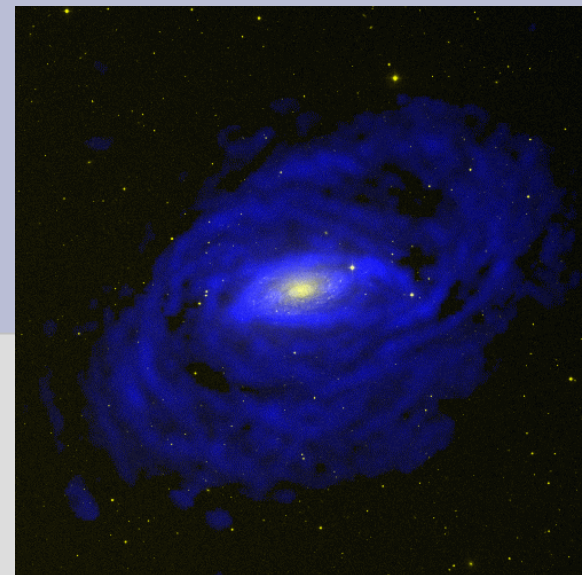




BAO project in radio



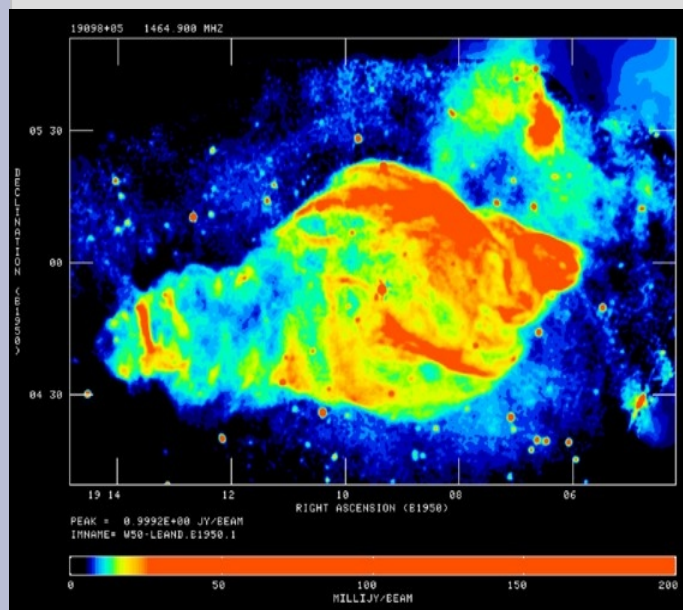
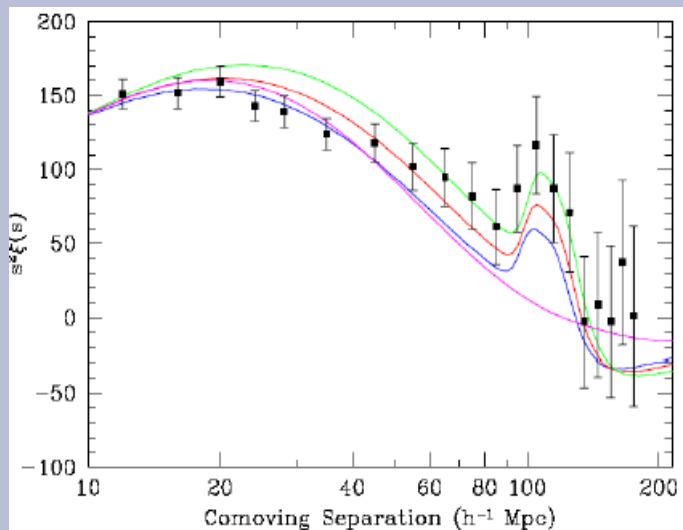
Fast acquisition system for 3D mapping of cosmological matter distribution in radio

CEA/Irfu IN2P3/LAL CMU Fermilab collaboration

D.Charlet, P. Abbon, C. Beigbeder, T. Caceres, H. Deschamps, B. Manssou,
C. Paille, M. Taurigna



BAO : Baryonic Acoustic Oscillations

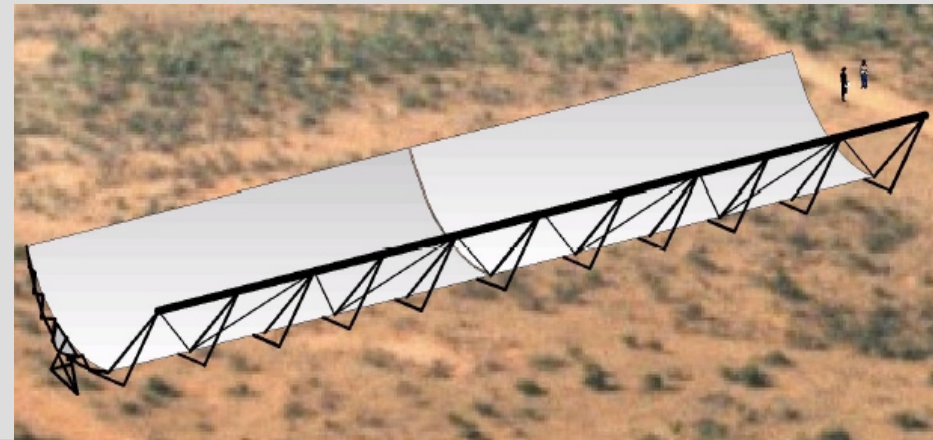
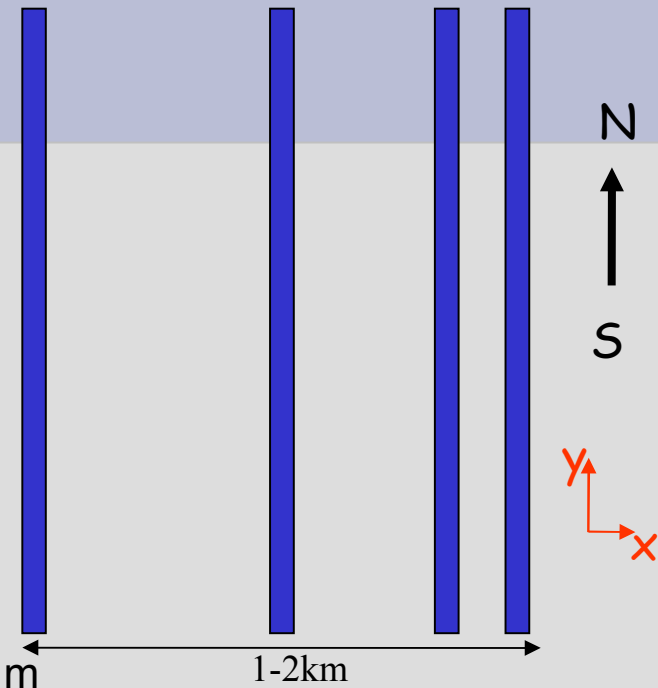


- Imprints left by the baryon-photon fluid (before recombination) in the distribution of ordinary (baryonic) matter
- Slight modulation of the distribution of matter, (and galaxies as tracers). Structure formation being mainly driven by CDM which dominates structure formation
- In Radio : Use 21 cm HI emission
- 3D HI mass distribution measurement through total 21 cm emission intensity mapping (No individual galaxy detection)
- Hyperfine transition (spin-orbit) of atomic hydrogen: $\nu \approx 1,420,405$ GHz $\rightarrow \lambda \approx 21$ cm



BAO Radio-CRT Instrument principle

- › Large field of view ($10-100 \text{ deg}^2$)
- › ≥ 1000 simultaneous lobes \rightarrow Digital interferometer
- › Wide band receivers 250 MHz
- › Digital interferometer (correlator / beam-former)
- › Resolution 10 arcmin, Surface $\geq 10\,000 \text{ m}^2$
- › Reflectors over an area of $\sim 1000-2000 \text{ m} \times 1000-2000 \text{ m}$
- › Cylindrical Radio Telescope concept : 12 cylinders 100 m x 8 m
- › 256-512 electronic channel by cylinder
- › 4 bands of 250MHz between 0.5-1.5GHz
- › Sampling at 500MHz
- › Possible implantation in China



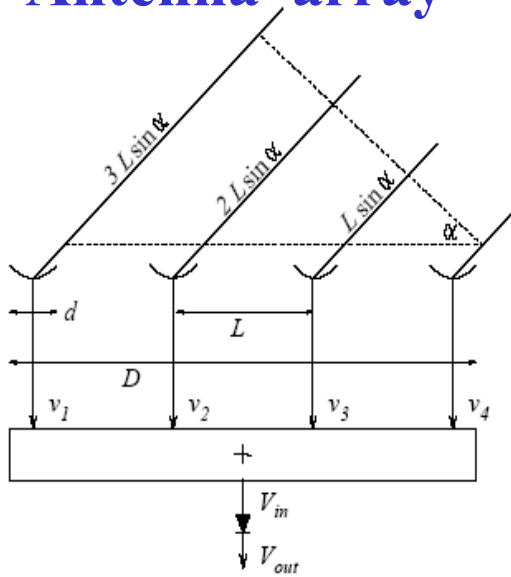
Multi ditch concept





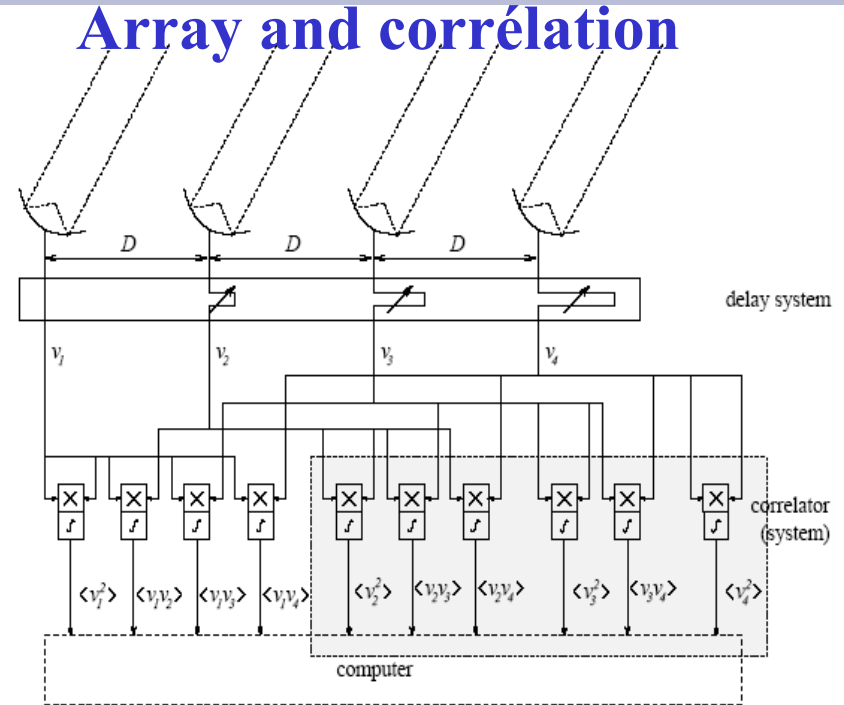
Standard Interferometry

Antenna array



- **Array: resolution gain**
 $\lambda/d \Rightarrow \lambda/D$
- we can observe only some directions
 $\sin(\alpha_N) = N \cdot \lambda / L$
- For $\lambda = 30\text{cm}$, $\sigma(\theta) = 1'$
 $\Rightarrow D = 1\text{km} !!!$

Array and correlation

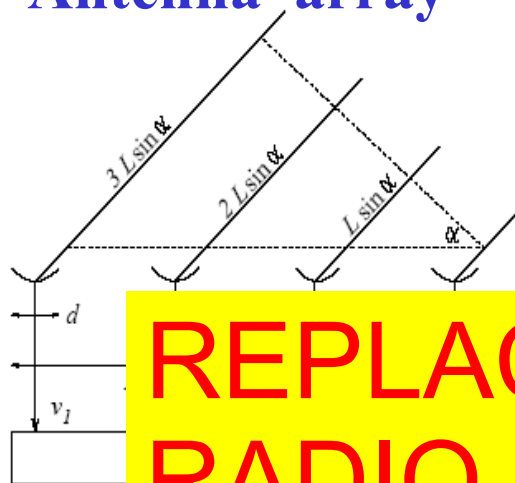


- Same gain in resolution
- With a correlator, all **directions** are available
- $N(N-1)/2$ independant correlations

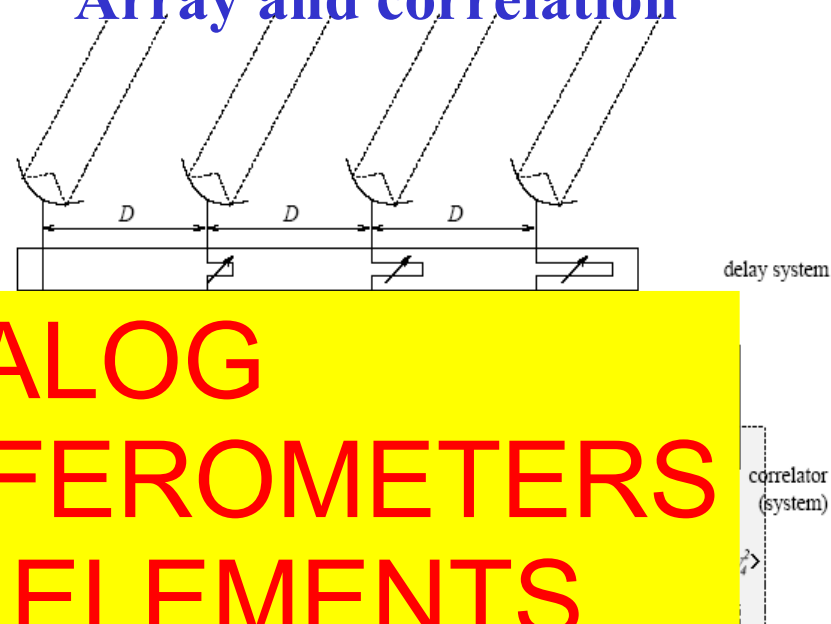


Interferometry

Antenna array



Array and correlation



**REPLACE ANALOG
RADIO INTERFEROMETERS
ELECTRONIC ELEMENTS
(filters, mixer, multipliers...) by
DIGITAL ELECTRONICS**

➤ Array

λ

➤ we can

direction

$$\sin(\alpha_N) = \frac{v_I}{\lambda}$$

➤ For $\lambda=30\text{cm}$, $\sigma(\theta) = 1'$

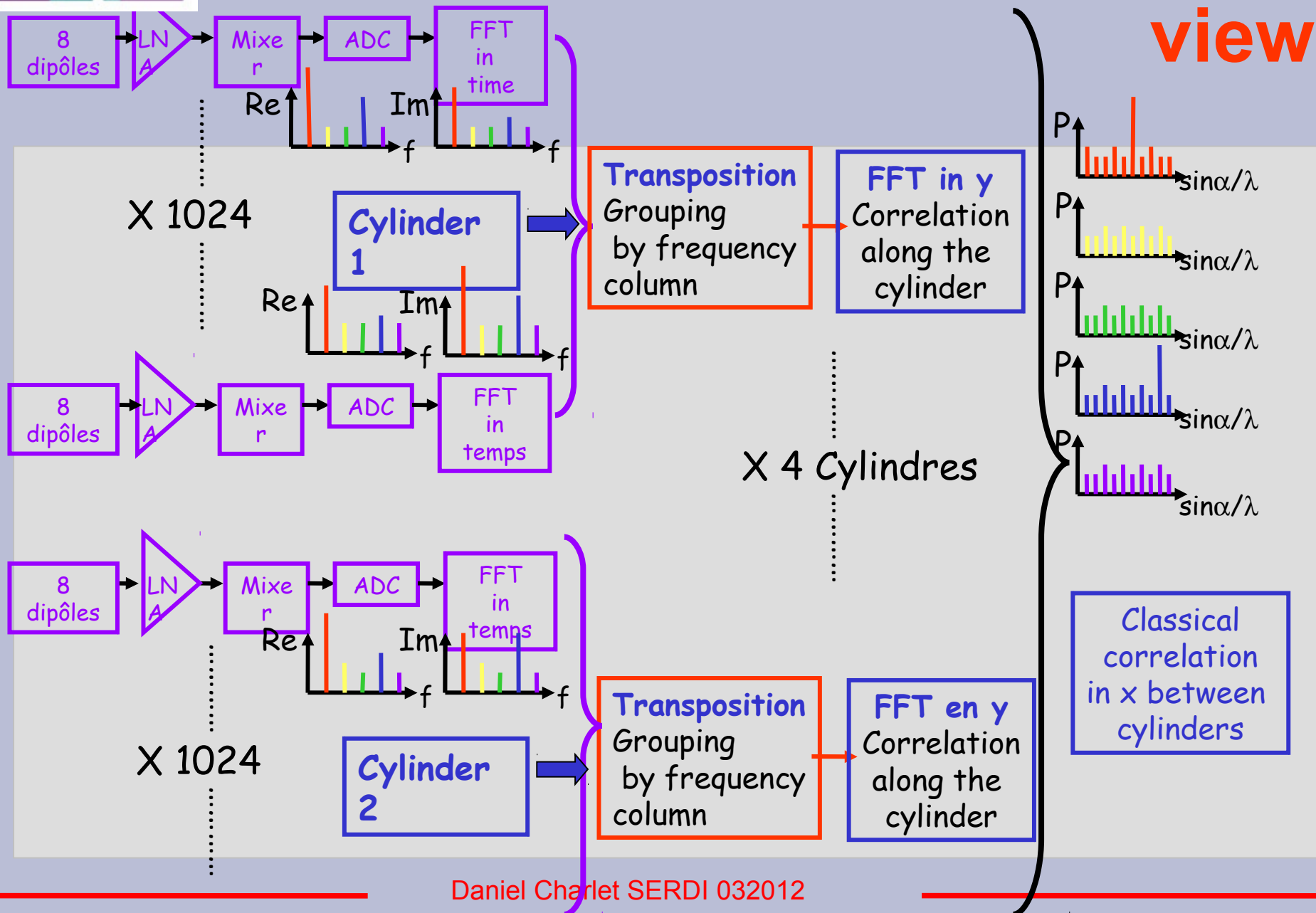
⇒ $D= 1\text{km} !!!$

directions are available

➤ $N(N-1)/2$ independent correlations

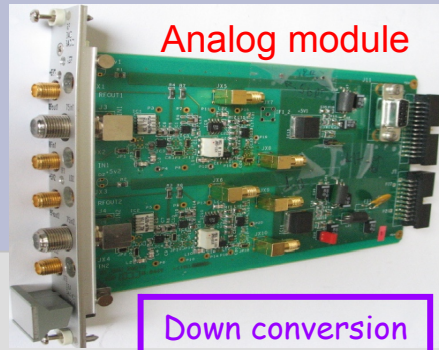


Electronic chain schematic



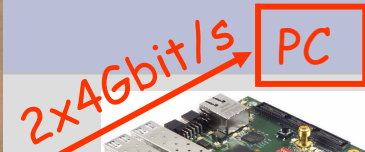
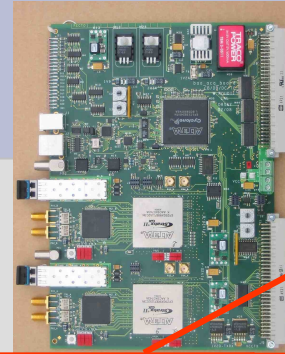


Electronics chain



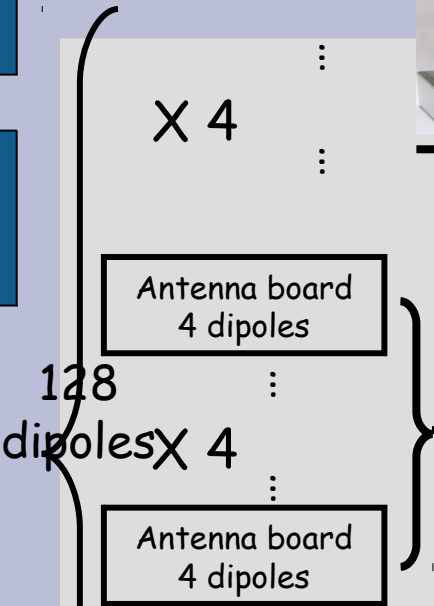
Analog module

ADC board

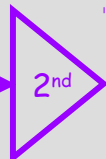


PC

PCIExpress board



Down conversion filtering



Down conversion filtering



Clock distribution

ADC (500 MHz) 4 channels

Time FFT FPGA

ADC (500MHz) 4 channels

Time FFT FPGA

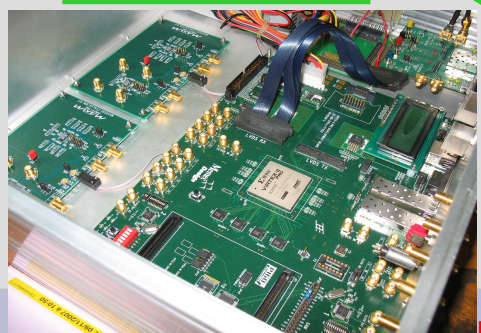
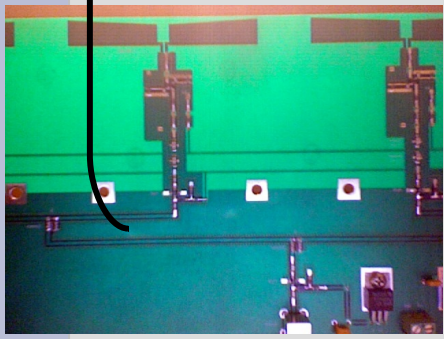
Spatial FFT (FPGA)

2x4 Gbit/s

2x4 Gbit/s

2x4 Gbit/s

PC

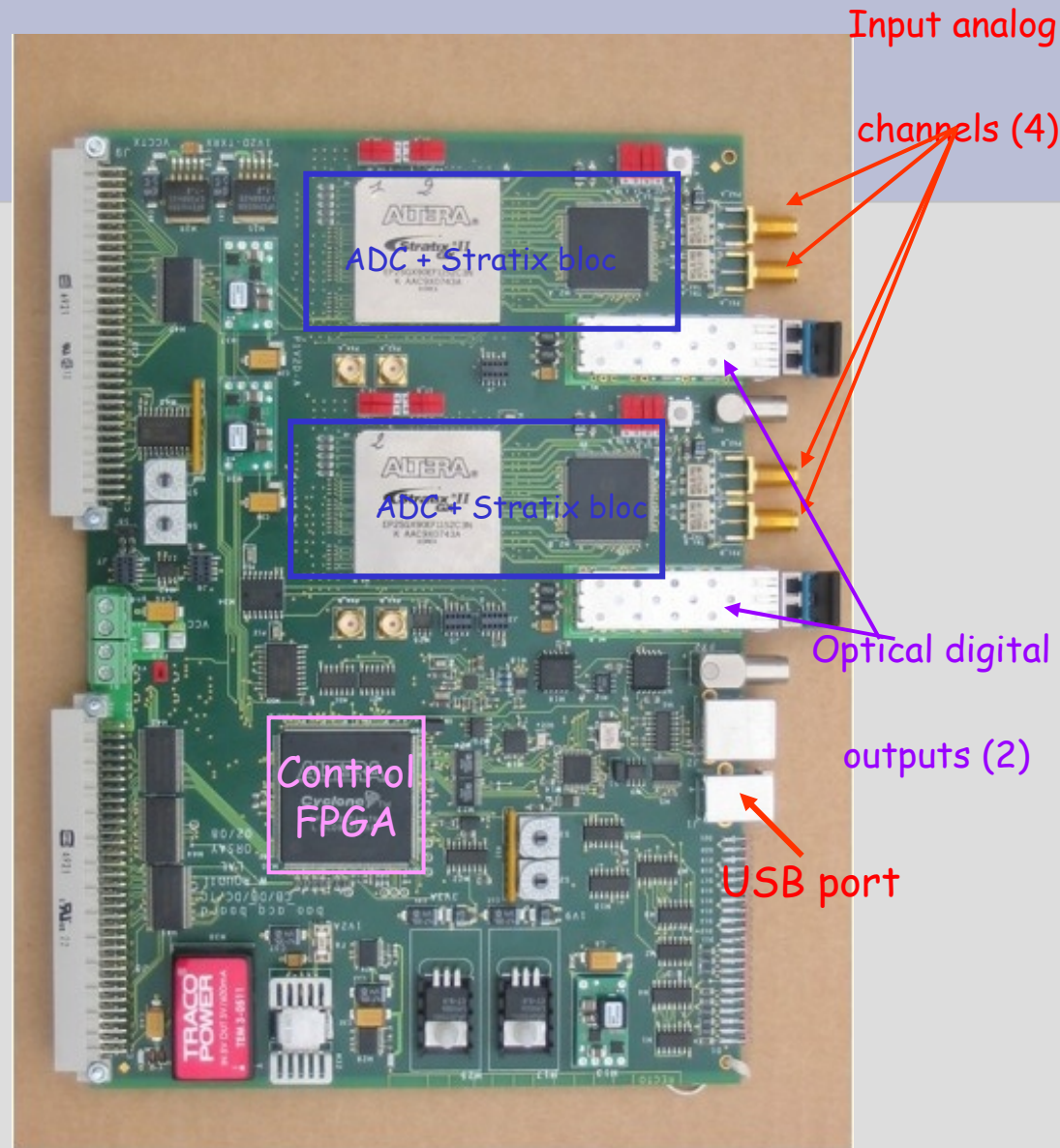




500MHz ADC board

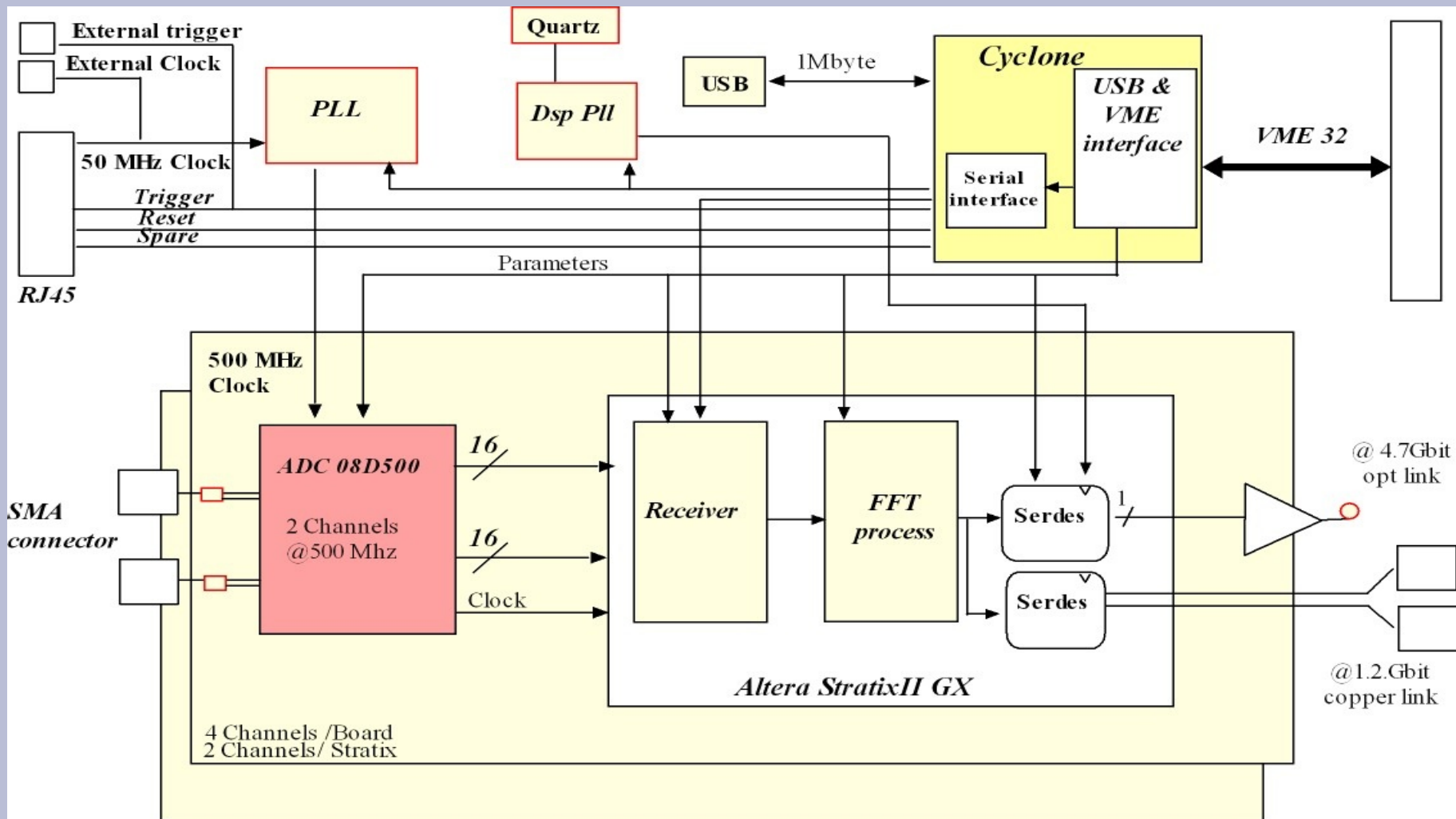
Each ADC board has :

- 4 input channels (digitized at 500 MHz max)
- Input clock + control (start/stop...) ports
- USB, and VME communications port (for control)
- 2 high speed (4.8 Gbit/s) optical outputs (data links to PCI-express boards)





LAL ADC board Synoptic

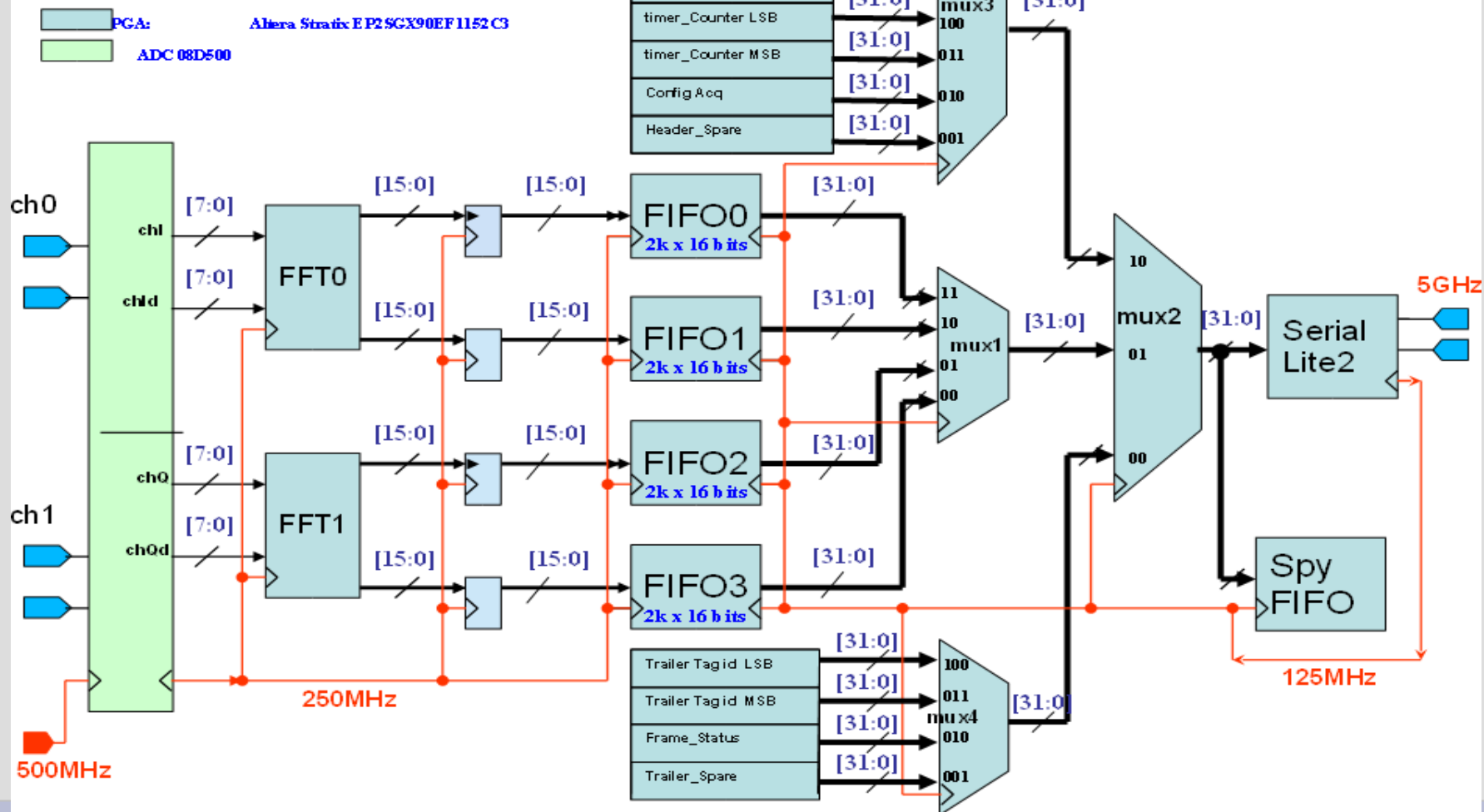




ADC board FPGA Synoptic

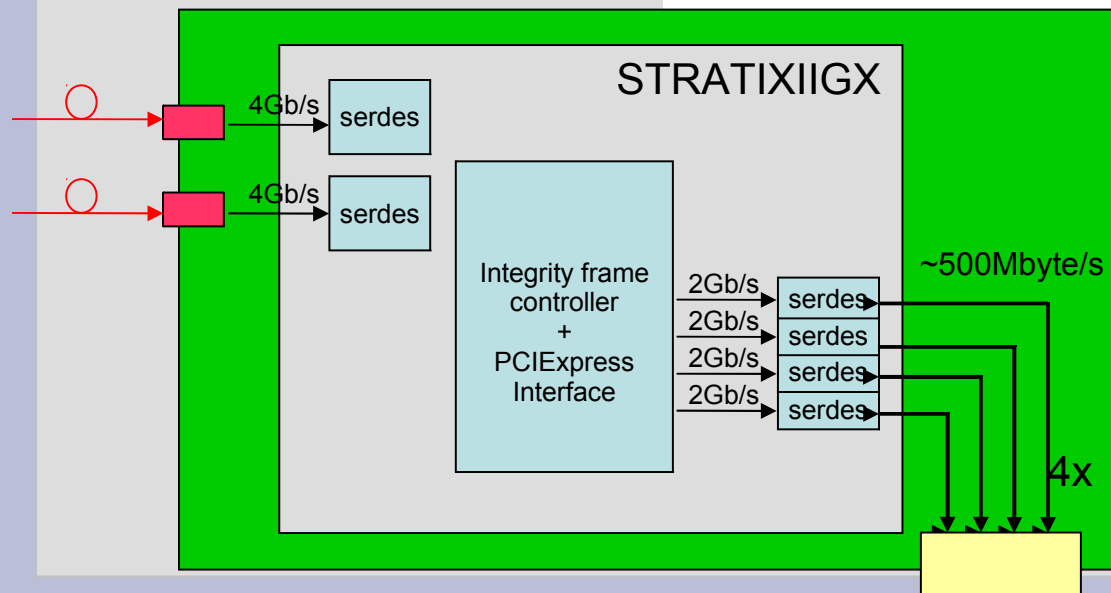
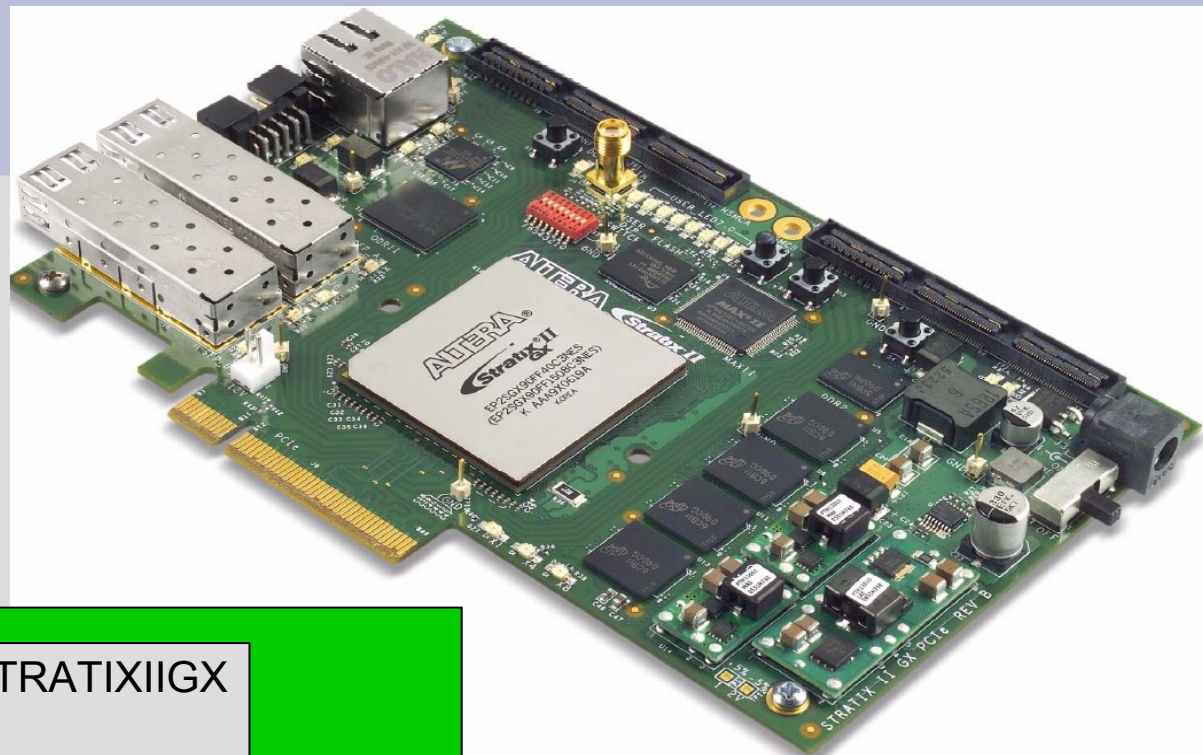
Firmware:BAO_FFT8192_2ch1000v24,v26

two FFT8k x 8bits transmitted
on one serial link.





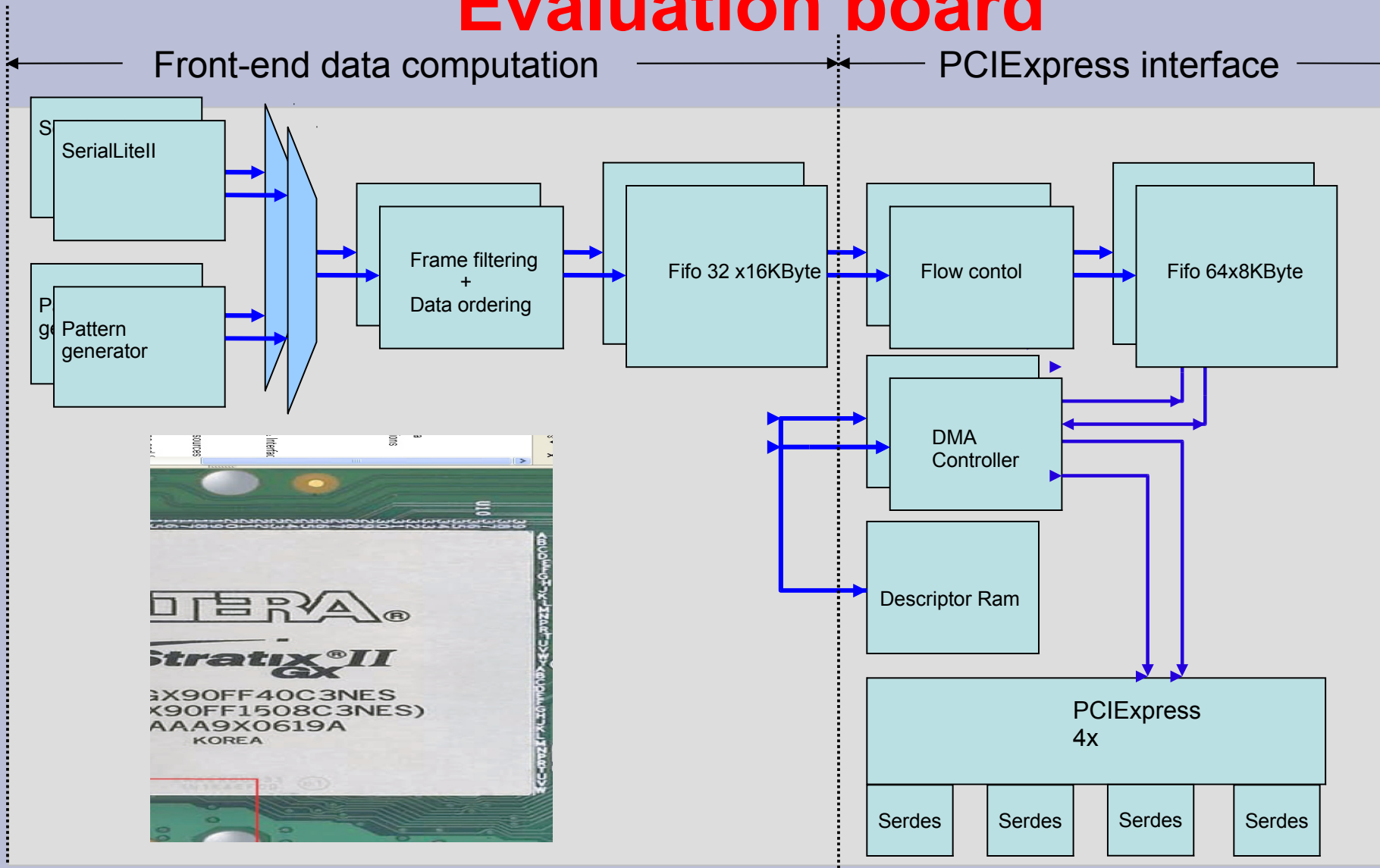
PCIExpress evaluation board





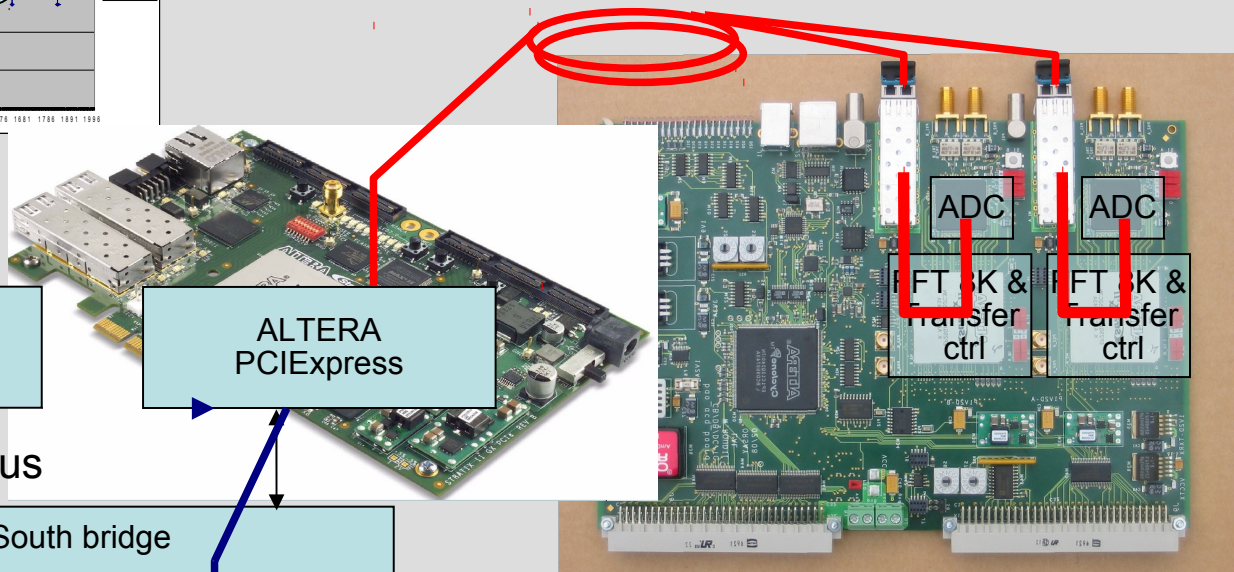
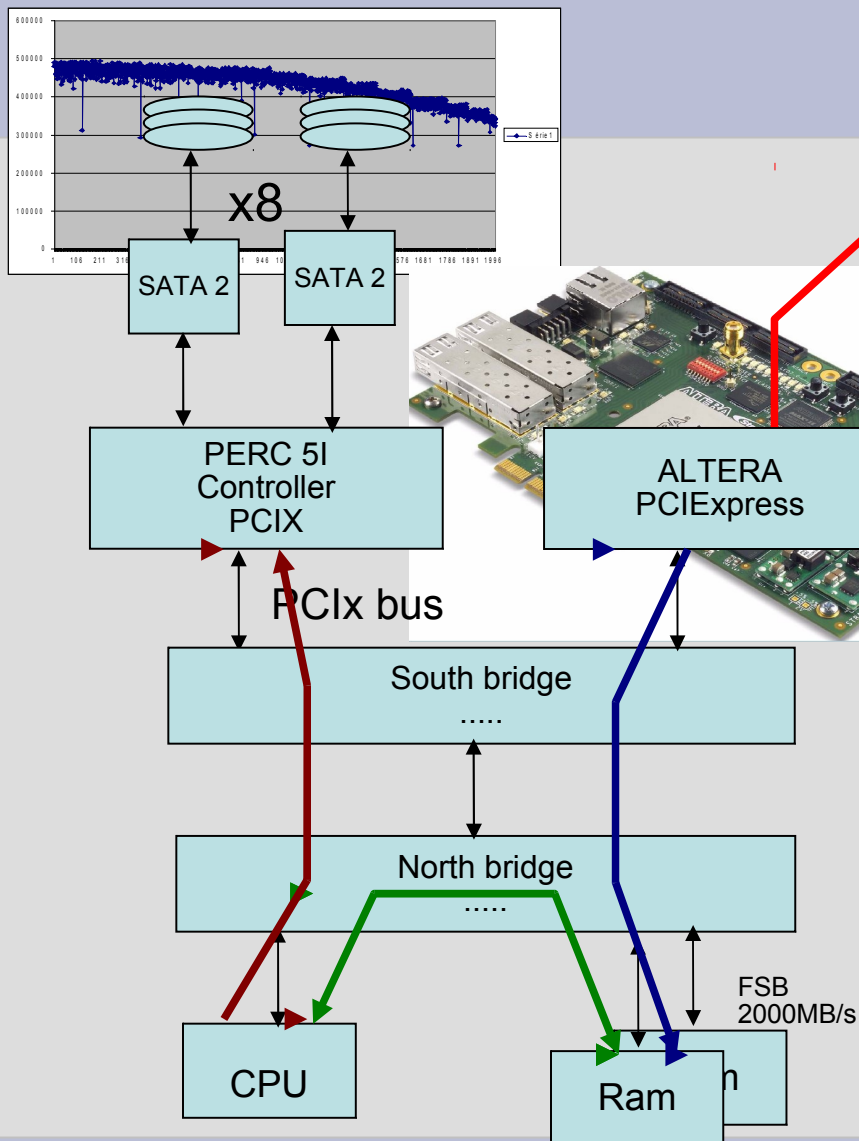
Synoptic FPGA PCIeExpress

Evaluation board





Aquisition test

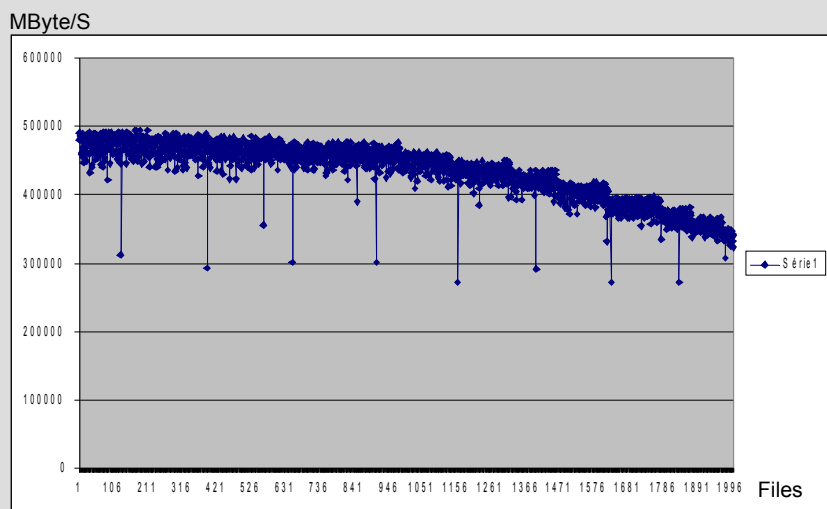


- DMA transfer
- Disk writing
- Cpu treatment
- Multi hardware tested
- Multi OS tested

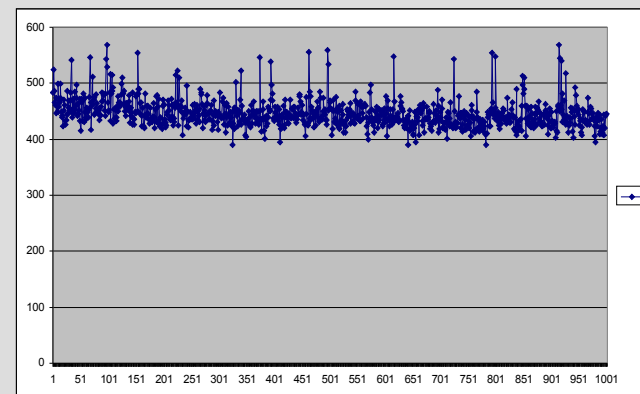


PC Data flow

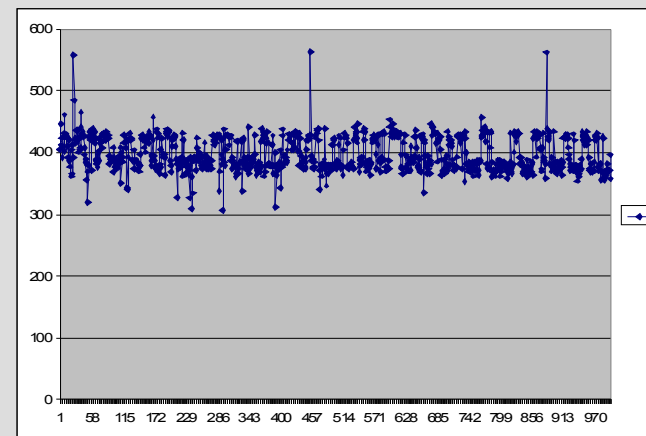
300MB/s sustained data rate from digitalizer to PC-disk
Average throughput 430MB/s



PowerEdge 2900 quad core

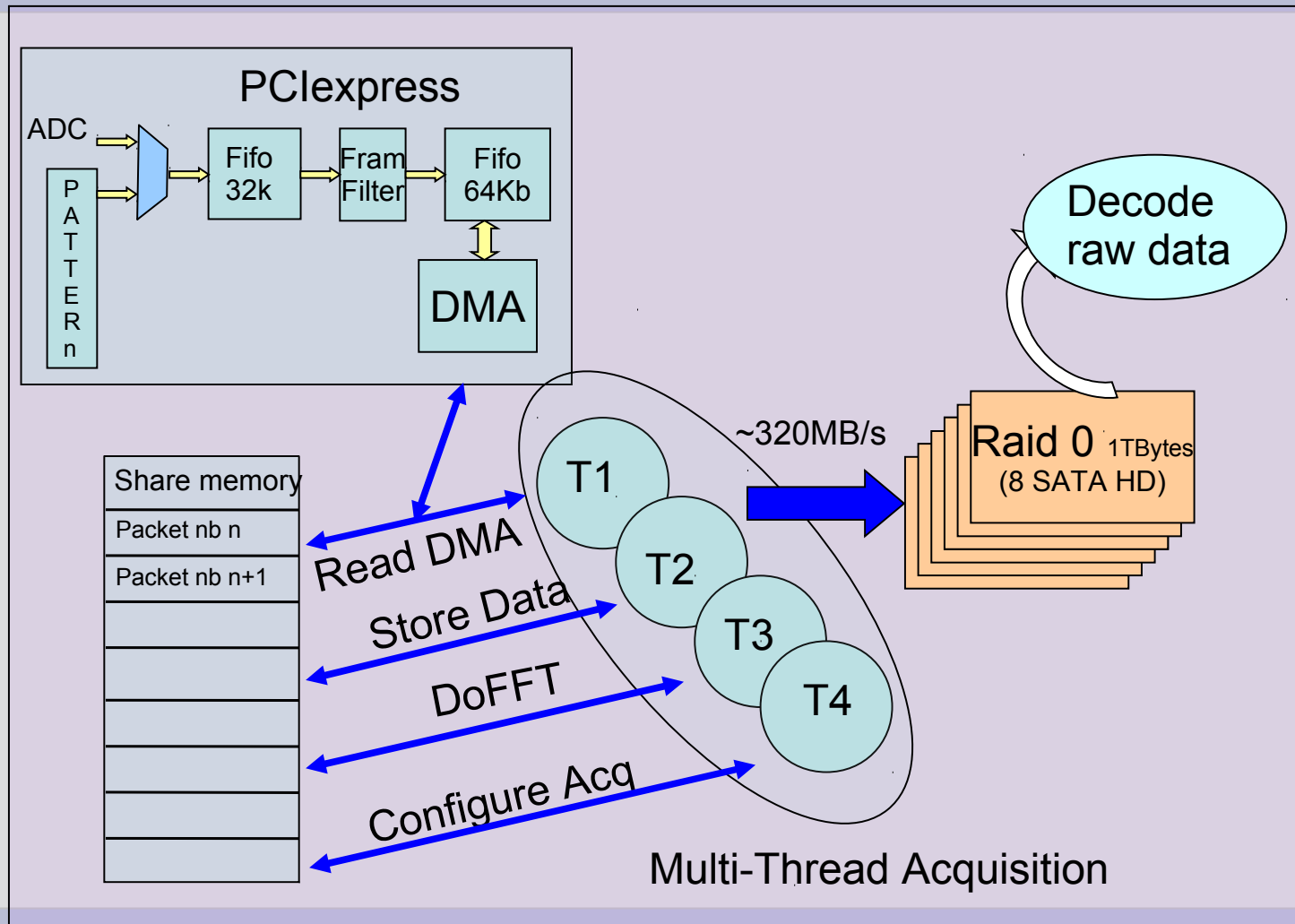


PowerEdge 2900 double core



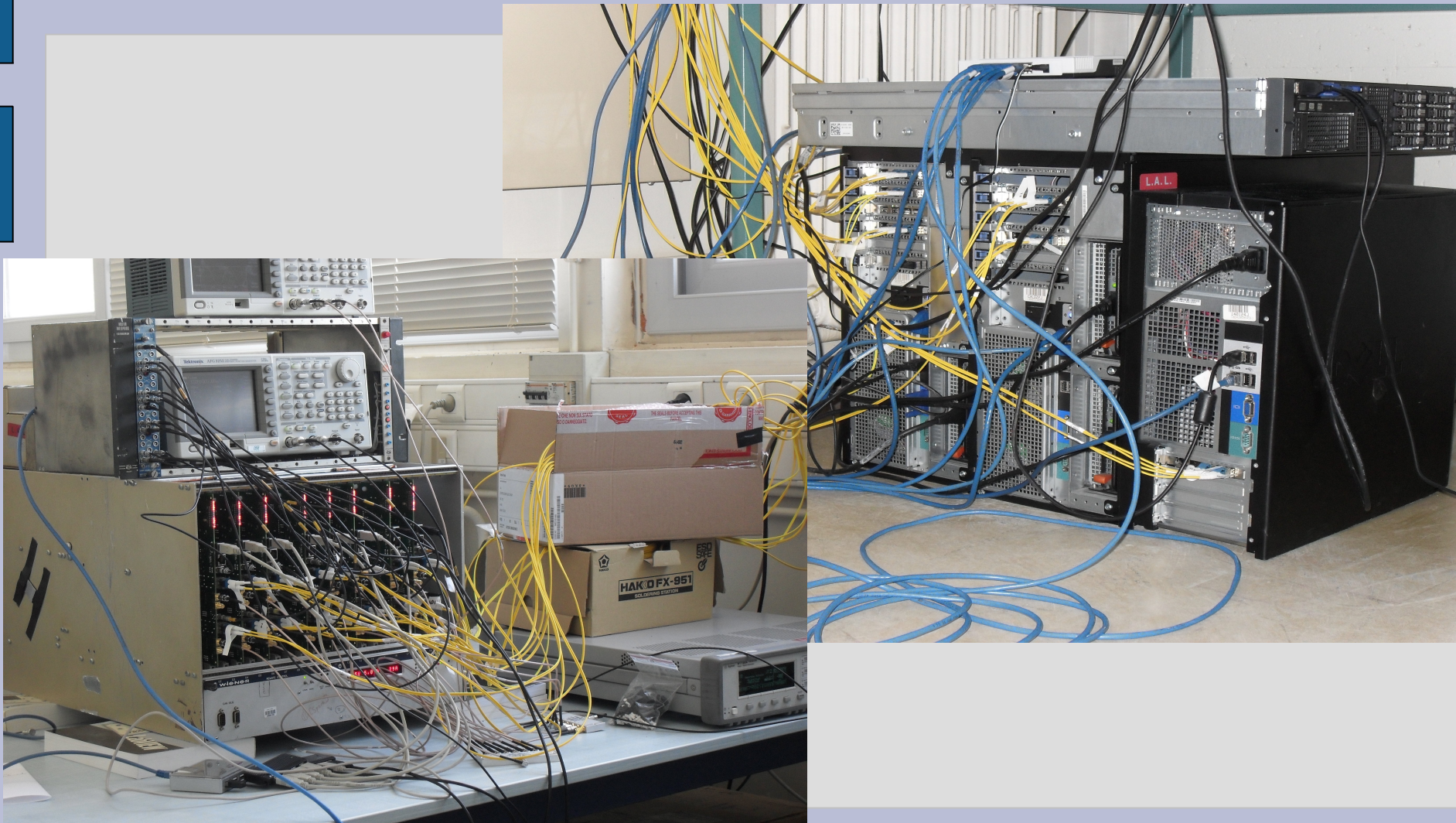


Data acquisition



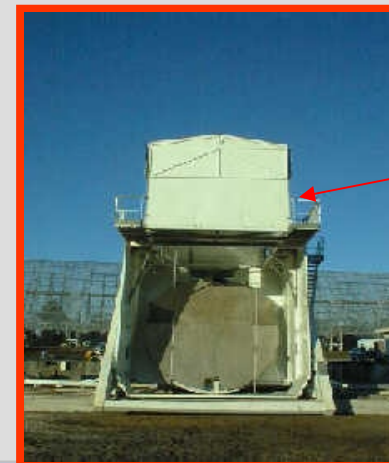
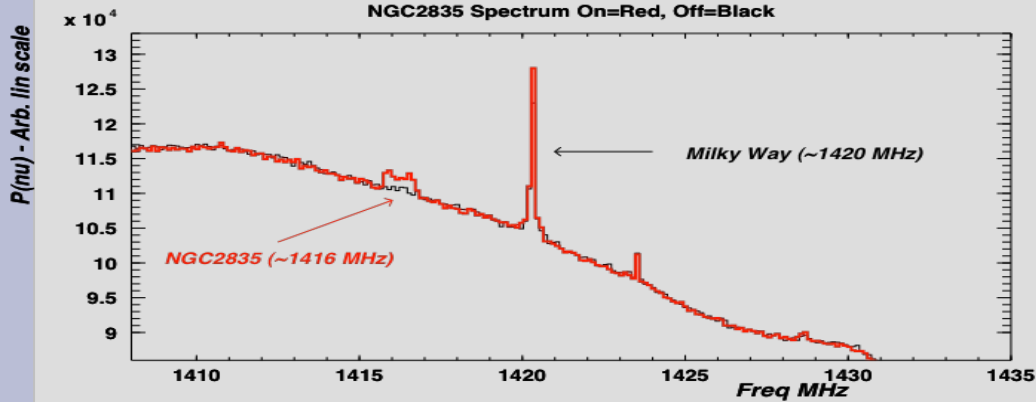
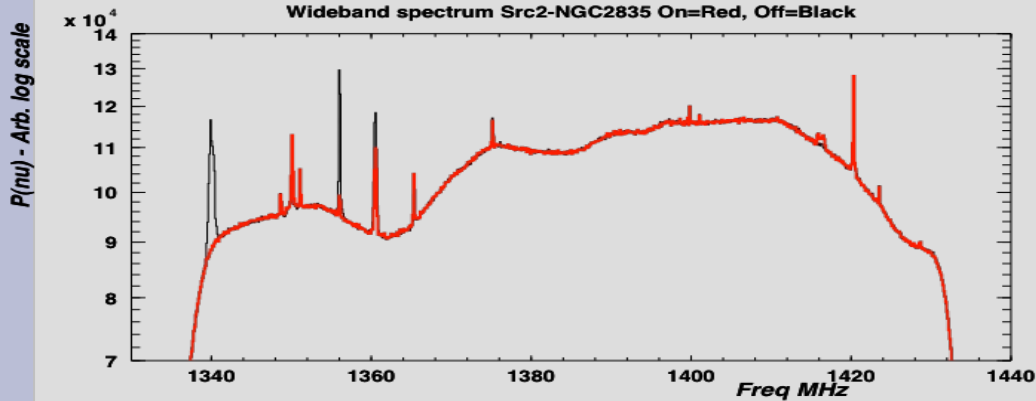


Acquisition system prototype





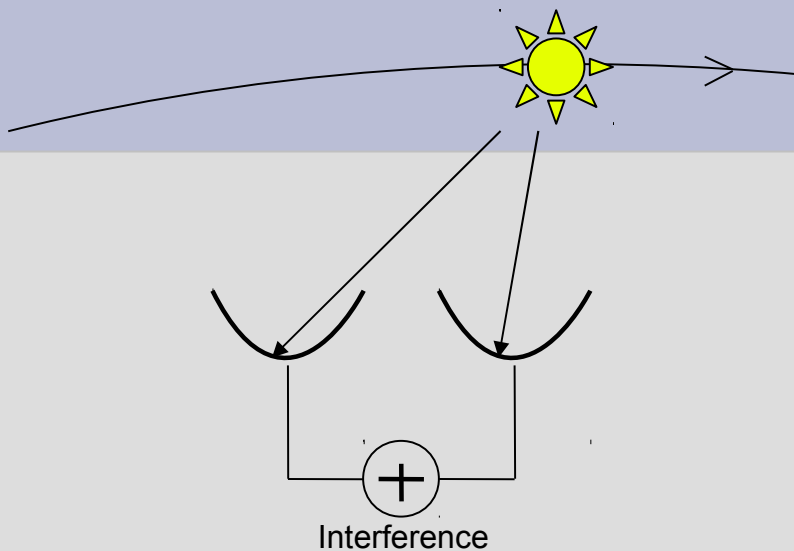
Test with Nançay Radio Telescope (NRT)



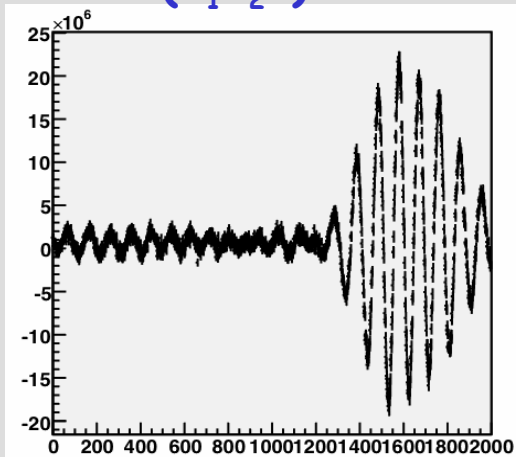
Focal carriage



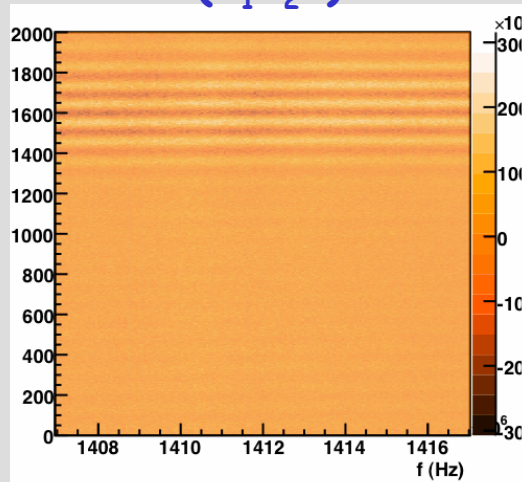
Test in Pittsburgh



$\text{Re}(a_1 a_2^*)$



$\text{Re}(a_1 a_2^*)$





Numerical correlator

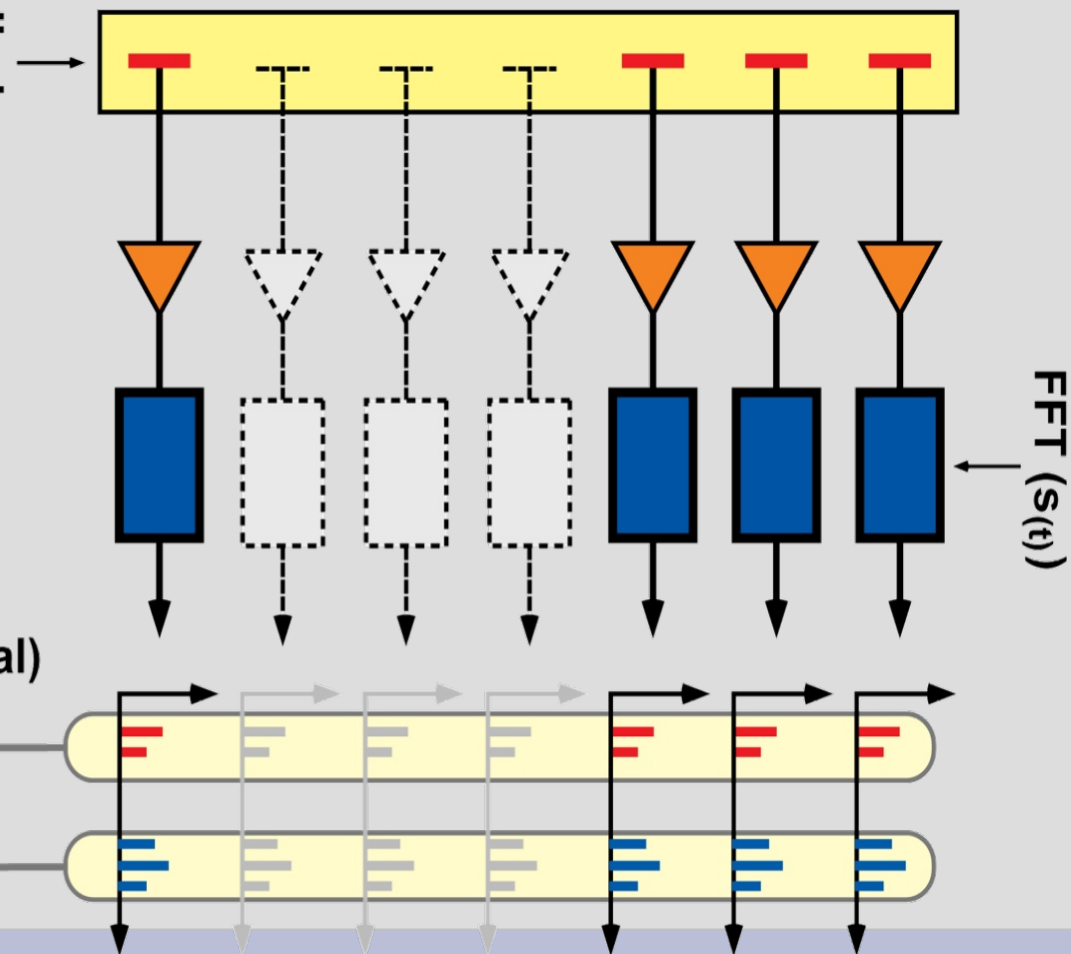
- Each channel:
 - Fast Fourier Transform
- ALL channel:
 - Combination of the
 - Same frequency

3 dimensions:
2 angles : FFT beam forming
Distance : frequency red-shift

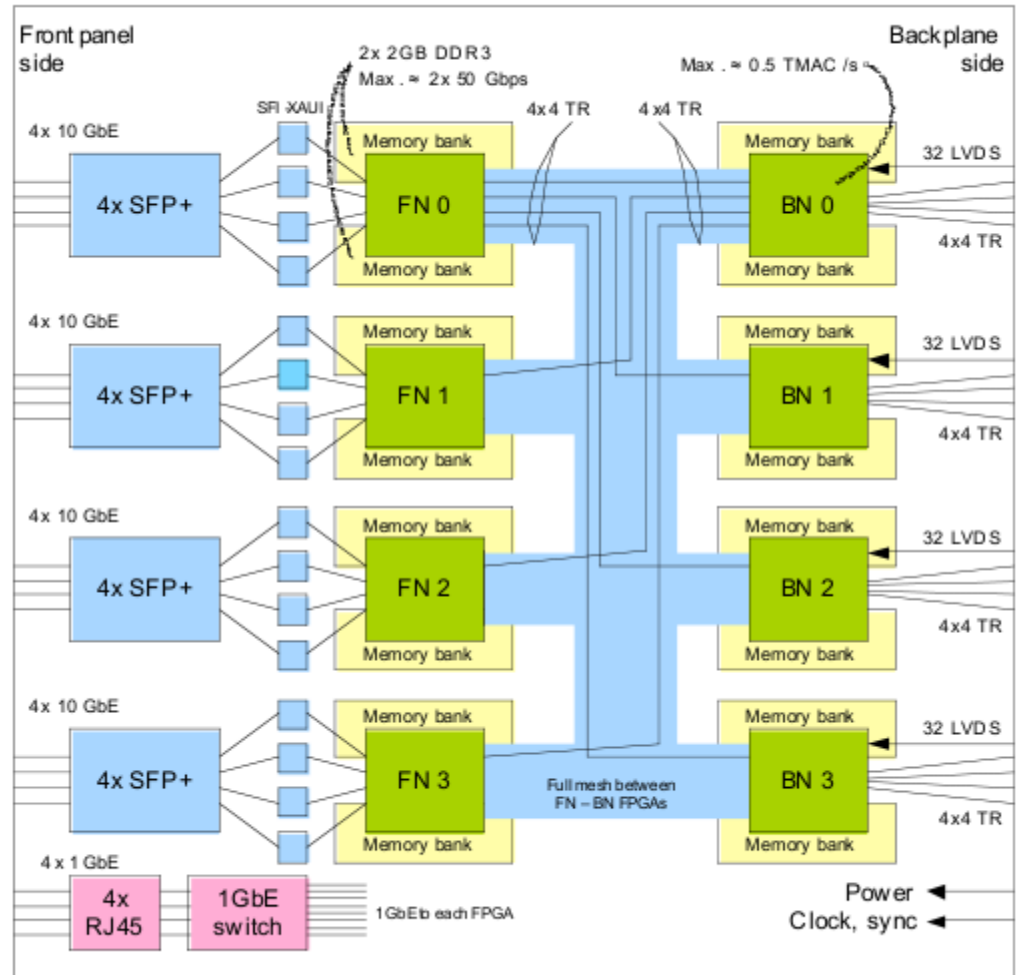
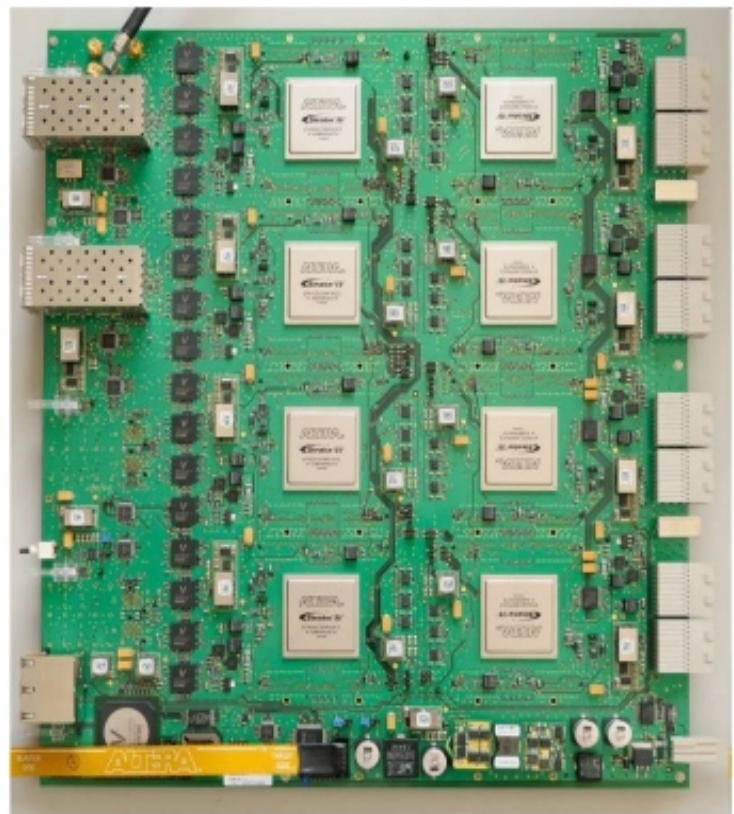
Reconstitution
de lobes sur le c
pour chaque fréquence

Beam forming
For each FFT
frequency

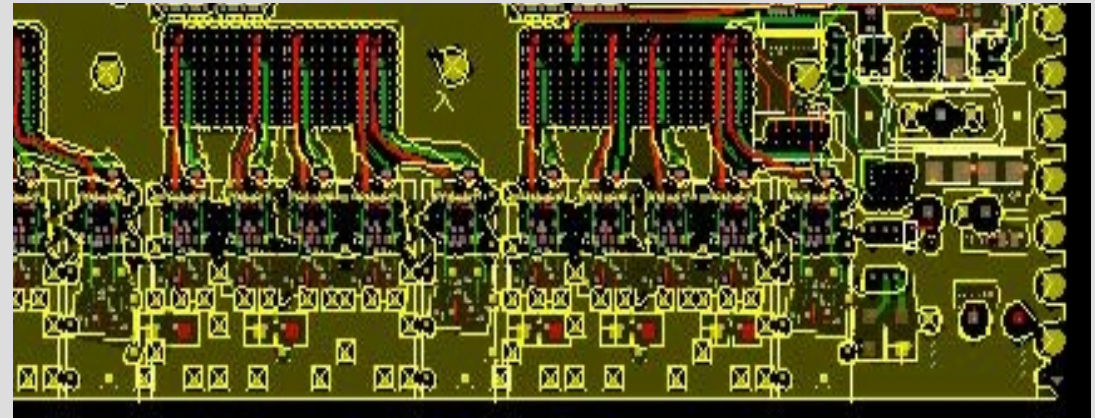
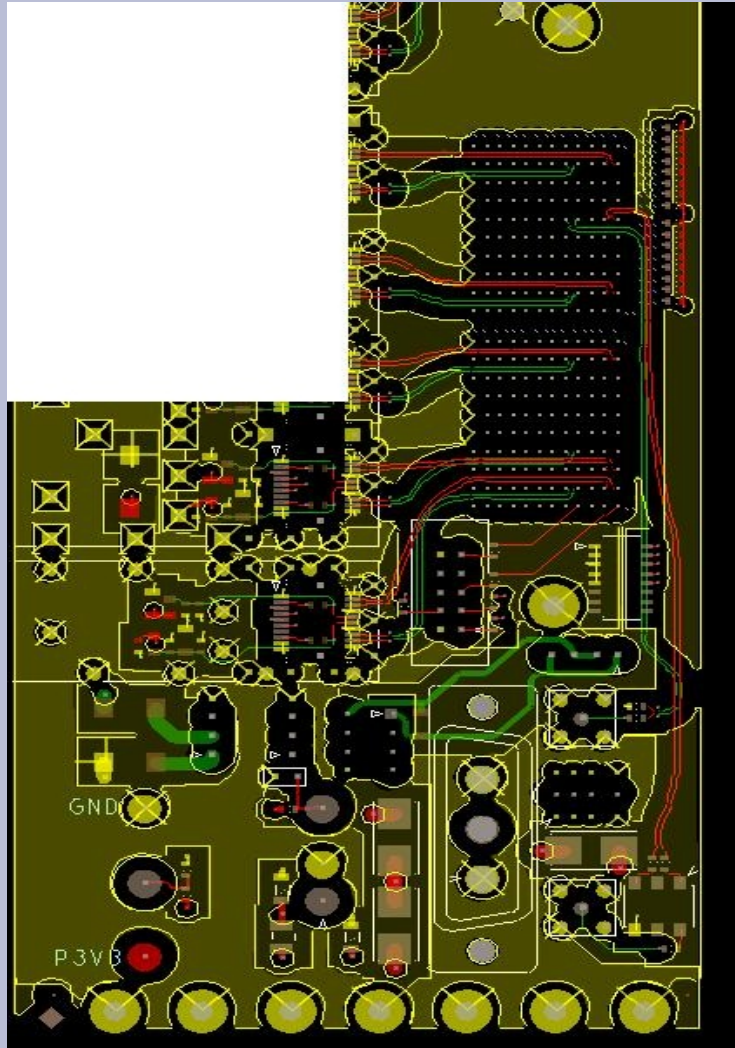
Cylindres (~ 2000 m x 50)



Uniboard (ASTRON)



Optical Connection Break-out





conclusion

- Evolution du temps ciel 25% à 100%
 - Trigger
 - 8bit → 4bits
- Test OCB
- Board configuration by optical link
 - Firmware ADC board
 - Firmware acquisition board
- Firmware carte Uniboard
 - Regroupement fréquentiel
 - Mise en œuvre Ethernet 10Gb

BAO Paraboles

Contrôle commande

Patrick Cornebise
Rodolphe Marie
Tristan Vandenberghe
François Wicek

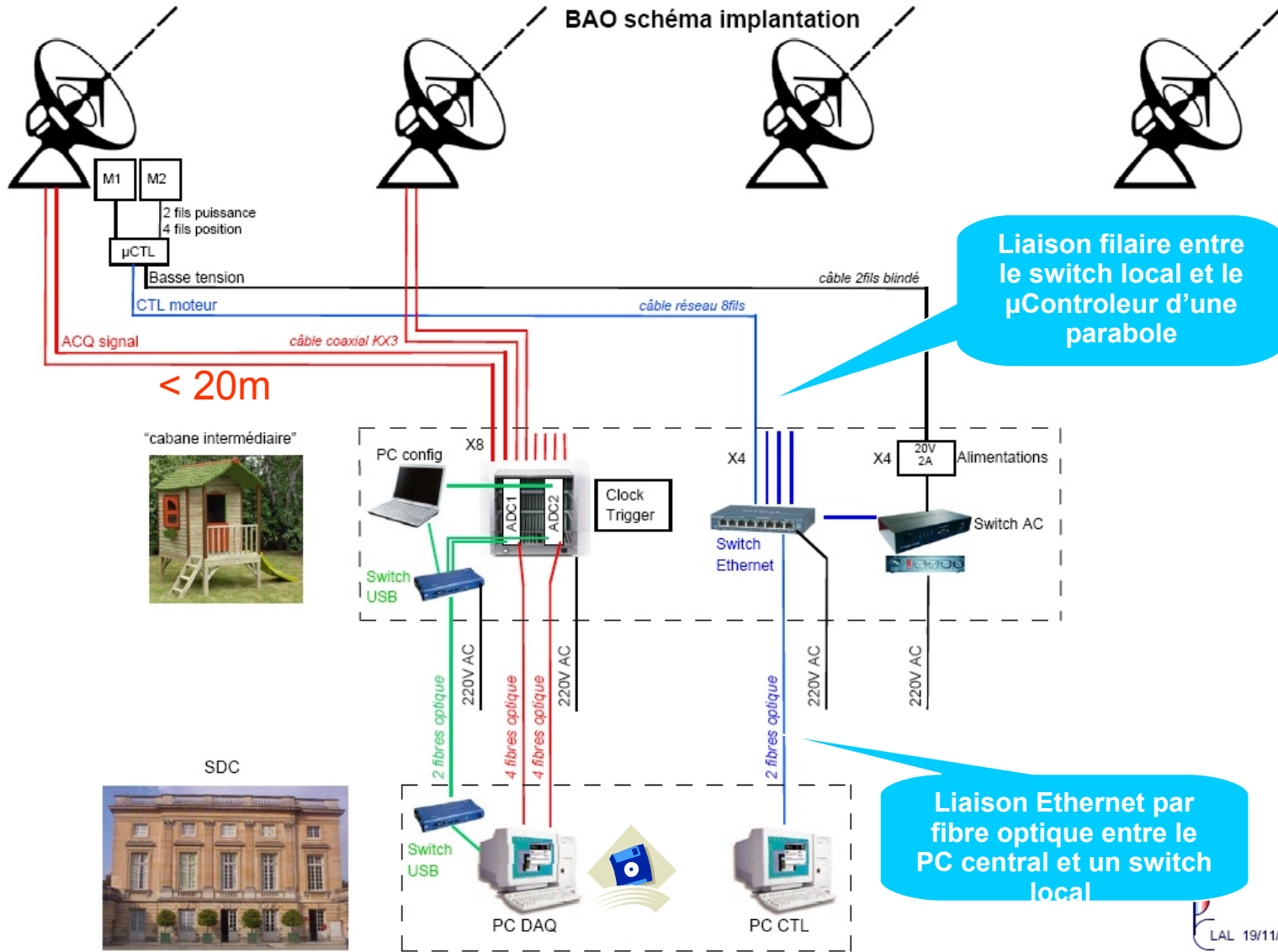
Physiciens: J.-E. Campagne et M. Moniez

Objectif: validation du concept BAO-Radio avec des paraboles

- **Objectif (fev. 2011): installer 2 puis 4 paraboles radio à Nancay en 2011**
- **Objectif intermédiaire: installer 2 paraboles à Orsay**

Schéma d'implantation à Nancy

BAO schéma implantation

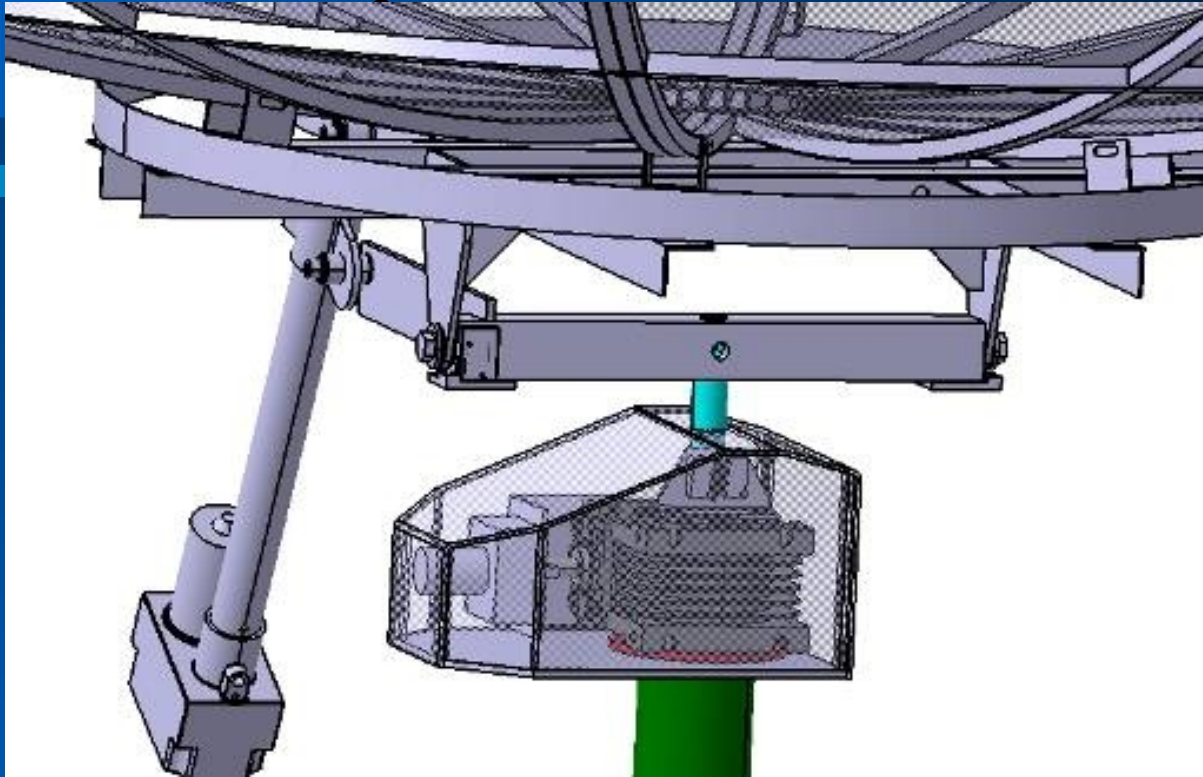


Liaison filaire entre le switch local et le µContrôleur d'une parabole

Liaison Ethernet par fibre optique entre le PC central et un switch local

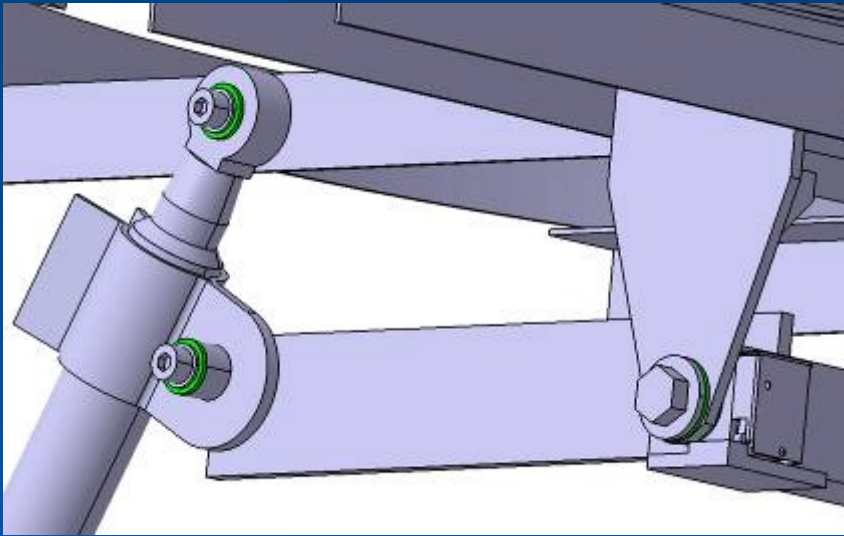


Mécanique



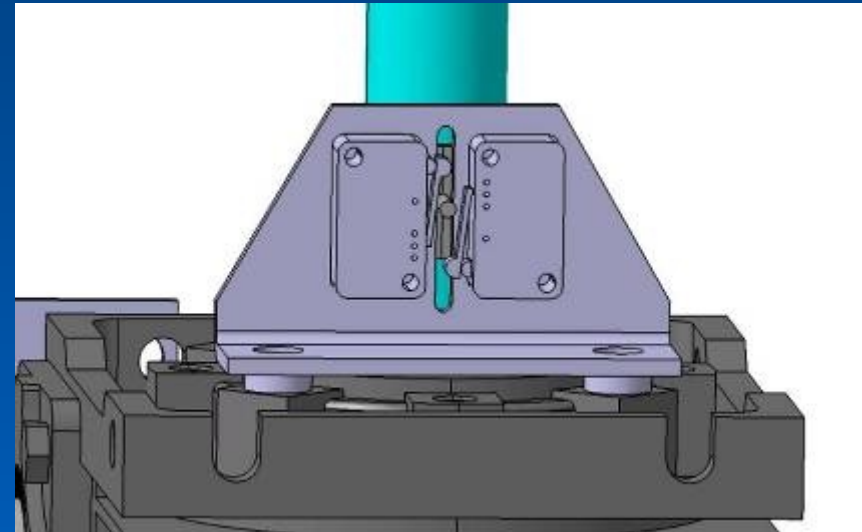
- Parabole de diamètre 3,5 m (puis 5m)
- Monture Alt- Azimutale « maison »
 - _ Altitude: vérin + moteur CC
 - _ Azimuth: couronne + moteur CC

Mécanique



Articulation vérin altitude

End switches en azimuth

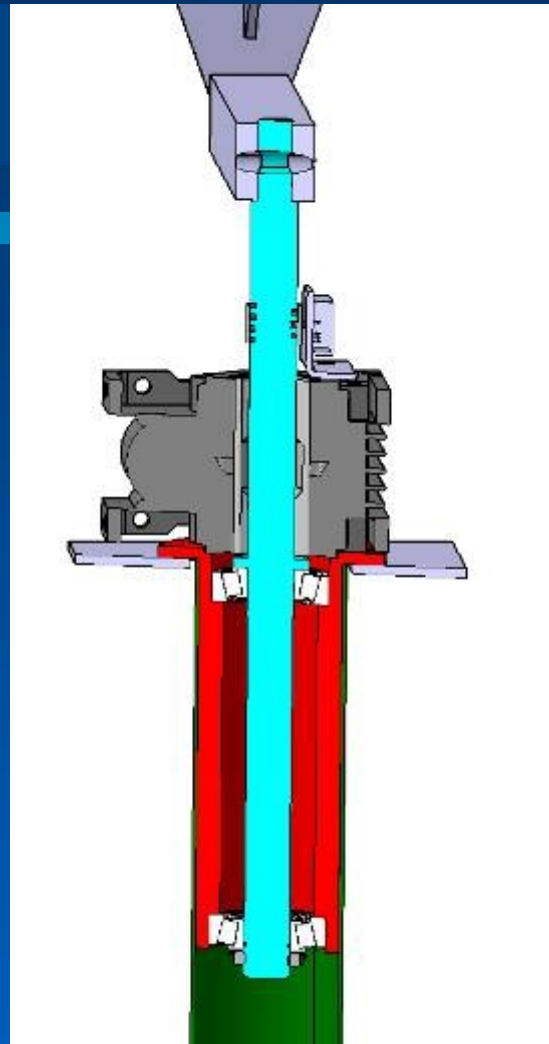


Mécanique

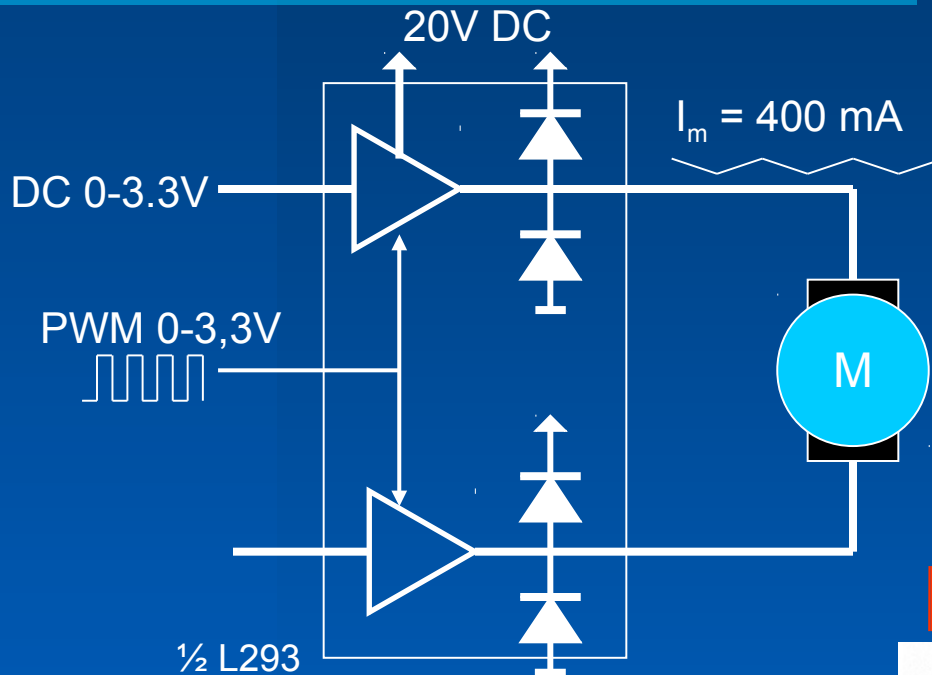
Axe azimuth (coupe)

Réducteur

Roulements coniques



Commande moteur



Altitude



Azimuth



Caractéristiques:

- Bonne protection contre la rouille:
- Peinture-poudre epoxy.
- Excellente protection contre l'eau:
 - Avec 2 joints et 3 trous de drainage.
- Super ILS:
 - Les contacts en Ruthénium assure une longue durée de vie à ILS.
 - Enfermé hermétiquement pour éliminer les effets du à la corrosion et à l'oxydation.
 - Nové dans du plastique, cela permet de le chargé facilement et sans risque.

Taille Suggérée parabole	60cm ~1.5 m
Charge	500lbs
Charge Dynamique	300lbs
Charge de vitesse évalué	6,2mm/sec
Resolution(Reed)	76 impulsions/pouce
Tension d'alimentation:	36VDC
Température de fonctionnement:	-30° C to +50° C

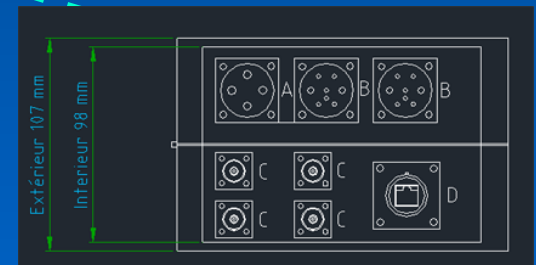
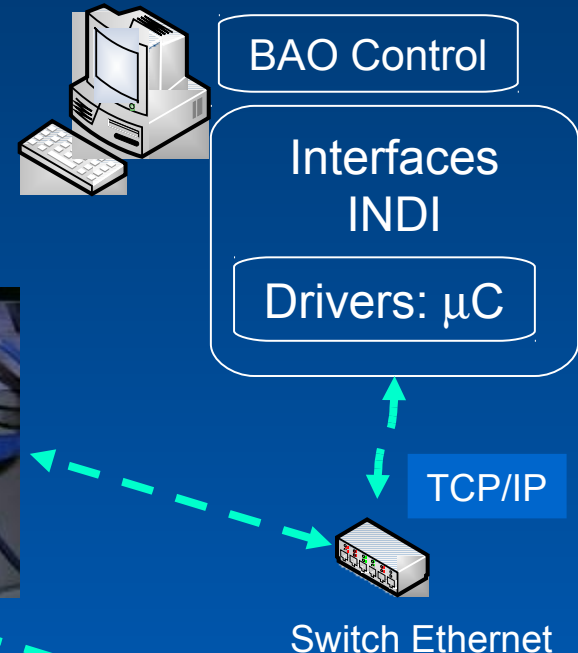
Caractéristiques techniques

<input type="checkbox"/> Couple de sortie	500N.cm
<input type="checkbox"/> Hauteur mm	65mm
<input type="checkbox"/> Puissance nominale	3,9W
<input type="checkbox"/> Tension	24V c.c.
<input type="checkbox"/> Type	Moteur noyau ferreux/Réducteur droit
<input type="checkbox"/> Vitesse de sortie	34t/min.

Commande moteur (suite)

- 1 PC central (linux)
 - Interface utilisateur « BAO control » (Franck Richard) ou K star
 - Pilote « INDI (*) » pour convertir les ordres de haut niveau (coordonnées) en nombres de pas moteurs
 - 2 documents existent: specif. + réalisation
- 1 μ -Contrôleur pour chaque parabole:
 - choix actuel : 8 bits Rabbit Core serie 3000 avec liaison Ethernet
 - Programmé en langage C
 - Il a en charge les 2 moteurs Az-Alt
 - Sécurités fins de course
 - Capteurs (optiques) de position
- Protocole PC- μ C:
 - Architecture client (μ C) – Server (PC)
 - Opérations: Goto, Park, Suivi, Abort, Monitoring, Stat ...
 - Testé avec un seul client (2 moteurs).

(*) <http://www.indilib.org>
Interface avec matériel grand public



État d'avancement



LAL 5 mars 2012

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Dernières nouvelles

- **Présentation de BAO Radio au CS LAL du 15 mars:**
- **4 paraboles « hollandaises » à Nançay**
 - Meudon/Nançay: 12 k€ (infrastructure, support, feed+fixation)
 - IRFU: 3 k€ (distrib. Clock + ampli bas bruit)
 - LAL: 27 k€
 - Réflecteurs diam. 4,5m : 4 x 2, 3 k€
 - Motorisation: 4 x 1,5 k€
 - câblage