iALMA

Technology Developments

iALMA collaboration
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Inaf/iasf Bologna

Terzo Workshop sull'Astronomia Millimetrica in Italia
Jan 21st, 2015

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- UNI TOR VERGATA
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- UNIMIB
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iALMA

GOAL of iALMA.tech

- To strengthen the scientific, technological and industrial Italian contribution to ALMA specifically for the band 2+3 development
  - Upgrade of Facilities for INAF
  - Development of Italian/European technologies in the field of PASSIVE COMPONENTS, OPTICS, FILTERS and WINDOWS, LNA,

CRYOWAVES TECHNOLOGIES

a Science and Technology branch mainly focused to develop technologies and facilities to build and operate wideband high performance radio, microwave, and mm-wave receivers and antennas to be operated in cryogenic environment.

CRYOGENICS

+

mm-wave TECHNOLOGIES

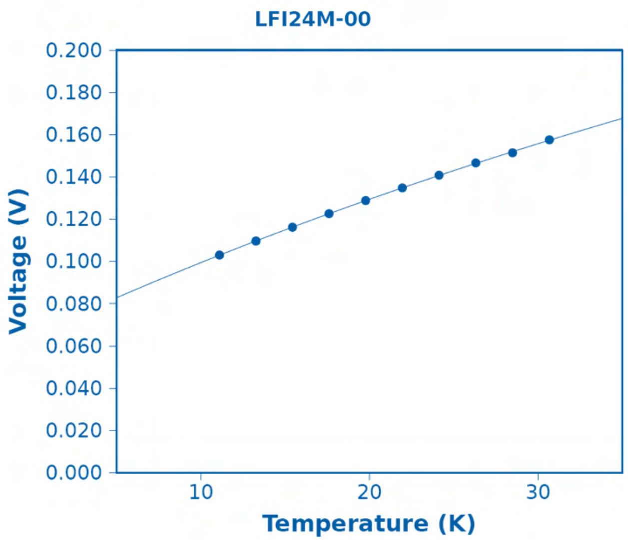
→ CRYOWAVES

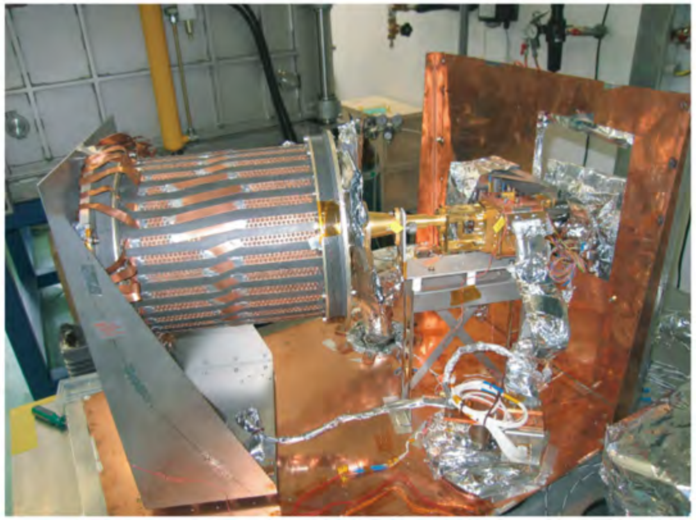
PLANCK, ALMA, SRT, LSPE, SKA, ...

EXAMPLE OF CRYOWAVES

$$V_{\rm out} = G_{\rm tot} \cdot (T_{\rm A} + T_{\rm N}),$$

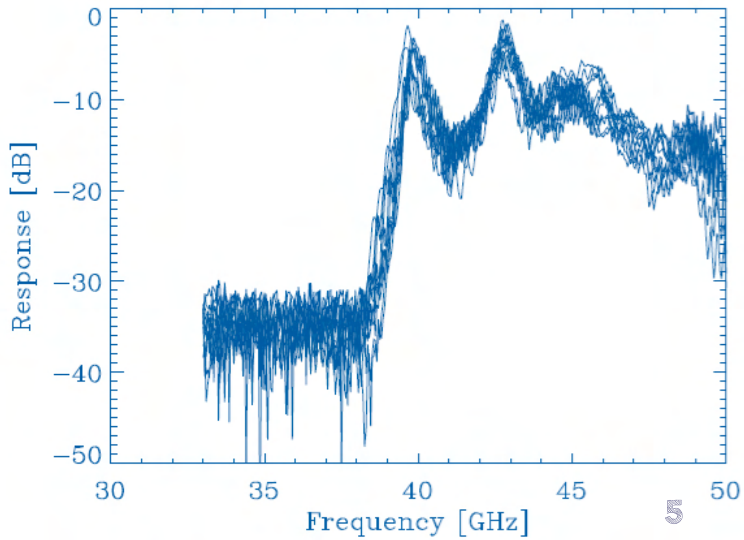
$$G_{\rm tot} = G_0 \left[\frac{1}{1 + b \cdot G_0 \cdot (T_{\rm A} + T_{\rm N})} \right]$$





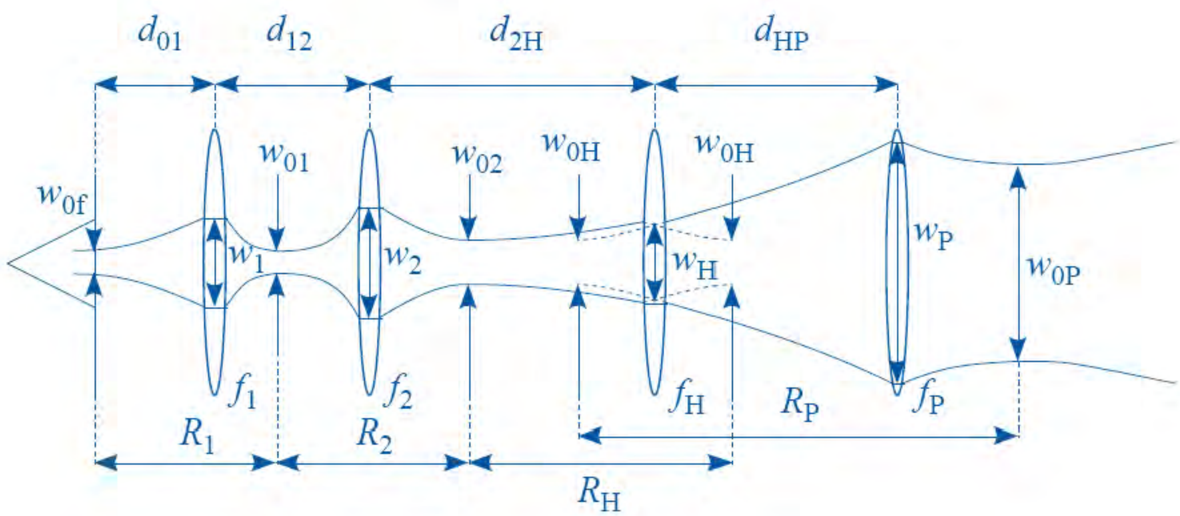
F. Cuttaia et al. (2009), JINST 4 T12013
A. Mennella et al. (2009), JINST 4 T12011
F.Villa et al. (2010), A&A 520 A6

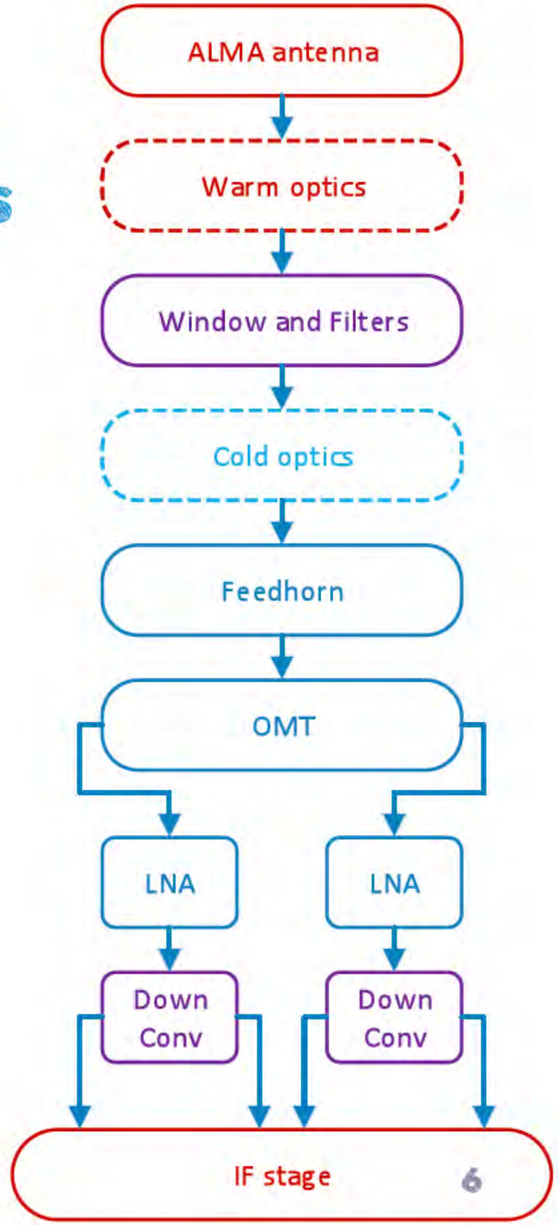
- LNA Tuning, Spectral response and (small) non linearity of the Planck/LFI RCAs



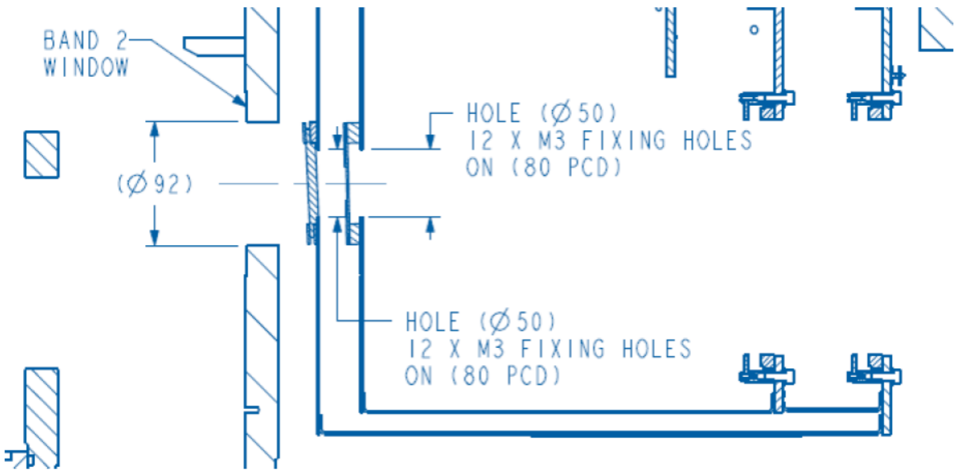
ALMA FRONT-END SYSTEM

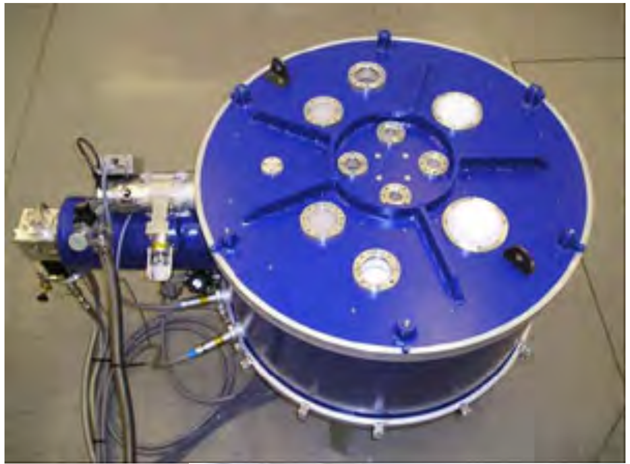
- **Efficiencies req., Noise performances, Thermal interfaces, Power specs., mass production, reliability, cost**
- **Band 2+3 critical because frequencies are between RF and quasi optical systems (from 67 to 116 GHz – 53% bandwidth)**





ALMA CRYOSTAT

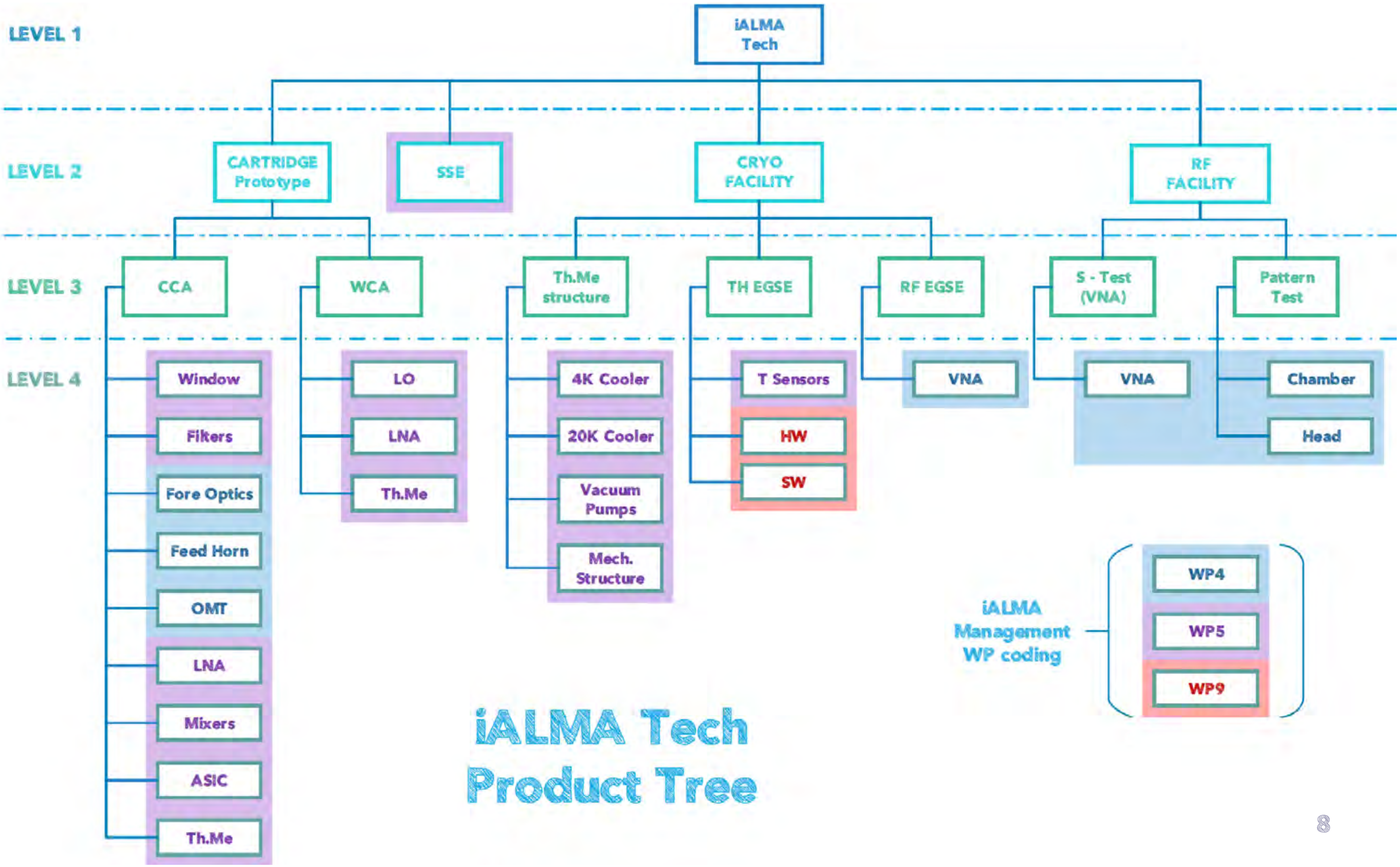




- **In the baseline configuration band 2+3 will occupy the band2 space without the 4K stage**

ALMA band 6 science.nrao.edu

LEVEL 1-2-3-4 PRODUCT TREE

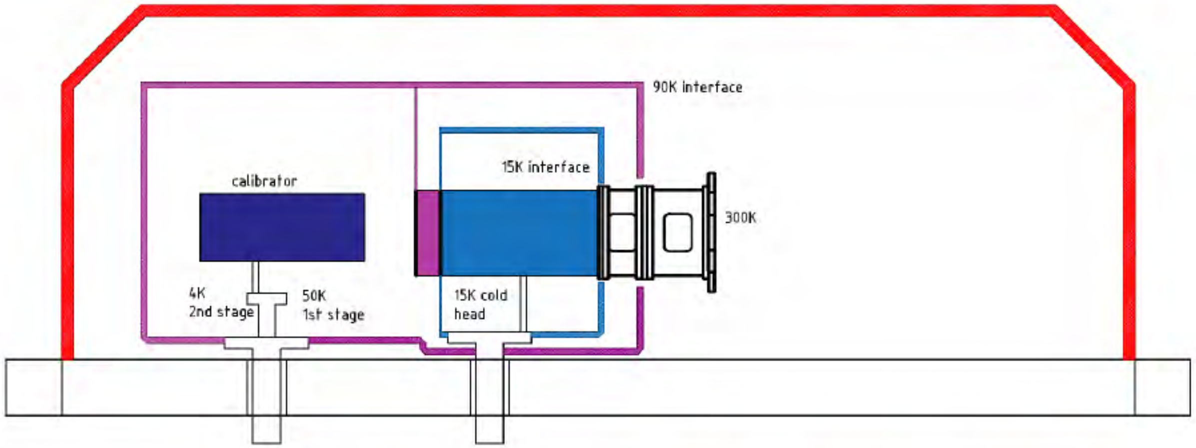


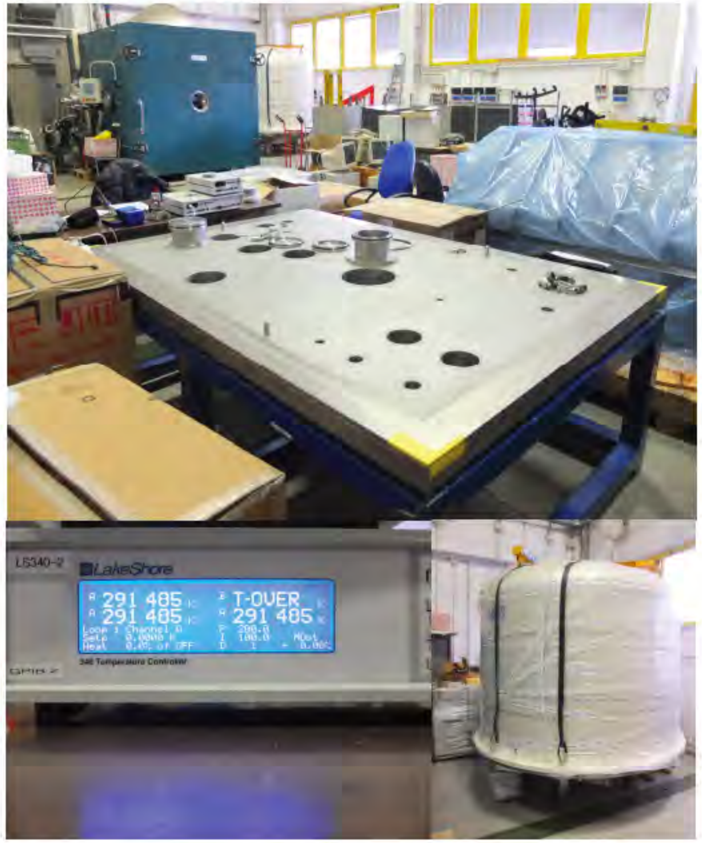
CRYOWAVES FOR ALMA

- Commissioning of a cryo-facility to test and calibrate cryogenically cooled instrumentation
- Design and develop prototype for band 2+3 cartridge passive components
- Fore Optics, Filters and Windows
- Calibrators
- Development of support electronics and software
- Support to LNA development

CRYOFACILITY(IES) @ IASF

- 1 cubic meter Cryofacility
  - From 4K to 300K adaptable controlled 5 stages interfaces





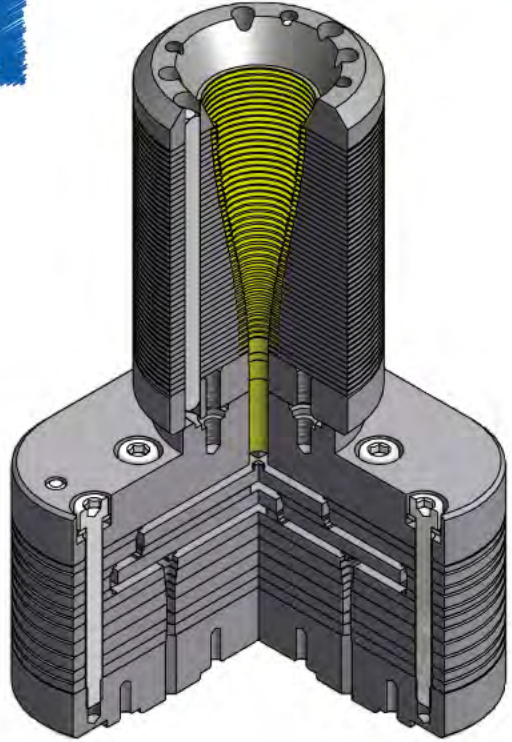
- DryRun expected on March this Year
- Will be available also for other experiments/instrumentation

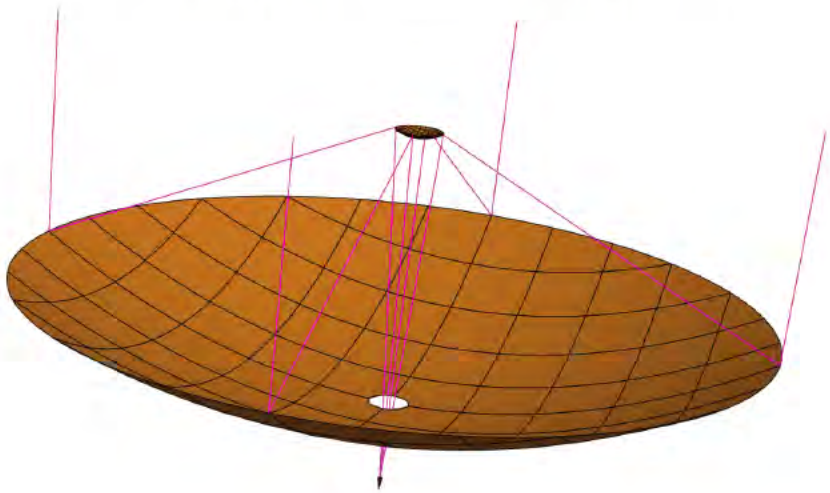
CRYOFACILITY @ IASF.bo

- Cryofacility with RF test equipment

- To perform precise and unique performance tests and characterization

PASSIVE COMPONENTS

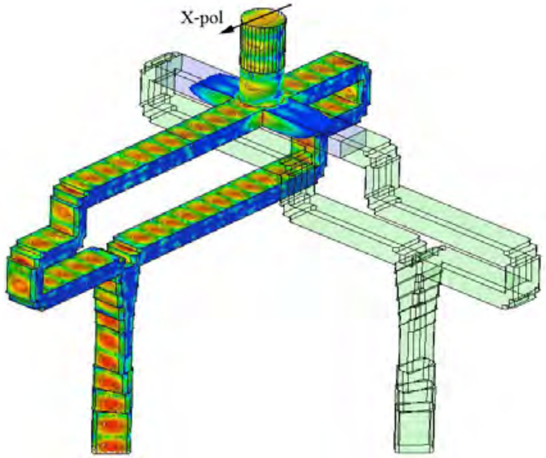




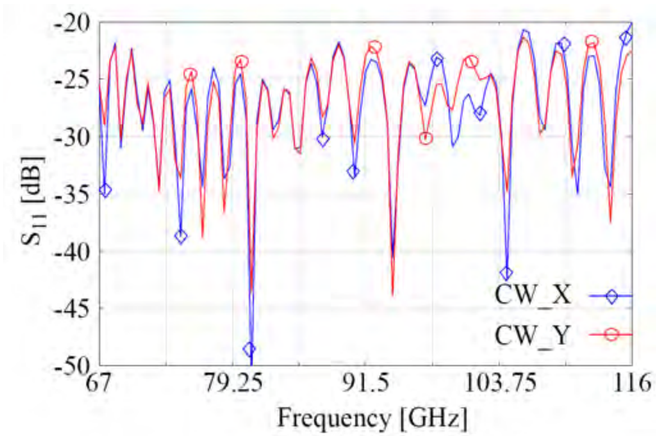
- Feed horn
- OMT
- Waveguide sections

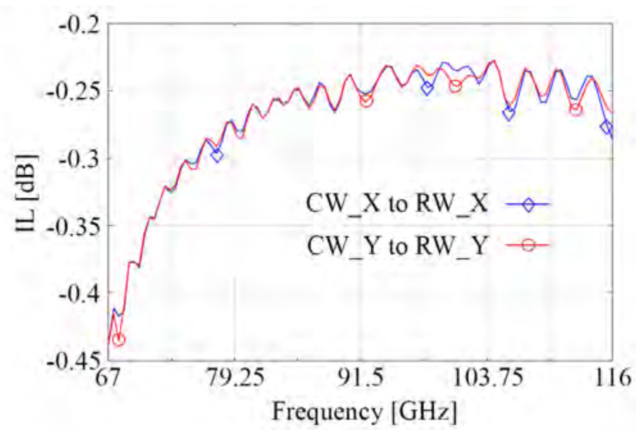
- Criticalities due to the very large operational bandwidth (67-116 GHz)

ORTHO-MODE TRANSDUCER



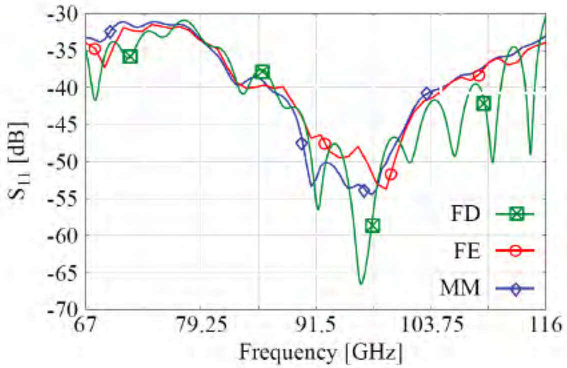
- Large bandwidth critical to obtain
- Manufacturing technology may impact final performances

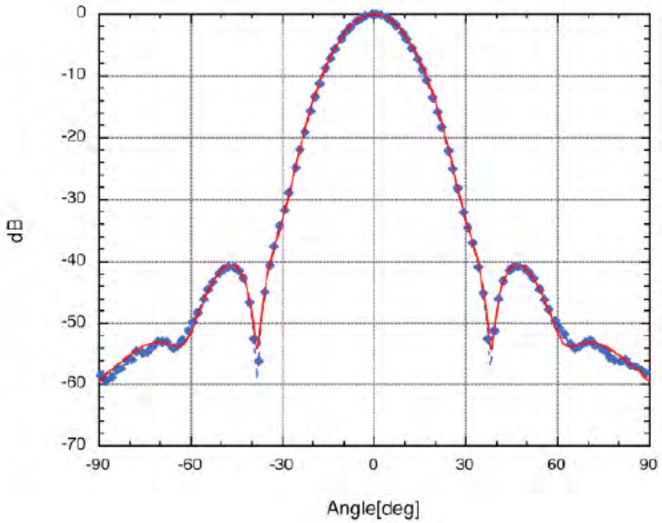




FEED HORN

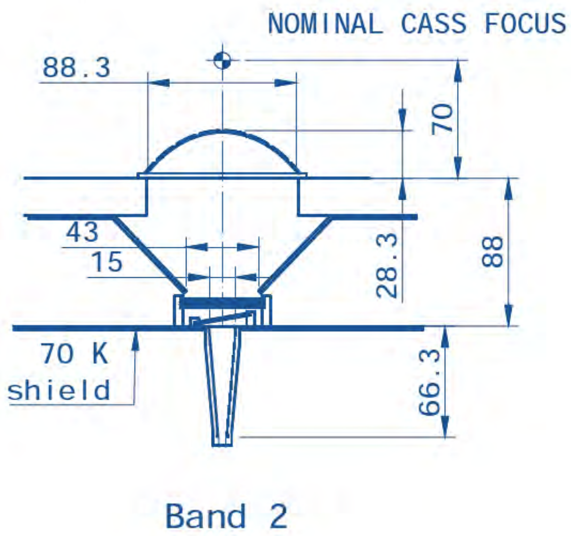
- INAF (OAA and IASF.BO) world leader in the design and development of high-performance corrugated feed horns for Astrophysics

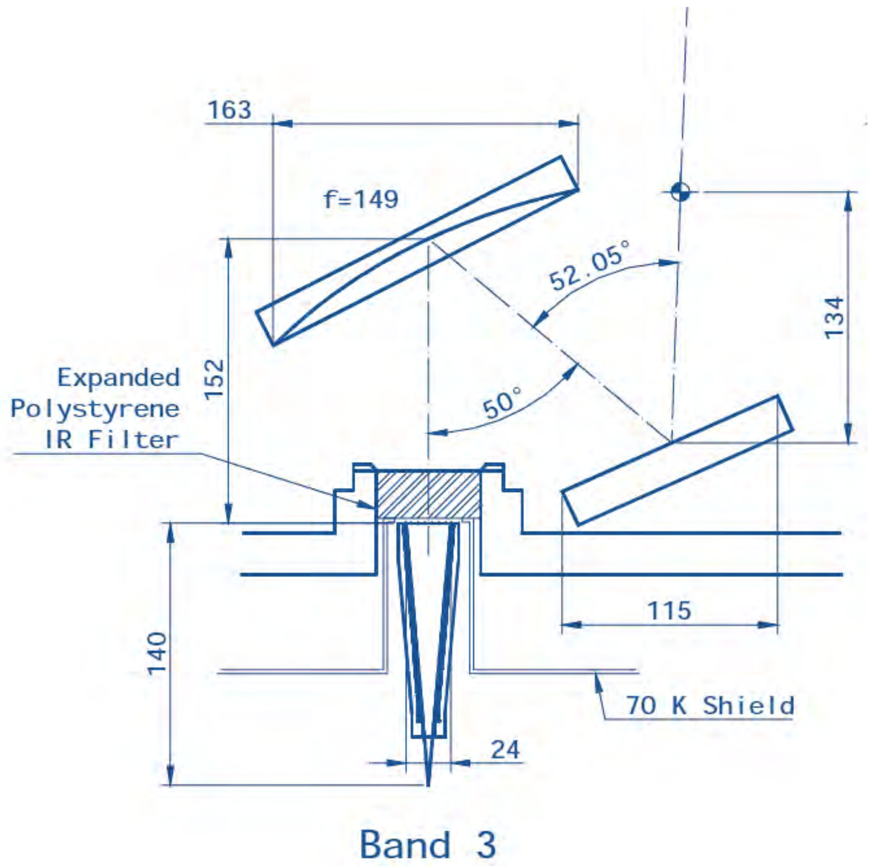




FORE- (RE-IMAGING) OPTICS

- To adapt the F#8 of the ALMA antenna to F#1-2 of FH
  - Cold optics
  - Warm optics

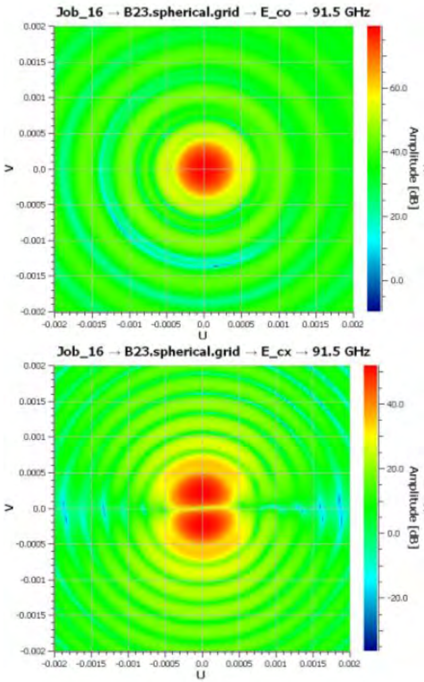


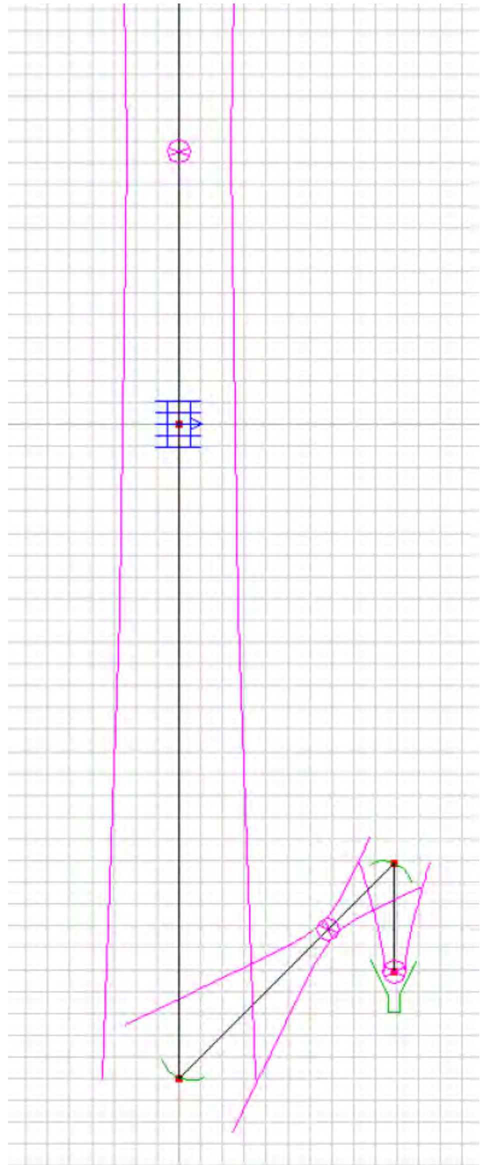


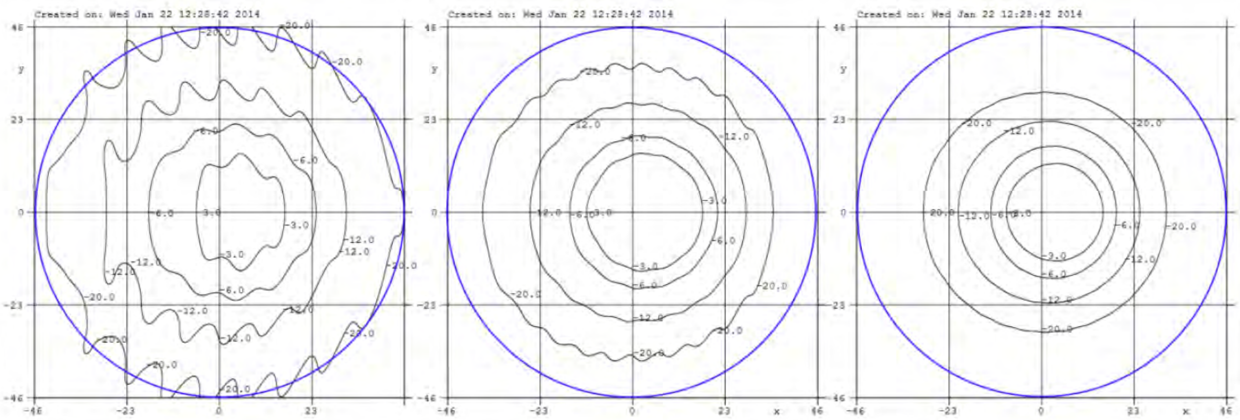
J.W. Lamb et al. (2001) ALMA memo 362

FORE- (RE-IMAGING) OPTICS

- To develop FO based on previous studies







LNA DEVELOPMENT

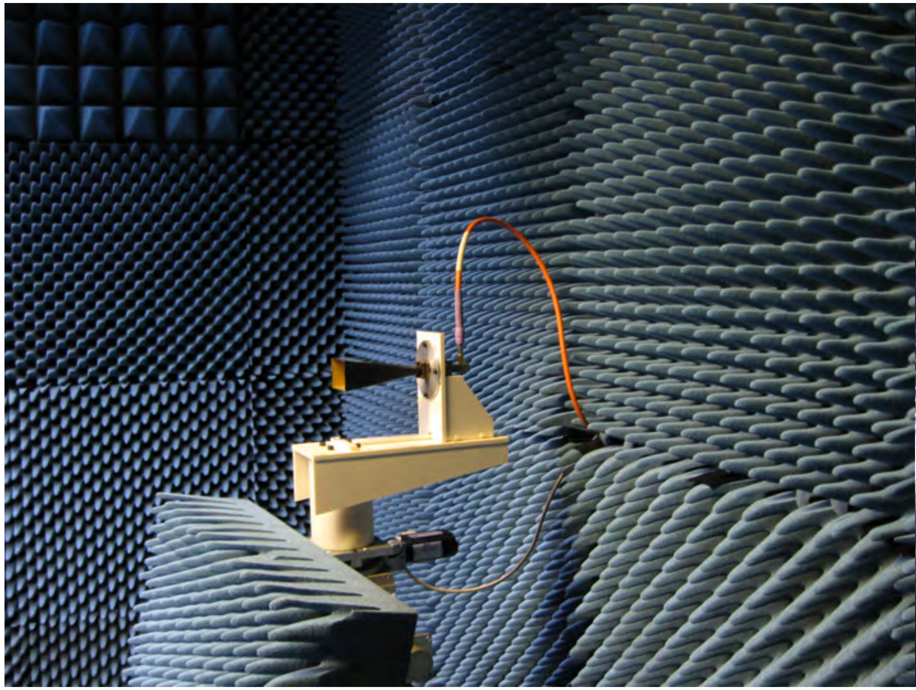
- Band 2+3 LNA critical unit of the system for noise and process reliability
- No amplifiers satisfy the ALMA specs but seems feasible in a time scale of few years.
- Agreed iALMA effort to investigate Italian/ European tech on LNAs
  - UTV, IRA, IASF
- setting up of a European consortium

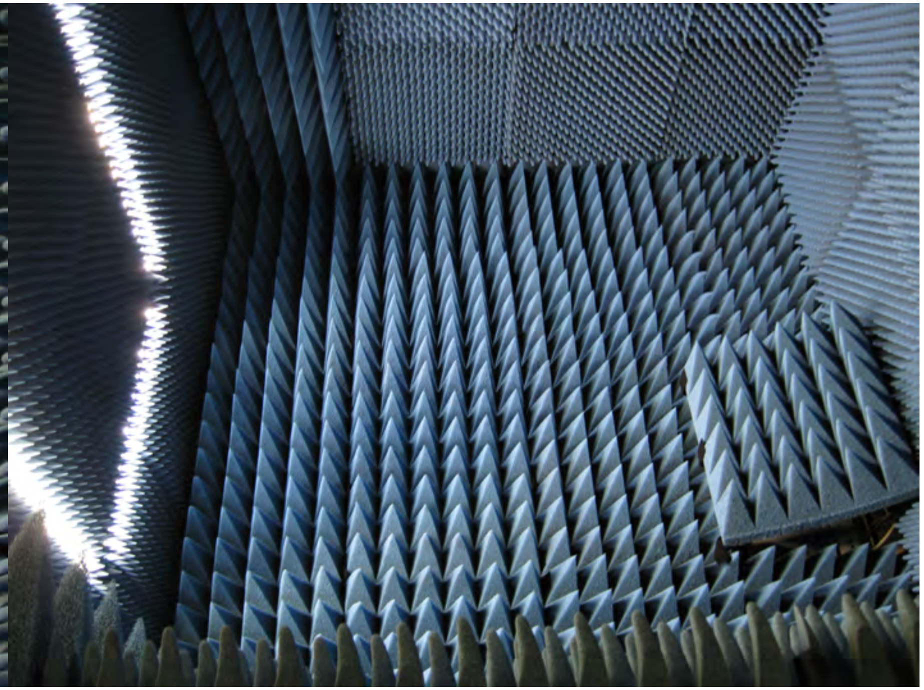
Not only a matter of
Noise of the Chip
RF chain impacts
final performances

Band 2+3 specs shall within band 2 specs and shall not degrade the band 3 specs.
Reference numbers (not specifications!!!):
34 K (80% bandwidth) 53K any frequency between 67-116 GHz

RF TEST FACILITY

- Chamber to measure radiation pattern of antennas
- S-parameter test bench (VNA) specifically optimized for the band 2+3 frequency range

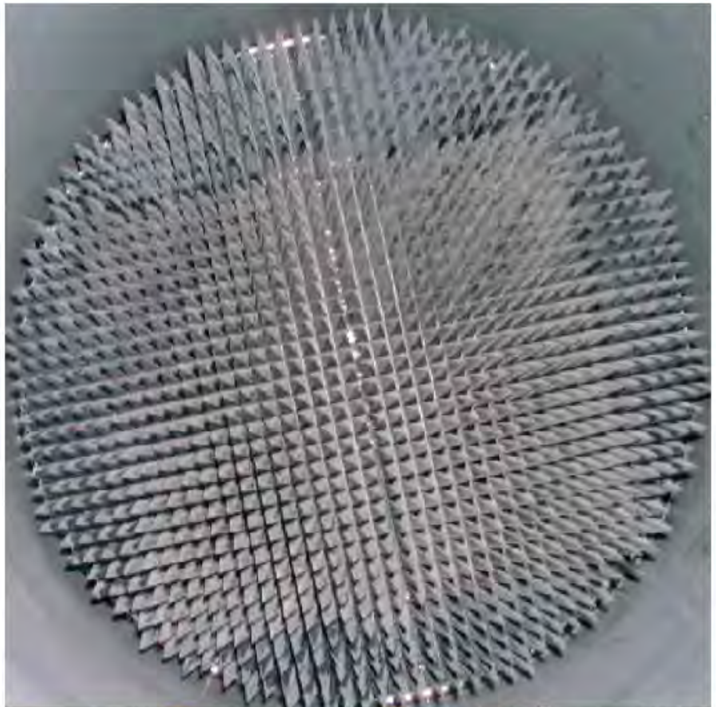


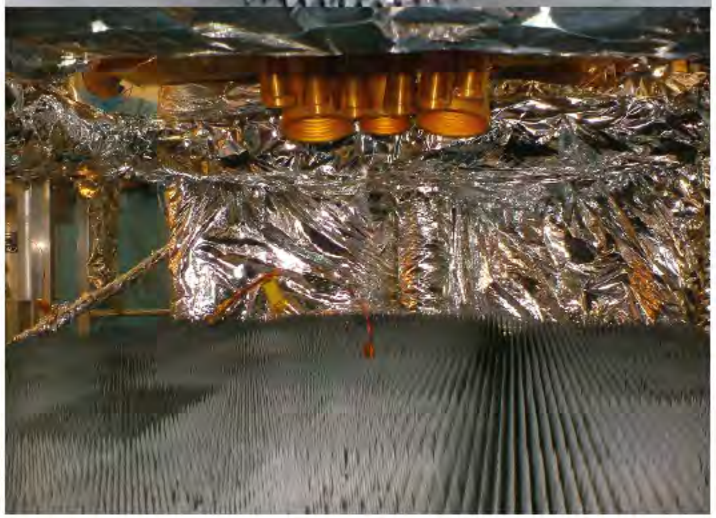


CALIBRAT(ORS) and (ION)

- development of cryogenic calibrators to measure the performances of the radiometer in polarization

- Development of calibration plan to investigate in details radiometer performances





SYSTEM ENGINEERING

- Optical, thermal, RF interfaces between components and ALMA
- To convert science requirements into design requirements
  – Impact of noise performance on Science
  – Calculation on Front-End efficiencies based on simulations

$$T_{\rm sys} = \frac{1+g}{\eta_{\rm eff} e^{-\tau_0 \sec z}} \Big(T_{\rm rx} + \eta_{\rm eff} T_{\rm sky} + (1-\eta_{\rm eff}) T_{\rm amb} \Big)$$

$$\sigma_{\rm S} = \frac{2\,k\,T_{\rm sys}}{\eta_{\rm q}\eta_{\rm c} A_{\rm eff} \sqrt{N(N-1)\,n_{\rm p}\,\Delta\nu\,t_{\rm int}}}. \qquad \eta_{\rm ap} = R_0 \exp\left(-16\,\pi^2\sigma^2/\lambda^2\right)$$

ALMA Technical Handbook cycle 2

CONCLUSIONS

- ALMA band (2) 2+3
  - Cryofacility to permit to test ALMA band (2) 2+3 cartridge and sub-units
    - Qualification tests
    - Performance tests and analysis
  - Development of Passive Components
    - Design, fabrication and test of FH, OMT
  - Development of fore-optics
    - Design, fabrication, and test
- Continuation of the activity already started in INAF with UTV and UNIMIB on LNA and Electronics development using Italian/European technologies
- Prototype cartridge to be used for first light in National Facilities (SRT)