ADVANCES IN WIDE-BAND VLBI TECHNOLOGY

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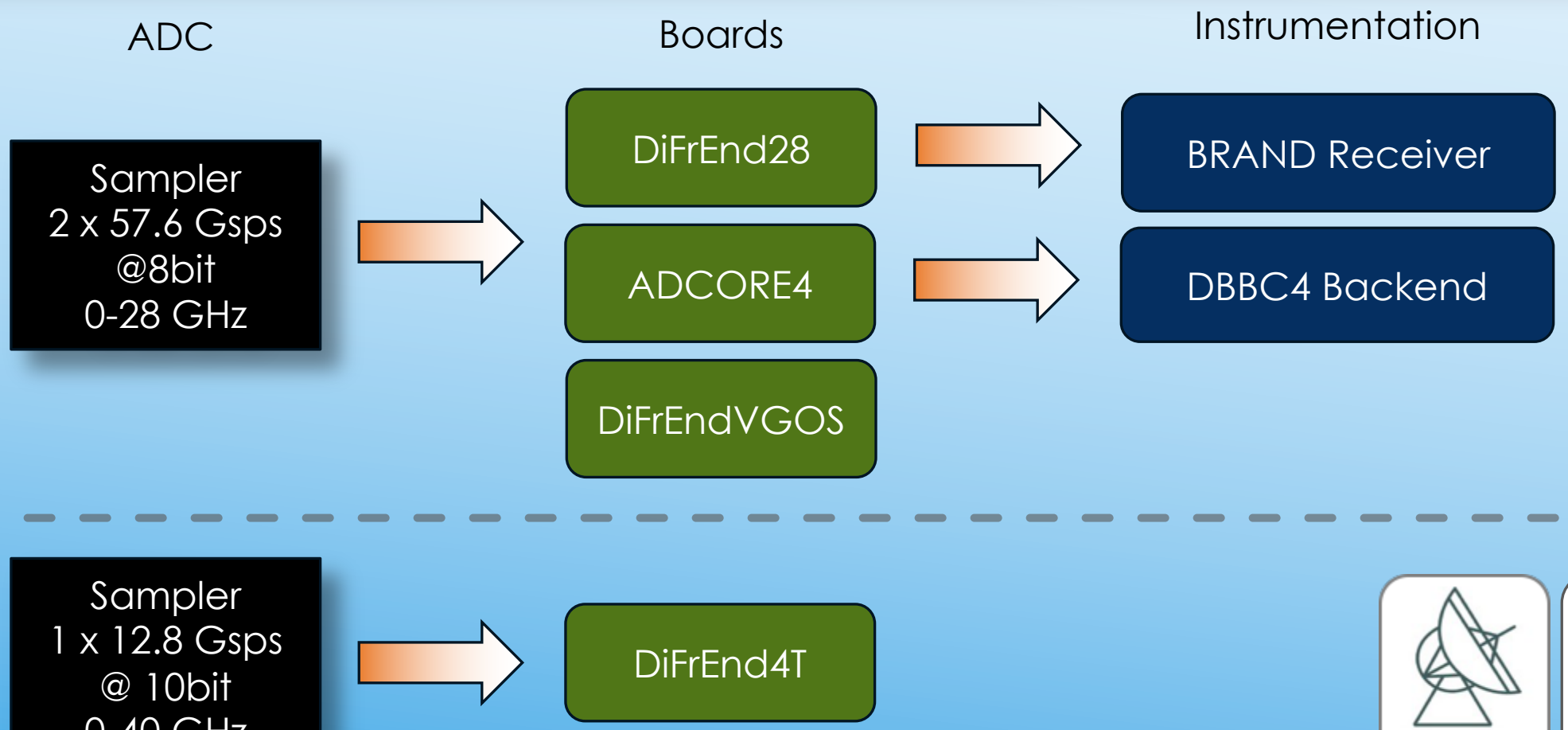
WIDE BAND SCIENCE PERSPECTIVES

- Improved sensitivity
- Multi-frequency data (more efficient use of observing time)
- Richer spectral information (e.g. line ratios)
- Magnetic field studies (e.g. Faraday rotation)
- Improved calibration (ionosphere, troposphere)
- Phase-stability between bands (astrometry)

Next-generation sampler chips open up opportunities for large increases in the wide-band (VLBI) instrumentation

RECENT DEVELOPMENTS MPIFR / INAF



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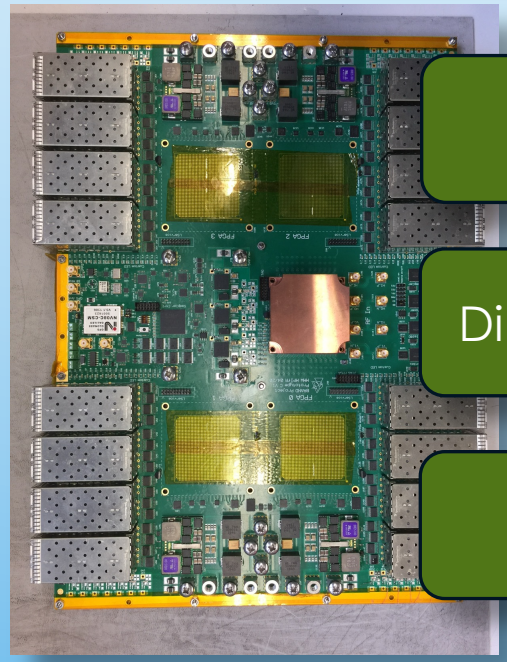
DIGITAL FRONTEND UNITS



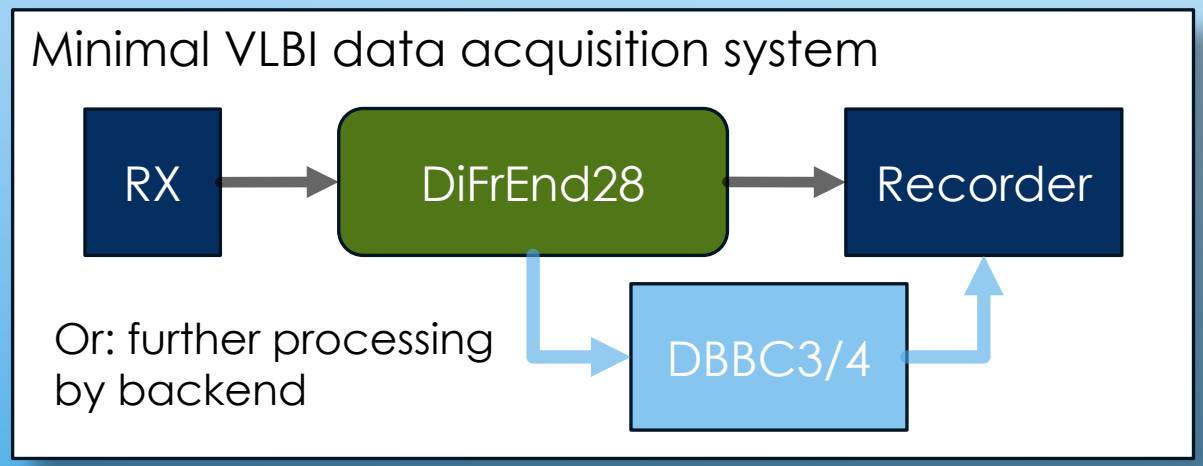
DiFrEnd28

DiFrEndVGOS

DiFrEnd4T

Provide frontend and (partial) backend functionality:

- Digitization
- Band filtering (e.g. 512, 1024 MHz etc.)
- Decimation
- VDIF formatting



DIFREND28 – WIDE BAND DIGITAL FRONTEND

Status: under final testing

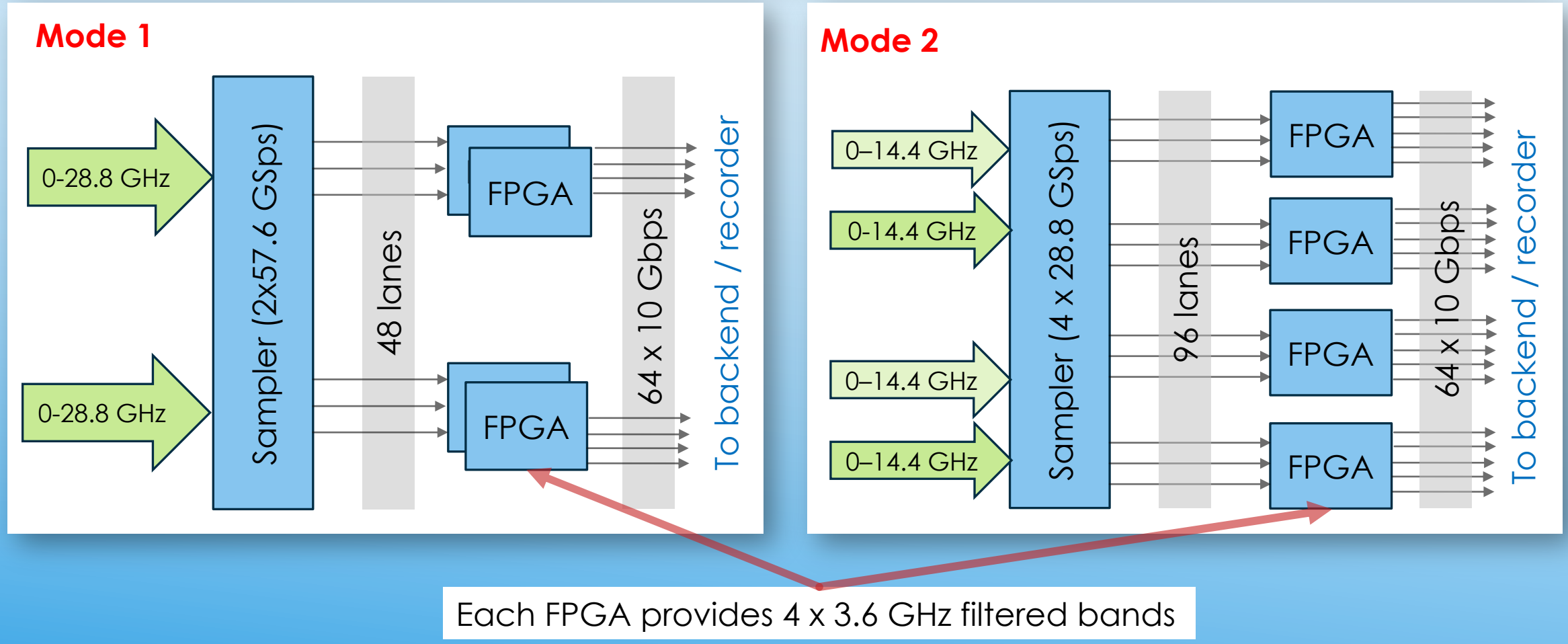
Sampler chip
- 2 x 57.6 Gsps @ 8 bit
- ENOB: 6.5

PCB
- Dimension: 30 x 40 cm
- Layout: 22 Layers

Digital processing
- 4 FPGA Xilinx Kintex UltraScale
- 1 Tbps data transport to FPGAs

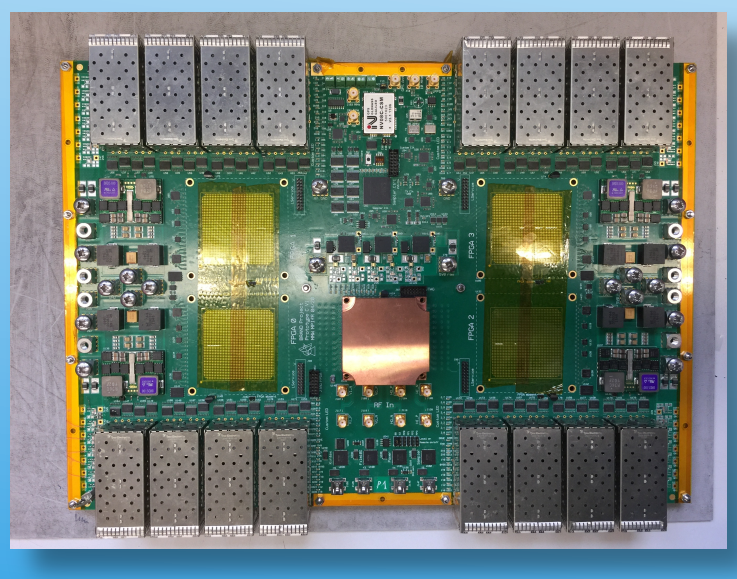
IO
- Input: 2 x 28.8 GHz / 4 x 14.4GHz RFs
- Output: 64 x 10 Gbps (VDIF / raw)

DIFREND28 PROCESSING MODES



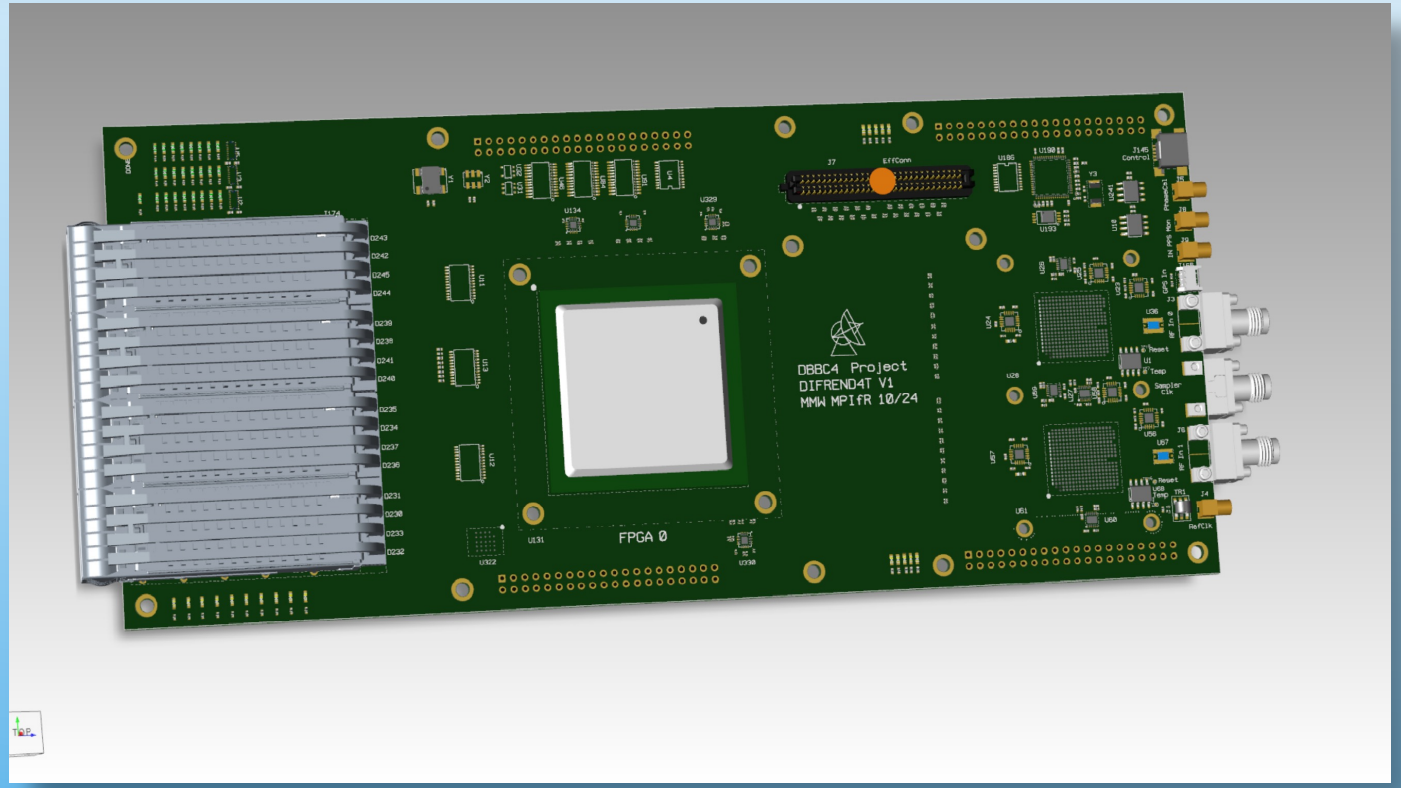
DIFRENDVGOS

- Based on DIFREND28
- Specially tailored to VGOS observations
  - 14 GHz input band width (VGOS band 2 – 14 GHz)
  - Will provide tunable BBCs with different sub-band widths e.g. 64 MHz, 128 MHz



Status: under development

DIFREND4T



Sampler chip:
Rate: 12.8 Gsps @10 bit
RF range: 0-40 GHz

- Max. input bandwidth:
  - 1 x 0-40 GHz
- Max. output bandwidth:
  - 1 x 6.4 GHz
- Output data rate:
  - 64 Gbps
- VDIF formatting

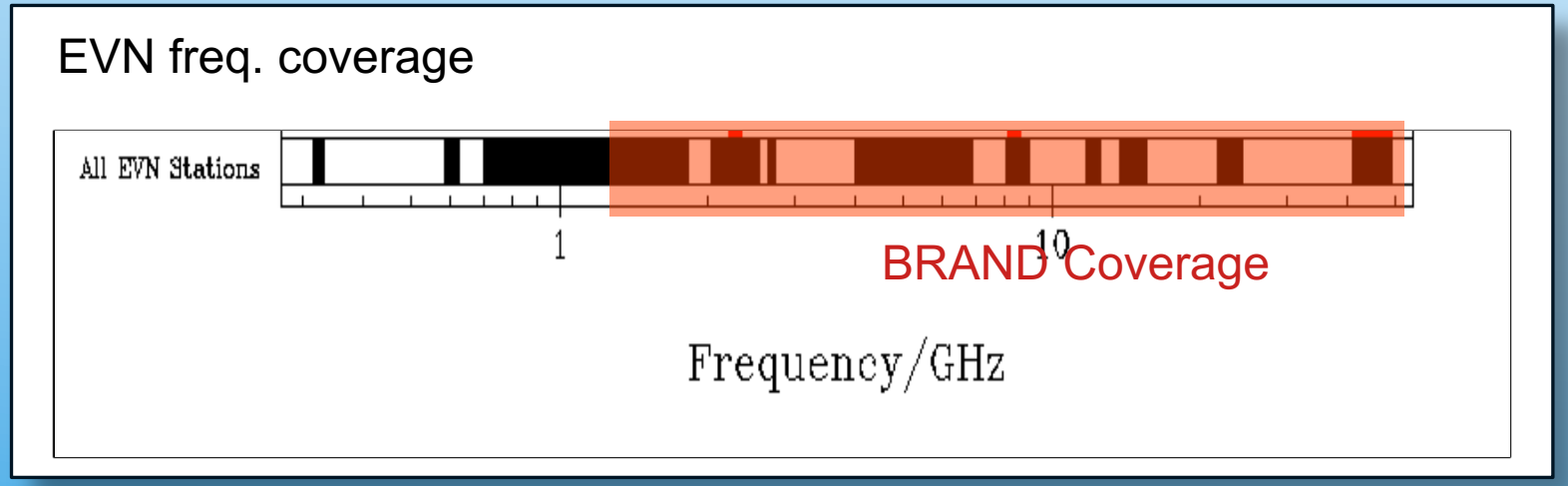
Status: 1st prototype under development

APPLICATION: BRAND RECEIVER

Very-wide band "digital" receiver

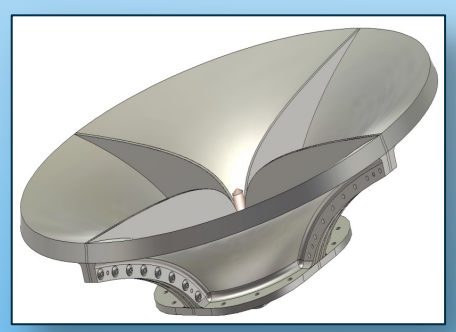
- Frequency range: 1.5 - 15.5 GHz
- Instantaneous bandwidth: 14 GHz
- Prototype BRAND receiver for the 100-m telescope (prime focus)

- Targets:
  - EVN VLBI array
  - VGOS array
  - Single dish



BRAND PROJECT HISTORY

- Joint Research Activity (JRA) in the Horizon2020 EU funding programme
- Partners: MPIfR, INAF/Noto, OSO, UAH/IGN, ASTRON, VUC

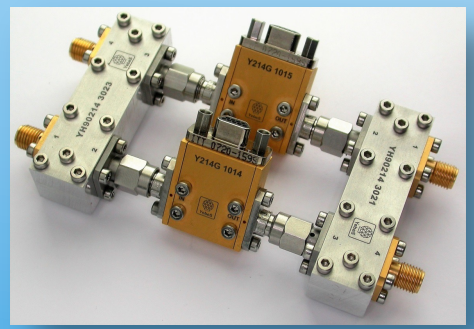


QRFH feed with dielectric inset
Opening angle: 160°
f/D: 0,3
(OSO)

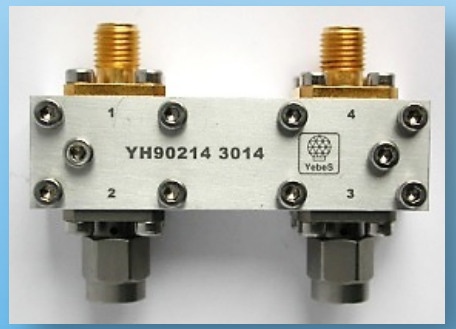
Digital frontend PCB (DiFrEnd28)
Sampling with 2x57.6Gsps
(MPIfR, INAF/Noto)

Cryostat
Window Ø 58 cm!
With support structure
(MPIfR)

LNA: Balanced amplifier with 2 hybrids and 2 LNAs (UAH/IGN)



Polarization conversion
With 3dB/90° hybrid
Noise penalty < 2.5K
(UAH/IGN)



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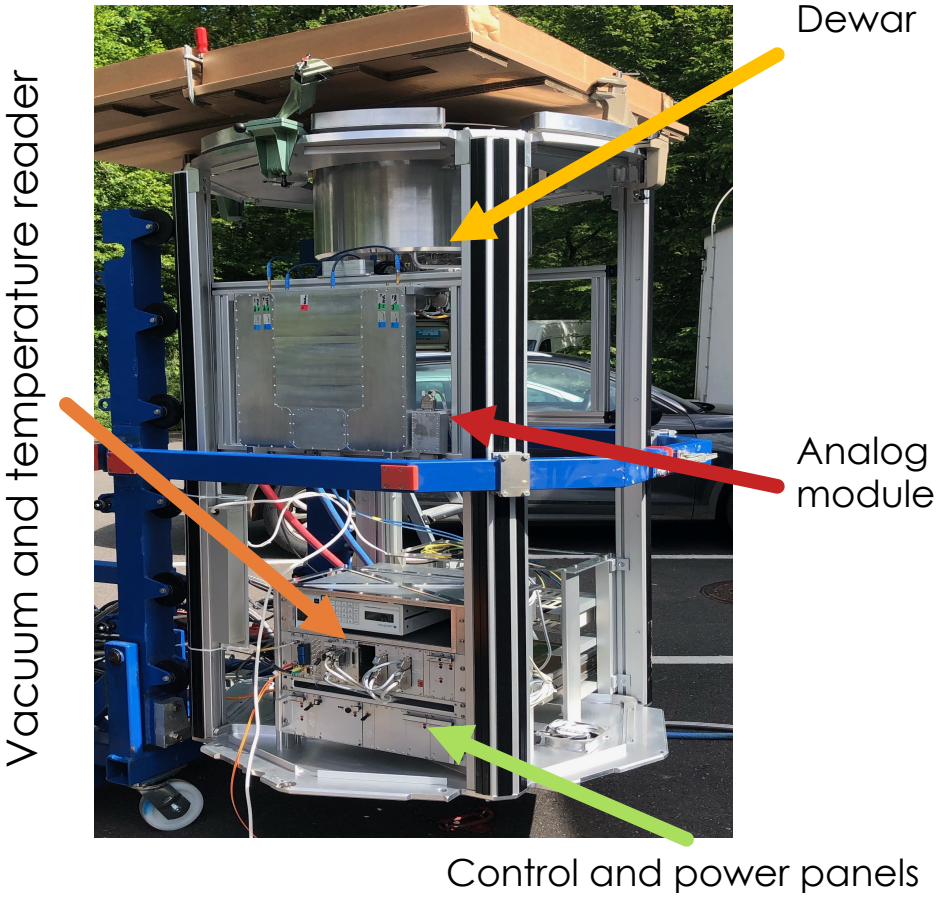
BRAND EFFELSBERG COMMISSIONING

2024

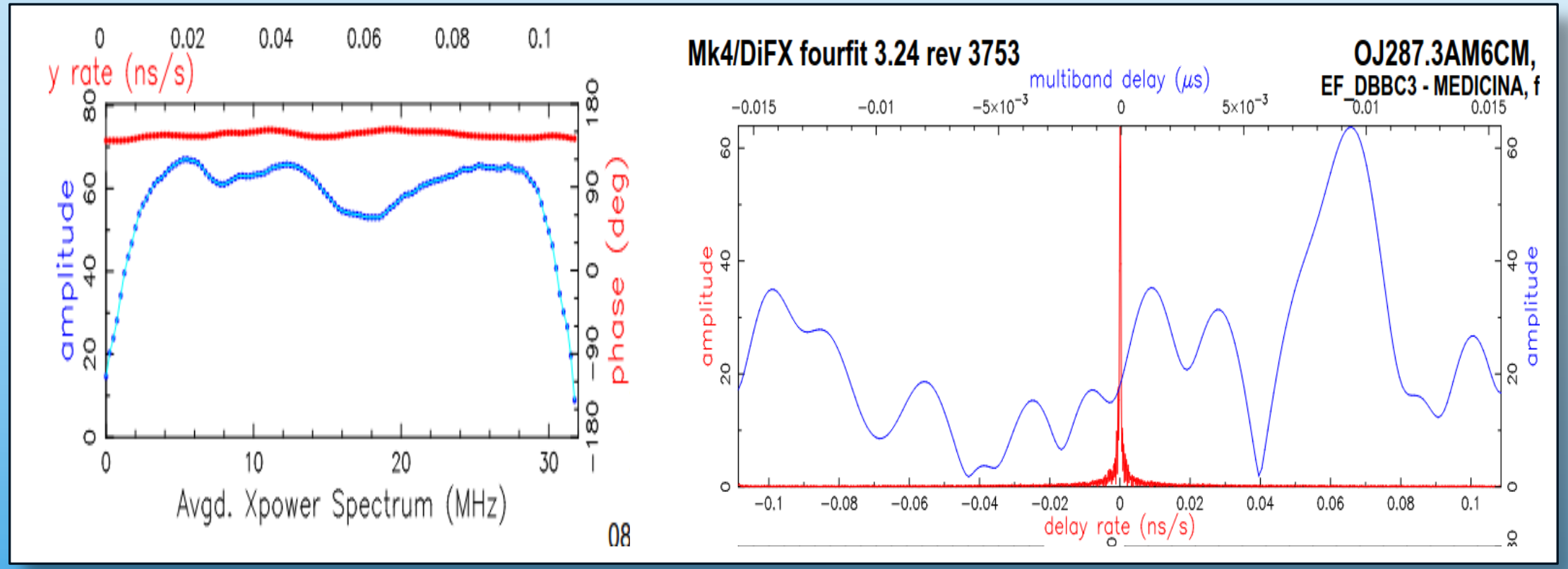
- Integration of components into full system
- Lab testing of full system
- Installation in Effelsberg telescope
- Final system tests

- Master thesis by Parisa Rahimi (in preparation)



BRAND FIRST FRINGES

First VLBI Fringes at 4.85 GHz (EVN NME N24C2 with Ef, Mc, On, and Ys)



APPLICATION: DBBC4 BACKEND

The DBBC4*) is the latest of the DBBC family of backends (DBBC, DBBC2, DBBC3)

Technical specs:

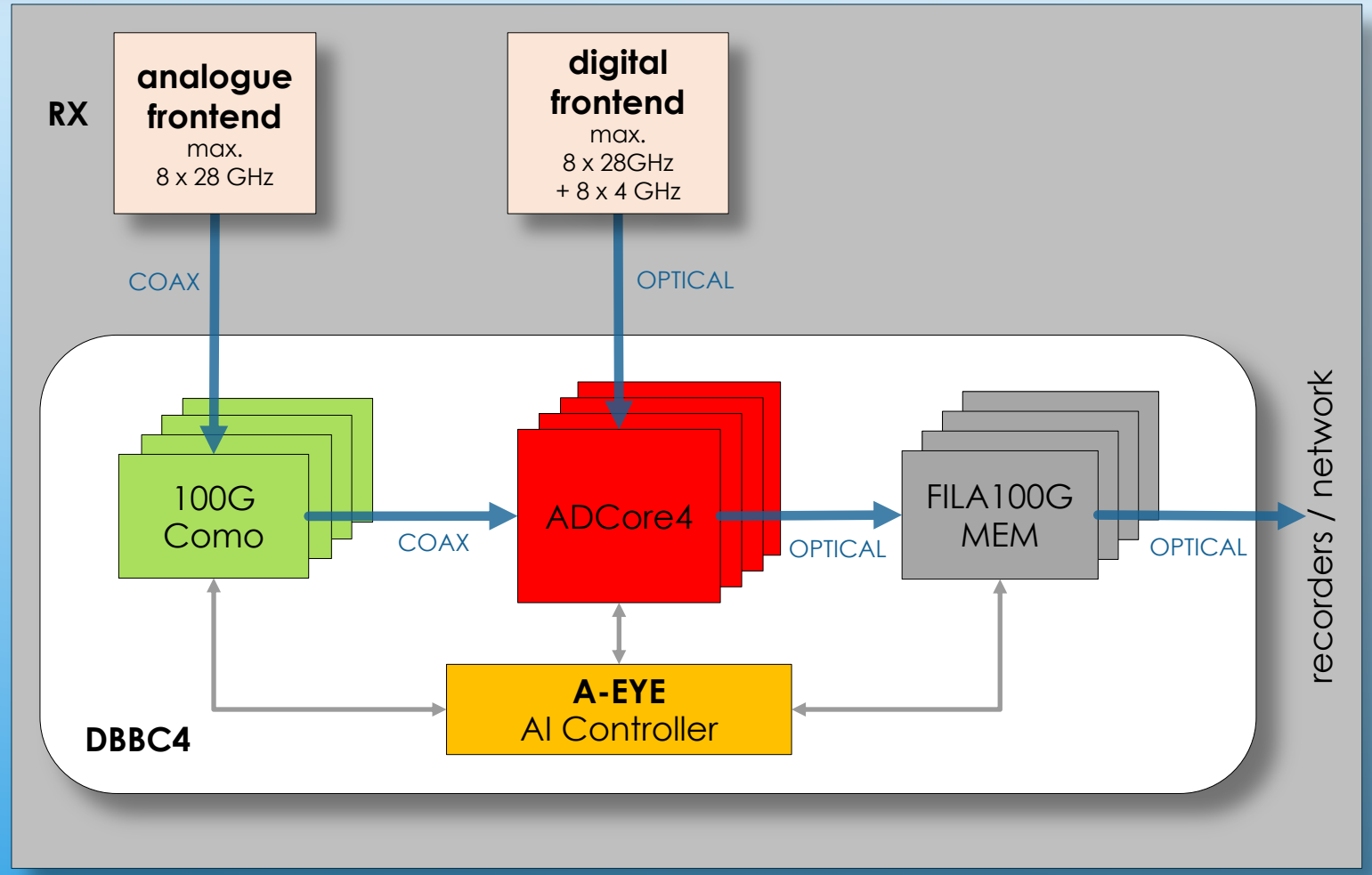
- Maximum input bandwidth: 8x28GHz + 8x4GHz= **256 GHz**
- Maximum output data rate: **1 Tbps** @ 2bit sampling

Novel capabilities:

- AI methodology:
  - Real-time interference mitigation
  - Transient search
- Output stream buffering, duplication and modification
  - Burst mode operations (match output data rate to recording rate)
  - Signal streaming to correlators for real-time fringe verification

*) The DBBC4 project has received funding from:
- the Max Planck Society
- the European Union's Horizon Europe research and innovation programme under grant agreement No 101093934

SYSTEM SCHEMATICS



Modular design:
1 – 4 signal chains

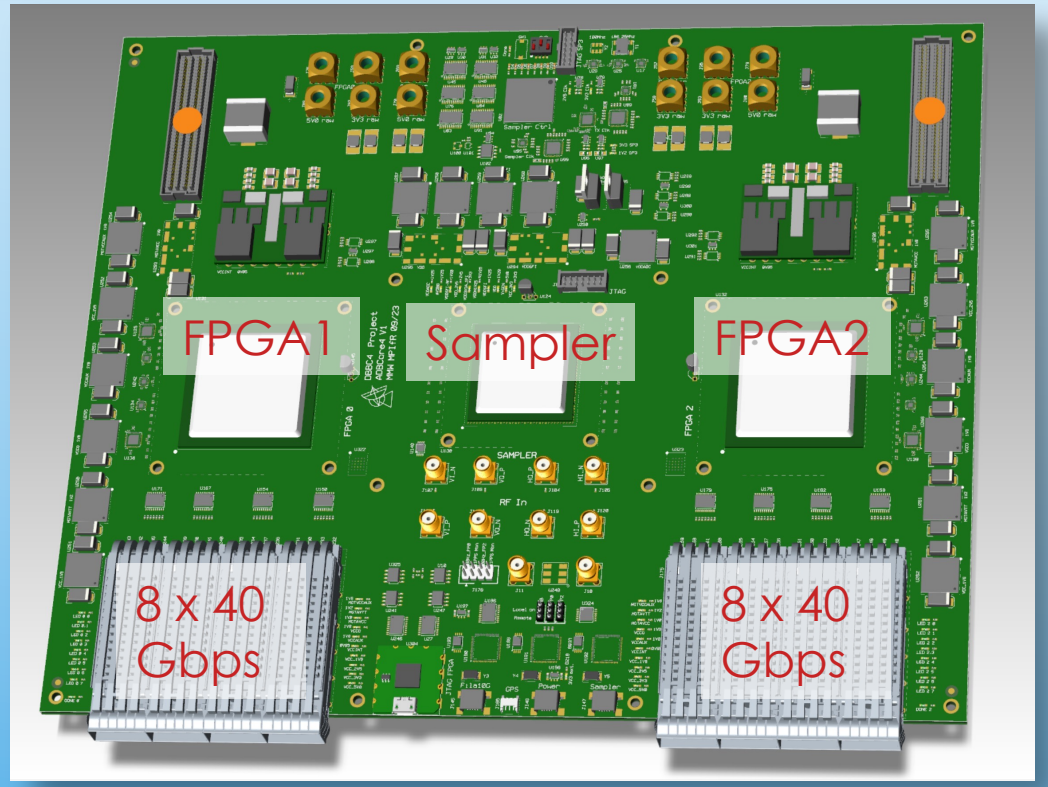
Two operational scenarios*:

1) Analogue-in
   - Sampling of 2 x 28 GHz
   - Analogue conditioning

2) Digital-in
   - 2 x 28 GHz
   - 2 x 4 GHz bw
     (in range 0-36 GHz)

* Input bandwidth per signal chain. Max 8x28GHz.

ADCORE4 PCB



- A/D conversion with 2x57.6 Gsps @8bit
- band processing in various modes
- VDIF formatting

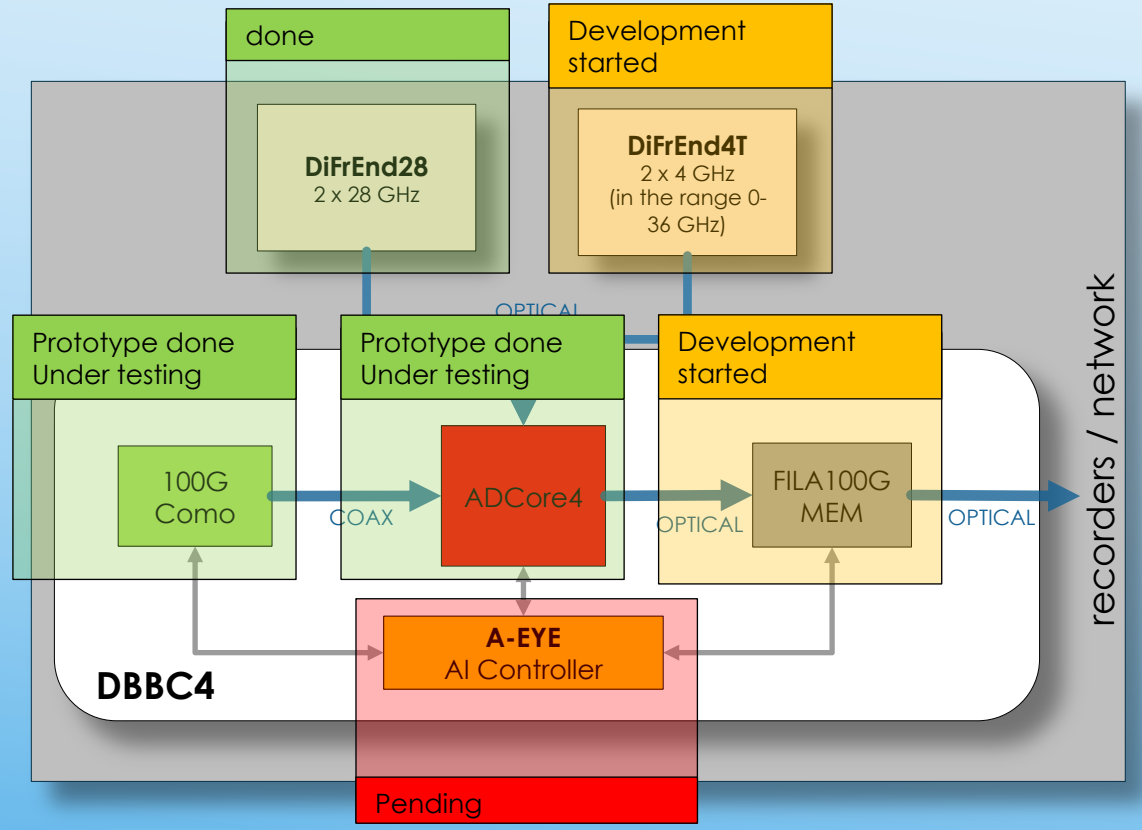
Processing modes

- **DSC**
  full 28GHz, direct sampling
- **OCT**
  full 28 GHz divided into sub-bands
  4 filters of sizes:
  225, 450, 900, 1800, 3600, 7200, 14400 MHz
- **DDC**
  tunable with sub-bands of various band widths:
  3.5, 7, 14, 28.1, 56.25, 112.5 MHz

DBBC4 STATUS AND TIMELINE

- Fully funded by MPG and EC
- Development started early 2023
  - Prototypes have been finished for several components and are currently under testing
  - Firmware/software development is ongoing. Can be adapted from DBBC3 with moderate effort

First functional prototype system is expected to be available in **2025**



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Thank you!
Any questions?