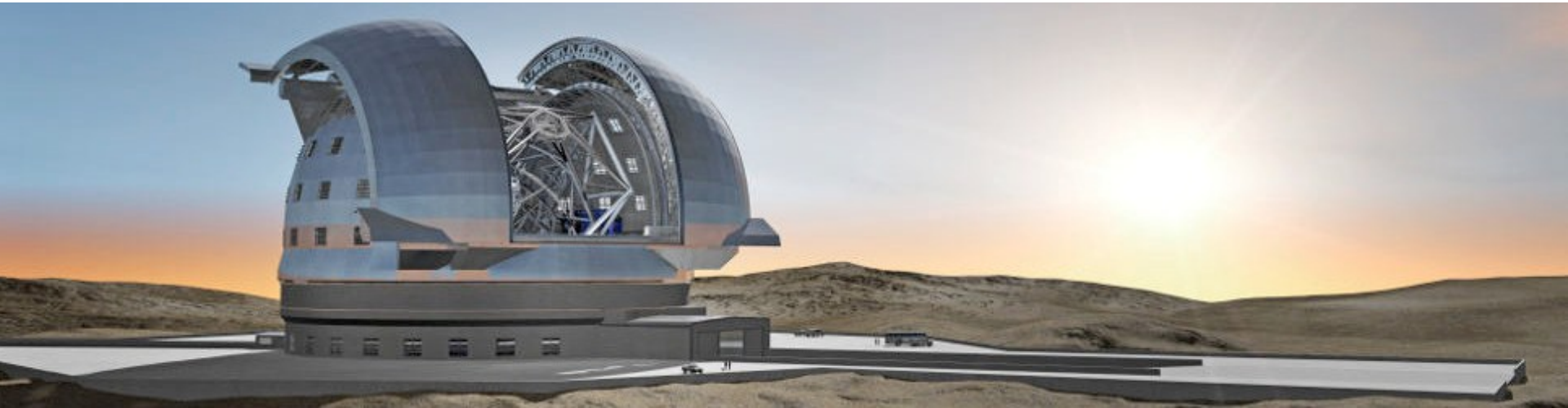
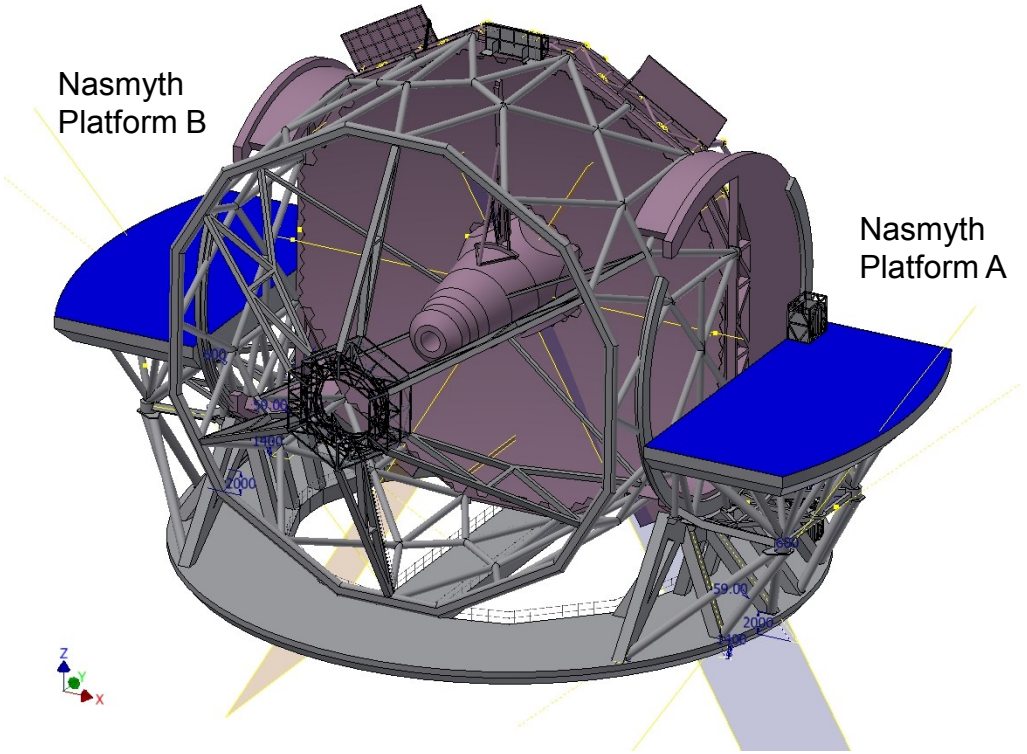
Instruments for ESO's Extremely Large Telescope

at Dispersing Elements for Astronomy, October 2017

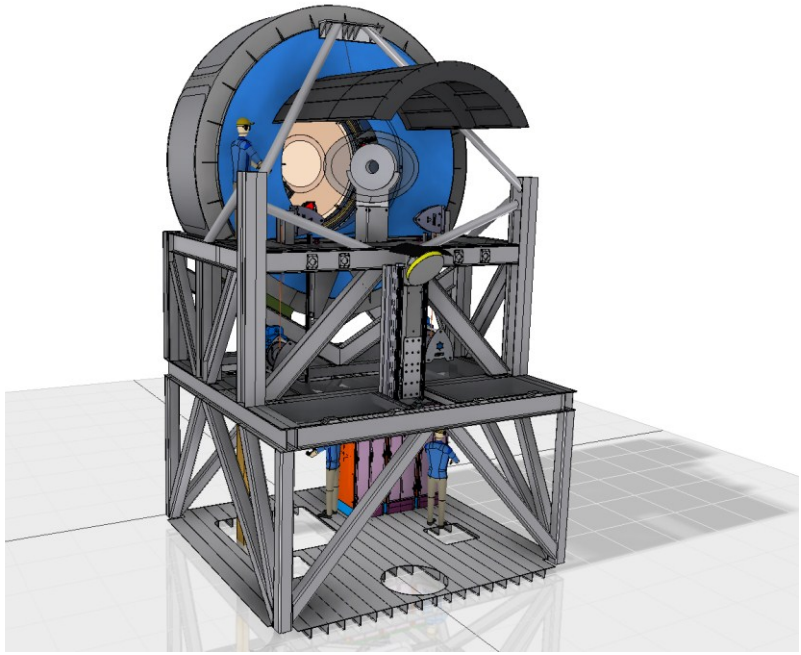
Suzanne Ramsay, ELT Instrumentation Project Manager
on behalf of many ESO colleagues and the consortia



Instruments on the ELT



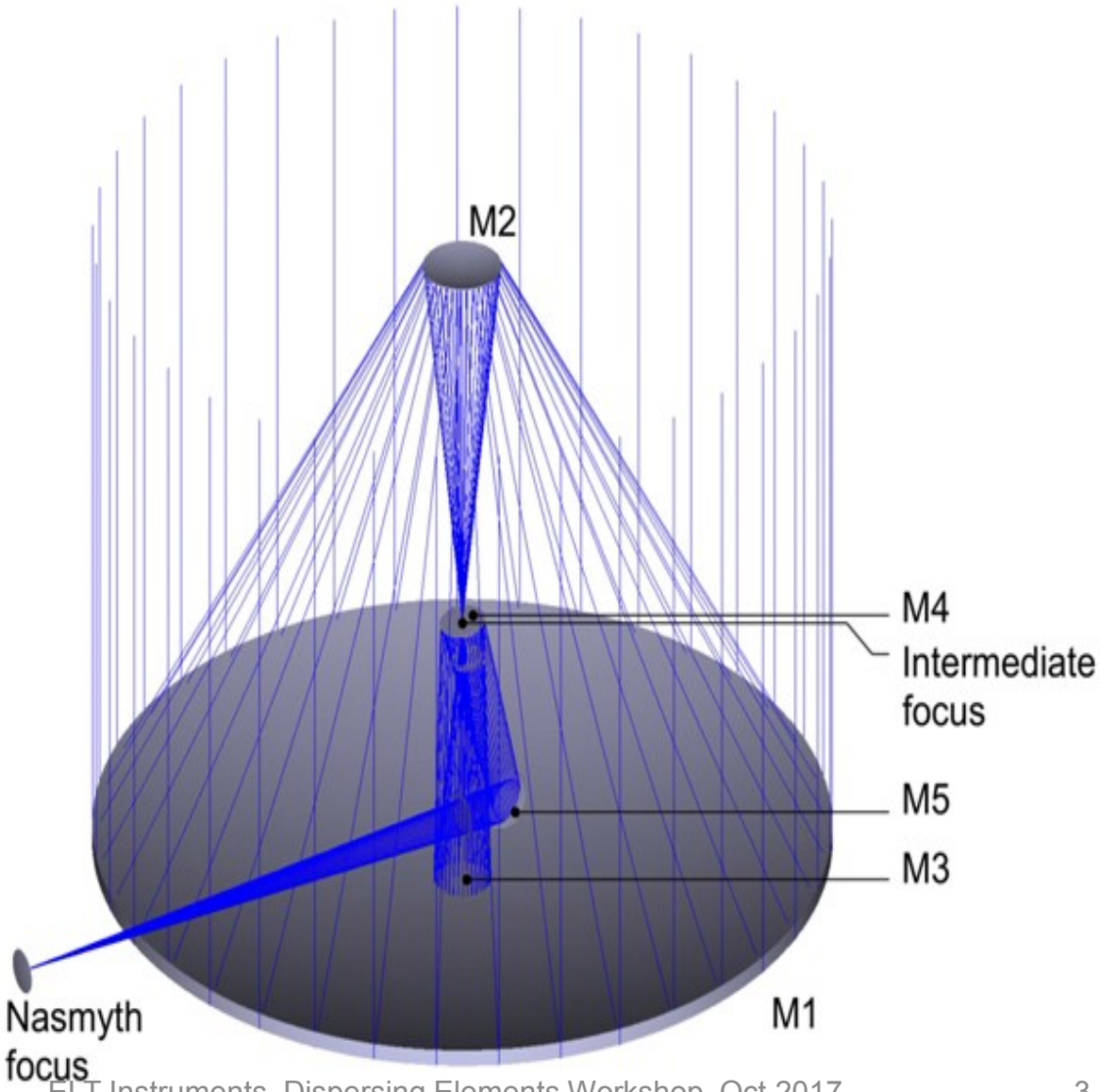
The Pre-Focal Station



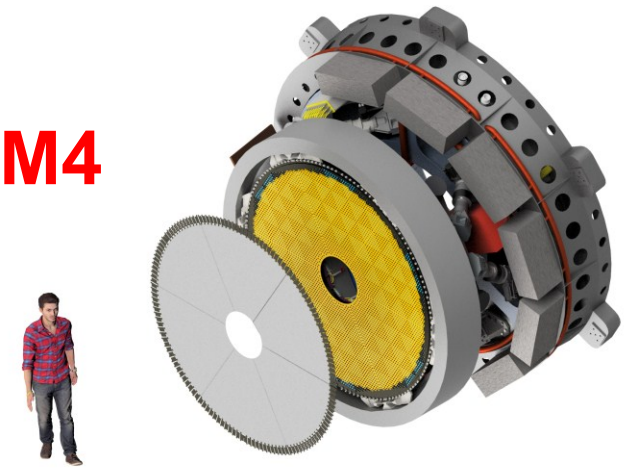
Courtesy Ch. Frank and P. Jolley

The ELT provides two tennis-court sized Nasmyth platforms that can each host three instruments. The "Pre-Focal Station" contains the wavefront sensors to control the telescope and has three instrument ports (two lateral, one direct).

ELT: a five mirror telescope

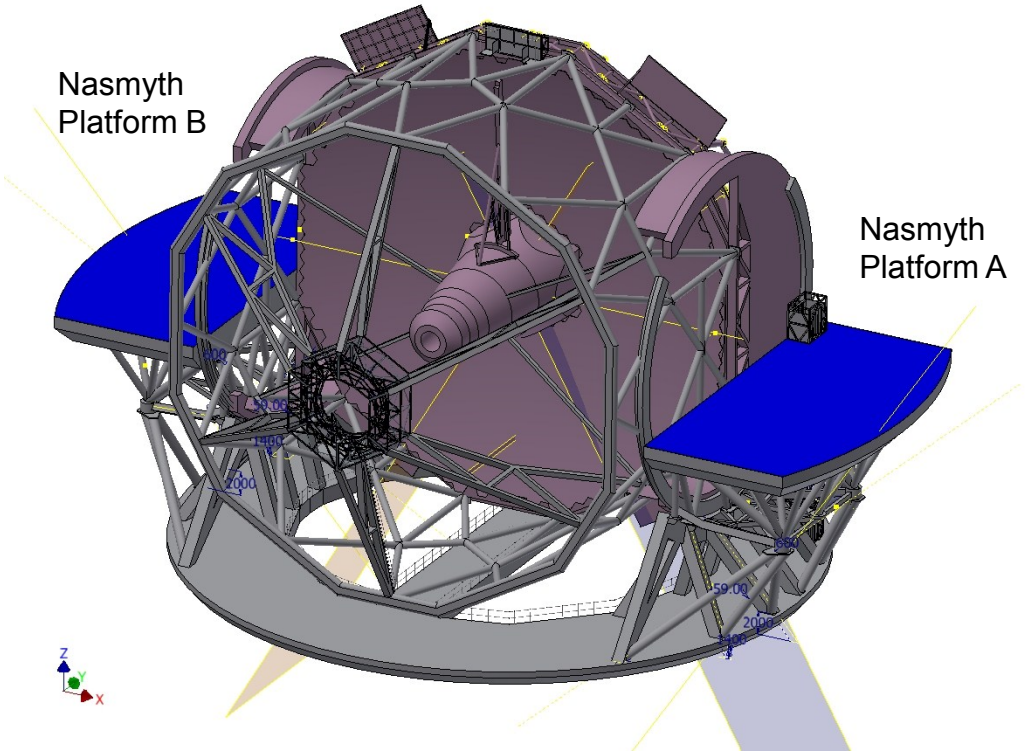


M4



- Contracts for Final Design and Manufacturing signed with AdOptica
- 2.4-m flat adaptive mirror – 6 thin-shell petals 1.95mm thick
- ~5300 contactless actuators driving the mirror shape at 1 kHz

Instruments on the ELT



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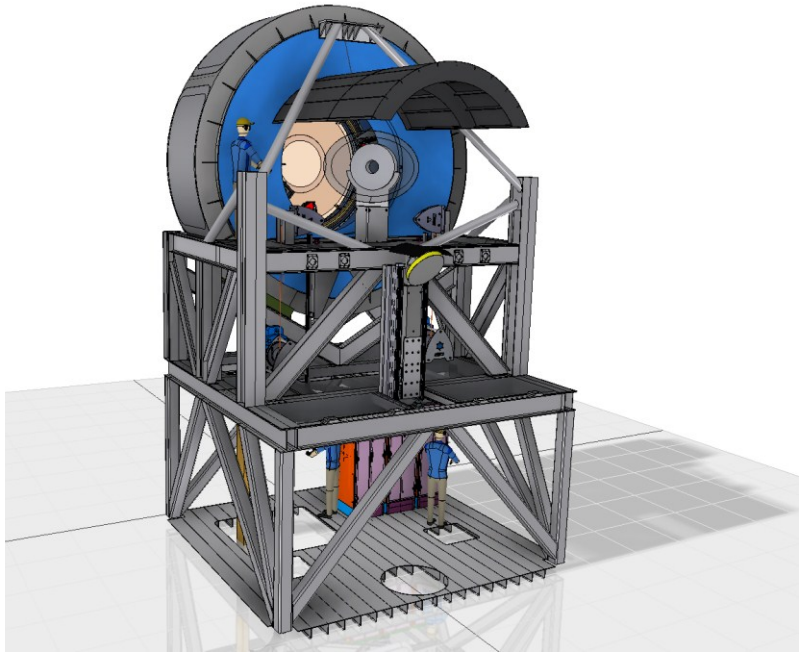
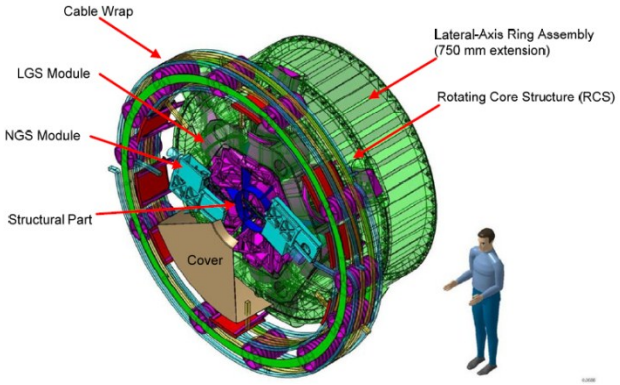


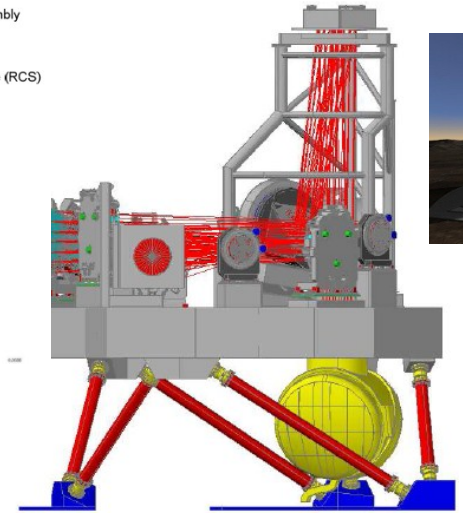
Courtesy Ch. Frank and P. Jolley

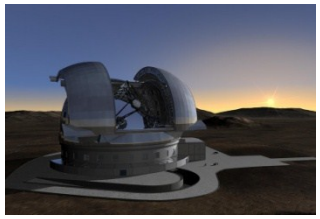
The ELT provides two tennis-court sized Nasmyth platforms that can each host three instruments. The "Pre-Focal Station" contains the wavefront sensors to control the telescope and has three instrument ports (two lateral, one direct).

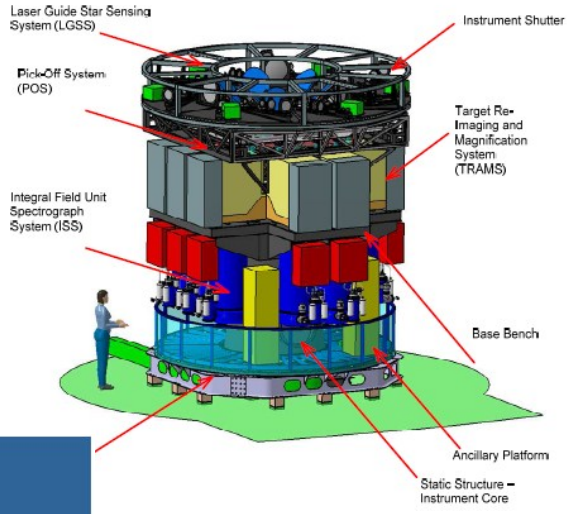
The Phase A instrument studies

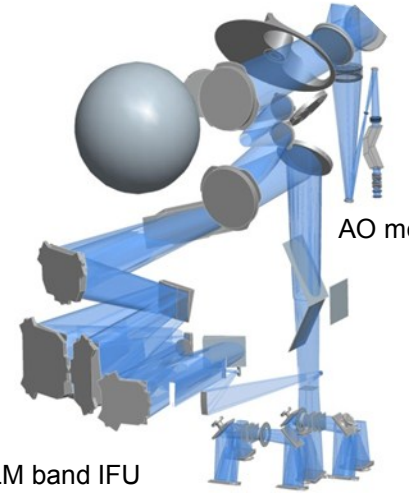
- The goal of this study programme was to carry-out a suitable number of instrument studies
  - to verify that instruments can be built at an affordable cost and that they properly address the highest priority scientific goals,
  - to work with the ESO community towards construction
  - to work with telescope and operation project offices to identify and define interfaces with the other subsystems and the observatory infrastructure.
- 9 instrument and 2 post-focal AO studies carried out by >300 scientists and engineers in 40 institutes throughout the ESO community





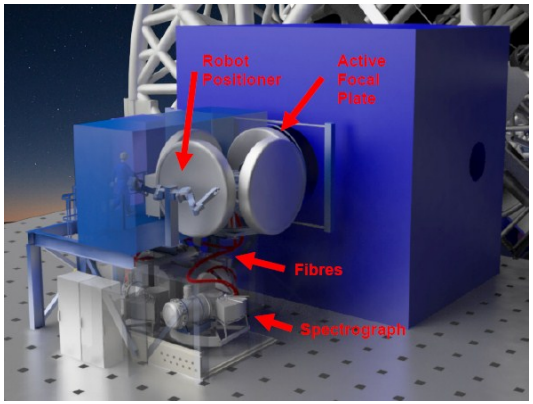




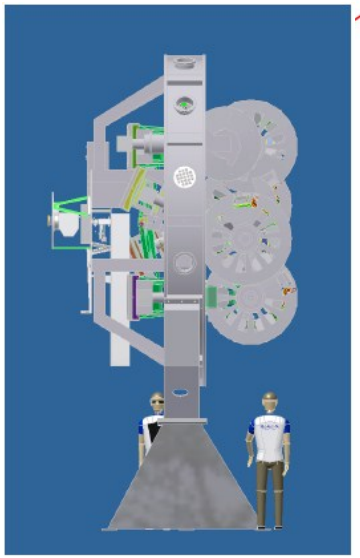


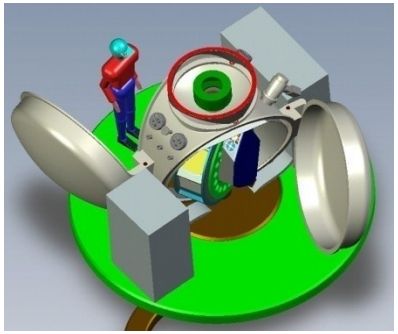
AO module

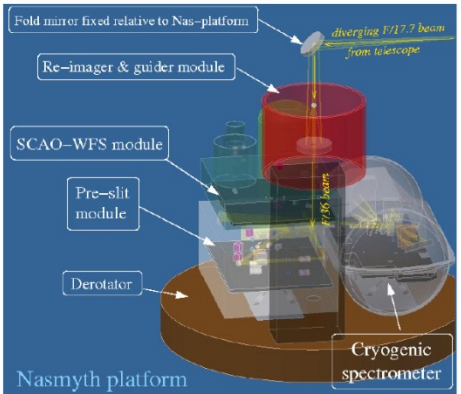
LM band IFU spectrograph

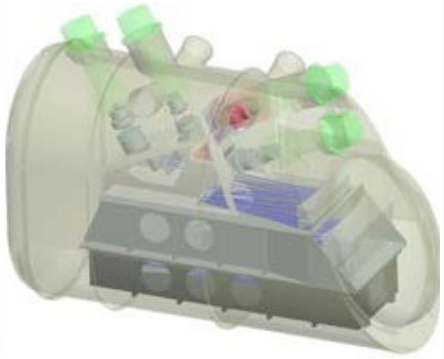


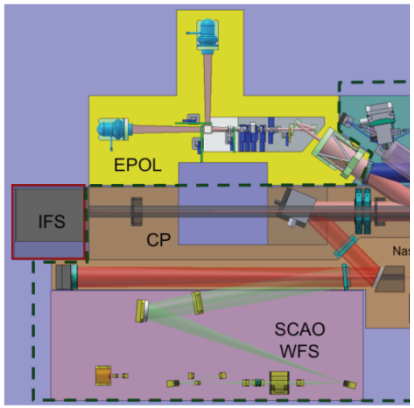
Imager (LM and N-band channels)

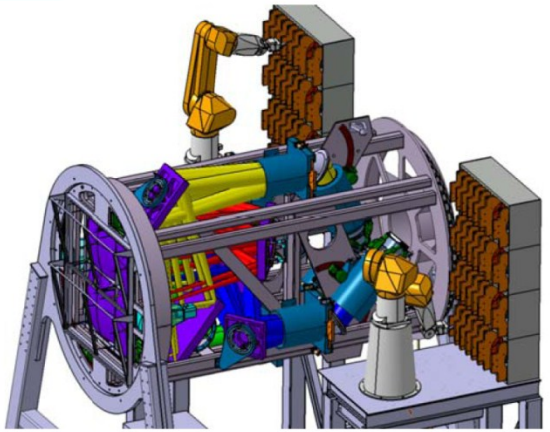












The E-ELT Instruments: Overview

- Following Phase A studies the ELT instruments were selected in consultation with the ESO committees and community based on
  - Scientific impact, return, flexibility
  - Complementarity to JWST, existing facilities
  - A plan to cover all observing conditions
- "First light pair"
  - ELT-IFU: adaptive optics fed optical to NIR integral field spectrograph
  - ELT-CAM: diffraction limited NIR camera with its AO module
- ELT-MIR, ELT-MOS, ELT-HIRES to follow the first pair
- ELT-PCS to start following technology and science case development

Overall status

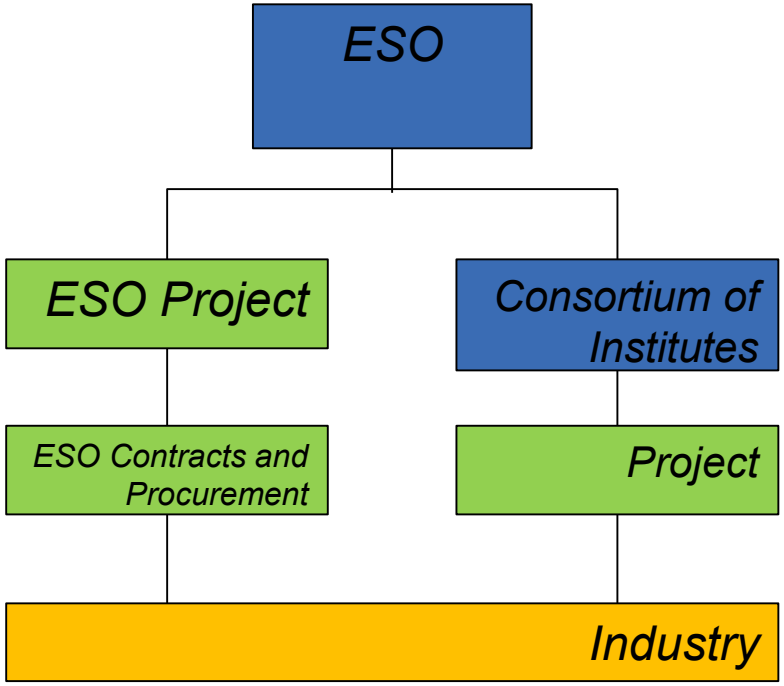
- Four instruments in the preliminary design phase
  - MICADO (ELT-CAM)
  - MAORY
  - HARMONI (ELT-IFU)
  - METIS (ELT-MIR)
- Two “Phase A studies” are underway
  - MOSAIC (ELT-MOS)
  - HIRES (ELT-HIRES)

Signing the agreements for the first instruments (Oct-Dec 2015)

- The first instruments are built by large consortia of external institutes, with ESO participating in some areas (detectors, AO)

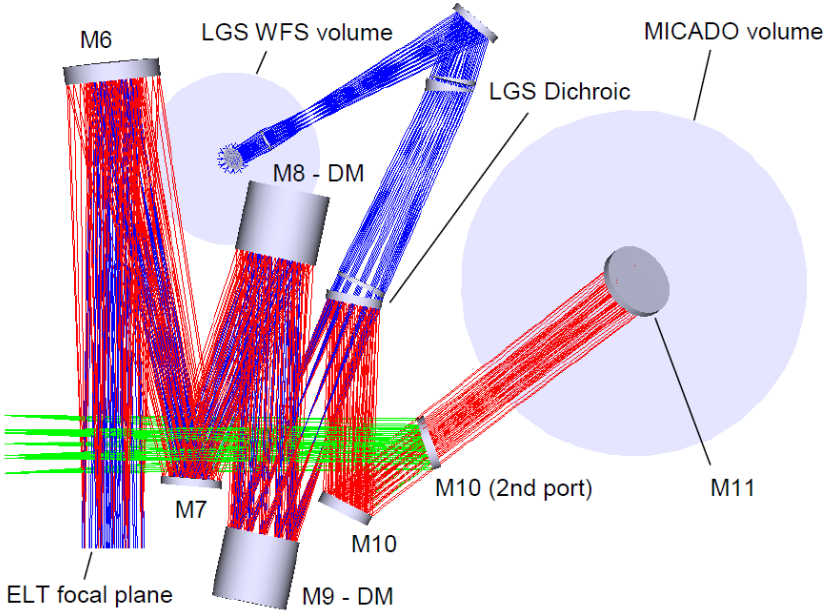
ESO's Instrument Procurement model

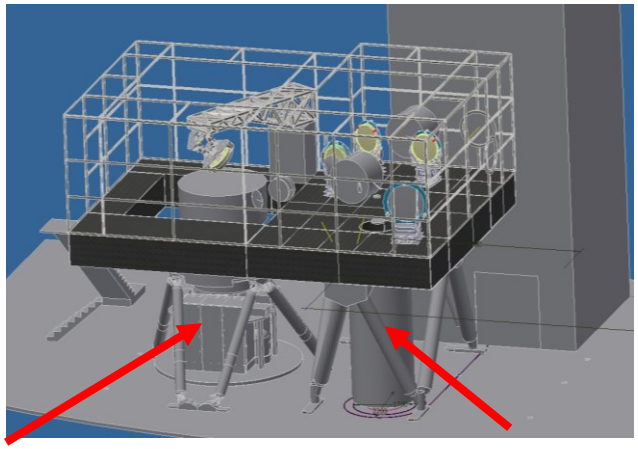
- The majority of instruments are obtained from consortia (teams) of member-state institutes
  - Some instruments led by ESO
- Normally ESO establishes an agreement for construction after a (competitive) Phase A
  - ESO pays hardware/industrial costs
  - Institutes pay for staff effort



ELT-CAM: MAORY+MICADO

- PI: E. **Diolaiti,** consortium of INAF institutes + INSU IPAG
- Multi-conjugate AO system using up to 6 laser guide stars and 3 natural guide stars
- 1 or 2 deformable mirrors in addition to ELT M4 to correct atmospheric turbulence
- Single-conjugate AO as Joint development between MAORY and MICADO
- Optical beam can feed MICADO or second instrument port
- Performance goal: 60% Strehl at 2.2 μm with excellent uniformity over 2arcmin in good conditions



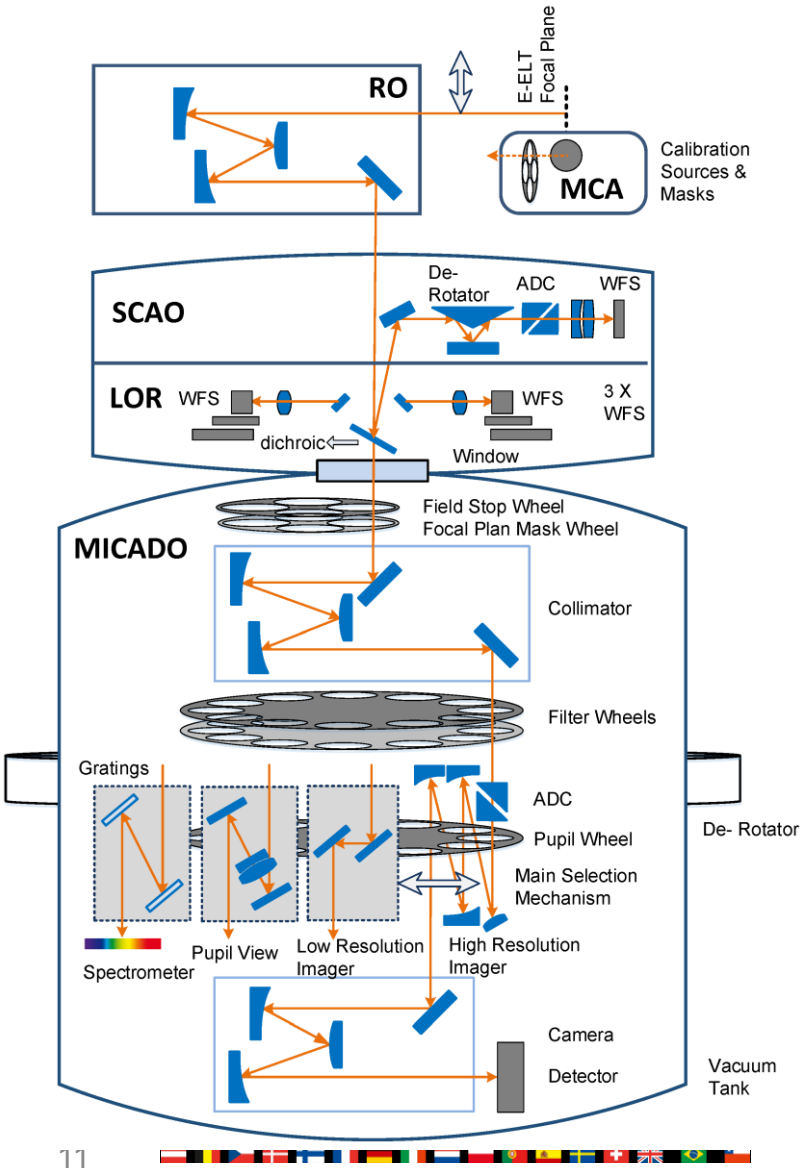


MICADO

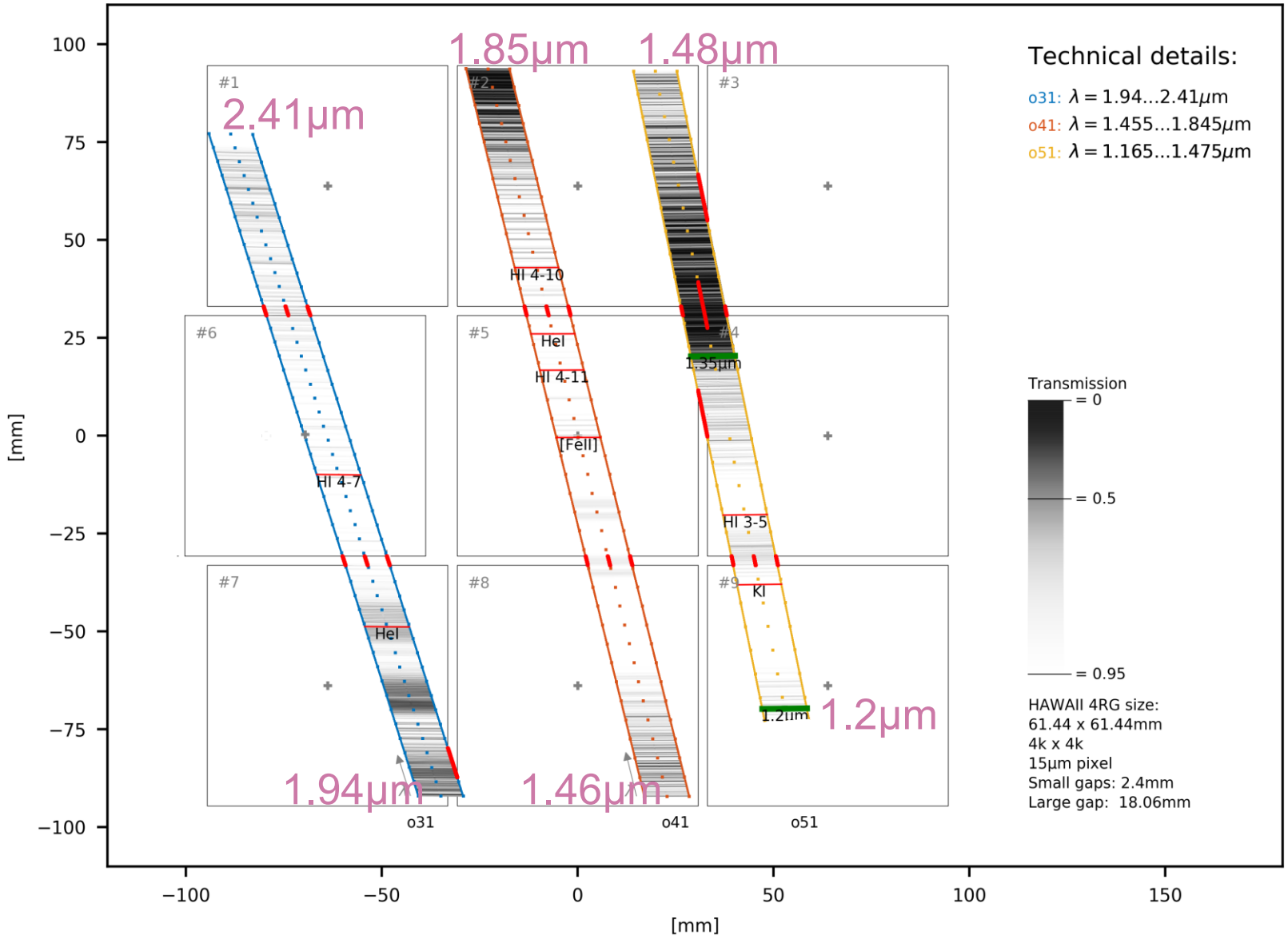
LGS WFS module

MICADO

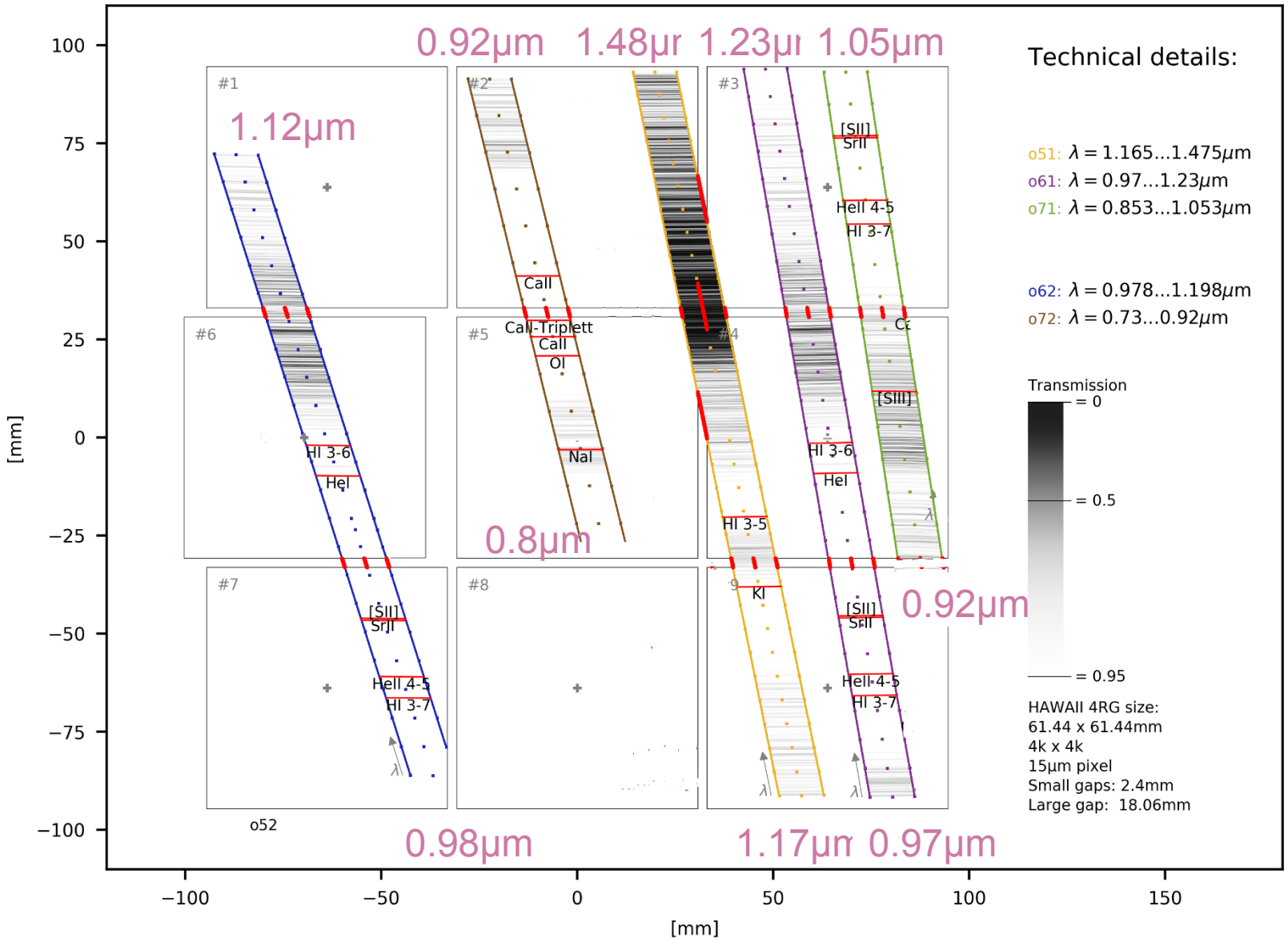
- PI: **R. Davies**, MPE, MPIA, USM, NOVA, IAG, CNRS, INAF, A*, ESO
- Imaging from 0.8-2.4μm, > 30 filters, an array of 3x3 detectors with 4096x4096 pixels each. Pixel scales of 4mas (FoV ~53") and 1.5mas (FoV ~20")
- Astrometric imaging to 50μarcsec precision across whole image
- Coronagraph plus single conjugate AO
- Time Resolved Astronomy up to 4mas
- Spectroscopy for single compact objects
  - two settings (0.8-1.44μm and 1.21-2.4μm) at spectral resolving power up to 20,000.
  - Baseline 3arcsec slit; >16mas width



Extended HK spectral layout



IzJ spectral layout



Technical details:

o51: $\lambda = 1.165...1.475\mu m$
o61: $\lambda = 0.97...1.23\mu m$
o71: $\lambda = 0.853...1.053\mu m$

o62: $\lambda = 0.978...1.198\mu m$
o72: $\lambda = 0.73...0.92\mu m$

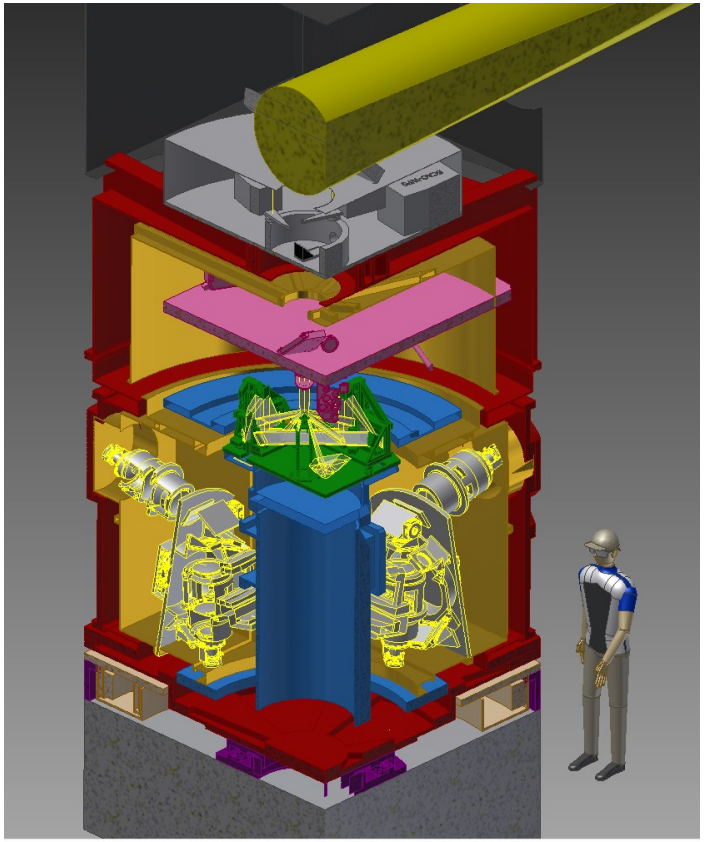
Transmission
= 0
= 0.5
= 0.95

HAWAII 4RG size:
61.44 x 61.44mm
4k x 4k
15µm pixel
Small gaps: 2.4mm
Large gap: 18.06mm

HARMONI: High Angular Resolution Monolithic Optical and Near-Infrared spectrograph

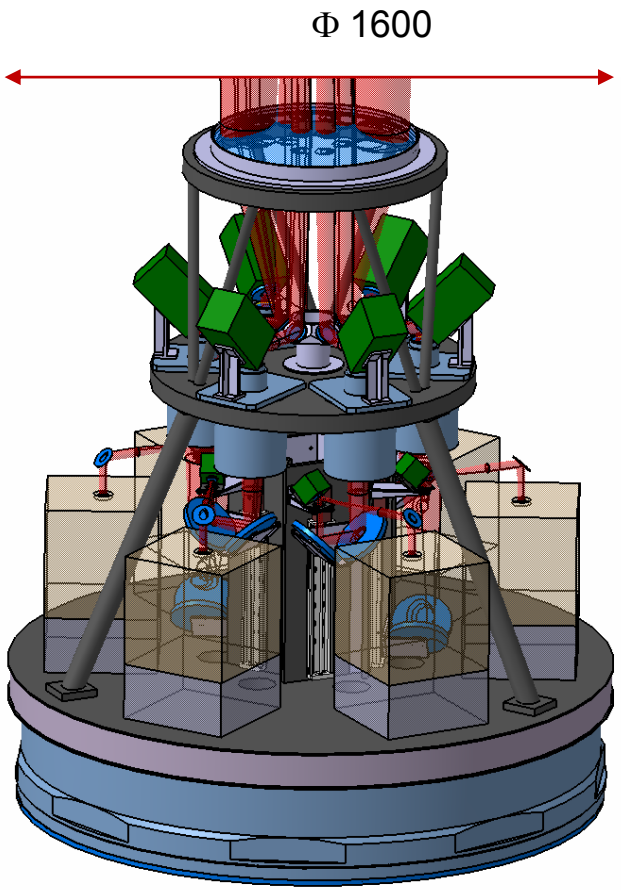
- PI **N.Thatte,** Univ Oxford, UK ATC, IAC, CSIC-CAB, CRAL, LAM, ESO as associate partner
- **"3D" Integral Field Unit spectrograph**
  - Think "MUSE+KMOS"
- Modular instrument: 4 spectrographs
- Covering **optical** (0.47μm) to **near-IR** (2.45μm)
- Resolving power from R=3500 to 20000
- **Range of spatial scales** with field of views from 9"x6" to 0.8"x0.6" and 32000 spatial pixels
- From **seeing limited observations** down to the **diffraction limit** with single conjugate AO (SCAO) and laser tomographic AO (LTAO)
- HARMONI Preliminary Design review to take place 9-10 November (spectrograph) and 7-8 December (AO)

Quarter view of the HARMONI spectrometer cryostat.
~ 4m in diameter, cooled to ~140K.



HARMONI LTAO to PDR

- A laser tomographic adaptive optics module is being designed to PDR
  - Minimal additional optical surfaces in the science beam (one dichroic mirror)
- Six laser guide star wavefront sensors and one natural guide star WFS
  - mounted on top of the HARMONI cryostat
- AO correction by M4

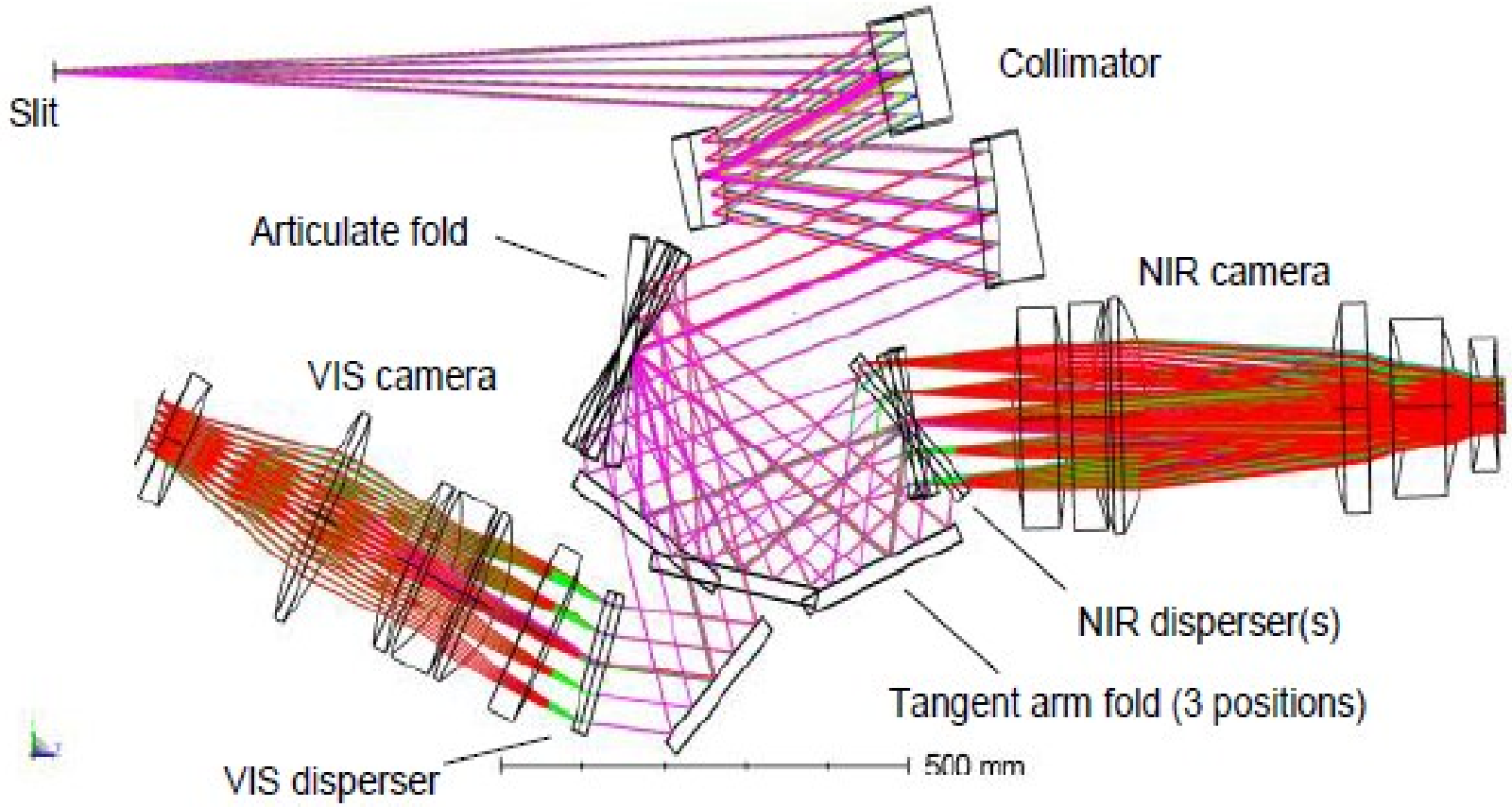


HARMONI-LTAO concept

HARMONI requirements

Bands	Wavelengths (µm)	R
"V+R" or "I+z+J" or "H+K"	0.45-0.8,0.8-1.35, 1.45-2.45	~3500
"I+z" or "J" or "H" or "K"	0.8-1.0, 1.1-1.35, 1.45-1.85, 1.95-2.45	~7000
"Z" or "J_high" or "H_high" or "K_high"	0.9, 1.2, 1.65, 2.2 (TBD)	~18000

HARMONI spectrograph

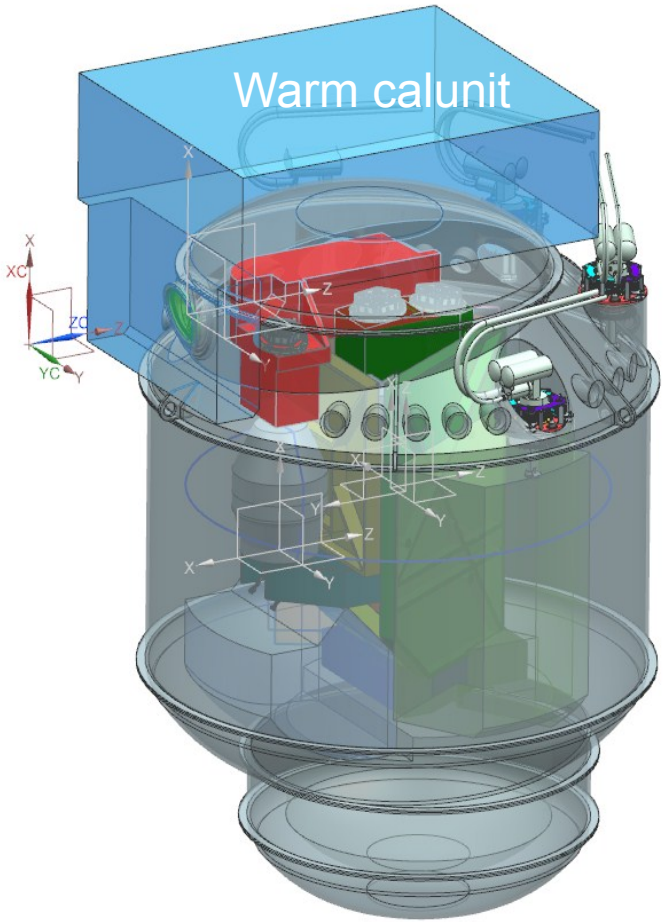


10 VPH gratings in three “families” (low, med, high resolving power)

Poster by John Capone “Grating Requirements for ELT-HARMONI”

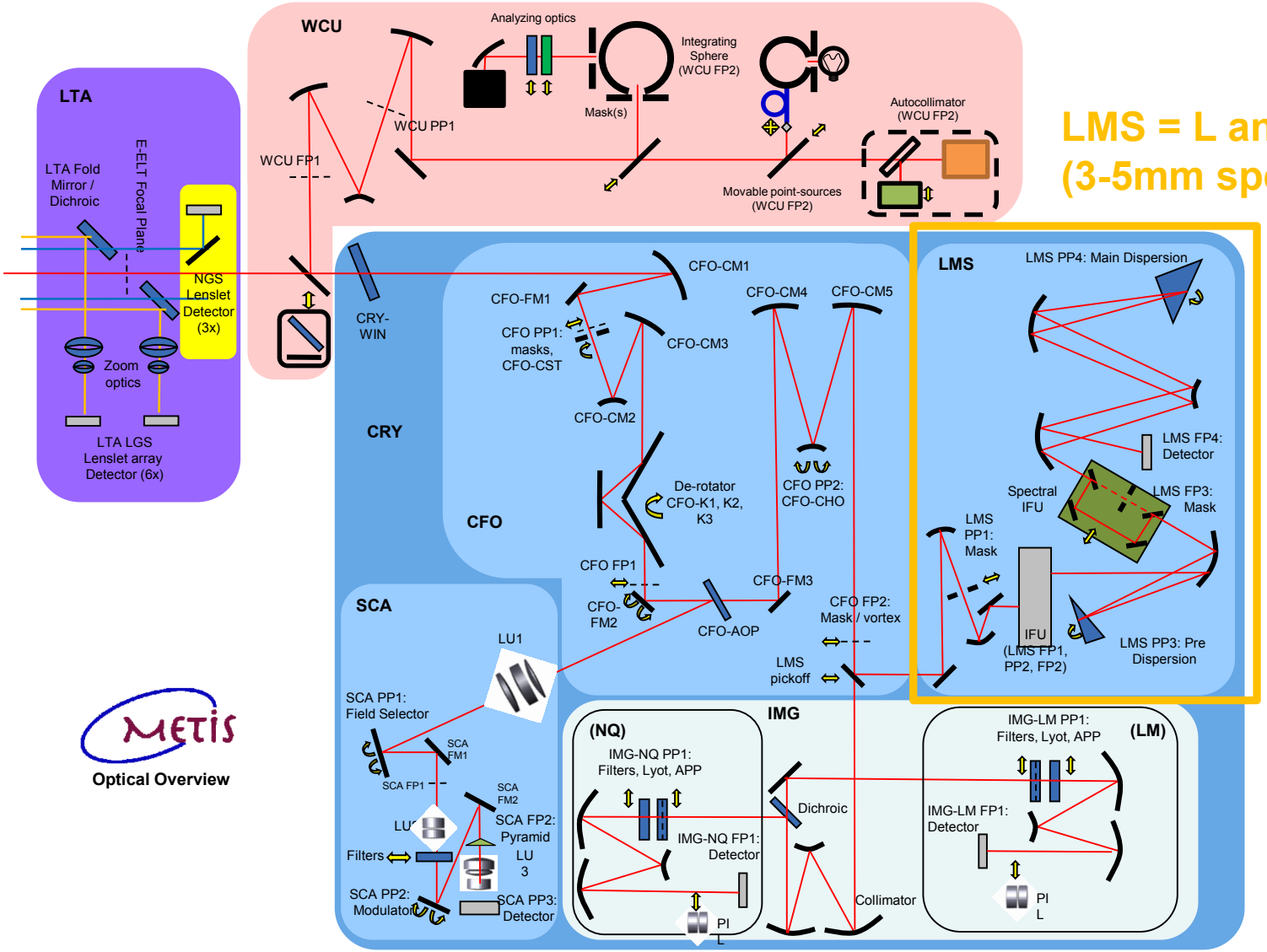
METIS

- PI **B.Brandl**, Nova, A-Star, CEA-Saclay, ETH-Zürich, KU-Leuven, MPIA-Heidelberg, UK-ATC (ESO and ASTRON as associate partners)
- Single conjugated adaptive optics fed imager (10”x10” FOV) and (3D) spectrograph
- Covers the thermal / mid infrared wavelength range from 3µm to 19µm
- Spectral Resolving power from ~100s-100 000 (with IFU)
- Coronography
  - for observations of exoplanets, disks



METIS Cryostat

METIS Optical Overview



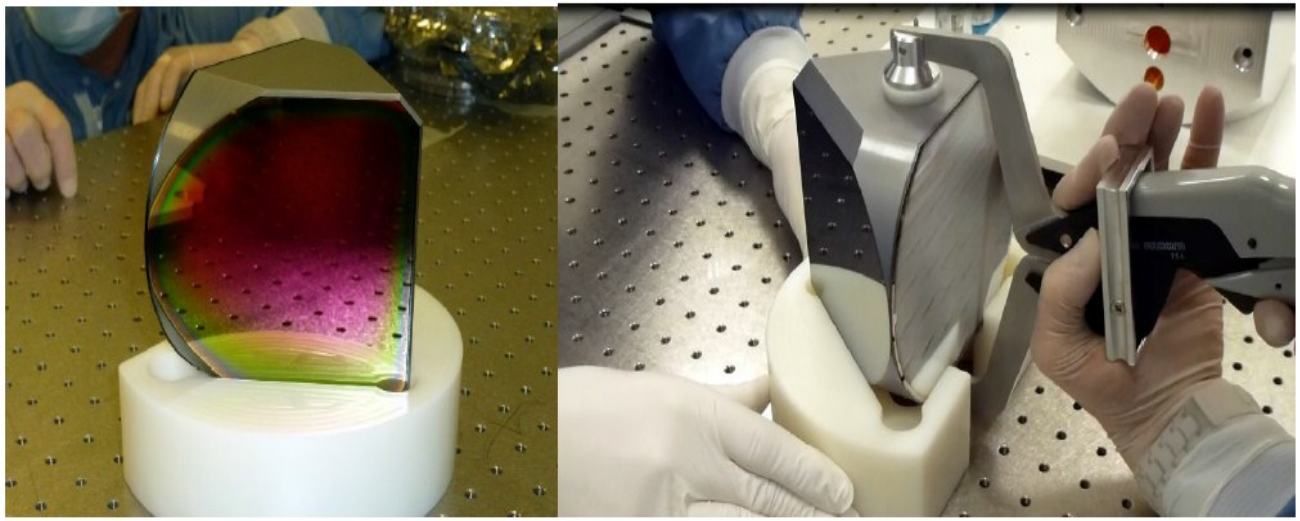
LMS = L and M band (3-5mm spectrograph)

METIS

Optical Overview

METIS silicon immersion grating

- To reach the R~100 000 required by the METIS science case implies ~400mm reflection grating
- METIS successfully developed a prototype silicon immersion grating post-Phase A on a 150mm wafer
  - see Agocs et al. 2016, SPIE 9912, 991215 and talk by Kohlhaas this afternoon



Instruments in Phase A

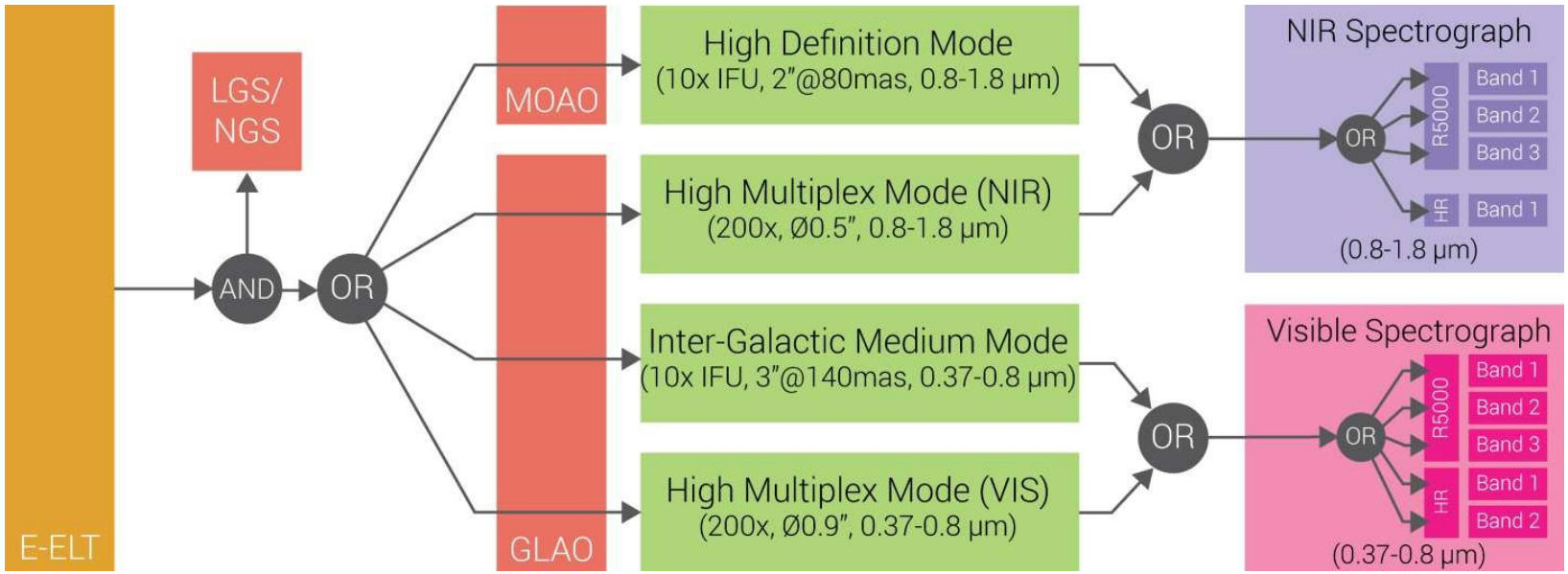
- ELT-MOS, -HIRES Call for proposals was 2015
- The Top Level Requirements for the MOS and HIRES spectrographs are very broad
- The Phase A studies are to explore the optimum design: science/cost/complexity
- HIRES Phase A review December 2017
- MOSAIC (ELT-MOS) Phase A review February 2017

Phase A ELT-MOS > MOSAIC

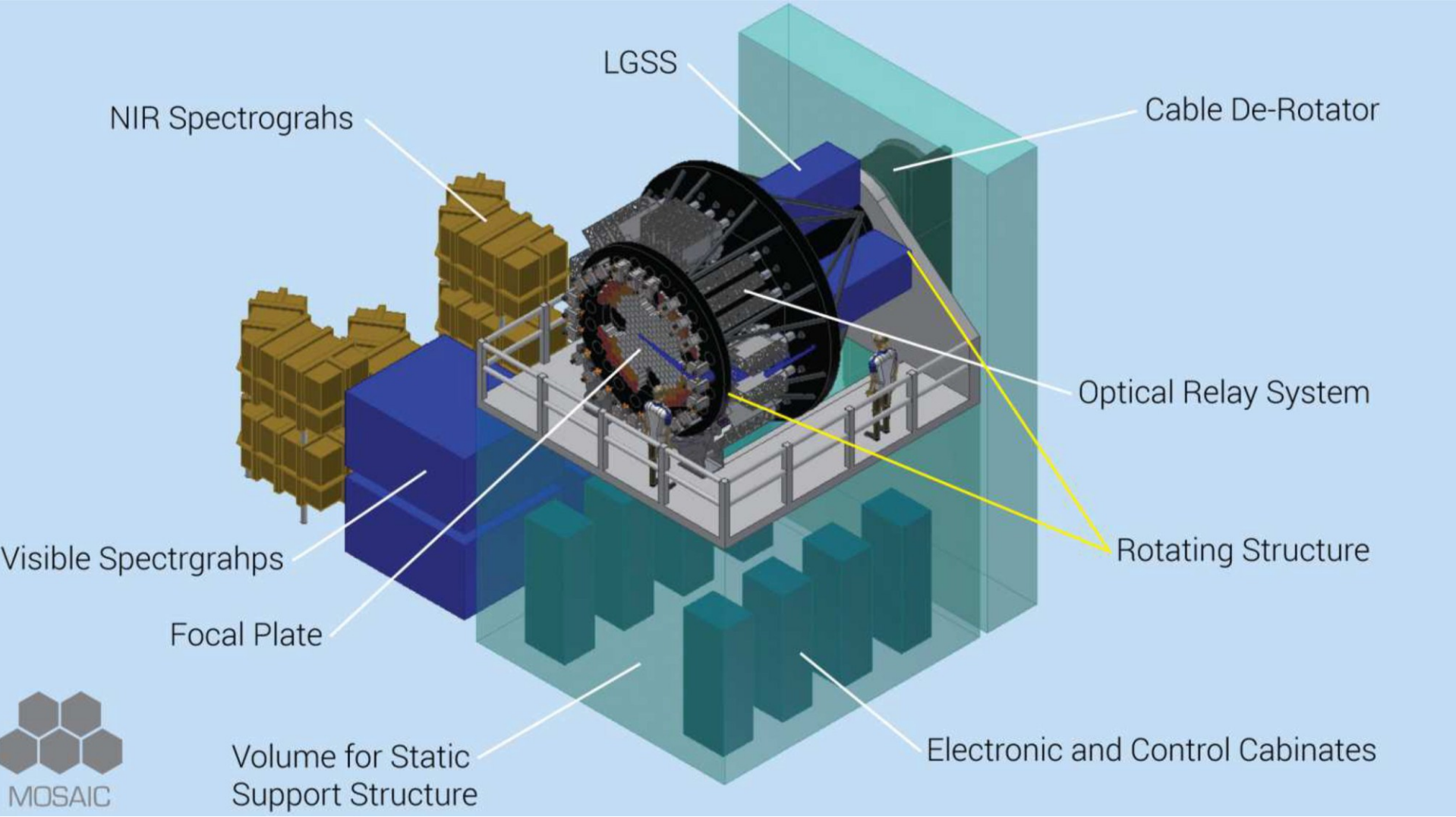
- Large consortium lead by **F. Hammer** (GEPI)
- White paper (Evans+15, arXiv 1501.04726)
  - SC1: first galaxies, reionisation
  - SC2: Large scale structures
  - SC3: Galaxies mass assembly
  - SC4: AGN/Galaxy coevolution
  - SC5: Resolved stars beyond the Local Group
  - SC6: Galaxy archaeology
  - SC7: Galactic centre
  - SC8: Planet formation in clusters

MOSAIC Concept

- Multi-purpose MOS
- Modes: high multiplex (~200) or high spatial resolution (IFU+AO)
- Fiber-fed, 0.37-1.8 µm
- Fixed spectral bands R=5,000, R ~ 15,000
- FOV > Ø 7 arcmin



MOSAIC on the Nasmyth platform



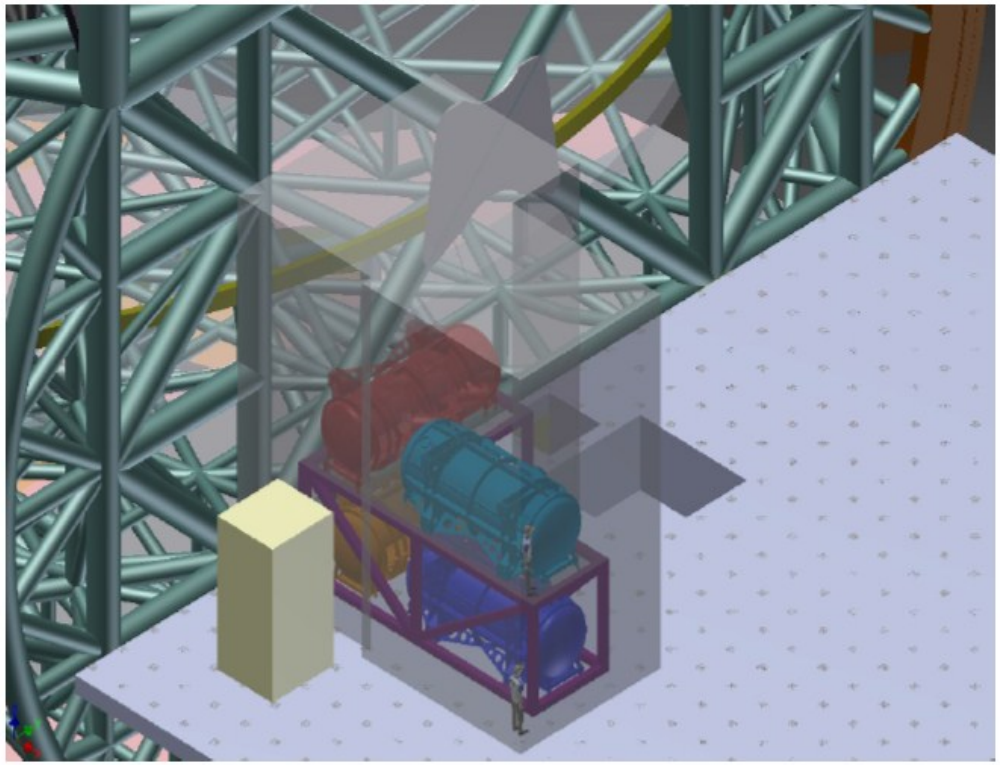
Phase A ELT-HIRES > HIRES

- Large consortium lead by **A. Marconi** (INAF)
- 4 top priority science cases
  - Exoplanet atmospheres
  - Fundamental constants
  - Exoplanet atmospheres in reflection
  - The Sandage Test
- The science cases above drive the instrument design
  - Other cases : stars and stellar populations, galaxy formation and evolution

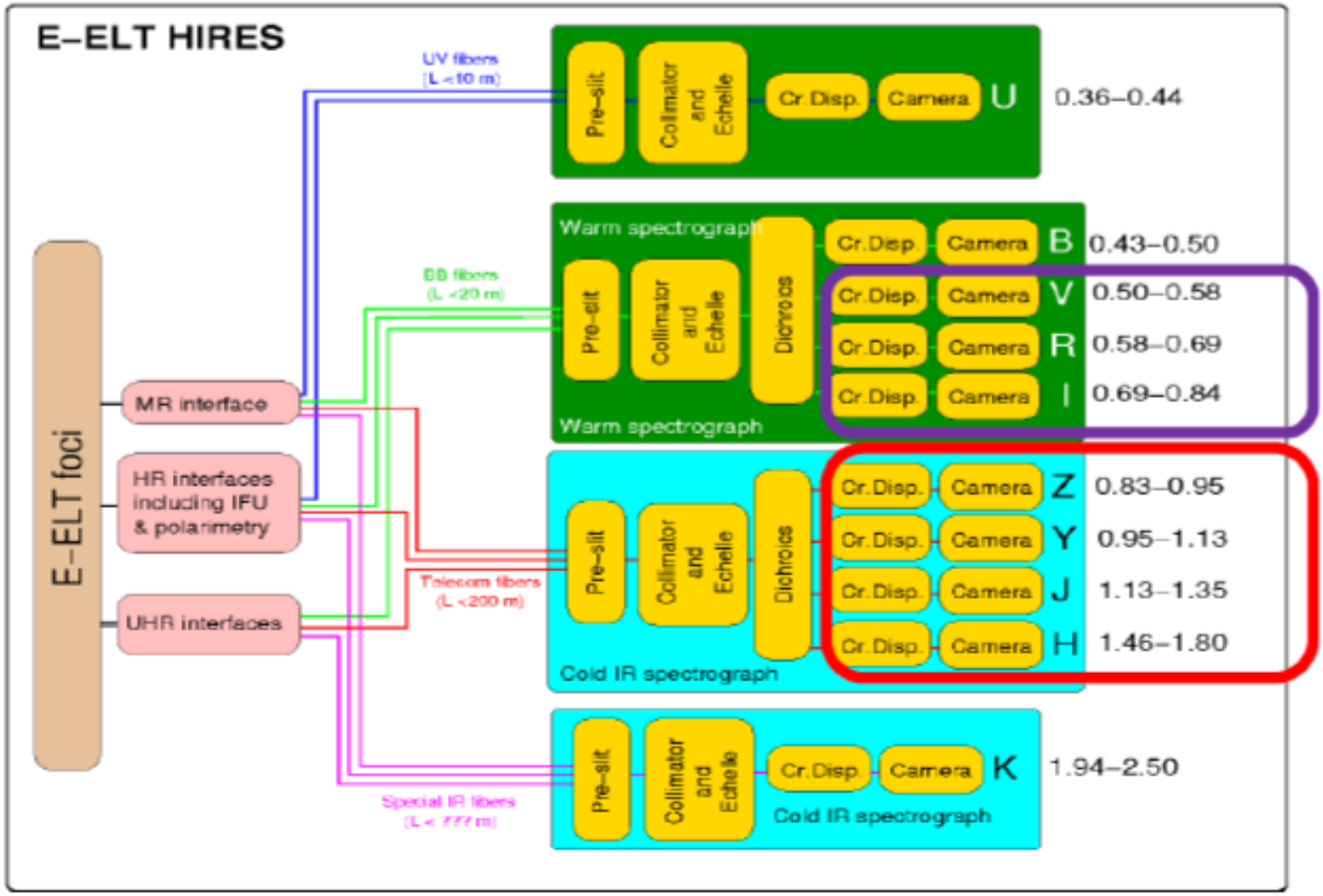
see also Maiolino et al. arXiv 1310.3163

HIRES Concept

- Wavelength range ~0.4-1.8 μm
- Spectral resolving power R > 100,000
- Stability ~1m/s
- Fibre-fed echelle spectrograph
- Modular design for adaptability to future science cases



HIRES concept: modularity




Thanks for your attention