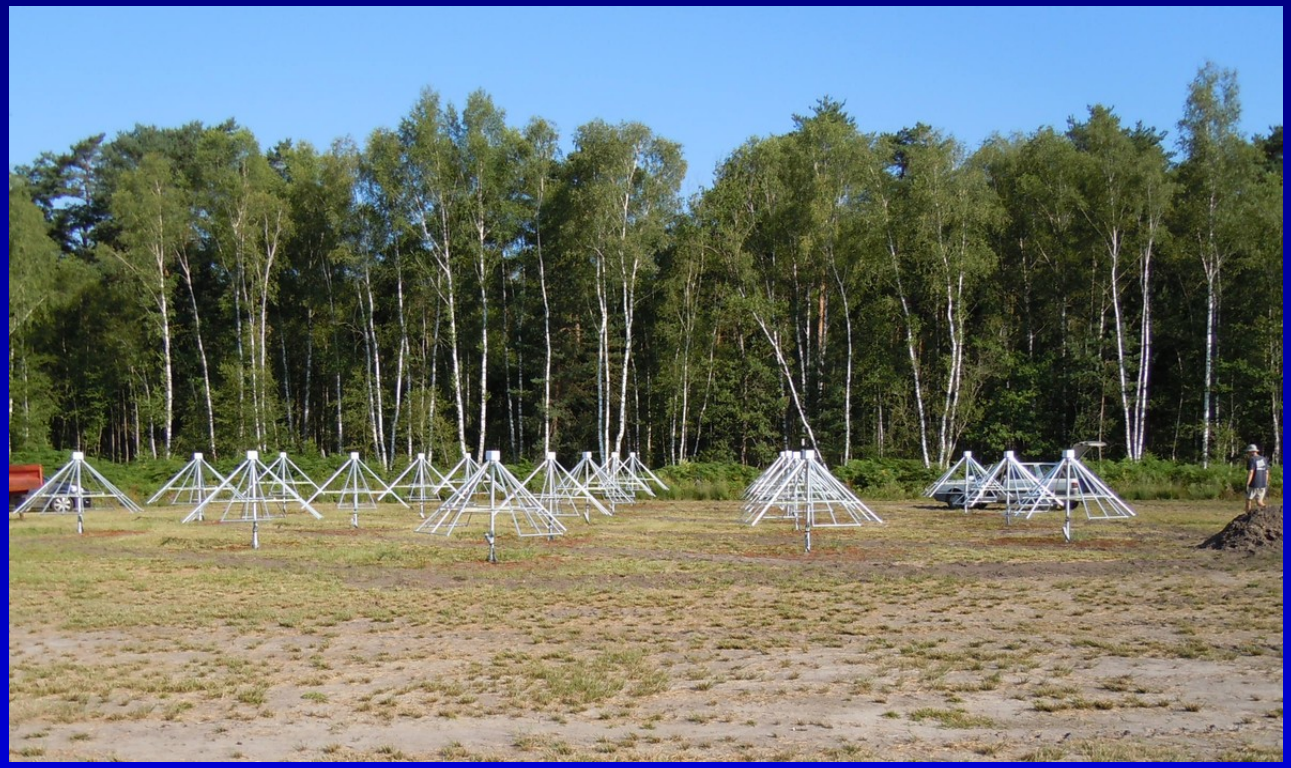
NenuFAR: Detection of transients with a dedicated receiver



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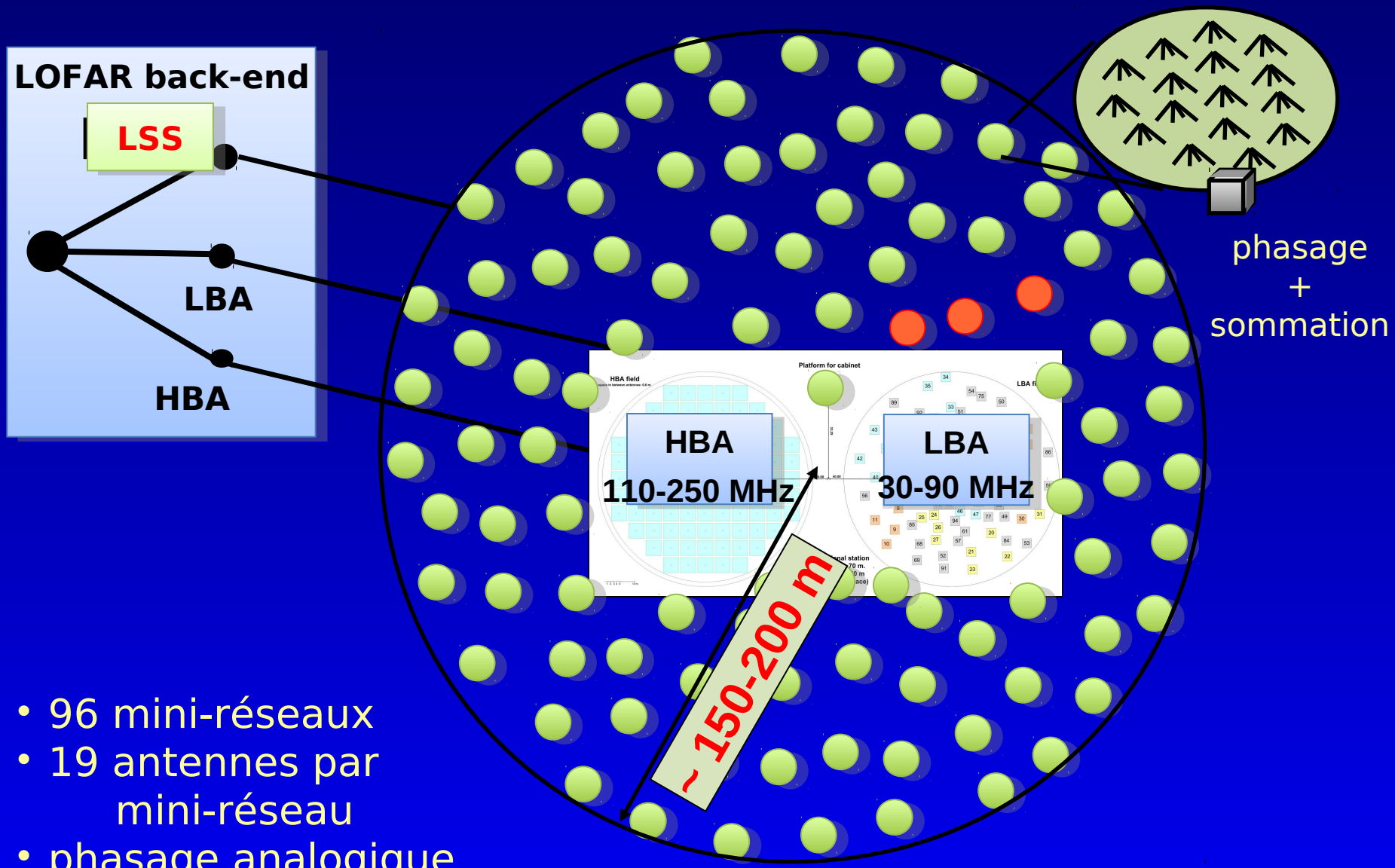
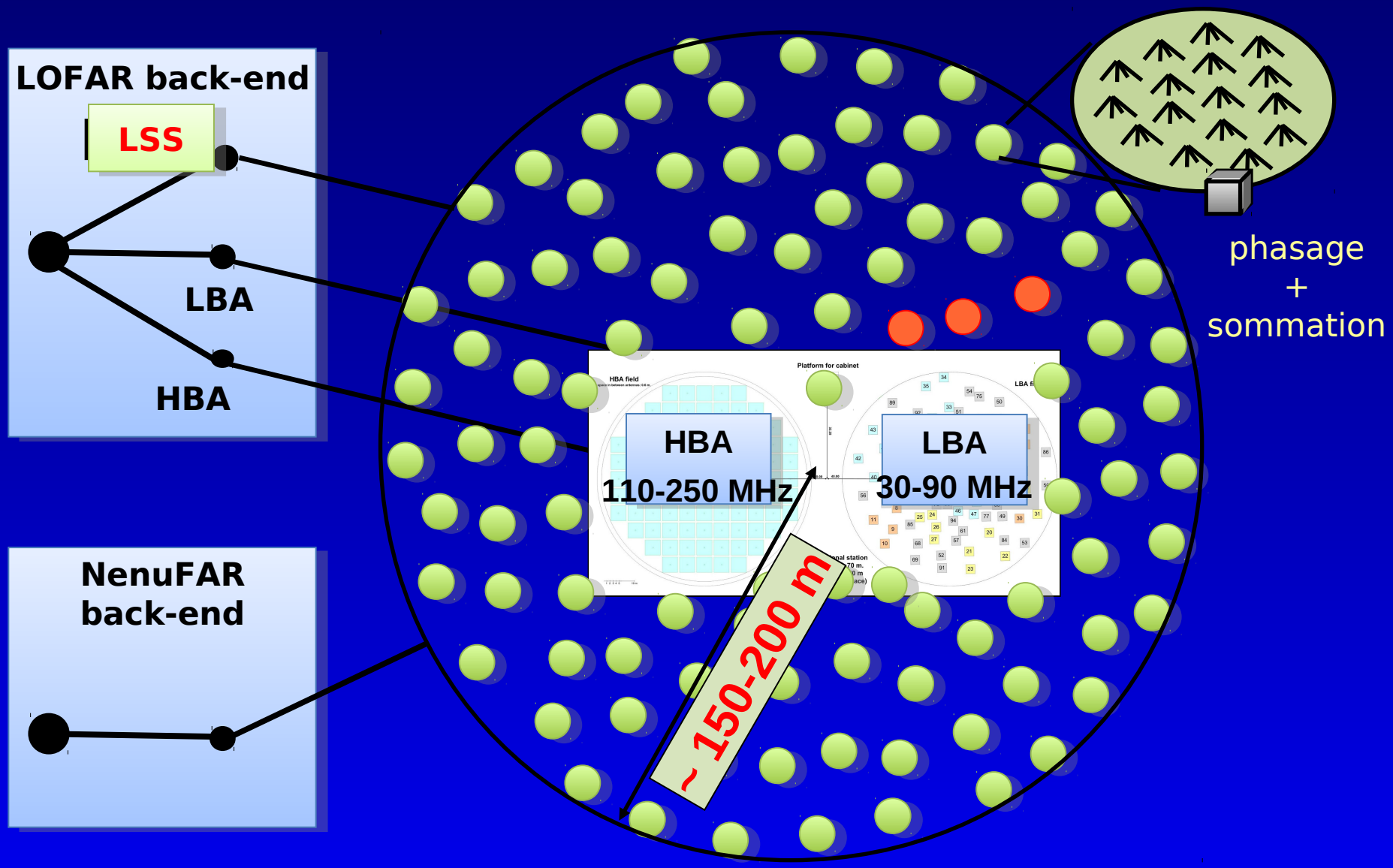
NenuFAR



- 96 mini-réseaux
- 19 antennes par mini-réseau
- phasage analogique

NenuFAR + dedicated receiver!



NenuFAR receiver

- LOFAR backend can process B x Ndir = 48 MHz
- NenuFAR antennae are 10-85 MHz (75 MHz)
  => Can't use the full antenna band!

- Cannot use NenuFAR when FR606 is used!

- Implementation of a new dedicated backend :

  LANewBa: **L**OFAR **A**dvanced **New** **Ba**ckend

  based on a LOFAR backend

  BW x Ndir = 160 MHz (2 beams full band)

  and some extra features...

NenuFAR receiver: Differences

- adapted to low band (10-85 MHz)
  - Sampling: 200 MHz clock only (no 160 MHz clock)
  - ADC dynamics: 12 -> 14 bits for RFI @ low frequency
- larger instrument (400 m)
  - Narrow band assumption for beamforming
  - -> 100 kHz beamlets (instead of 200 kHz)?
- faster cross-correlation computation for calibration
- add polarization (Full Stokes) for beamlet statistics
- hardwired external trigger (particle detectors)

output:

- beamlet data (compatible with LOFAR CEP)
- sub-band data (all mini-arrays) for full-band correlation

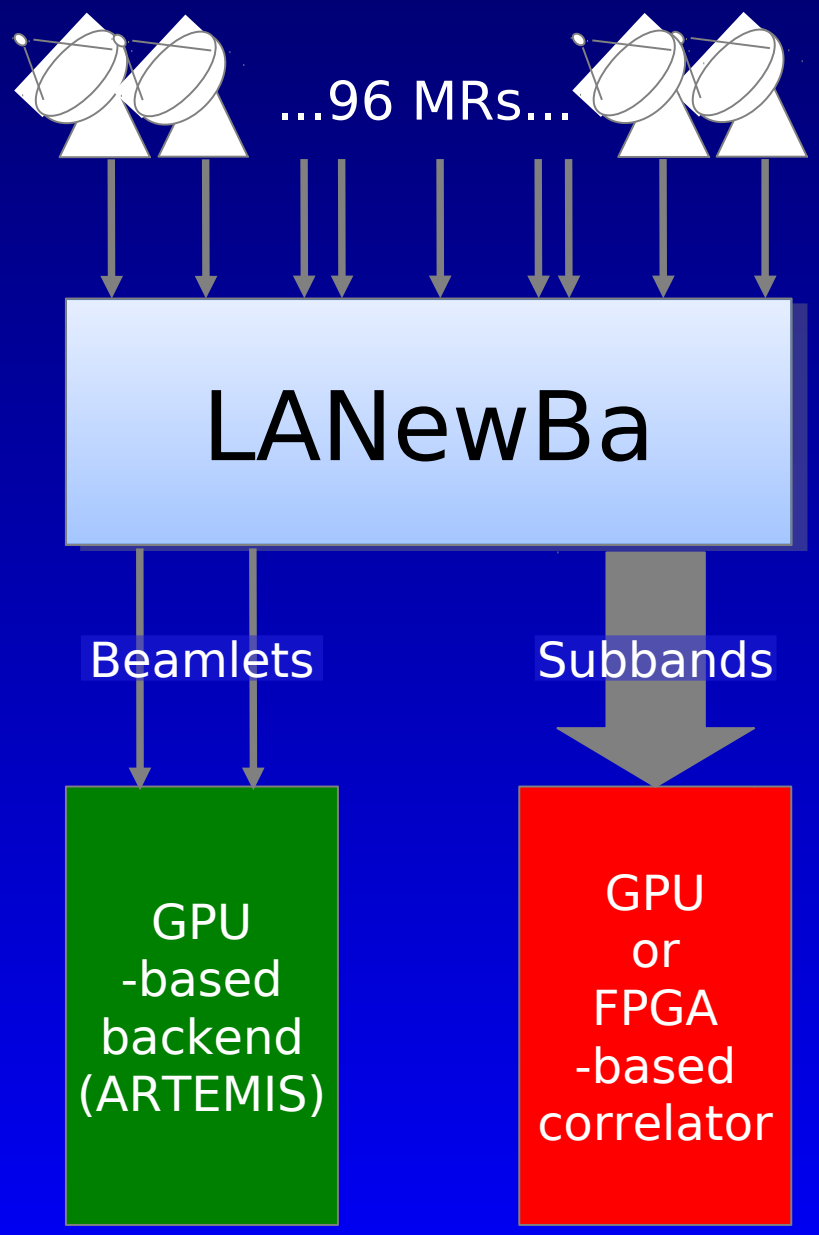
Processing *after* LANewBa

Beamlets:

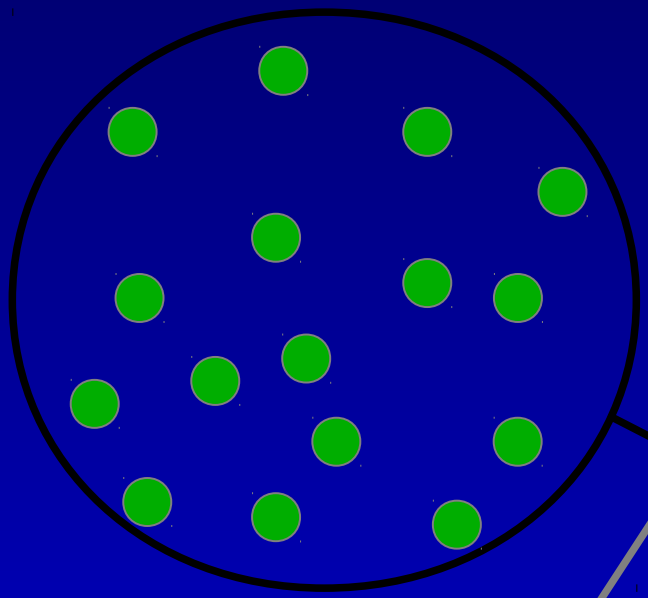
- 2 x 5 Gb/s
- ARTEMIS-like backend
  - Channelization
  - pulsar dedispersion
  - S-burst detection
  - RFI mitigation ...

Subbands:

- # of MR x 2.5 Gb/s
- NenuFAR-1: 75 Gb/s
- NenuFAR: 480 Gb/s
- FPGA or GPU based correlator?
- -> Spectro-polar-imaging
- 16x16-pixel skymap
- ~1s dump time
- Transient search, Dark Ages, ...



NenuFAR



NenuFAR

2*96 complex voltages

8 digital beams
bW: 6 MHz
channels: 200 kHz

LaNewBa

ARTEMIS

Super-ARTEMIS?

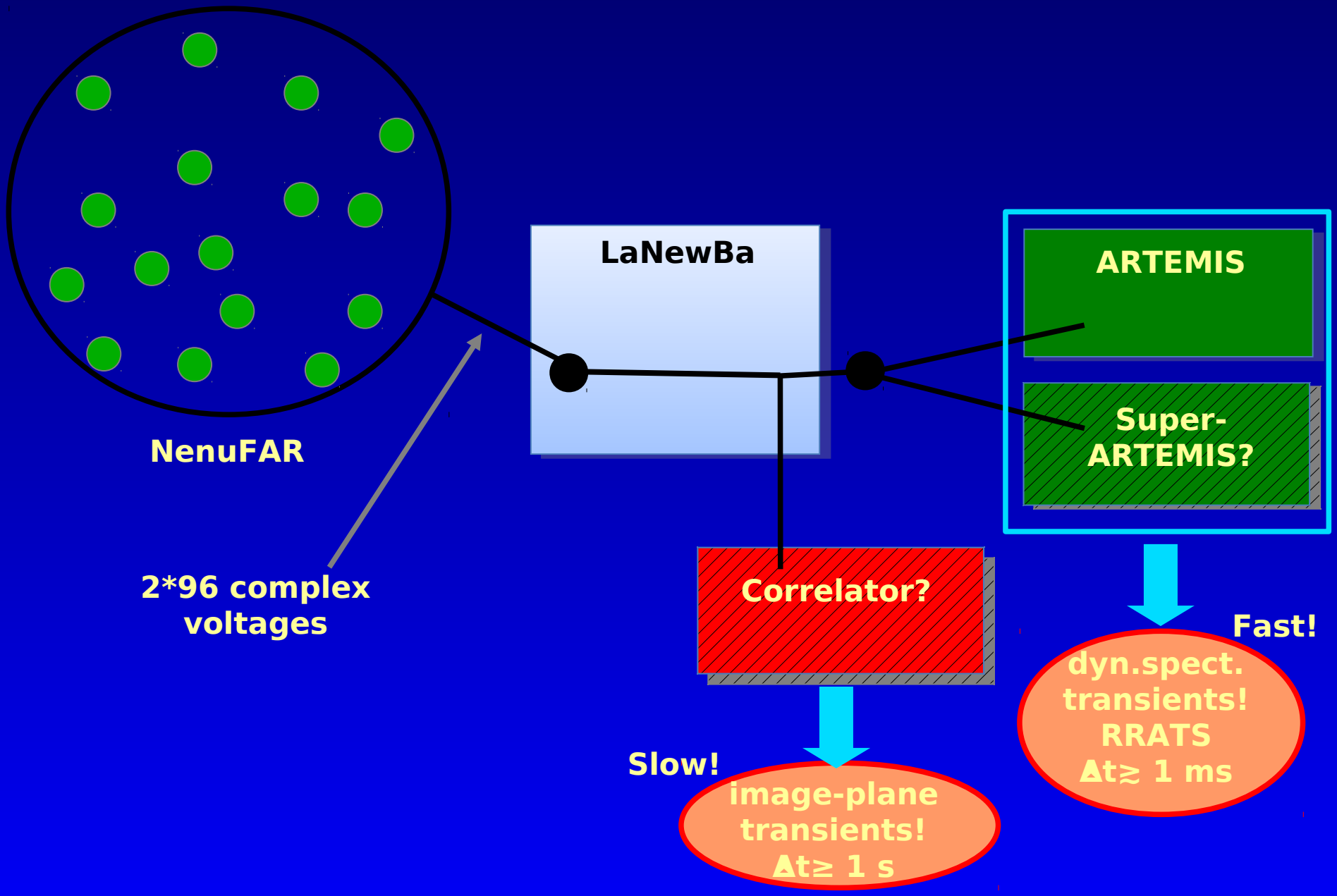
2*96 analog signals

correlations
$(16)^2$ pixel
1 image/sec

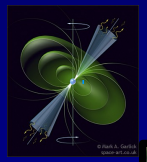
Correlator?

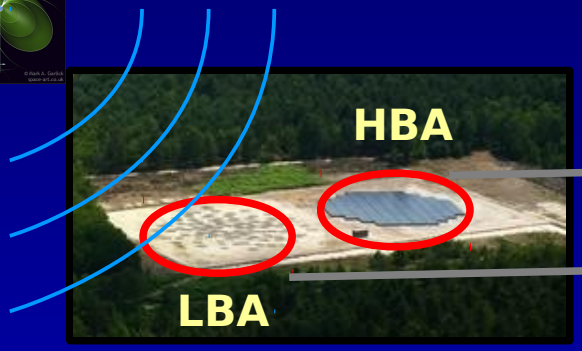
2 digital beams
bW: 70 MHz
channels: 100 kHz?
200 kHz?

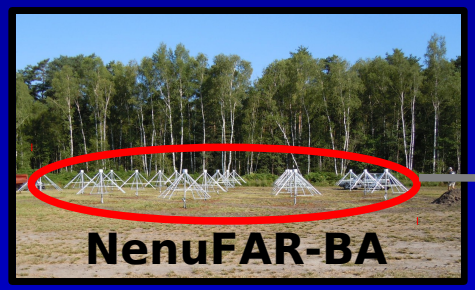
NenuFAR


NenuFAR
2*96 complex voltages
LaNewBa
ARTEMIS
Super-ARTEMIS?
Correlator?
Fast!
dyn.spect. transients! RRATS Δt≳ 1 ms
Slow!
image-plane transients! Δt≥ 1 s

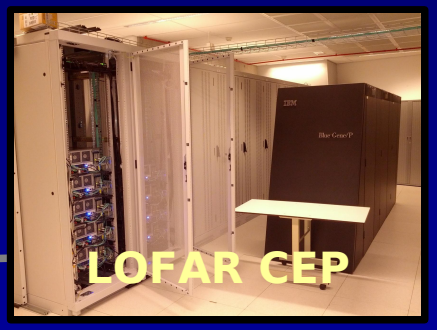
LOFAR / NenuFAR







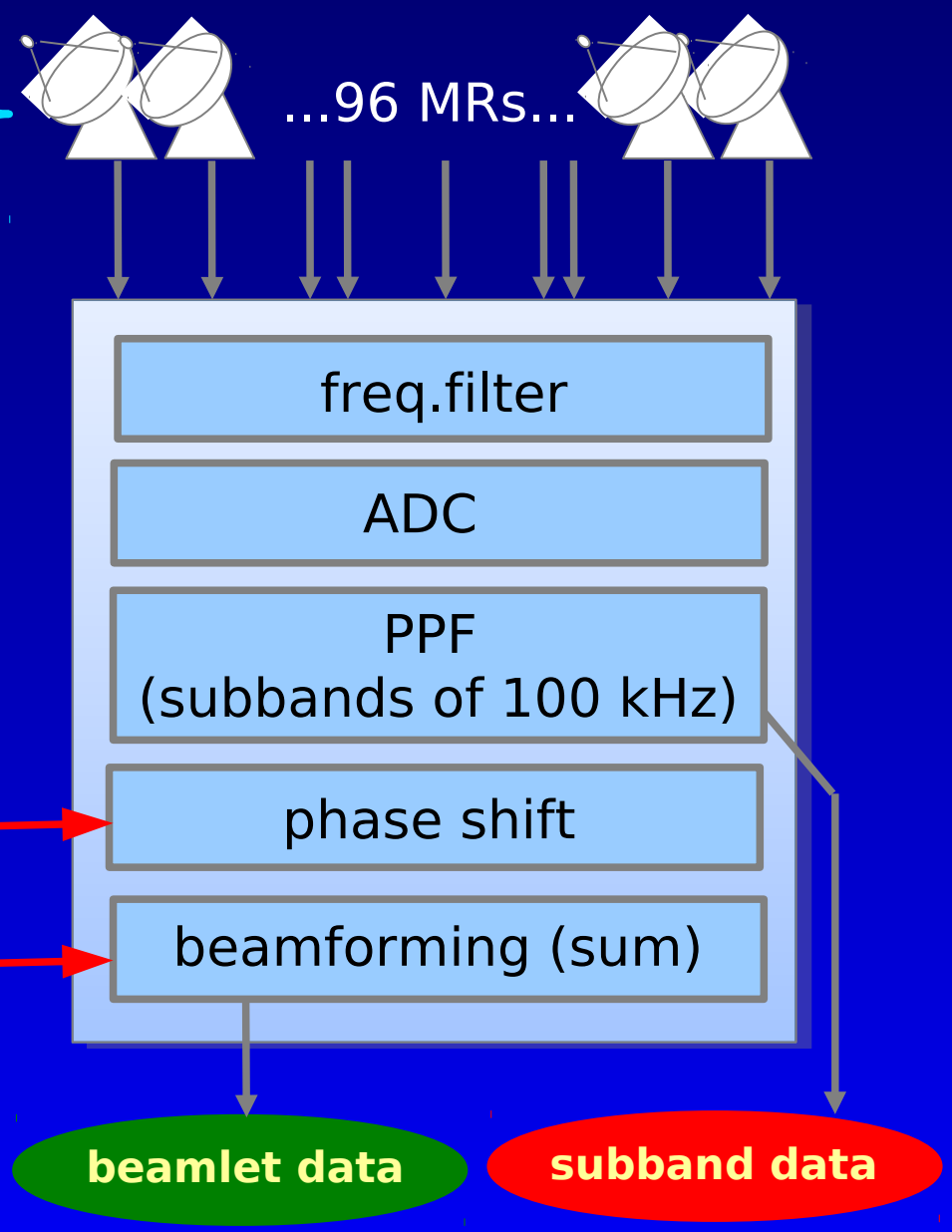
LaNewBa



Super-ARTEMIS?

Correlator?

Processing *in* LANewBa

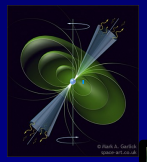


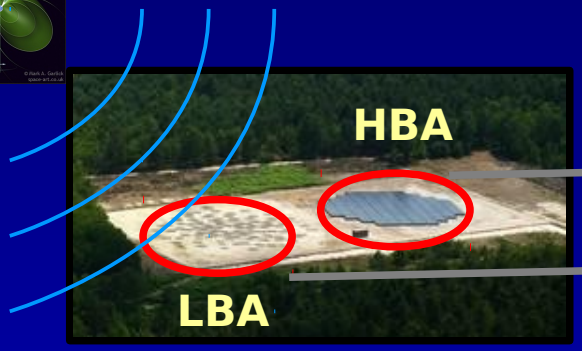
Analog phasing:
delay lines → no chromatic error

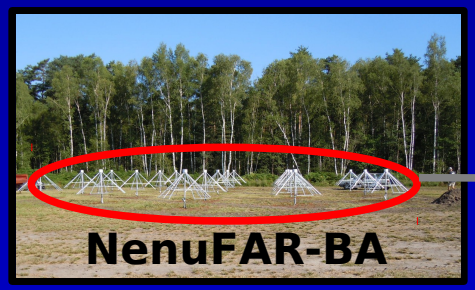
Digital phasing:
phase shift → chromatic error
error prop. to subband BW

Sum:
errors of distant antennas add up
error prop. to distance

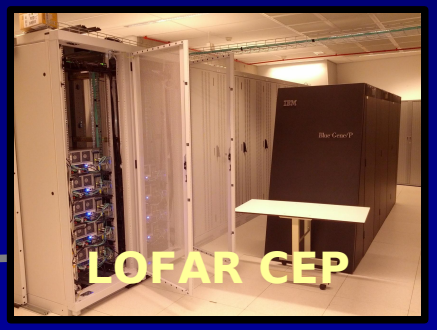
LOFAR / NenuFAR







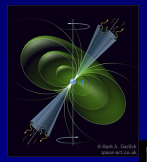
LaNewBa

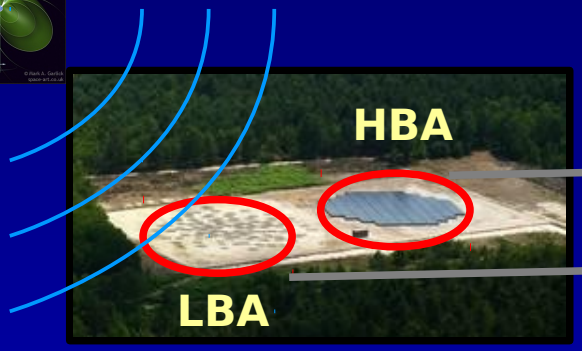


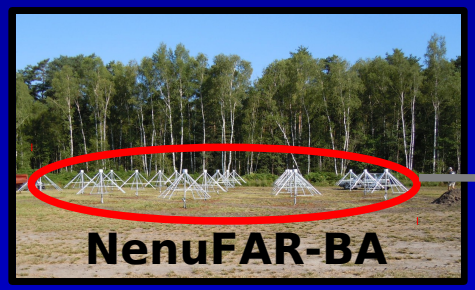
Super-ARTEMIS?

Correlator?

LOFAR / NenuFAR







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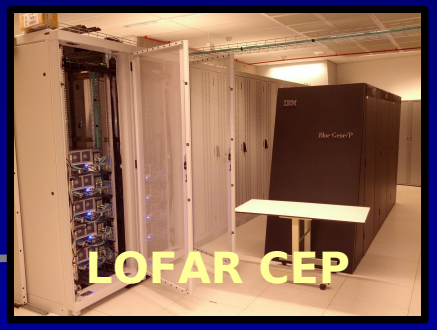


Super-ARTEMIS?

Correlator?

ARTEMIS

- 4 machines,
- 2 x Intel Xeon X5650,
- 48 GB RAM per box,
- nVidia GTX 580,
- water cooling,
- Gentoo Linux,
- 500 GB system disk,
- 2 TB HDD archive/backup,
- 8 TB RAID0 (4 x 2 TB HDD),
- Intel C/C++ compiler,
- pulsar software packages (TEMPO2, PSRCHIVE, DSPSR, SIGPROC etc.),
- AMPP processing pipeline.

Transient search

Figure of Merit (FoM): ~speed of survey

pulsar detection

$$FoM_1 = N_{beams} \frac{A^2}{D^2}$$

[Smits et al. 2009,
Stappers et al. 2010]

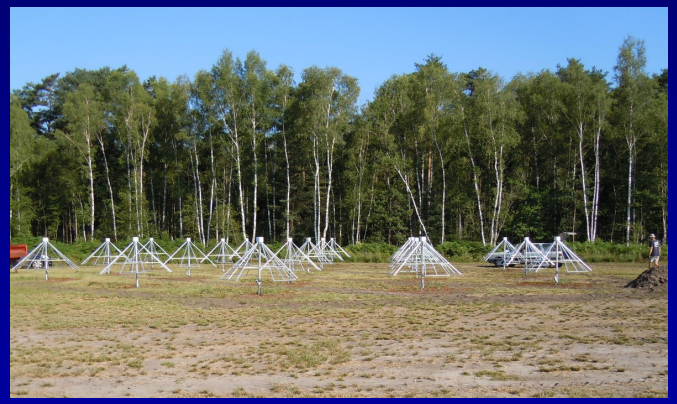
pulsar detection &
precise position

$$FoM_2 = N_{beams} \frac{A^2}{D}$$

[Stappers et al. 2011]

LOFAR: spare array (A/D << 1) → FoM not ideal
LSS: dense array(A/D ~ 1) → good FoM

LOFAR / NenuFAR



	LOFAR core	LOFAR int-1	NenuFAR-1	NenuFAR-all
sensitivity	“1”	“0.1”	“0.3”	“1.7”
sens. 15 MHz	“0.15”	“0.015”	“0.12”	“0.7”
frequency [MHz]	10/30-90	10/30-90	10/30-85	10/30-85
bandwidth [MHz]	48 MHz	8 MHz	70 MHz	70 MHz
multi-beam	>100	4	2	2 or 4
time resolution	5.12 µs	5.12 µs	5,10,20 µs?	5,10,20 µs?
TOO support	yes	yes	yes	yes
PSR FoM 2	“1”	“0.01”	“0.1”	“2” or “4”
PSR FoM 1	“1”	“0.1”	“0.4”	“3” or “6”

Pulsar surveys

low frequency PSR search – how many candidates?

at 20 MHz [Zakharenko et al. 2013]:

- 40 pulsars seen (74 observed)
- expect 15 more pulsars in long integrations
- expect 20 new, undiscovered pulsars

at 10-90 MHz [Kondratiev et al. 2014]:

- 3 MSPs detected (9 observed)
- for the other MSPs: turnover, or scattering?
- ~30 slow PSRs detected (priority is on HBA)

Pulsar observation goals

pulsar survey:

- NenuFAR-1 very well suited
- NenuFAR-all very well suited
- small number of low-frequency candidates?
- good if turn-over at low frequency

transient search:

- NenuFAR-1 very well suited
- NenuFAR-all very well suited
- number of targets unknown (probably low)
- single detection valuable!
- limited DM range

wide-band observations (profile evolution):

- NenuFAR-1 well suited
- NenuFAR-all very well suited

Pulsar observation goals

DM monitoring (MSPs):

- time resolution critical (5, 10, 20 μs?)
- few targets at low frequency (LOFAR/HBA better)

DM monitoring (slow PSRs → ISM):

- sensitivity needed (otherwise HBAs better)!
- NenuFAR-1 not better than LOFAR-int-1-HBA
- NenuFAR-all well suited
- few targets at low frequency (LOFAR/HBA better)

AIPs, giant pulses:

- NenuFAR-1 well suited
- NenuFAR-all well suited
- time resolution critical (5, 10, 20 μs?)
- low DM targets only