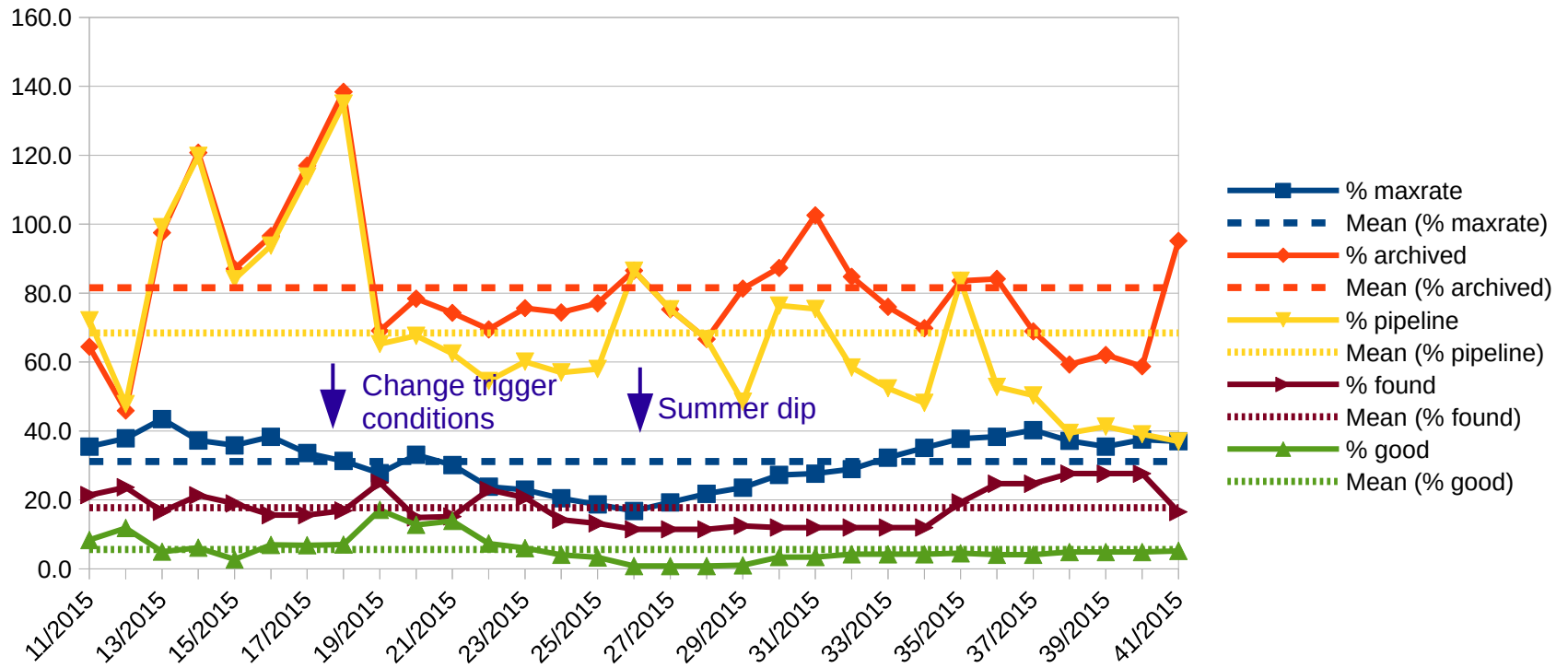
Trinh+: Influence of **Atmospheric Electric Fields** on Radio-wave Emission from Cosmic-Ray Induced Air Showers. ← **Submitted to PRD, referee report received**

11 presentations at ICRC 2015 (Den Haag, August 2015)

Observatory Performance
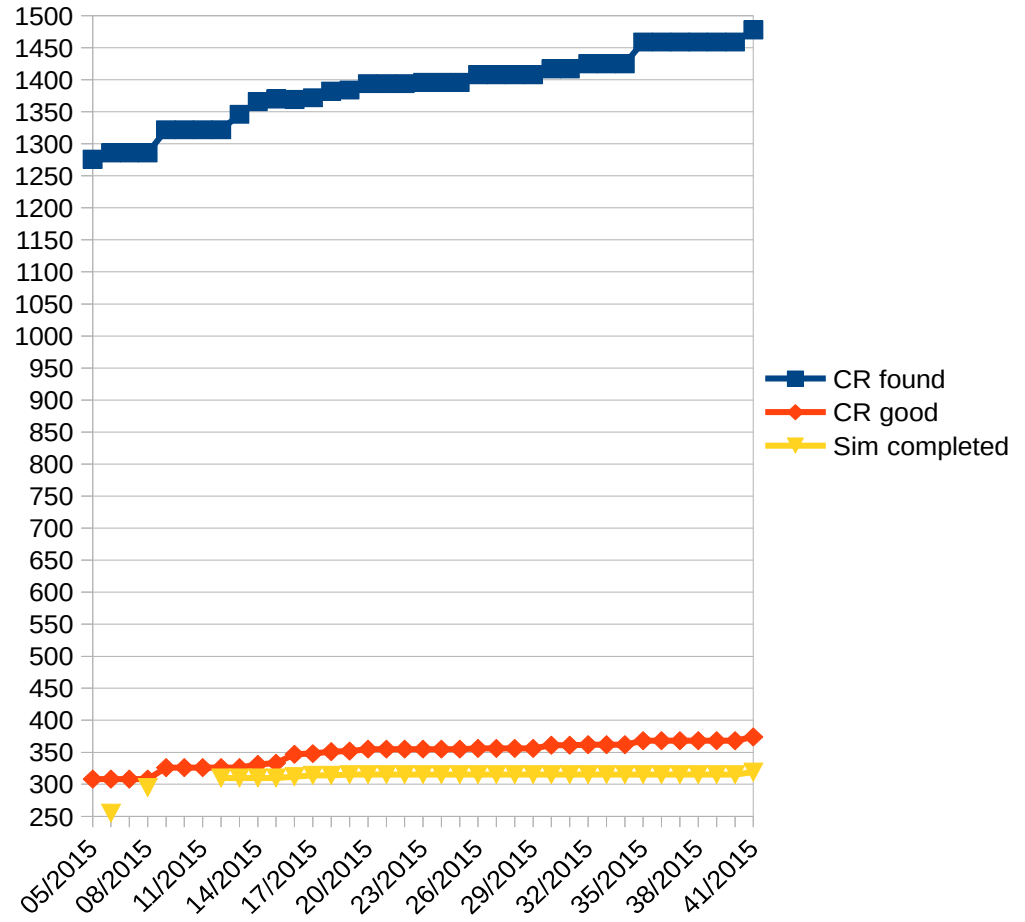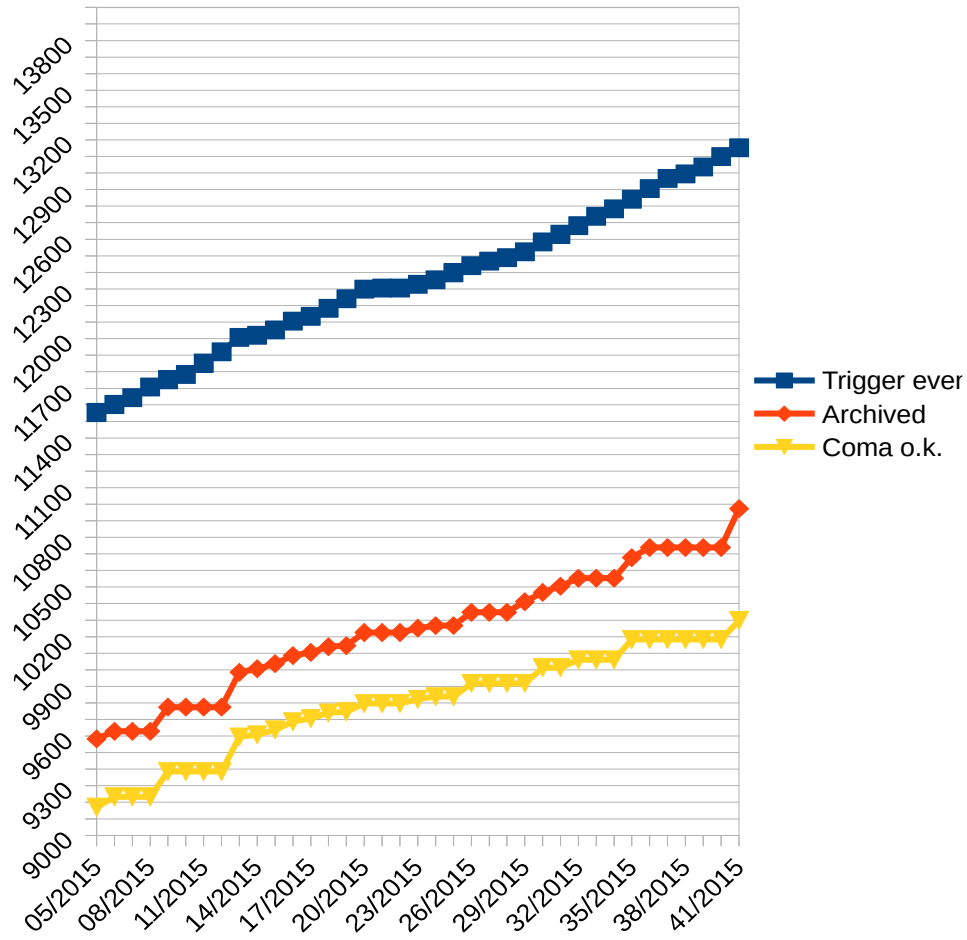
Observatory Performance

Comments:

Trigger Rate: low – often no observations, bad LORA cable

Fraction[1] archived events: o.k.

Fraction[1] pipeline events: low – bug in archiving pipeline (now fixed), maybe problem with datawriters

Fraction[2] CR found: o.k.

Fraction[2] CR good (i.e. for composition analysis): bit low, decreasing fraction of LBA observations

[1] relative to valid triggers   [2] relative to events analysed (i.e., with good metadata)

TBB Integration

- Design and Planning Document Draft:
  - Under review

- Review of new data format (ICD001)
  - 1 file per station!
  - Metadata to be added automatically
  - Optional metadata groups (e.g., dependent on trigger type)

- Current Priority: Move to CEP4
  - Old infrastructure first to be adapted
  - Concerns datawriter control, archiving pipeline, etc.
  - To be finished when CEP2 is switched off

- Implemenation of new (ASTRON managed) structure
  - Bottom up (from TBB control over datawriter to LTA ingestion)
  - Start after CEP4 operation is established, targeted within 2016 (TBC)

TBB Firmware Upgrade (FPGA)

- Requirements from FRB search projects (J. v. Leeuwen)
  - Subband mode with sliding stoptimes to catch highly dispersed signals
  - Planned to be implemented first half/mid 2016

- Additions for radio self triggering (VHECR group)
  - Bandpass-filter(s) and inherent time coincidence checks between antennas could mitigate RFI and diminish false positives
  - Could be used for hybrid trigger mode with LORA
    - ➔ Extend sensitivity to lower CR energies
    - ➔ Test mode for radio trigger development
  - Successful radio triggering would open new opportunities for radio CR experiments
  - More tests with archived and potentially new data planned
    - ➔ E.g., extensive RFI event set using currently installed full-band threshold trigger
  - **No decision yet about implementation**

FRB Searches

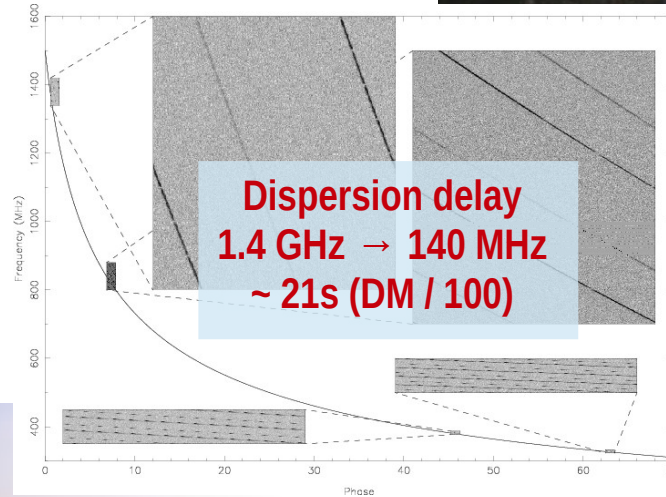## Receiving triggers from the Effelsberg 100m telescope

Comet Bonn VOEvent broker

~ 30s after detection

Comet LOFAR VOEvent handler

TBB control software

**Dispersion delay
1.4 GHz → 140 MHz
~ 21s (DM / 100)**

Taken from Voute et al., A&A 385, 733 (2002)

- Cooperation MPIfR Bonn
  (L. Houben, L. Spitler, D. Champion)
  and RU Nijmegen / ASTRON
  (J.P. Rachen, S. ter Veen)

- First communication test successful
  October 8

- Development of VOEvent handler
  ongoing

- Test observations of pulsars
  (DM~30-140) planned for Nov 11-13
  (commissioning proposal tbd)

- **Science goal:
  detect FRBs (DM ~ 1000)
  at LOFAR frequencies
  (unprecedented)**