DE LA RECHERCHE À L'INDUSTRIE

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Ultra-Fast Reflectometry Upgrade within the framework of the WPSA

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CEA, Cadarache

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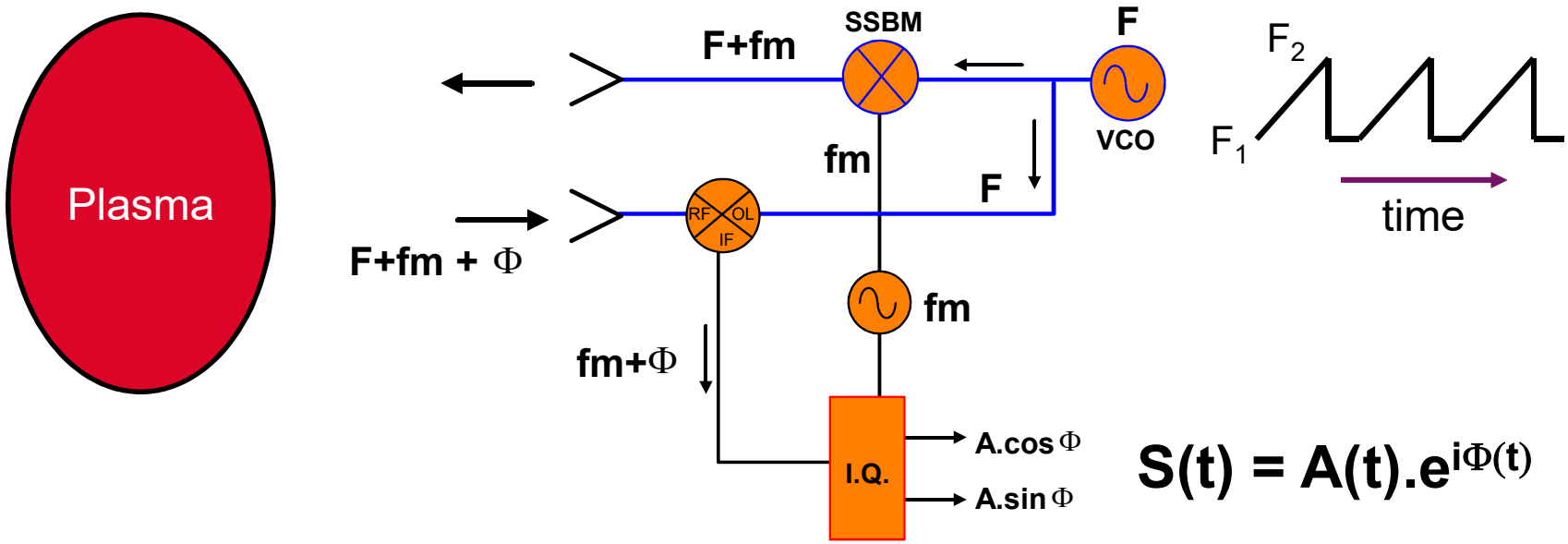
WEST ultra-fast sweeping reflectometer

Clairet *et al.* RSI 2017

FM-CW reflectometry caracteristics

- 50-110 GHz (V-band & W-band)
- Heterodyne detection : **S/N > 30 dB**
- Ultra-fast sweeping : **1 µs (dead time 0.25 µs)**
- Acquisition : **1 Gs/s / 2 Gbytes**



$$S(t) = A(t).e^{i\Phi(t)}$$

Measurement principle

2 propagating modes :

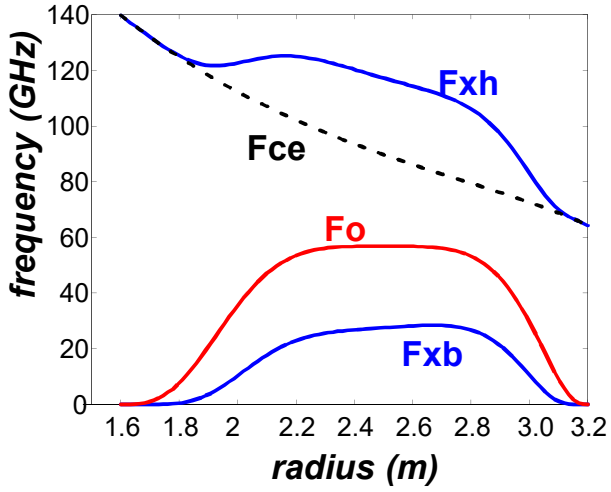
O-mode : $\mathbf{E_{wave}}$ // $\mathbf{B_{plasma}}$

$$N_O^2 = 1 - \frac{F_{pe}^{\ 2}}{F^2}$$

X-mode : $\mathbf{E_{wave}} \perp \mathbf{B_{plasma}}$

$$N_X^2 = 1 - \frac{F_{pe}^{\ 2}}{F^2}\frac{\left(F^2 - F_{pe}^{\ 2}\right)}{\left(F^2 - F_{ce}^{\ 2} - F_{pe}^{\ 2}\right)}$$

Wave reflects at cut-off frequencies :



$$Fo = F_{pe}$$

$$F_{Xh} = \frac{F_{ce} + \sqrt{F_{ce}^2 + 4F_{pe}^2}}{2}$$

$$F_{Xb} = \frac{-F_{ce} + \sqrt{F_{ce}^2 + 4F_{pe}^2}}{2}$$

Density profile & fluctuations

Signal : S = A . $e^{i\Phi}$

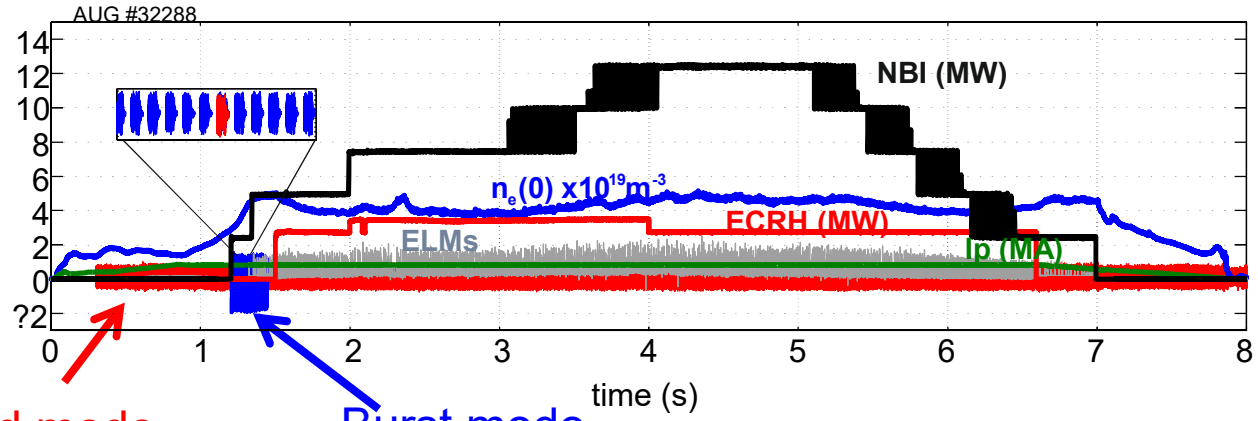
Density profile reconstruction from the phase :
(Bottollier algorythm)

$$\Phi_{i+1} = \frac{4\pi F_{i+1}}{c}\int_{r_l}^{r_i} N(r, F_{i+1})\,dr + \frac{4\pi F_{i+1}}{c}\left\{\frac{4}{3}\left[N(r_{i+1}, F_{i+1}) - N(r_i, F_{i+1})\right]\left(\frac{r_{i+1} - r_i}{2}\right)\right\}$$

Density fluctuations are determined from the signal fluctuations

$A = \langle A \rangle + \delta A$ and $\Phi = \langle \Phi \rangle + \delta\Phi$

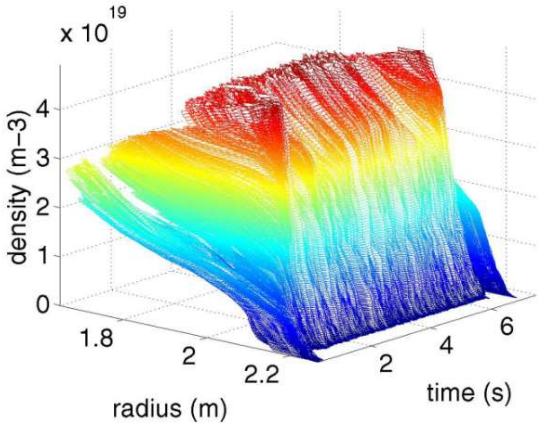
2 OPERATING MODES : STANDARD & BURST



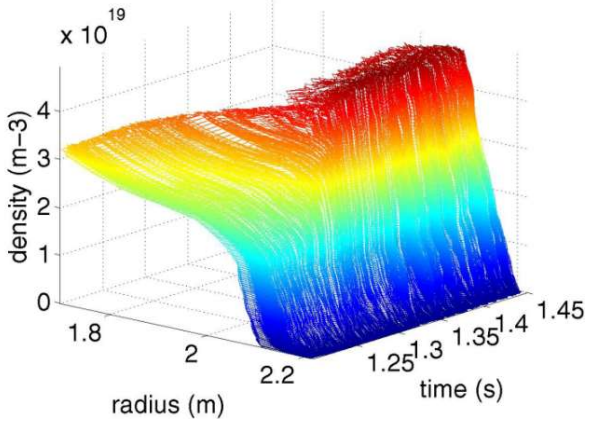
Standard mode
(dead time 0.5 ms)

Burst mode
(dead time 0.25 µs)

Standard mode ➔ whole discharge

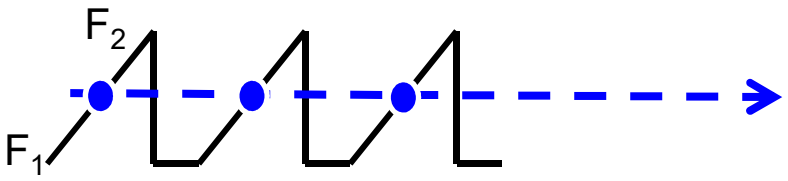


Burst mode ➔ fast events

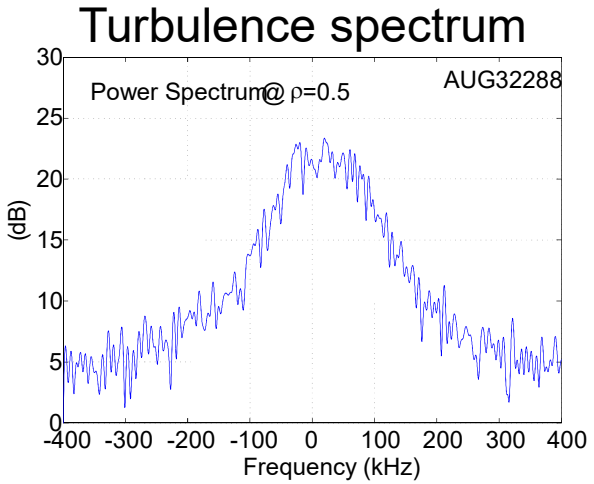


BURST MODE : TURBULENCE STUDIES

Fixed frequency analysis

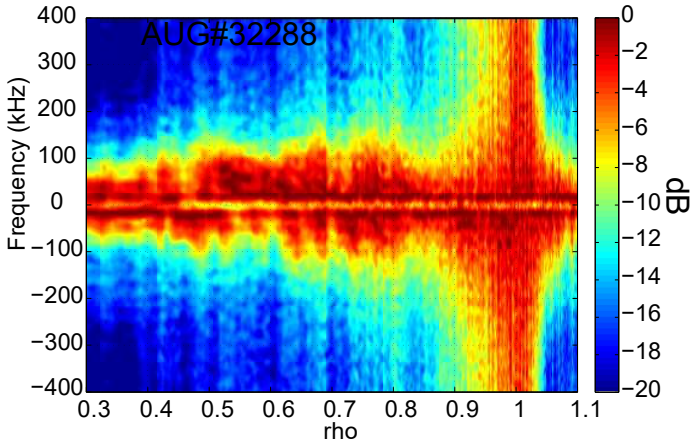


1µs / 0.25µs : fs = 800 kHz



Equivalent to 2000 fixed probing frequencies

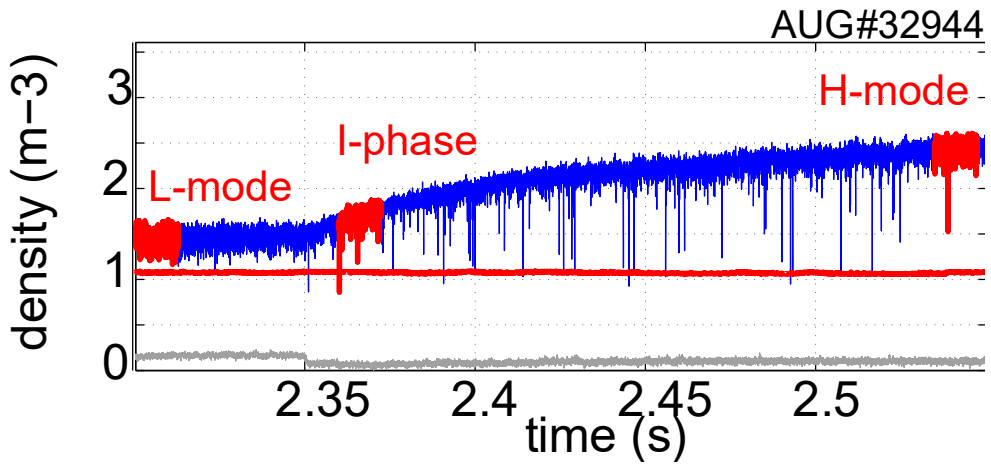
➔ Radial profile of the turbulence spectrum

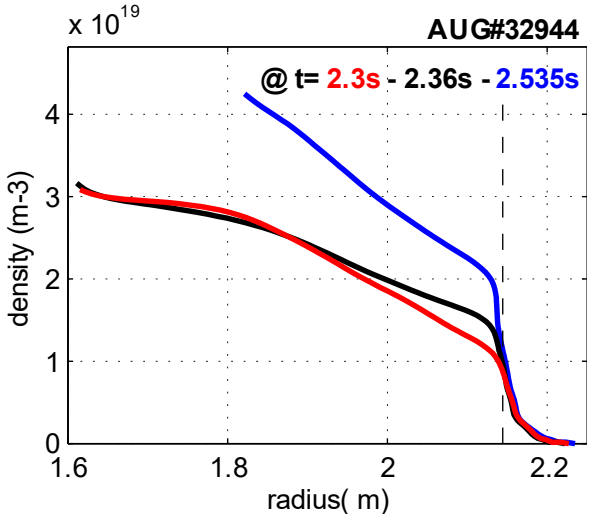


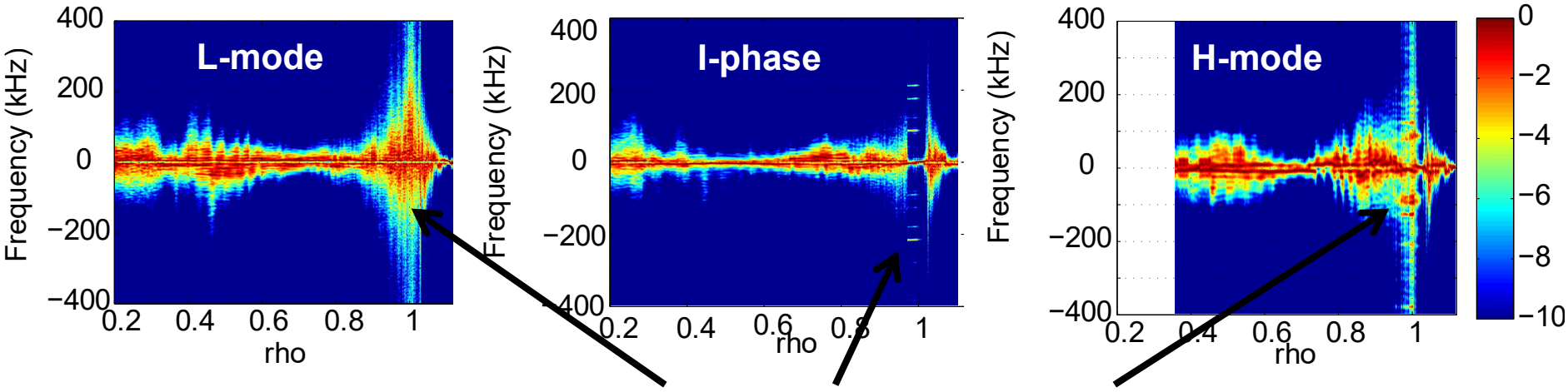
Improved sweeping rate : Extend the frequency coverage of the turbulent spectra and reduces aliasing effect.

Example : L - I - H transition

CEA reflectometer moved to AUG during 3 years as TS turned to WEST…







Pedestal turbulence : From broadband to coherent mode

Medvedeva et al. PPCF 2017, 2019

JT-60SA : FREQUENCY BANDWIDTHS NEEDED

JT-60SA
R = 3 m
a = 1.18 m
B = 2.3 T

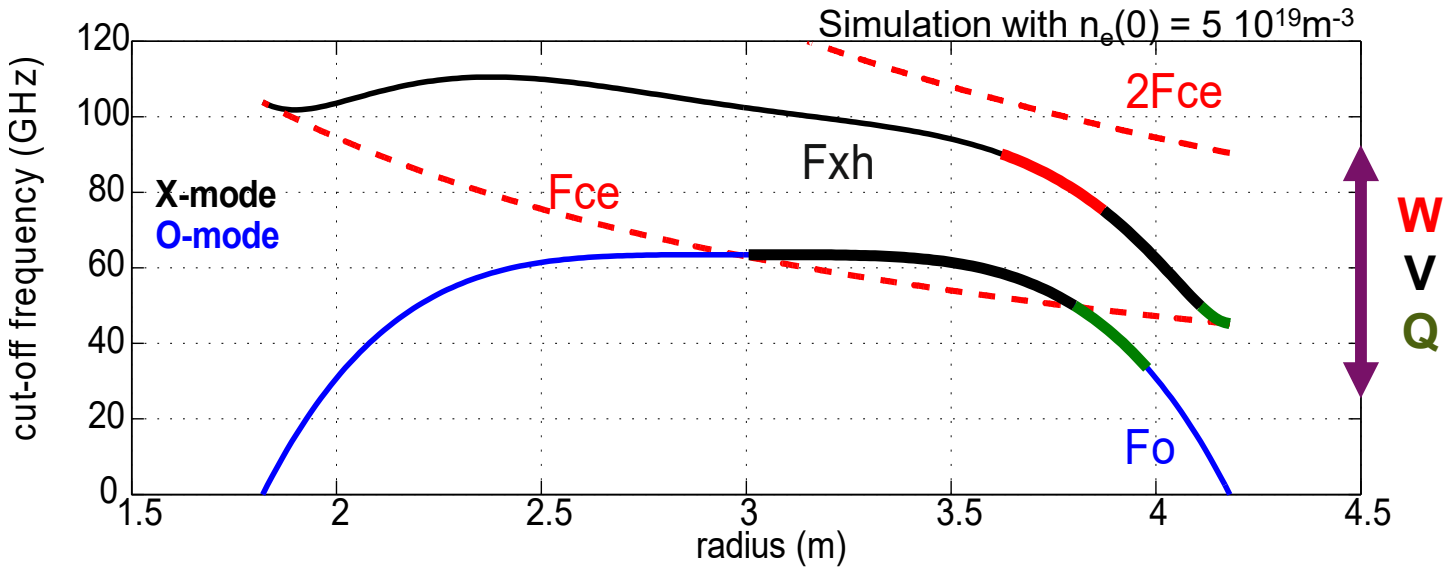
Similarities with JET

3 frequency bandwidths are required

Q-band (33-50 GHz)

V-band (50-75 GHz)

W-band (75-110 GHz)

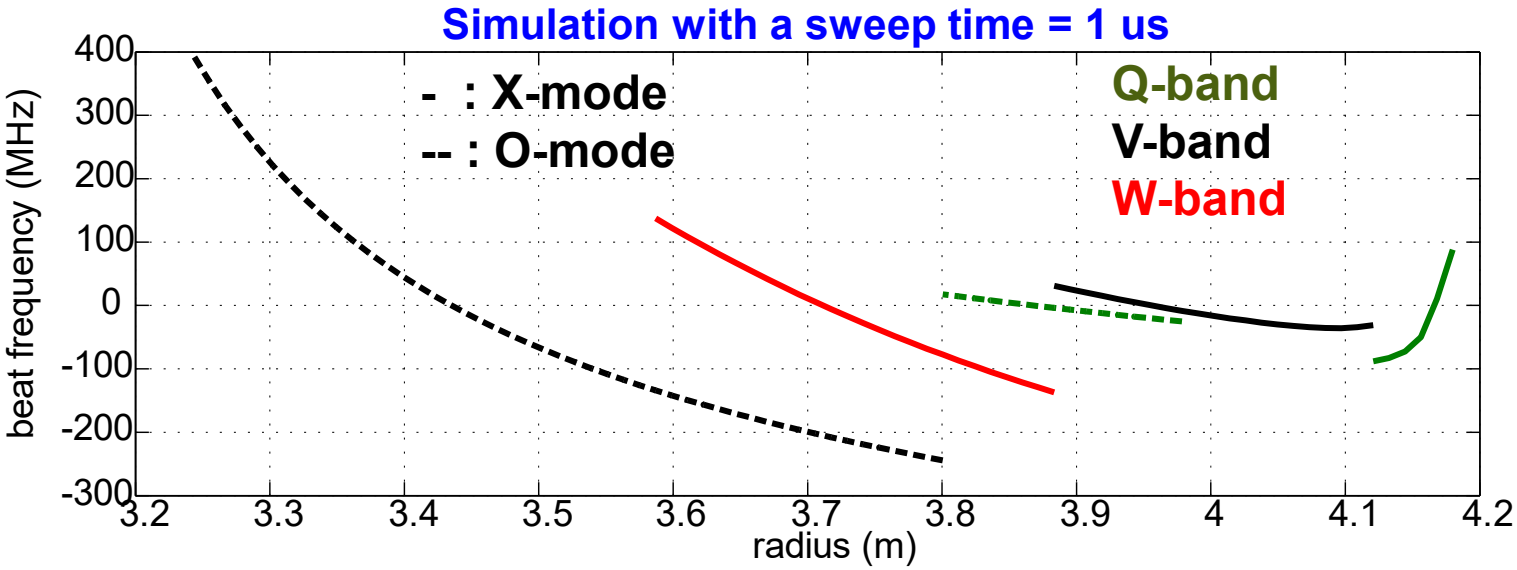


Q, V and W-bands in X-mode provides edge measurement.
Q and V bands in O-mode would allow core access for high density plasmas.

ACQUISITION REQUIREMENTS

Signal frequency (or beat frequency) :

$F_b = \tau \times dF/dt$ (τ : group delay)



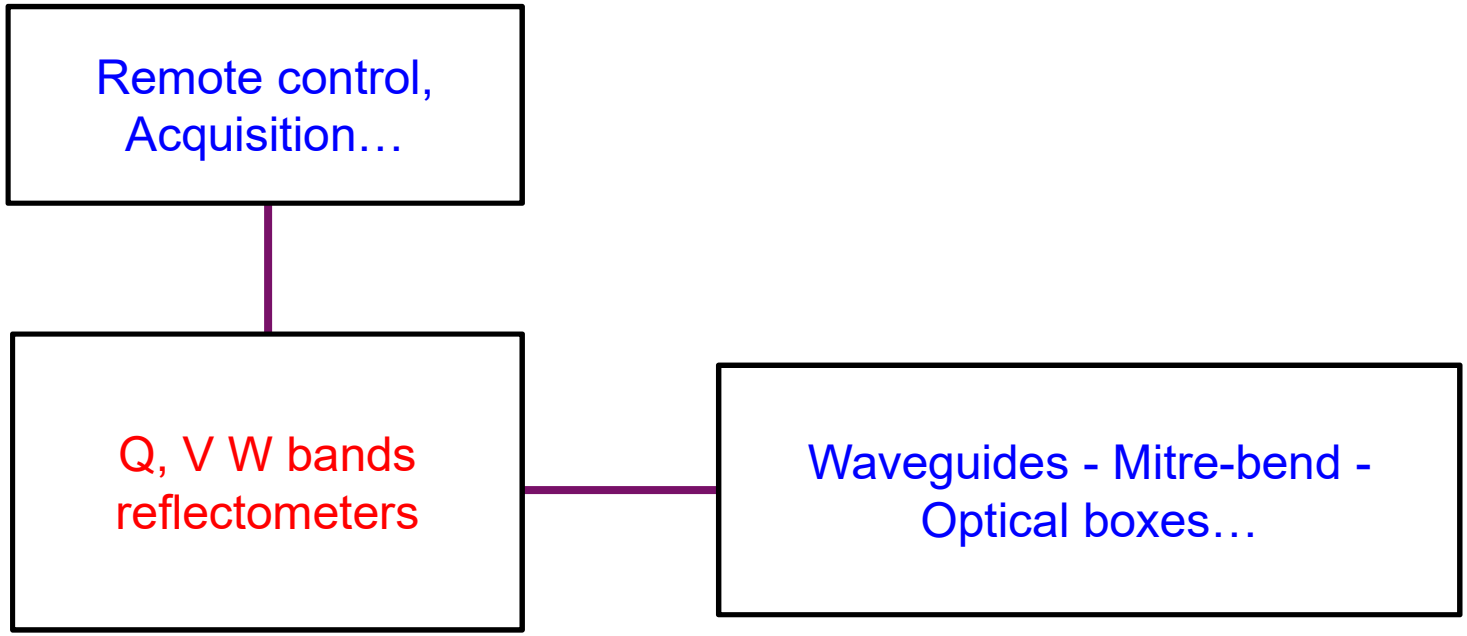
Expected signal bandwidth +/- 300 MHz

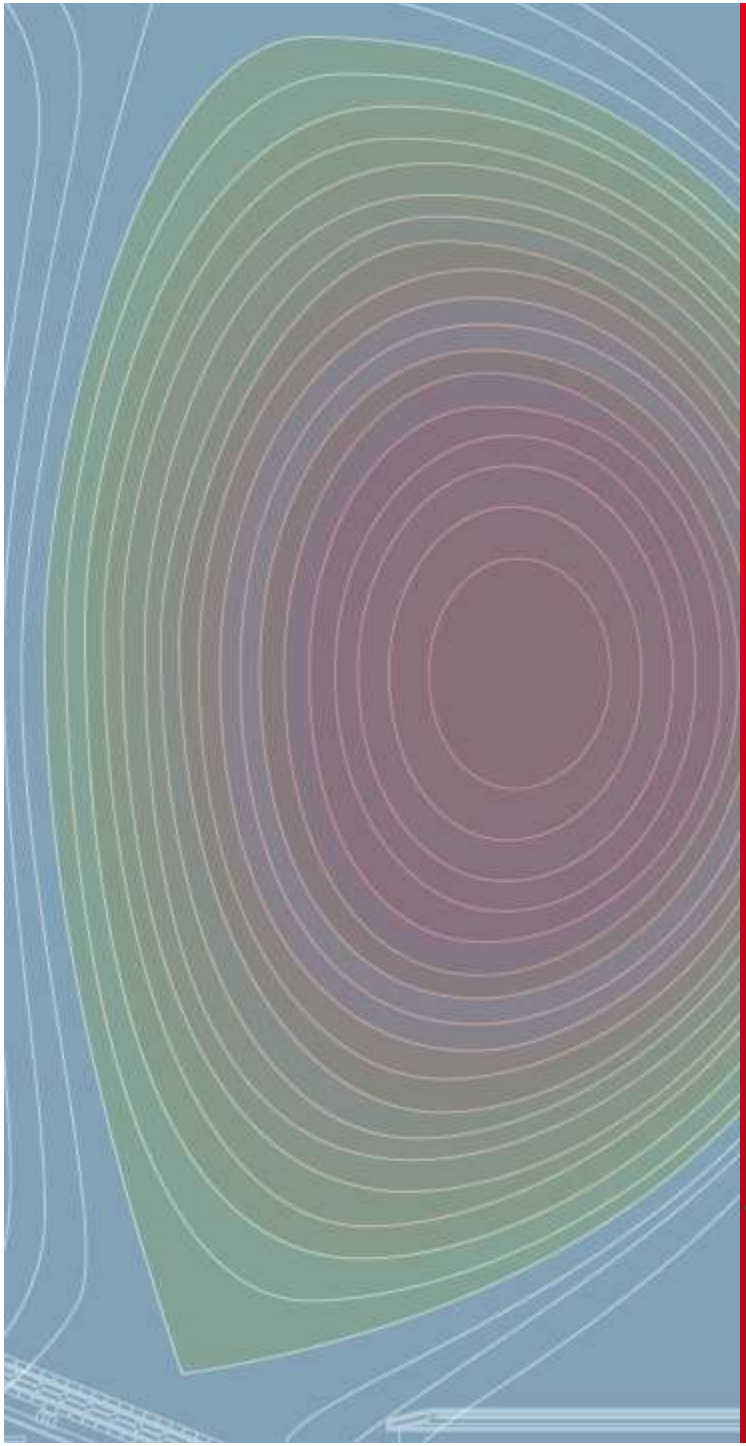
➔ **Recommanded acquisition rate : 1 Gs/s**

PROJECT ORGANISATION AND SHARED PARTS

I. **Interfaces (JA?)**
   - Waveguides, antenna, optical boxes, integration to the machine…
   - Programing, CODAC…

II. **Reflectometers (EU)**
   - Electronic, microwave, ramp generators…





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