



Study of short time noise pulses

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UHEP mode:

Search for ultra short (ns) pulses induced by Ultra High Energy Particles hitting the Moon

Method: ~50 tied array beams of core stations at CEP

→ invert to time domain

→ search for pulse → trigger → dump TBBs (~ 2Gb)

Study of noise pulses @ LOFAR:

How many?

» Important for trigger rate

Any positional dependence?

» Moon

» Horizon

Unexpected pulses?

Data set

Raw station beam formed data

(with special thanks to Jan David Mol and Sander ter Veen)

HBA_0, both polarizations of all 6 superterp stations

1 file per station, tied array beamforming by hand

5 minutes of data with stations pointing at the Moon,
elevation: 33.9° azimuth: 185.8°

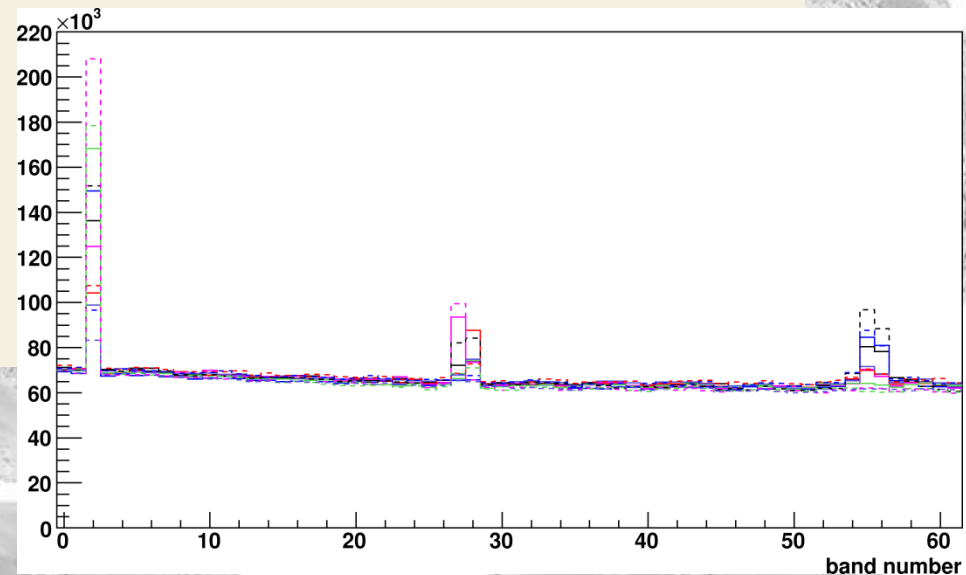
1 minute of data pointing at 3C196 for calibration purposes

62 Subbands ($\sim 139 - 151$ MHz)

August 2010:

Single clock

No station calibration



Forming a tied array beam

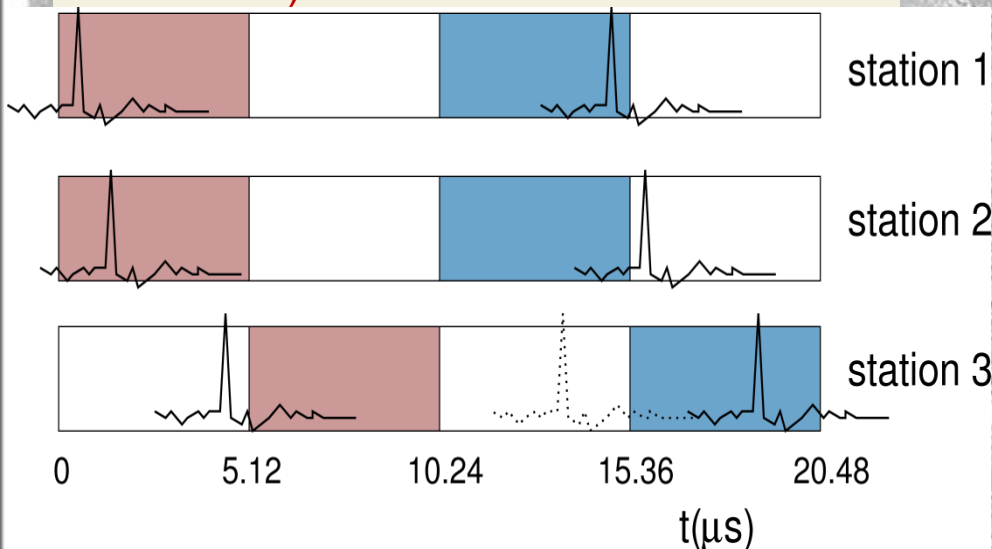
Blockshift problem:

Data of stations are aligned with the resolution of a page ($5.12 \mu\text{s}$)

Additional time differences are taken care of by applying correct phase

For signals with time duration $\leq 5.12 \mu\text{s}$ it can happen that the signal resides in different pages for different stations
→ the signal will lose power in the tied array beam

To recover full power it is needed to align at best time resolution (5ns , at station before PPF)



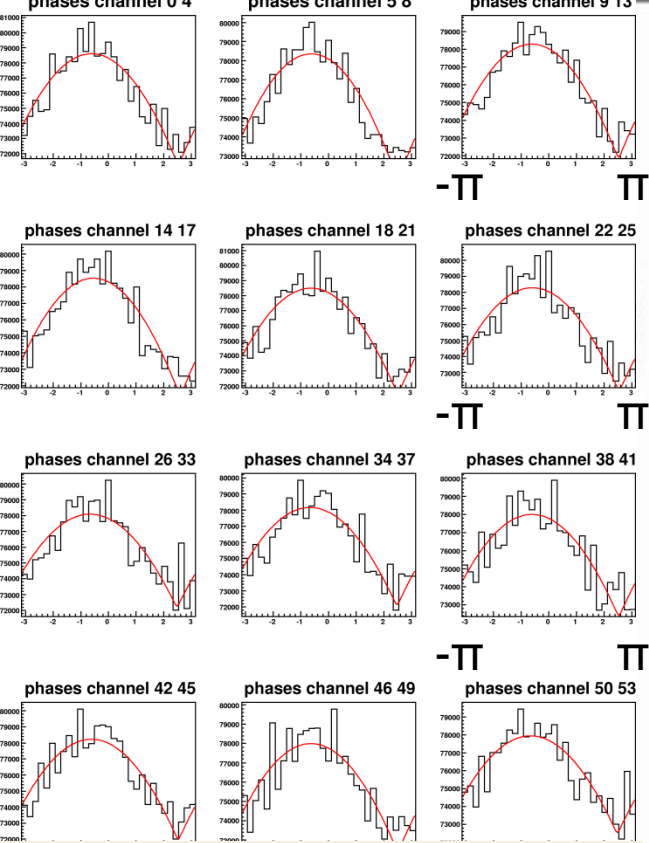
Steps :

- oversample 62 subbands to 512
- convert to time domain
($\text{PPF}^{-1} + \text{iFFT}$)
- determine (geometric + other) delays between stations
- align data to 5 ns level (for central beam)
- FFT
- Coherently add data (25 beams)
- iFFT → timeseries for each beam
- Search for pulses

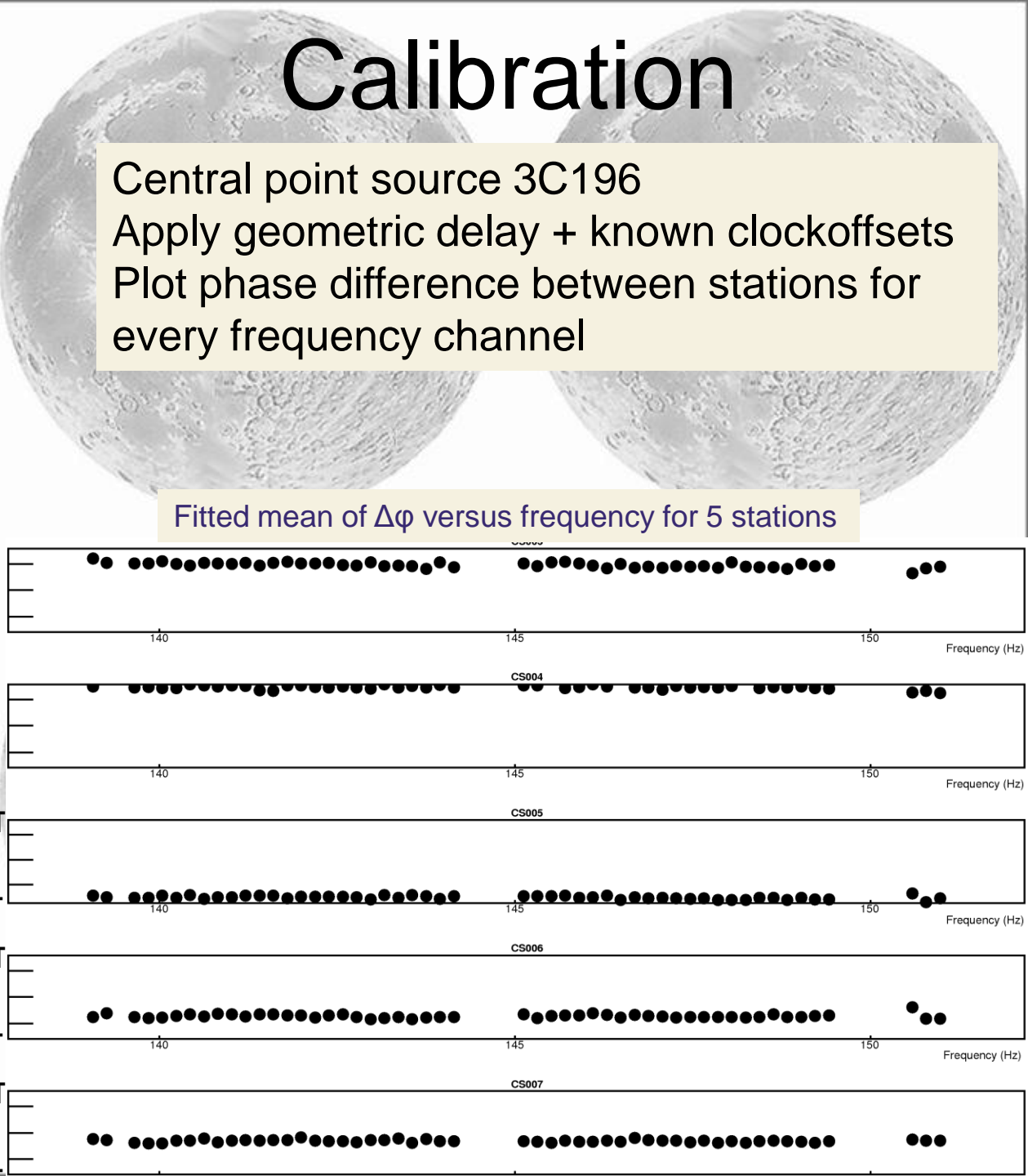
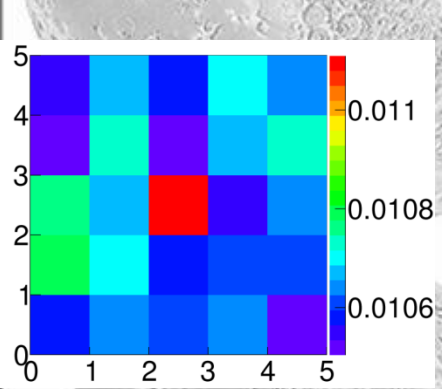
Calibration

Central point source 3C196
Apply geometric delay + known clockoffsets
Plot phase difference between stations for every frequency channel

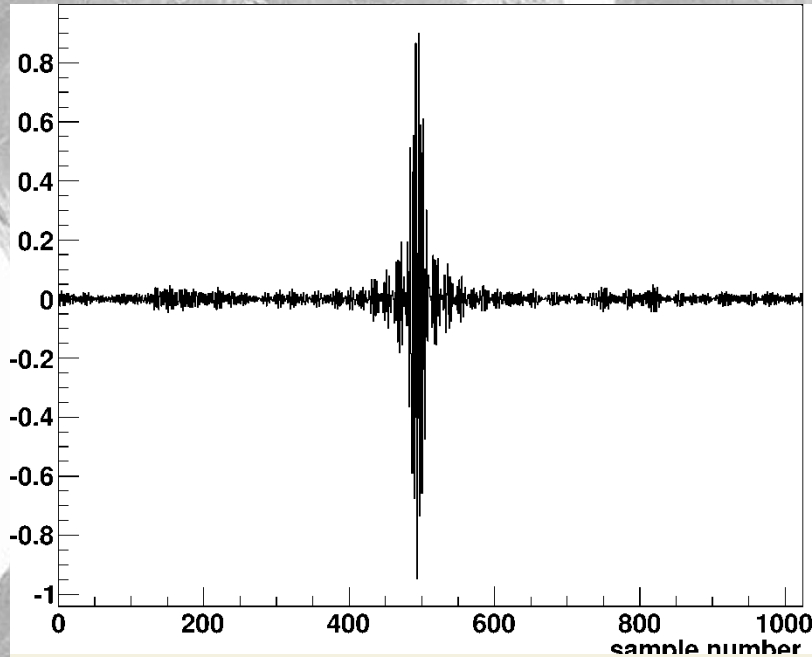
Fitted mean of $\Delta\phi$ versus frequency for 5 stations



Histograms of phase difference between 2 stations for different bands (summed over 4 bands) + fitted Gaussian



Simulation



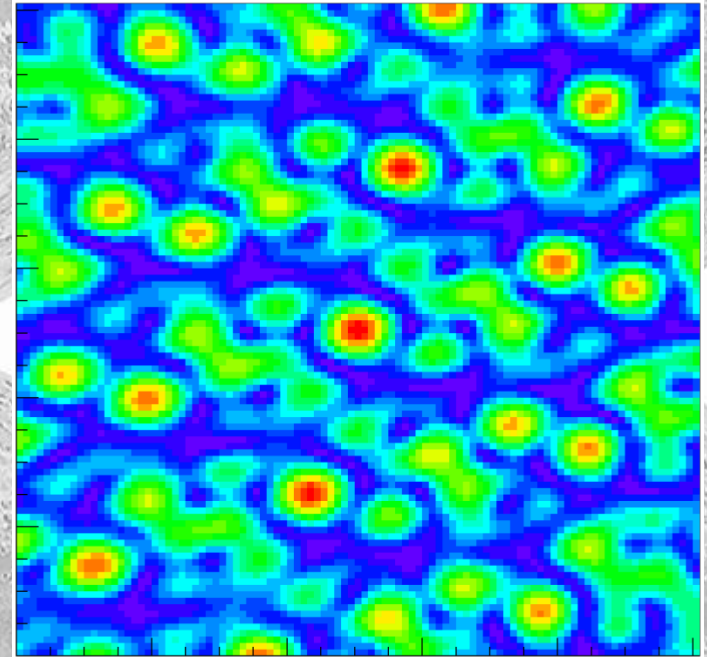
Bandwidth limited pulse

Add power of 10 consecutive bins
to search for pulses P_{10}

Data analysis:

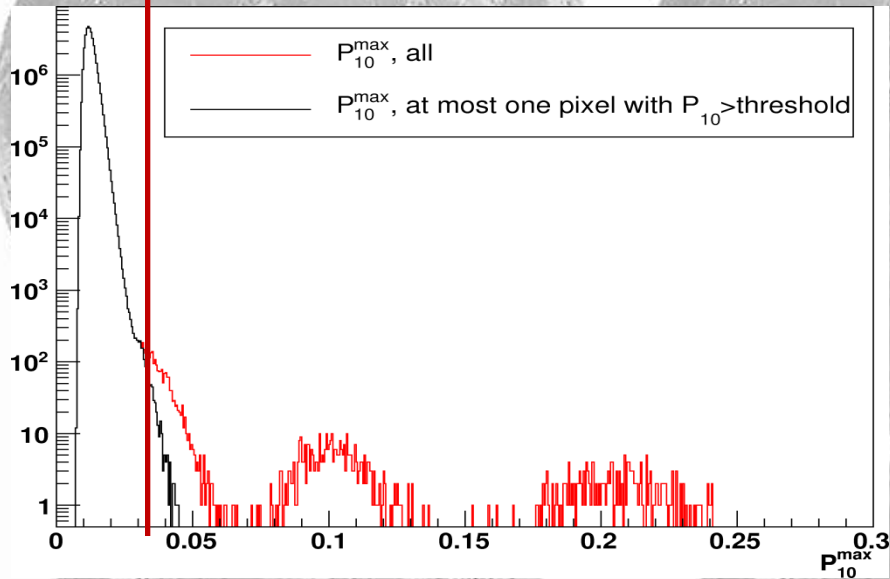
Store data when $P_{10} > 0.031$

Elaborate analysis of optimum 248
channel selection and value for N in
 P_N in trigger paper (K. Singh et al.)



7x7 degree image of simulated pulse
at elevation: 33.9° az: 185.8°
For data analysis: use 2 square
degree image with 5x5 pixels

Trigger value



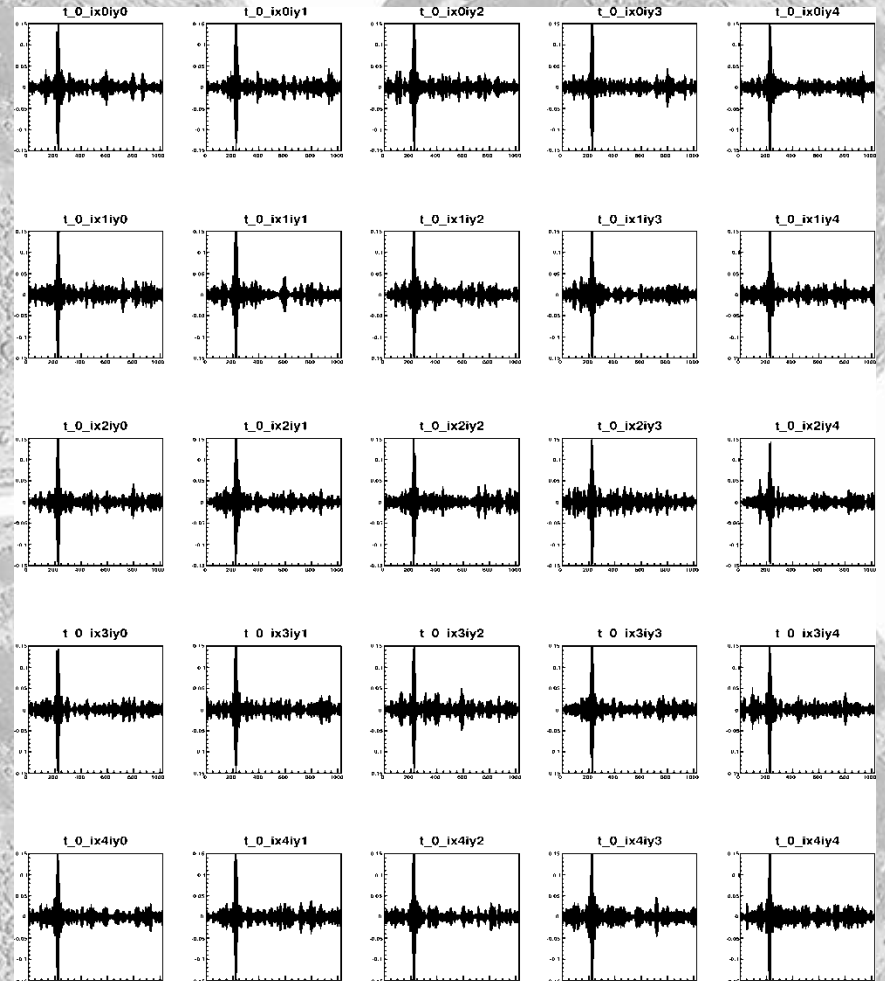
Maximum P_{10} value per page for all 25 beams and both polarizations

High power pulses:

Strange three lobe structure

Visible in all 25 beams:

Most can be discarded with anti-coincidence requirement



Timeseries for all 25 beams (X-pol) for one of the high P_{10} -value events

High power pulses:

Per event:

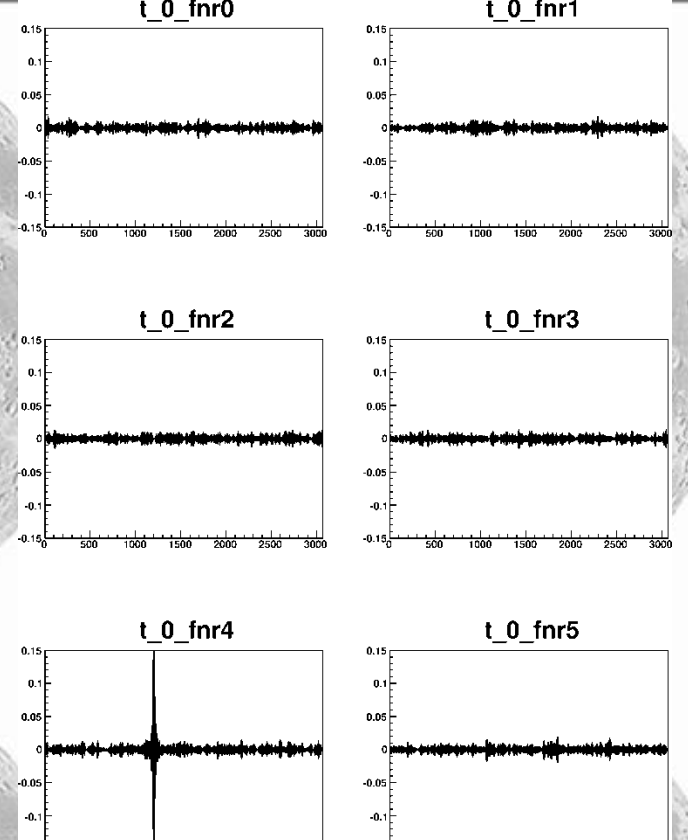
Only visible in one station,
one polarization

Pulses observed in all stations all polarizations

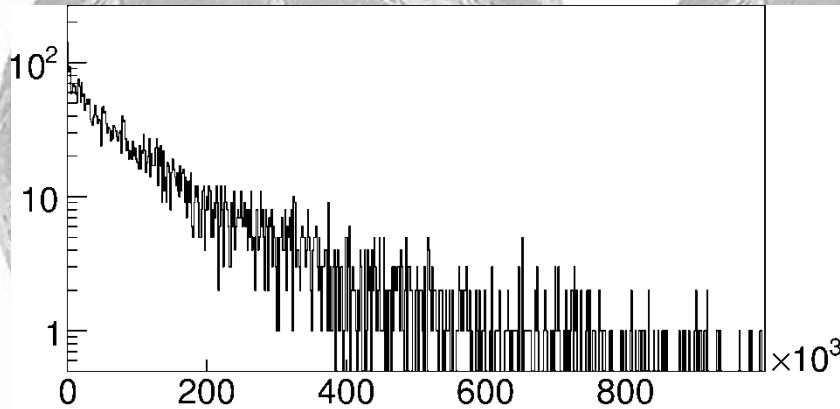
No time correlations

Clearly some instrument induced pulse

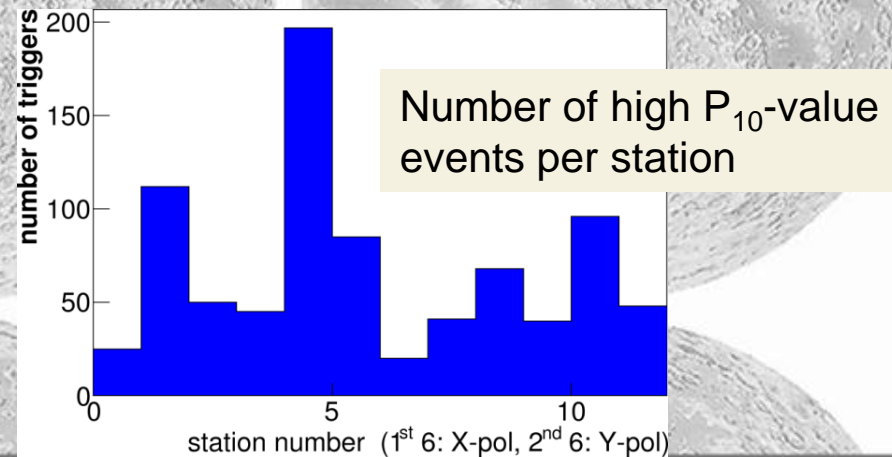
Correlated to “bit flips” observed by S.terVeen
in TBB data? i.e. instrumental pulse from 1 tile?



Timeseries of all stations (X-pol) of one of the high P_{10} -value events

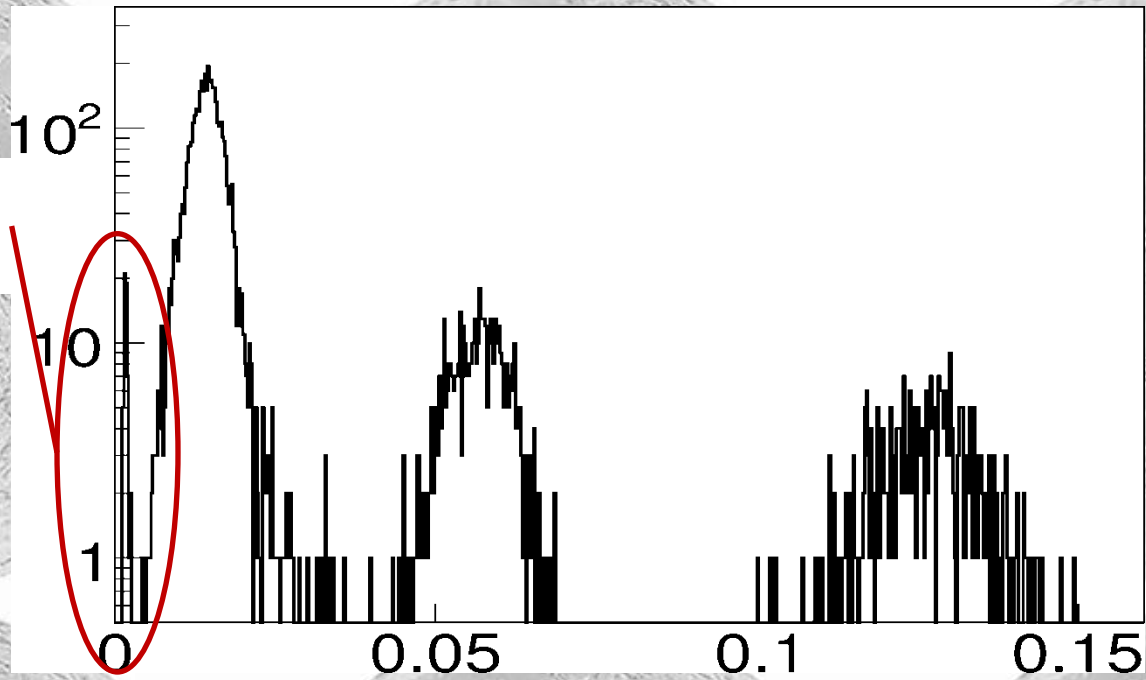


Number of pages between two high P_{10} -value events in one station



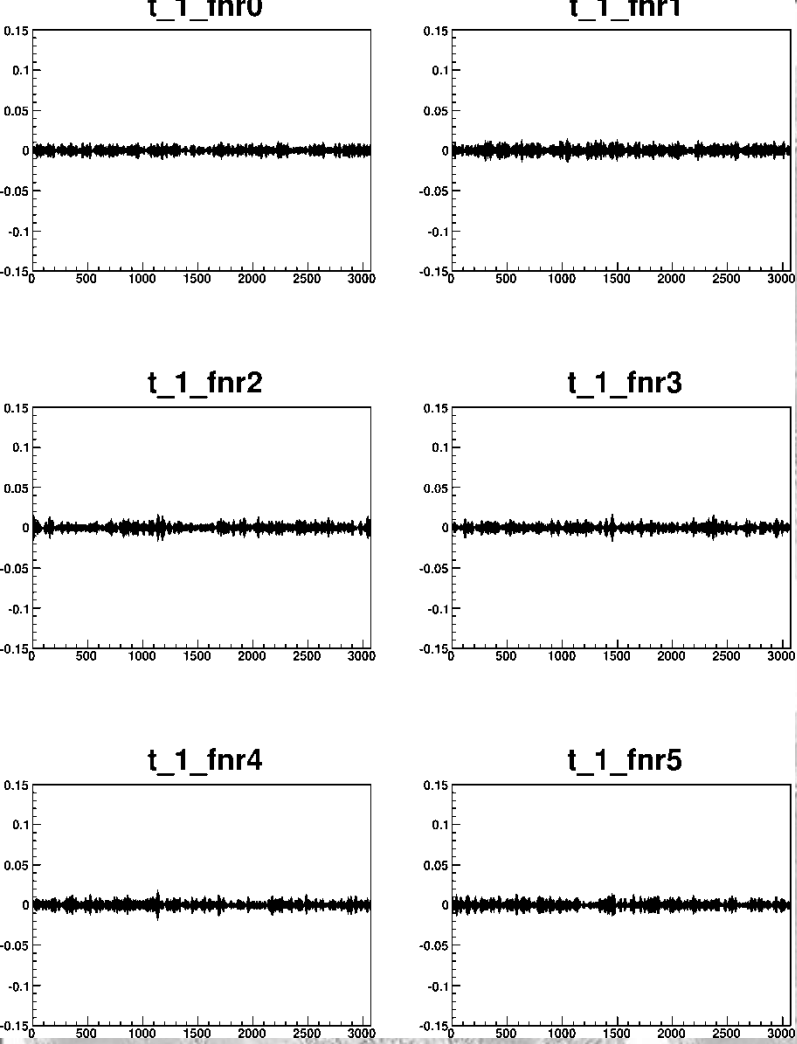
Number of high P_{10} -value events per station

These could be genuine pulses

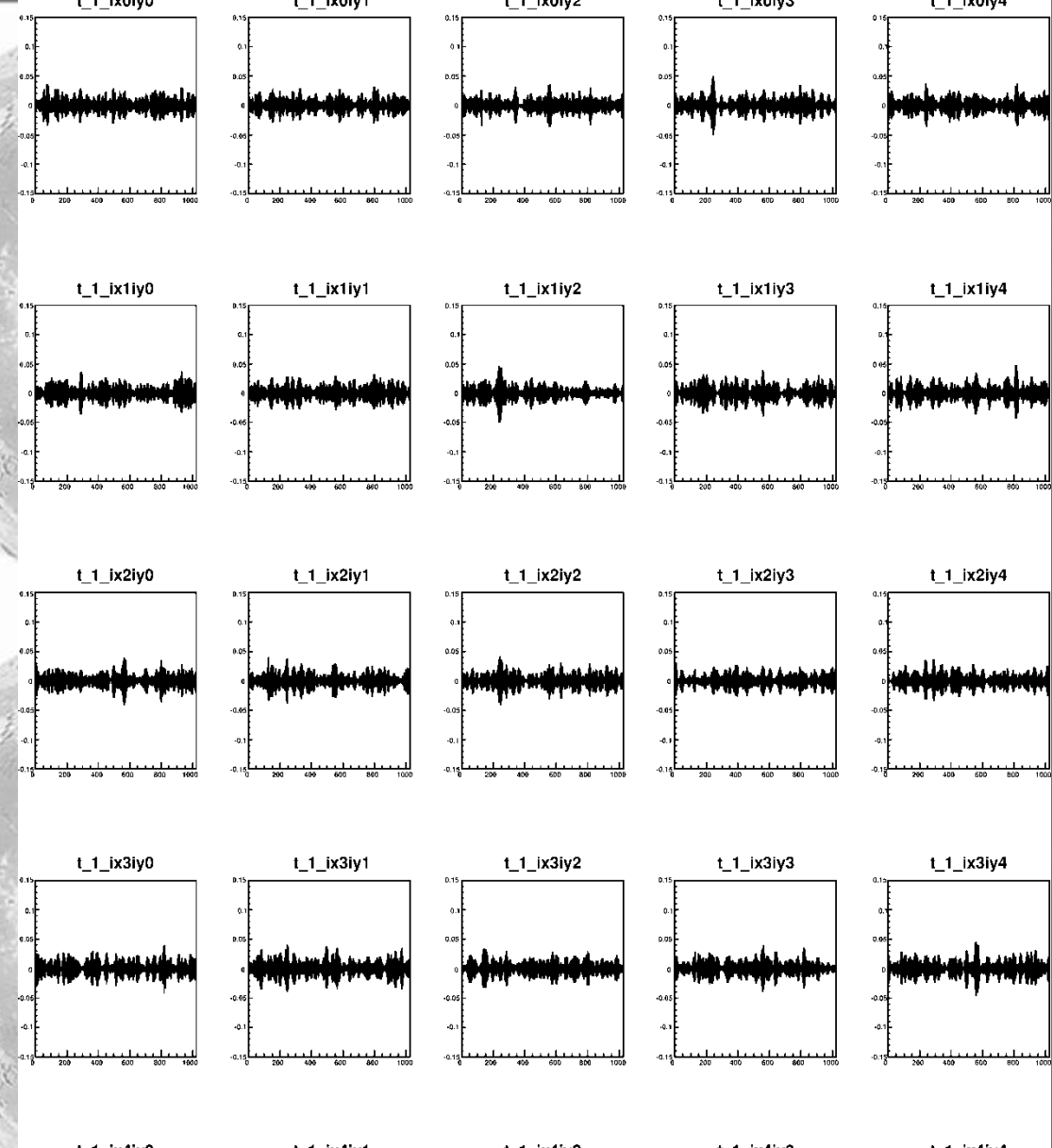


P_{10} -value of the station with maximum P_{10} after trigger

55 pulses above trigger level that are not clearly instrumental
All of them only in one polarization
Simulation of white noise, expected triggers in 5 minutes: 54
Consistent with Gaussian noise



Timeseries of all stations (Y-pol)



Timeseries for all 25 beams (Y-pol)

Conclusion

- Station data needs to be aligned with best time resolution
- Analysed 5 min. of superterp data pointing at the Moon:
 - 4812 pulses found
 - most of them due to some instrumental effect
 - Can be discarded with (anti-) coincidence criterium
 - » Coincidence between polarisations
 - » Anti-coincidence between beams
 - 55 other pulses, consistent with Gaussian noise
 - Data much cleaner than expected from WSRT analysis
 - Excellent for setting competitive limit on UHEP flux
 - More recent data (station calibration) + larger bandwidth needed to confirm