ELT instrumentation procurement webinar

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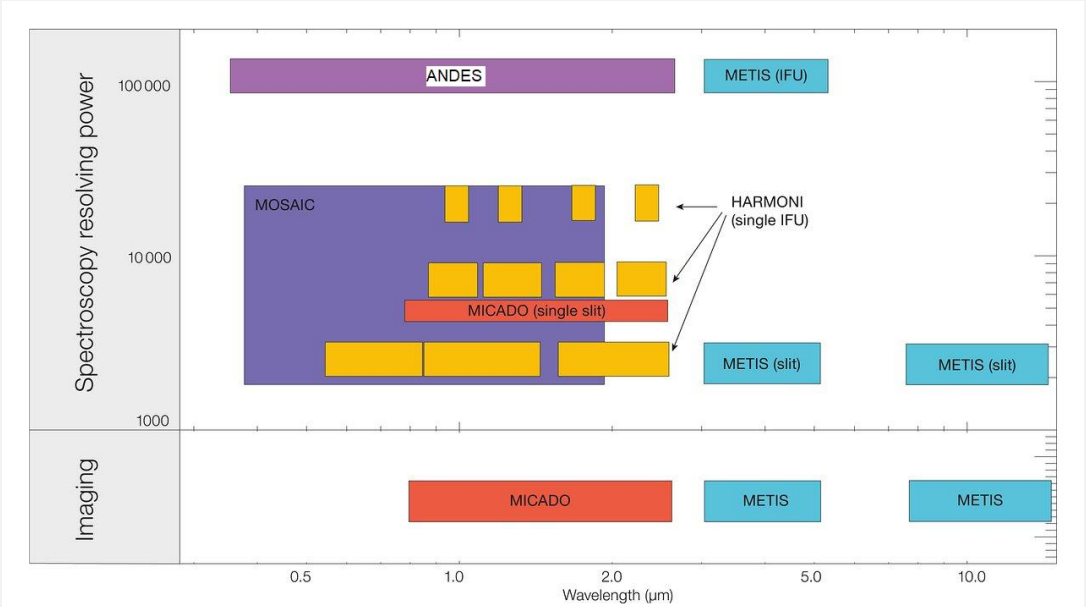
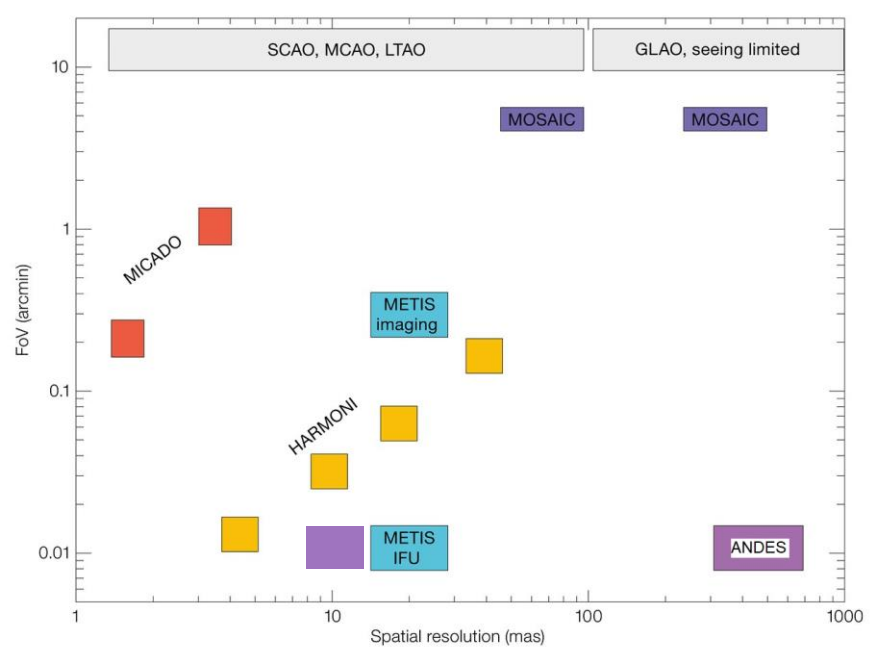
ANDES parameters space

ANDES (ArmazoNes high Dispersion Echelle Spectrograph) is the high-resolution, high-precision, modular, fiber fed, optical-infrared spectrograph for the ESO/ELT (European Southern Observatory/Extremely Large Telescope) thought to study astronomical objects that require highly sensitive observations.



© ESO



© ESO

- Simultaneous spectral range 0.4-1.8 μm (0.37-2.4 μm goal)
- Spectral resolution ~100,000
- Interchangeable, observing modes: seeing limited & SCAO+IFU
- Sensitivity: 1h, 10σ, AB = 21.7

ANDES history

- ESO commissioned two phase-A studies for high-resolution spectrographs, CODEX and SIMPLE, in the framework of “ESO instrumentation roadmap for ELT construction proposal” (successfully completed in 2010)
- HIRES initiative: merging of CODEX and SIMPLE with a preparation of community white paper (2013)
- HIRES Phase A study: started 2016, successfully concluded beginning 2018
- the “waiting-for-approval phase”: new partners (USA and Canada) joined the (existing) consortium, modified baseline design adopted, new organisation of consortium developed, preparation of agreements
- ESO Council approves HIRES Construction (December 2021)
- New name adopted: ANDES (ArmazoNes high Dispersion Echelle Spectrograph)
- Start of the construction phase with SAR (System Architecture Review) as a first milestone

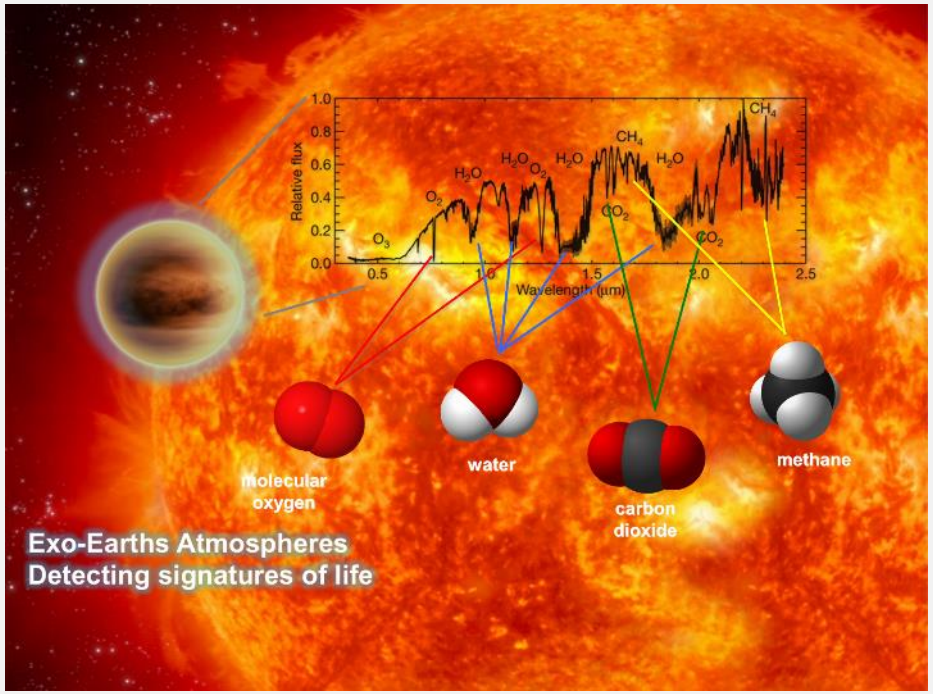
Signature of construction agreement

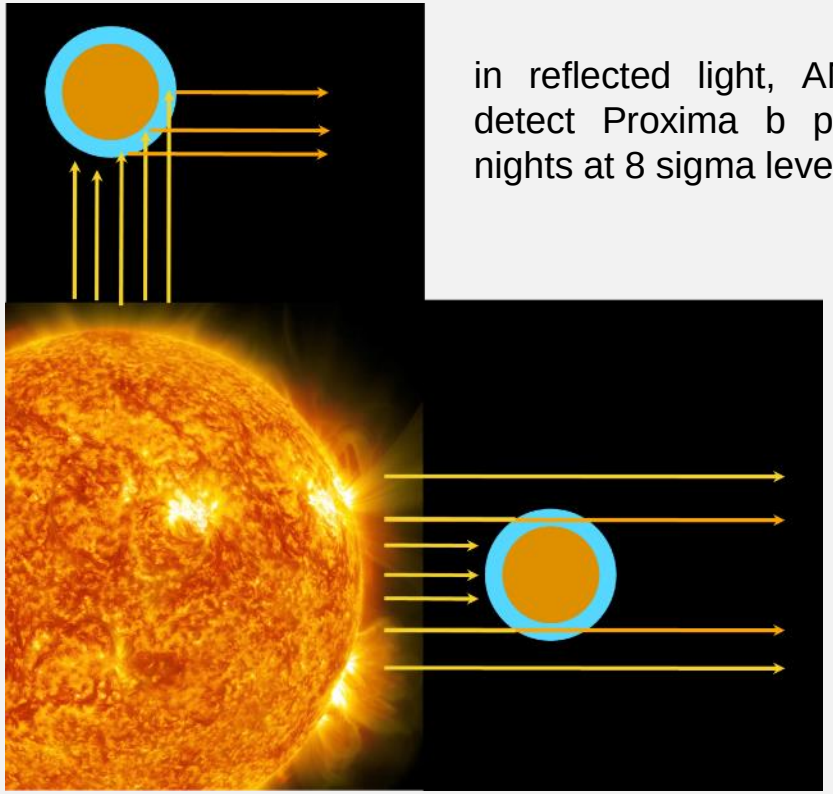
Signing of the ANDES agreement | ESO , 5 June 2024

ANDES key scientific objectives I

Ground-breaking Exoplanet Science with the ANDES spectrograph at the ELT
Palle et al. 2024 https://arxiv.org/abs/2311.17075

- Exoplanets and Circumstellar disks (characterization of exoplanets atmospheres, detection of signatures of life and dynamics, chemistry and physical conditions of disks)





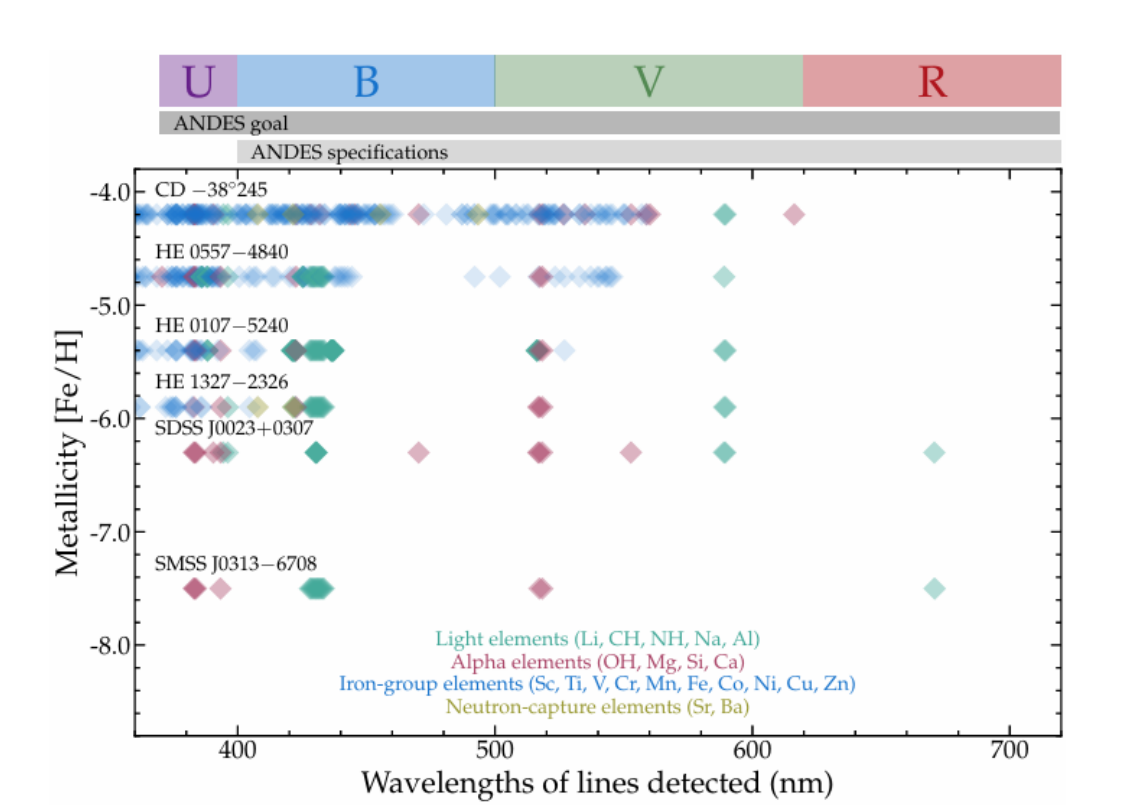
in reflected light, ANDES can detect Proxima b planet in 7 nights at 8 sigma level

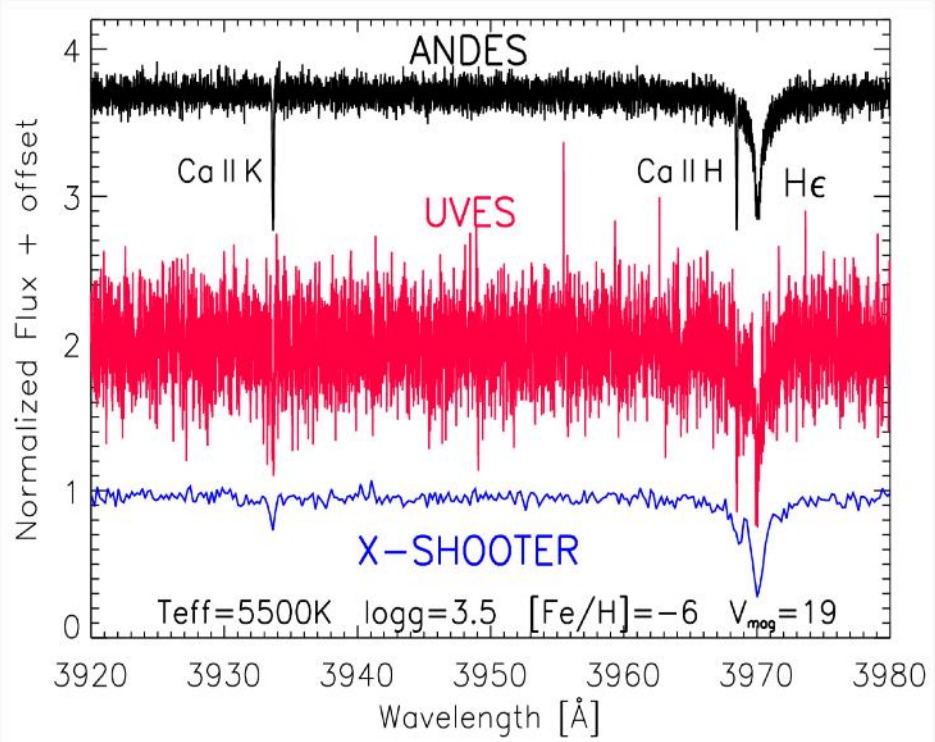
Detect key molecular bands, including those of H_2O, O_2, CO_2, CH_4, NH_3, and other biomarkers

ANDES key scientific objectives II

The discovery space of ELT-ANDES. Stars and stellar populations
Roederer et al. 2024 https://arxiv.org/abs/2311.16320

❖ Stars and Stellar Populations (abundances of solar type and cooler dwarfs in our and nearby galaxies, tracing chemical enrichment of Pop III stars in nearby universe, early chemical enrichment)



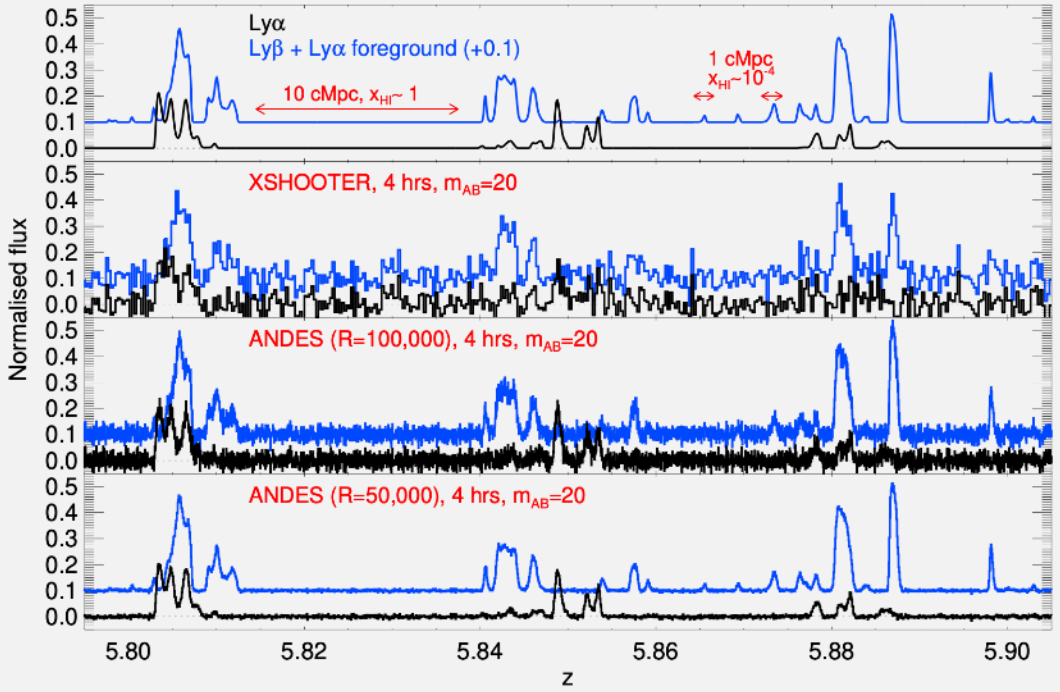


Simulated 1h spectrum of a sub giant second generation star with $Z = 10^{-6}\ Z_{Sun}$

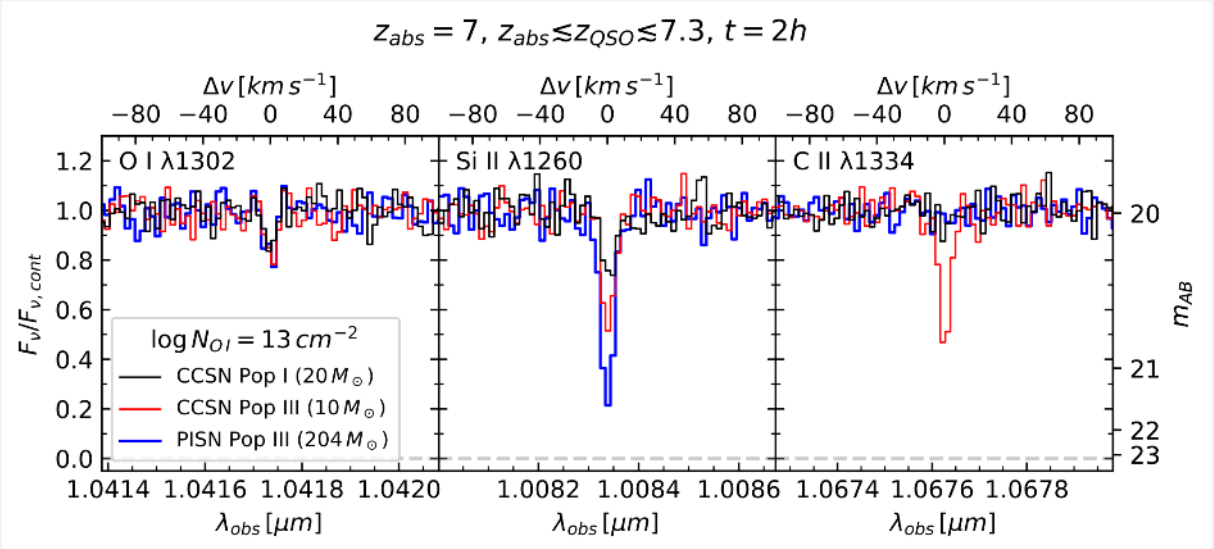
ANDES key scientific objectives III

Galaxy Formation and Symbiotic Evolution with the Inter-Galactic Medium in the Age of ELT-ANDES
D'Odorico et al. 2024 https://arxiv.org/abs/2311.16803

❖ Galaxies (formation and evolution) and Intergalactic Medium (signatures of reionization and early enrichment of IGM observed in high-z quasar spectra, evolution of massive early type galaxies during epochs of formation)



Lyα and Lyβ forests in the spectra of z>6 quasars and GRBs: ANDES will map the distribution of neutral and ionized hydrogen in the IGM, tracking the progress of reionization

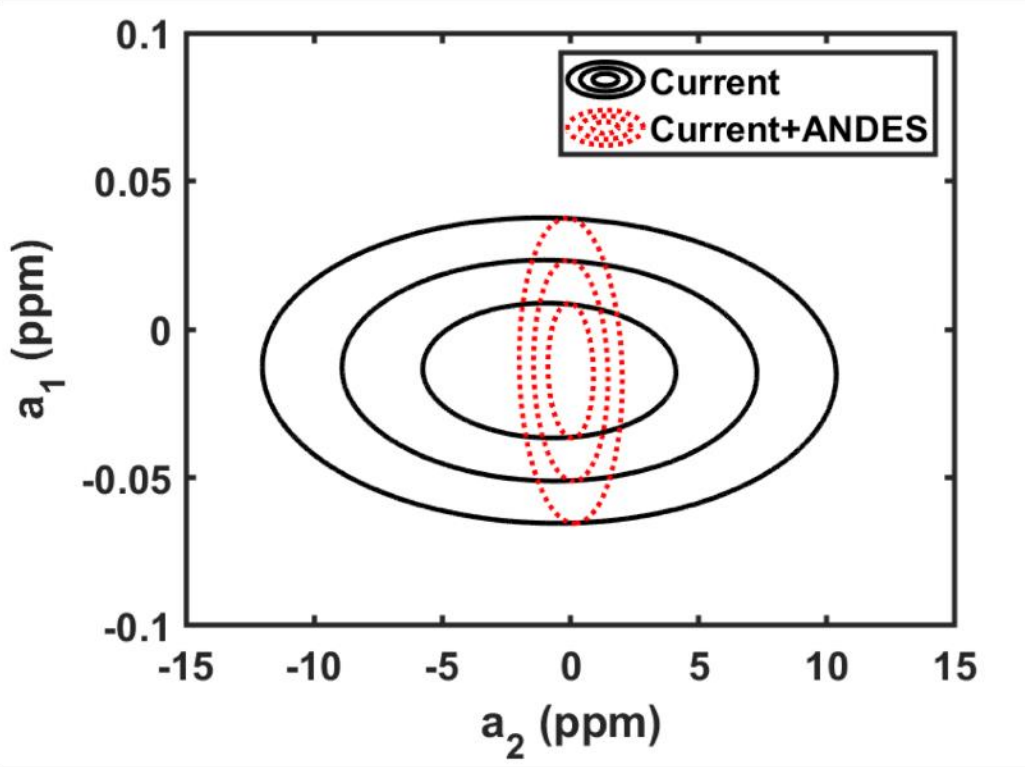


Absorber at z=7.0 with N(OI) = 10^{13} cm-2: ANDES will detect the chemical enrichment of the IGM due to Pop III supernovae (maybe the only way to clearly detect Pop III stars)

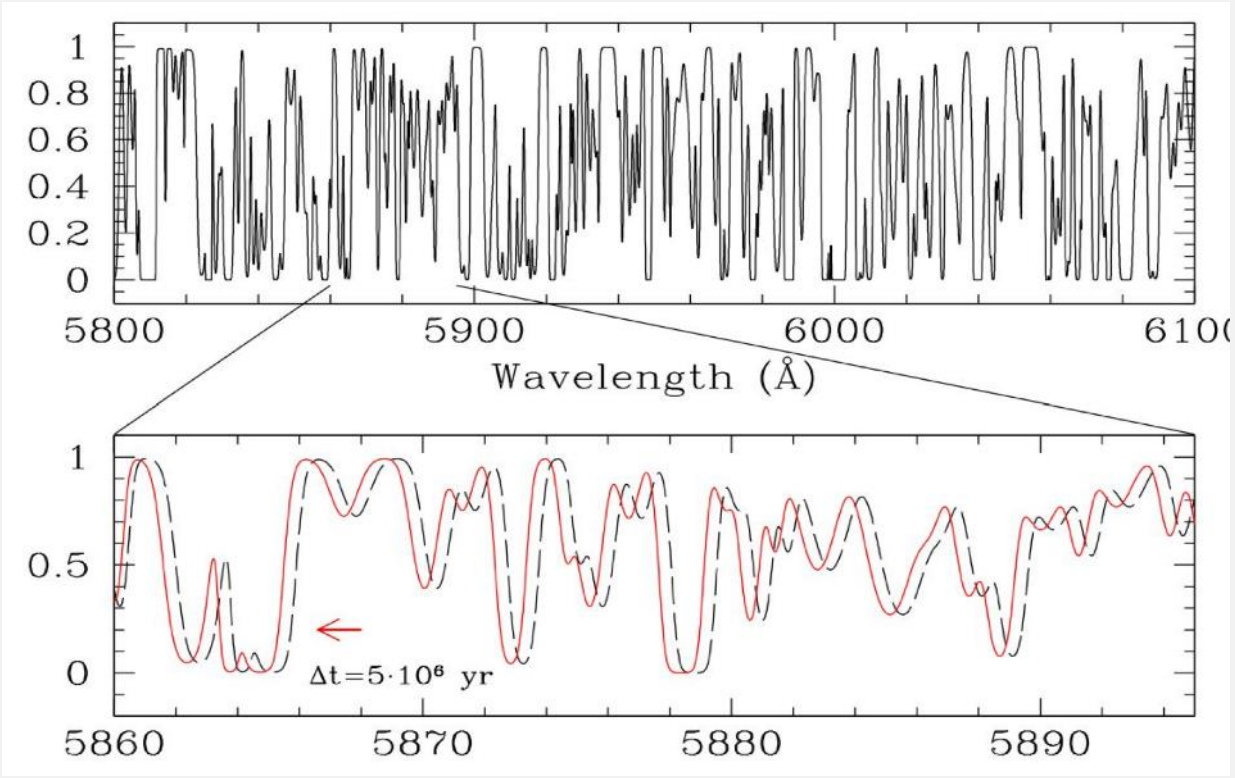
ANDES key scientific objectives IV

Cosmology and fundamental physics with the ELT-ANDES spectrograph
Martins et al. 2024 https://arxiv.org/abs/2311.16274

- Cosmology and Fundamental Physics (variation of fundamental constants, Sandage Test)



Constraints on the redshift variation of the fine structure constant with ANDES



Redshift drift: measurement of dz/dt of a source due to acceleration/deceleration of universe expansion: model independent!

ANDES Science Prioritization

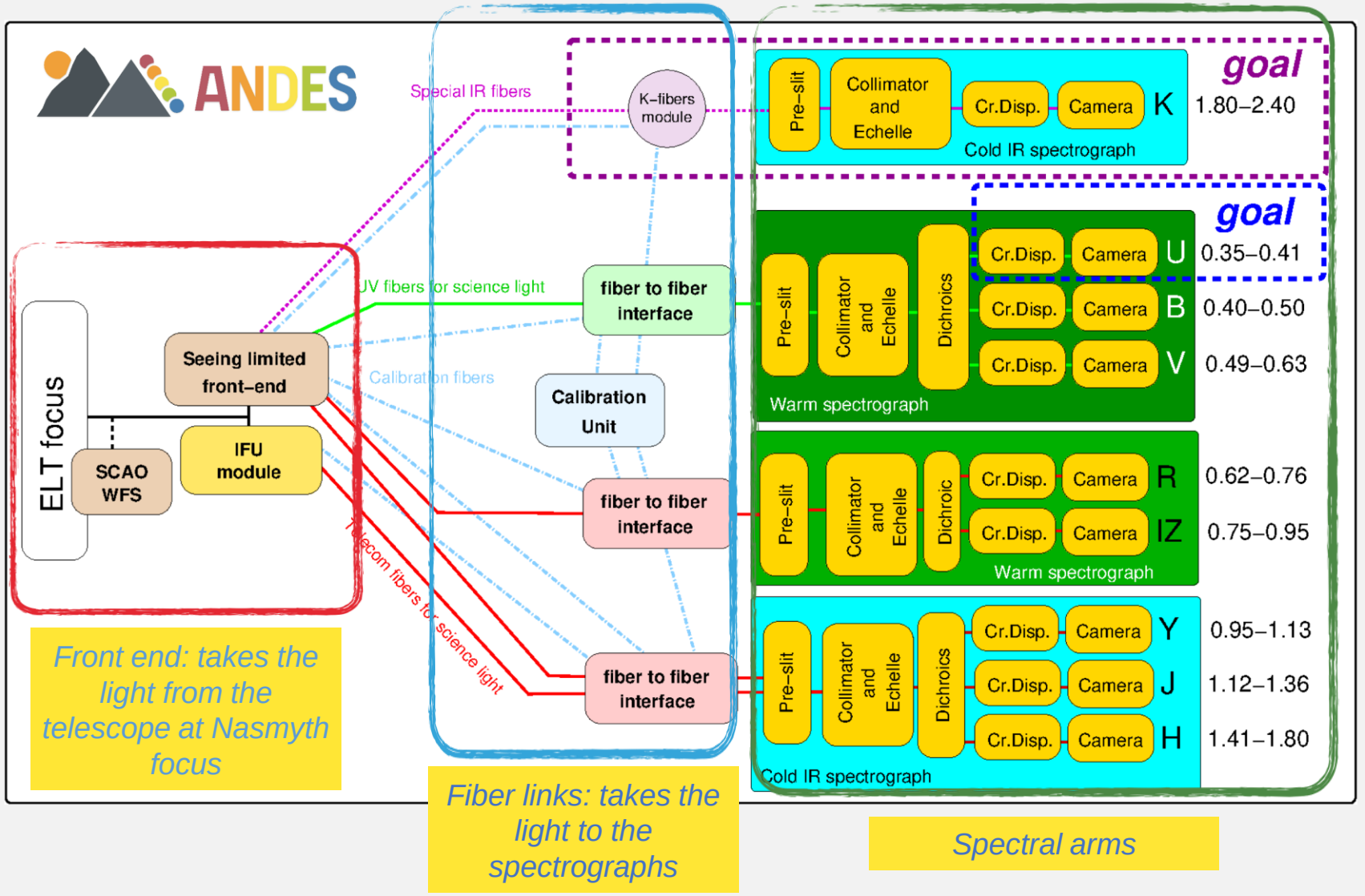
- Priority 1: Exoplanet atmospheres via transmission spectroscopy (potential detection of bio-signatures)
  - TLR 1: R > 100,000, 0.5-1.8 μm; drive the ANDES baseline design
    - Enables: reionization of Universe; characterization of Cool stars
    - Doable: detection and investigation of [illegible] of the CGM; Extragalactic transi[illegible]
- Priority 2
  - TLR 2:
  - Enables [illegible] abundance; investiga[illegible]
- Priority 3: [illegible] signatures)
  - TLR 3: S[illegible]
    - Enable[illegible] eres; Search of low [illegible]
    - Doable[illegible] protostary disks
- Priority 4: R[illegible]
  - TLR 4: λ accuracy 2 cm/s, stability 2 cm/s
    - Enables: Mass determination of exoplanets (Earth-like objects)
    - Doable: Radial velocity search for exoplanets around M-dwarf stars

THIS IS NOT A PRIORITISATION OF SCIENCE CASES, IT IS A PRIORITISATION TO DRIVE THE BASELINE DESIGN

THE DERIVED TECH SPECS ALLOW ADDRESSING MANY SCIENCE CASES

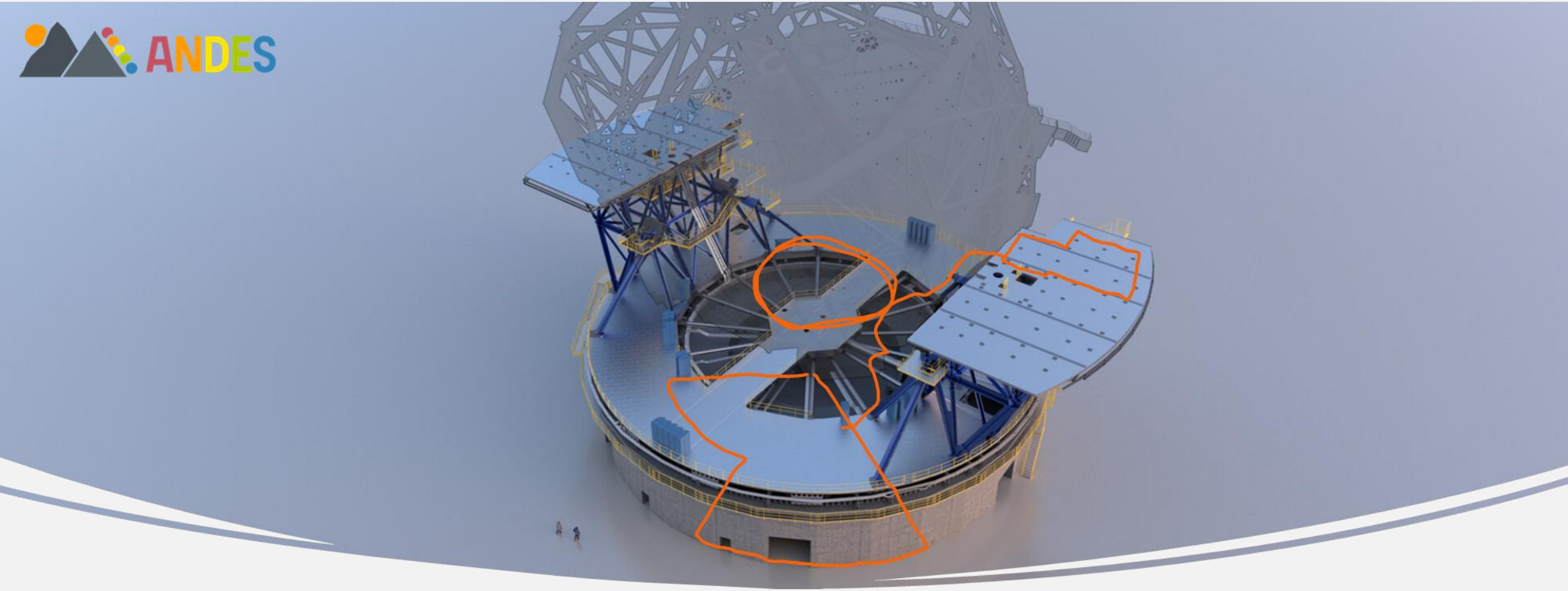
CHECK THE WHITE PAPERS!

Instrument architecture

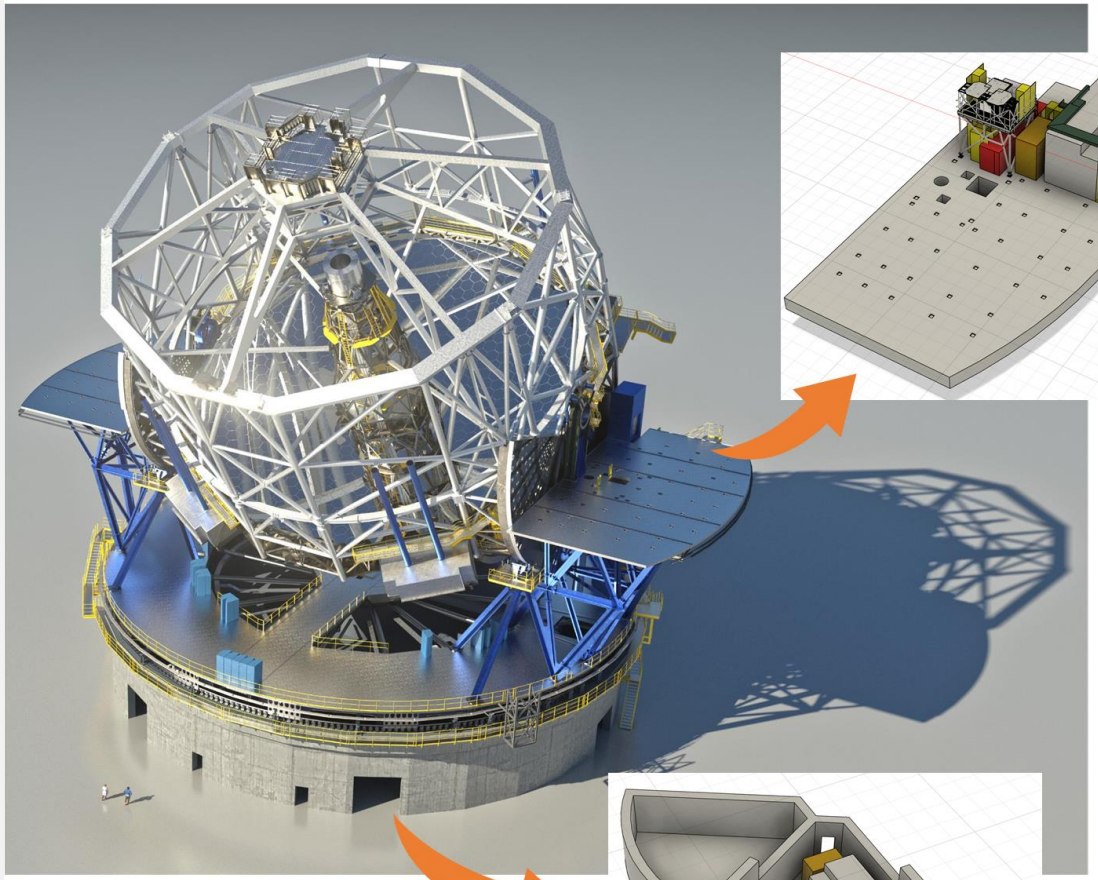


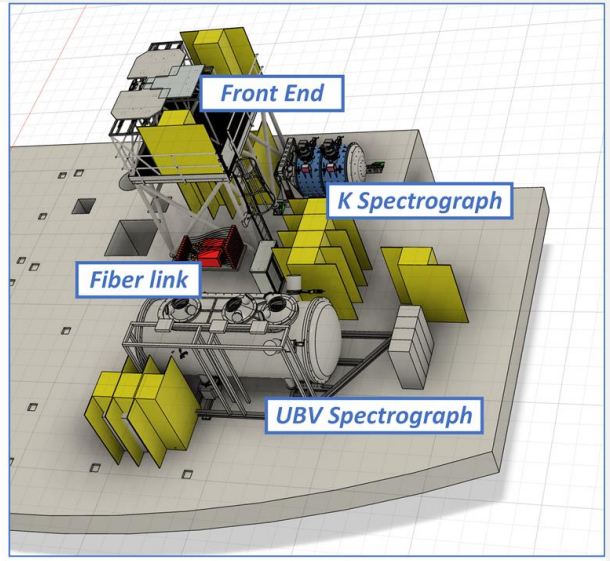
- Modular fiber-fed cross dispersed echelle spectrograph
- Simultaneous range 0.4-1.8 µm (ultra-stable BV+RIZ+YJH) Goal 0.37-2.4 µm (with U and K); Resolution ~100,000
- Several interchangeable, observing modes: Seeing limited & SCAO+IFU

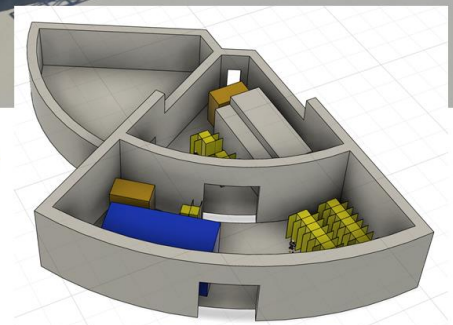
ANDES: deployment - concept

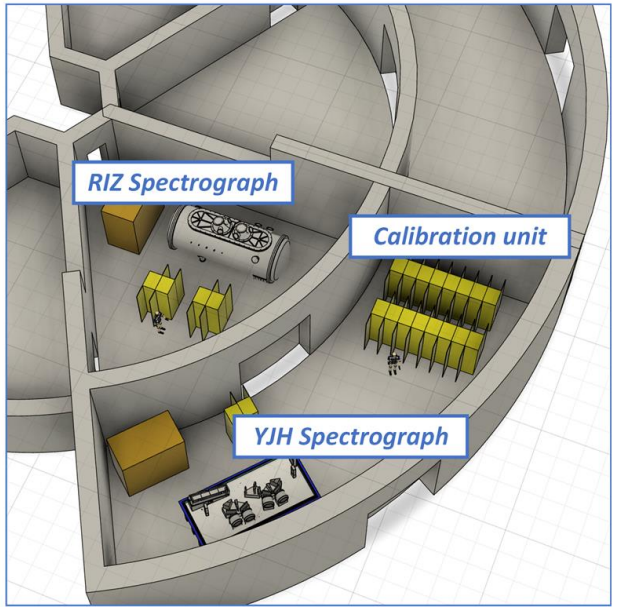


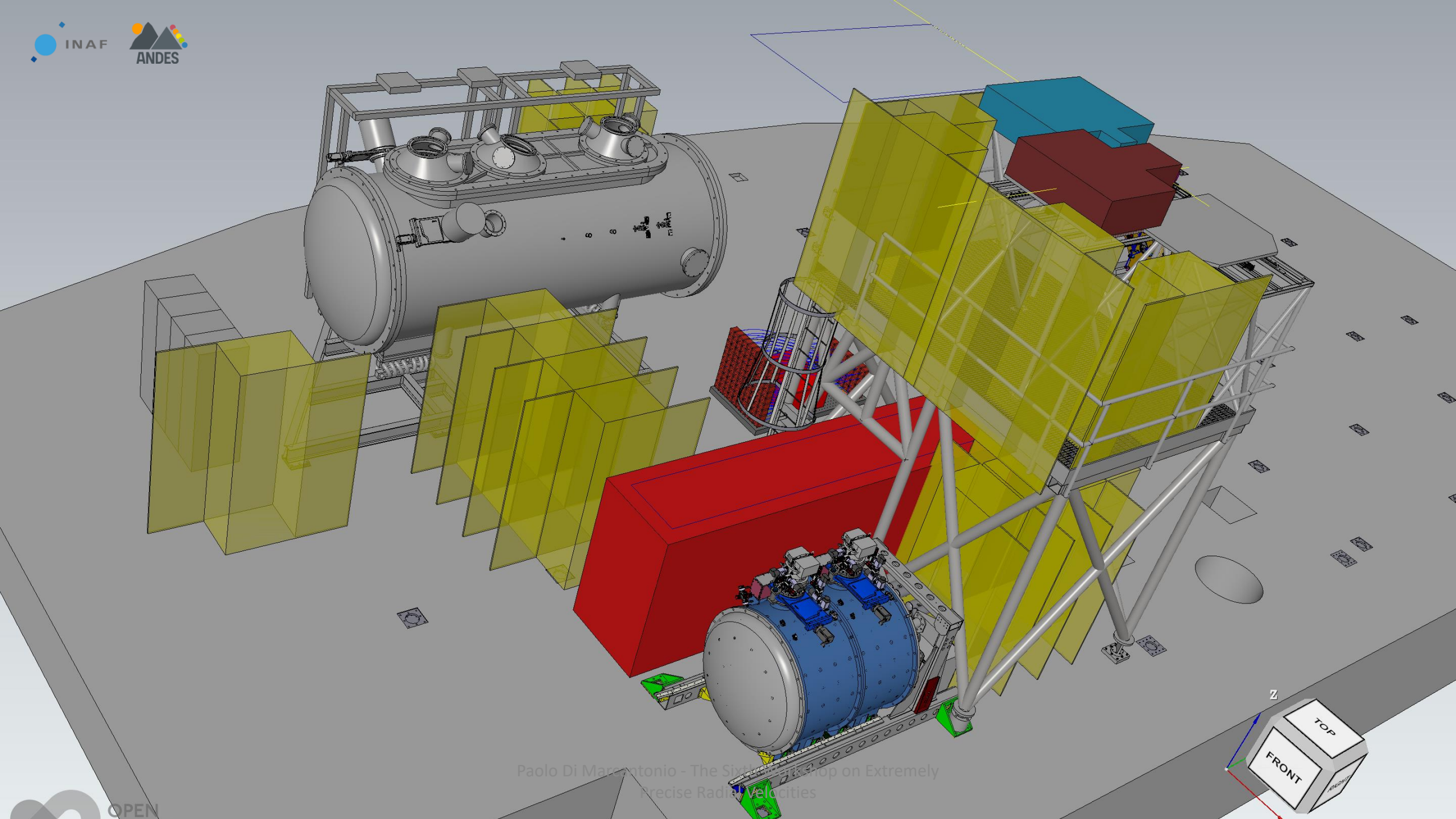
ANDES: deployment - preliminary design

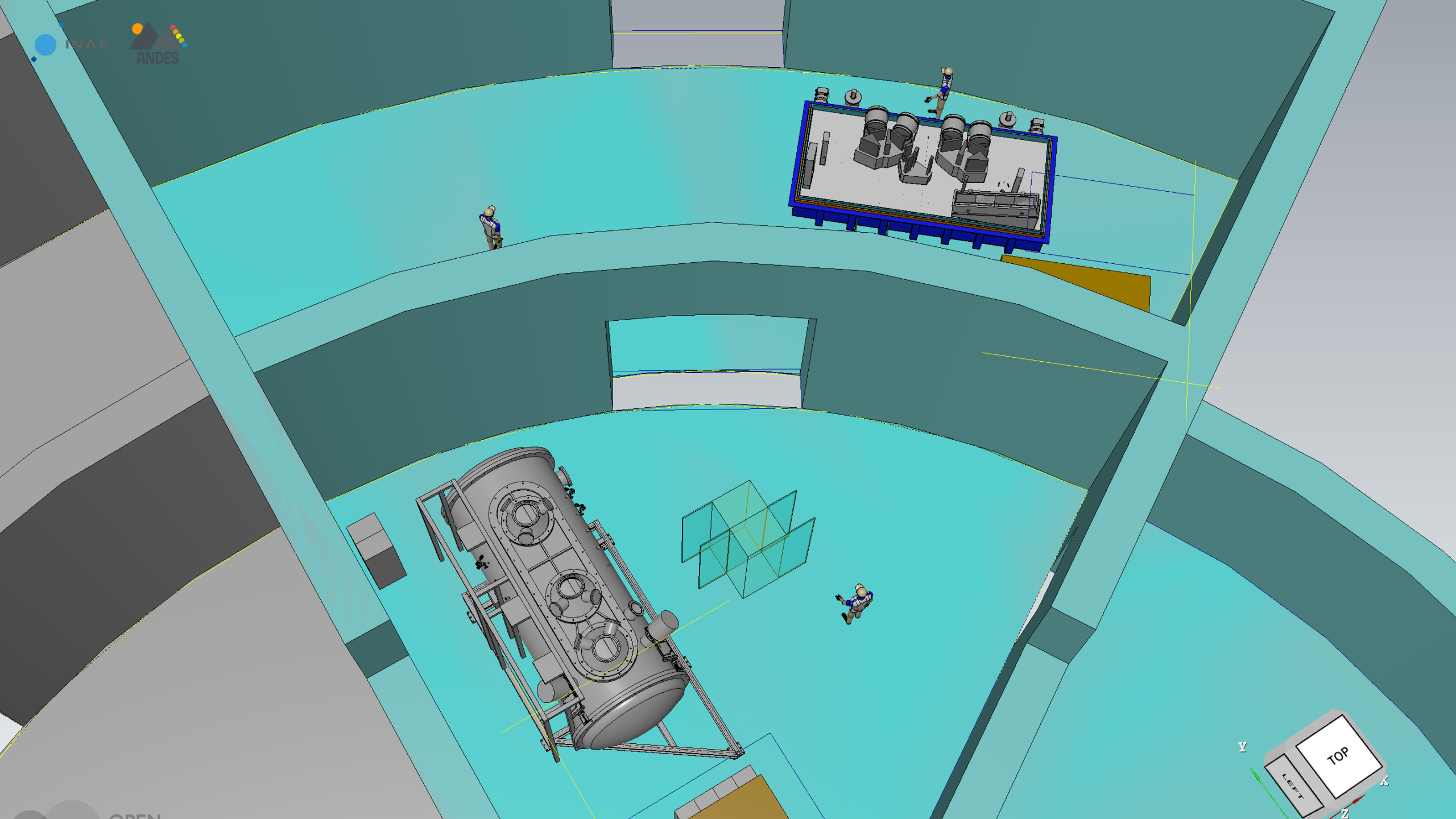








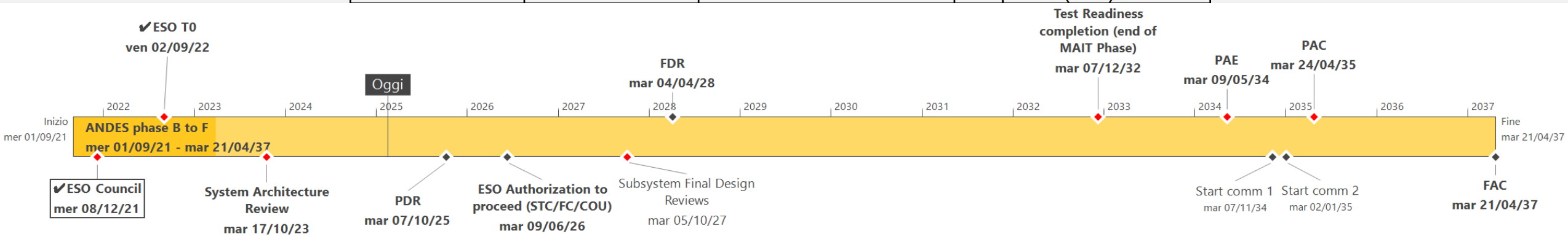



INAF
ANDES
TOP
LEFT
Y
X
Z

ANDES Schedule

We're at an early phase

Project timeline			
Project phases	**Milestones**	**Duration**	**Name**
Phase B	KM.1	T0	Kick-off (KO)
	KM.2	T0 + 9 months	System architecture completion (SAR)
	KM.3	T0 + 22 months	Preliminary design completion (PDR)
		T0 + 26 months	Funding review (FR)
Phase C	KM.4	T0 + 48 months	Final design completion (FDR)
Phase D	KM.5	T0 + 80 months	Integration readiness completion (IRR)
	KM.6	T0 + 88 months	Test readiness completion (TRR)
	KM.7	T0 + 108 months	Preliminary acceptance Europe completion (PAE)
Phase E	KM.8	T0 + 120 months	Provisional acceptance Chile completion (PAC)
Phase F	KM.9	PAC + 2 years	Final acceptance completion (FAC)

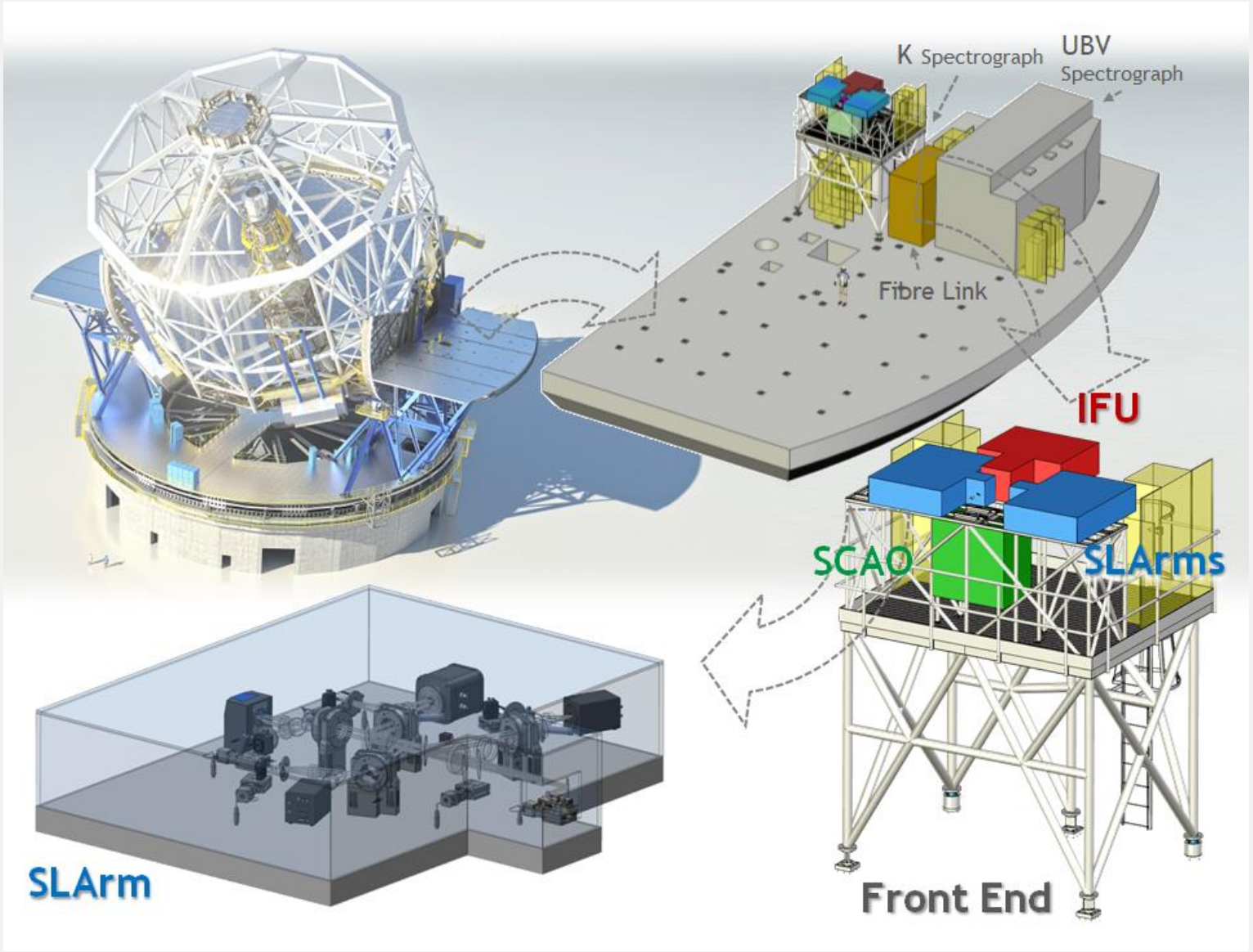


Front End

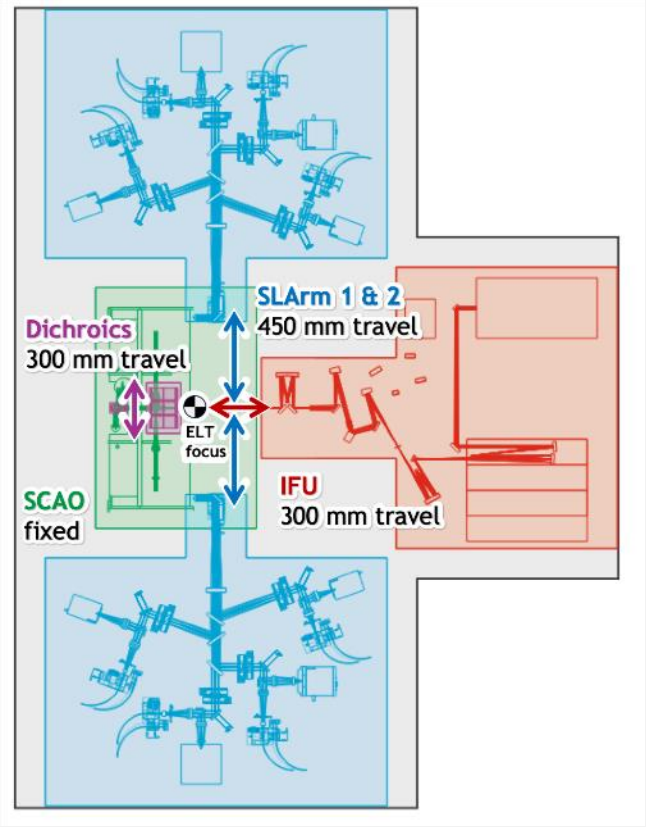
Credits:
- Instituto of Astrofísica e Ciências do Espaço (Porto)
- Centro de Investigação em Astronomia/Astrofísica da Universidade do Porto (CAUP)
- Instituto of Astrofísica e Ciências do Espaço at Faculdade de Ciências da Universidade de Lisboa

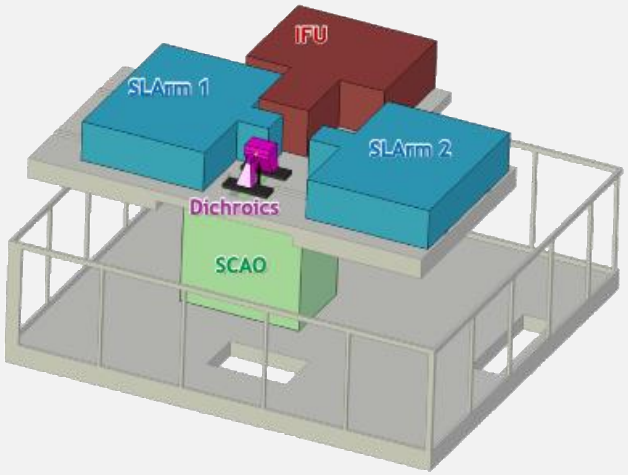
The key functions of the FE are:

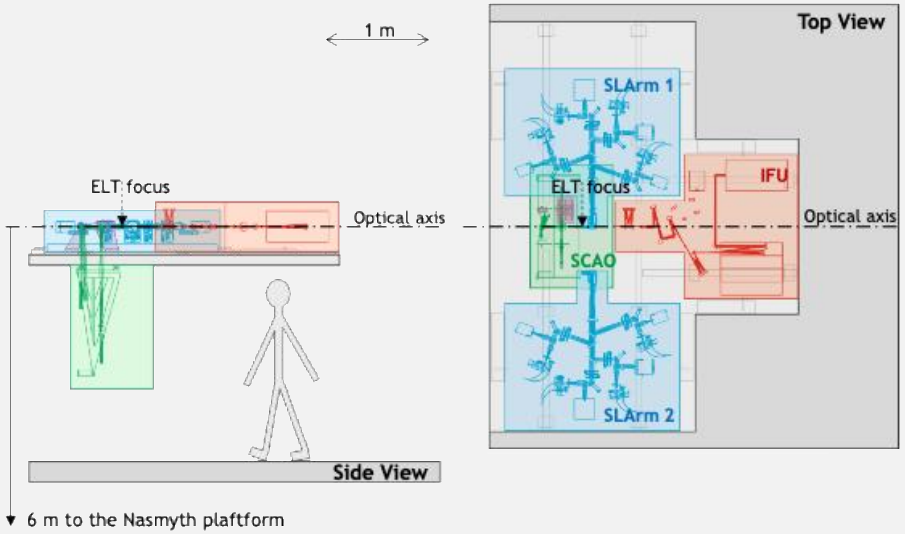
- Support all the FE sub-units and related sub-systems (IFU/SCAO) at the Nasmyth focus
- Provide selection of dedicated observing mode, SLArms, or IFU/SCAO
- Manage fibre bundles and cable distribution

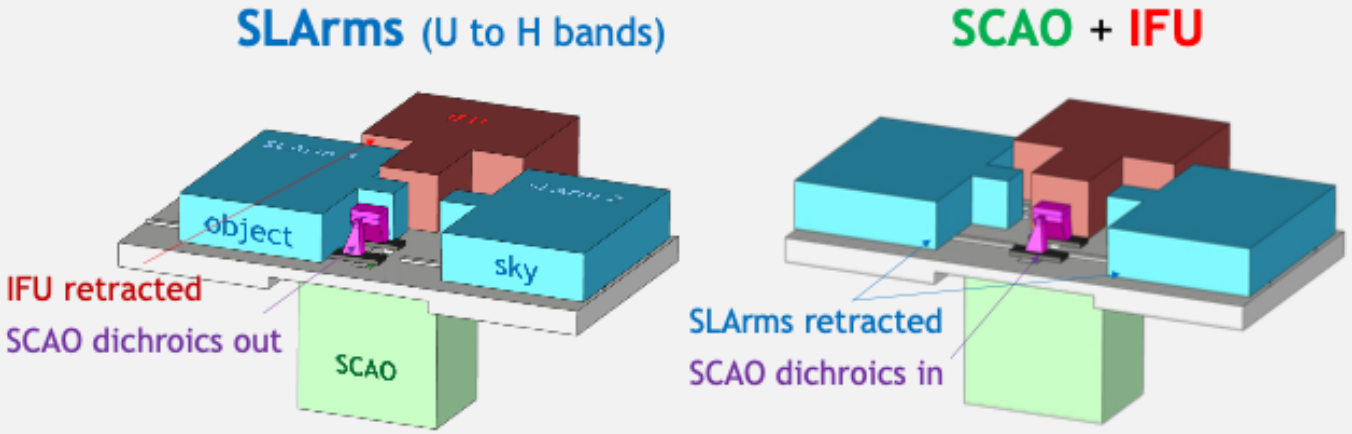


Front End

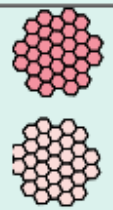
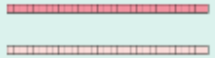

SLArm 1 & 2
450 mm travel
Dichroics
300 mm travel
ELT
focus
SCAO
fixed
IFU
300 mm travel

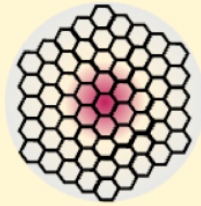
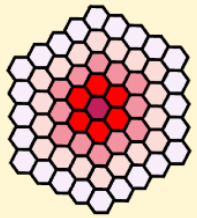
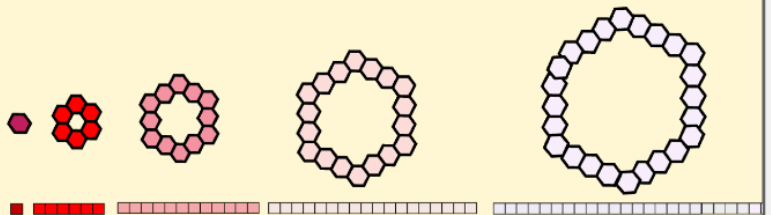

IFU
SLArm 1
SLArm 2
Dichroics
SCAO


1 m
ELT focus
Optical axis
Side View
6 m to the Nasmyth plaftform
Top View
SLArm 1
ELT focus
IFU
Optical axis
SCAO
SLArm 2

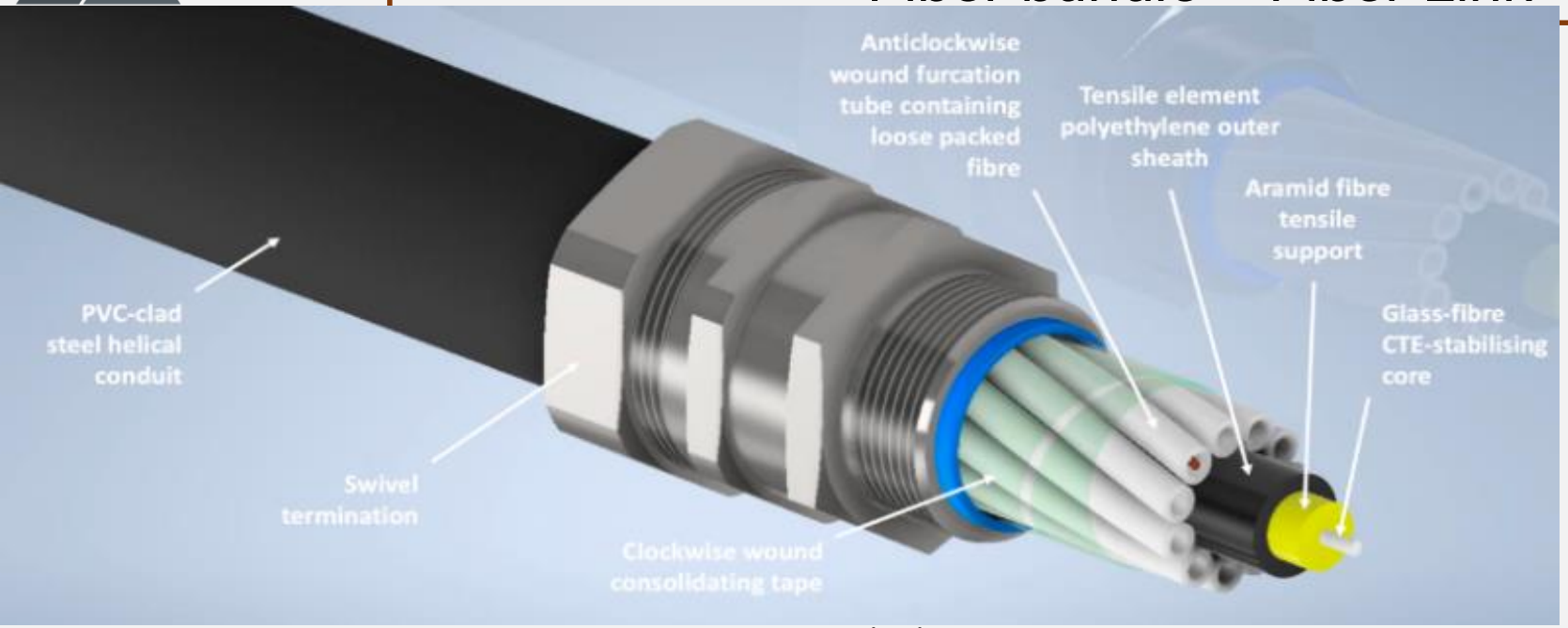

SLArms (U to H bands)
SCAO + IFU
object
sky
IFU retracted
SCAO dichroics out
SCAO
SLArms retracted
SCAO dichroics in

Observing modes

observing mode	FE	FL	along the spectrograph slit
SL_UNI [U]BV+RIZ+YJH two identical apertures simultaneously illuminated by target and sky, or target and wavelength calibration. If needed, beam-switching of the two apertures can be performed.	input light on two, individual large fibres	2 bundles of small fibres, uniformly illuminated after scrambler & slicer to maximize spectral fidelity	2 segments of uniformly illuminated fibres
SL_UNI_TS Target + Sky			
SL_UNI_TC Target + Wavelength Calibration			

Observing mode	FE	FL	along the spectrograph slit
IFU_SCAO YJH IFU of maximum 61 spaxels. 4 spaxel scales in the 5-100 mas range are foreseen. Off-axis guiding out to 3 arcsec is also possible.	input PSF on microlenses array and fibre bundle. 	fibre bundle after fiber2fiber couplers. 	4 segments (S1, S2, S3, S4), one per each hexagonal annulus around the central spaxel, + the central spaxel (S). 

Fiber bundle – Fiber Link



Contact point:
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FIBRE DISTRIBUTION IN THE CABLE WARP			
furcation tube ED		5	mm
furcation tube ID		3,1	mm
cable size		30	mm
# of tubes		16	
tube area		7,5	mm^2
occupable	60%	4,5	mm^2

CABLE#1

				Size (mm)								
		Type	**Qty**	**Core**	**Cladding**	**Buffer**	**Jacket**	**Fiber area (mm^2)**	**Max in a tube**	**# fibers/tube**	**# tubes**	**Min bend radius (mm)**
RIZ	SL-UNI	Ceramoptec WFNS	2	0,612	0,673	1,224	1,836	2,6	1	1	2	86
YJH	SL-UNI	Polymicro ULOH	2	0,462	0,508	0,924	1,386	1,5	3	2	1	65
RIZ	FE-SL-CAL	Ceramoptec WFNS	2	0,800	0,880	1,600	2,400	4,5	1	1	2	112
YJH	FE-SL-CAL	Polymicro ULOH	2	0,800	0,880	1,600	2,400	4,5	1	1	2	112
YJH	FE-IFU-CAL	Polymicro ULOH	1	0,800	0,880	1,600	2,400	4,5	1	1	1	112
UBV	FE-CAL	Ceramoptec WFNS	2	0,800	0,880	1,600	2,400	4,5	1	1	2	112
UBV	SIM-CAL	Ceramoptec WFNS	1	0,500	0,550	1,000	1,500	1,8	2	1	1	70
									TOTAL		**11**	
									SPARES		5	

CABLE#2

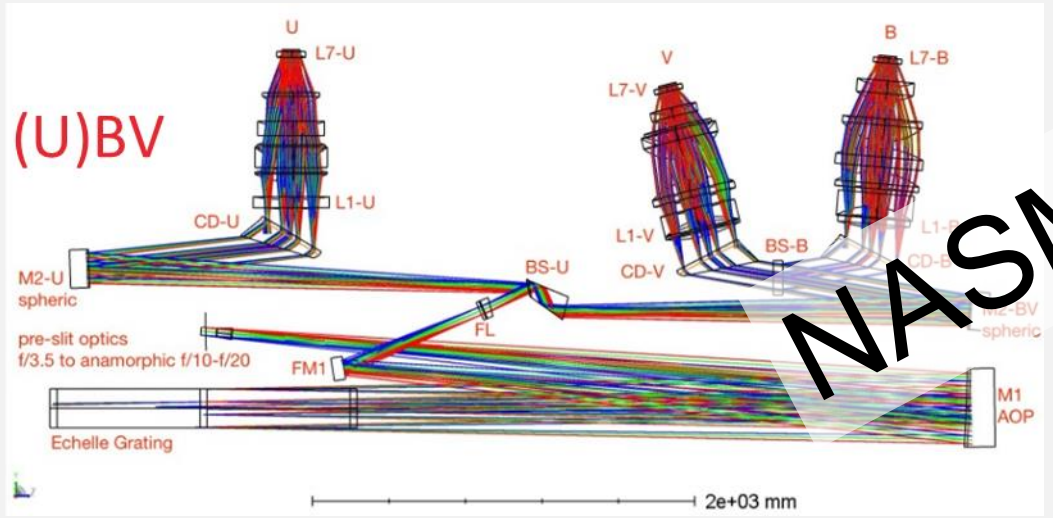
		Type	**Qty**	**Core**	**Cladding**	**Buffer**	**Jacket**	**Fiber area (mm^2)**	**Max in a tube**	**# fibers/tube**	**# tubes**	**Min bend radius (mm)**
YJH	IFU-AO	Polymicro ULOH	37	0,083	0,091	0,166	0,249	0,05	92	37	1	12
RIZ	SL-PSF	Ceramoptec WFNS	38	0,177	0,195	0,354	0,531	0,22	20	19	2	25
YJH	SL-PSF	Polymicro ULOH	38	0,150	0,165	0,300	0,450	0,16	28	19	2	21
									TOTAL		**5**	
									SPARES		11	

Fiber bundle - location

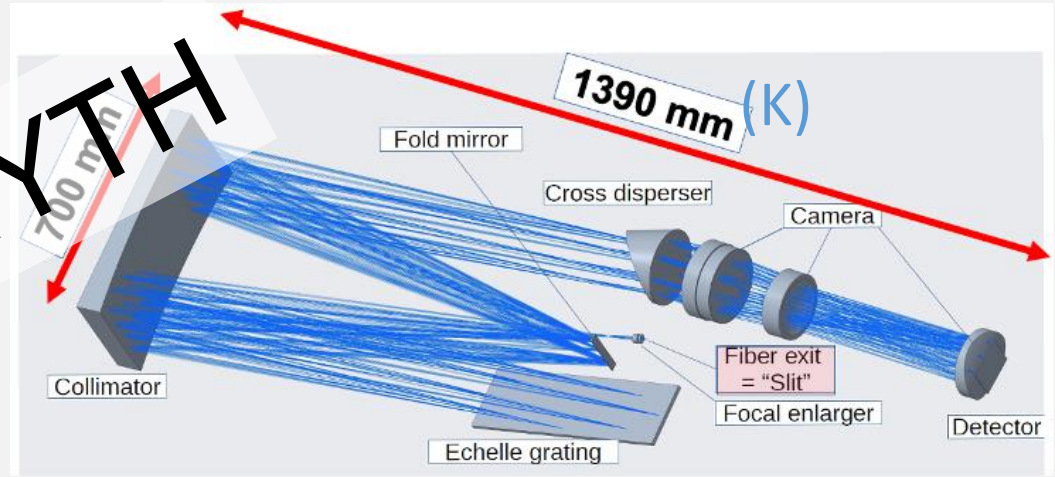
The total path-length from Nasmyth to Coudè rooms is 150 meters

This drone image from October 2023, taken on the summit of Cerro Armazones, where ESO's Extremely Large Telescope (ELT) is under construction, almost looks like a second, miniature ELT dome is being constructed. This device is an azimuth cable wrap, ensuring that the extensive network of cables helping to operate the telescope moves smoothly when the telescope rotates horizontally. This cable wrap has already been installed on top of the telescope pier.

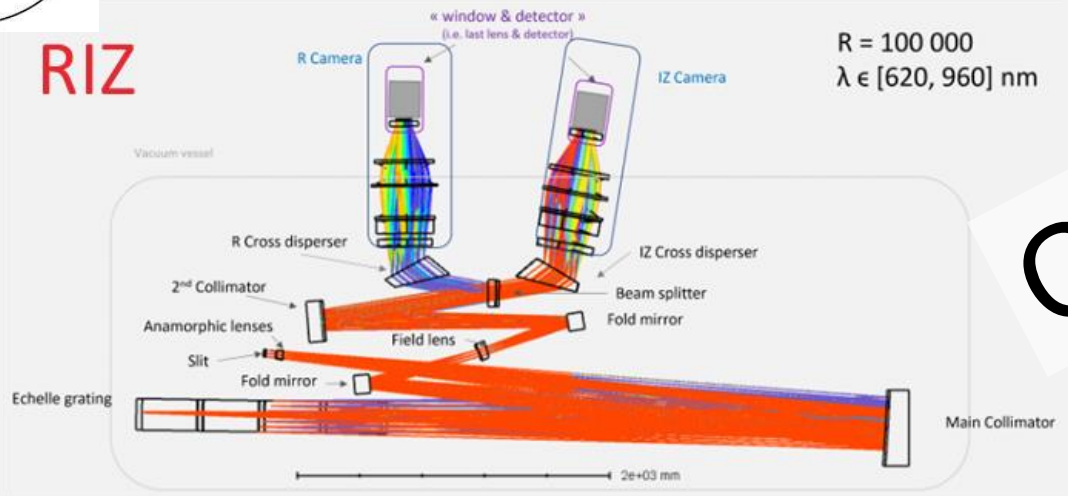
Spectrographs



NASMYTH

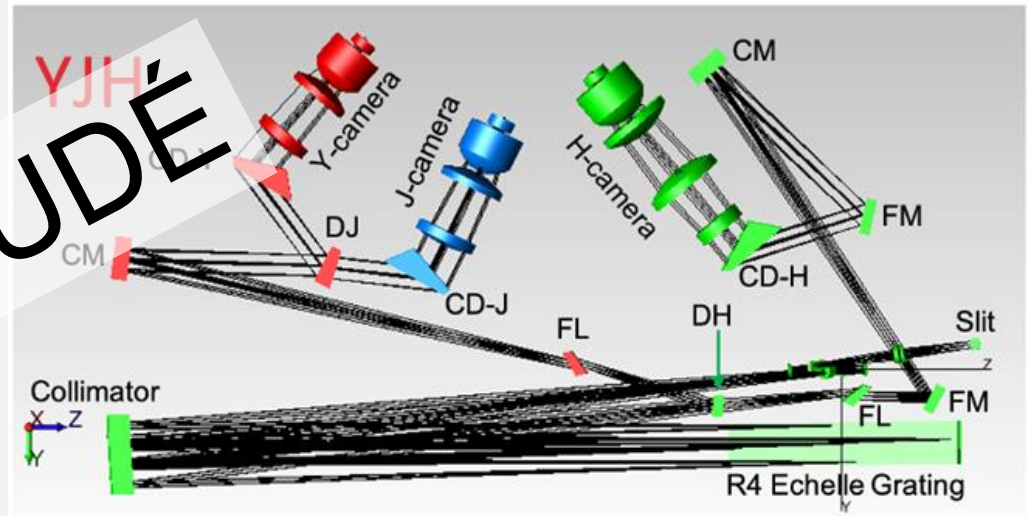


RIZ



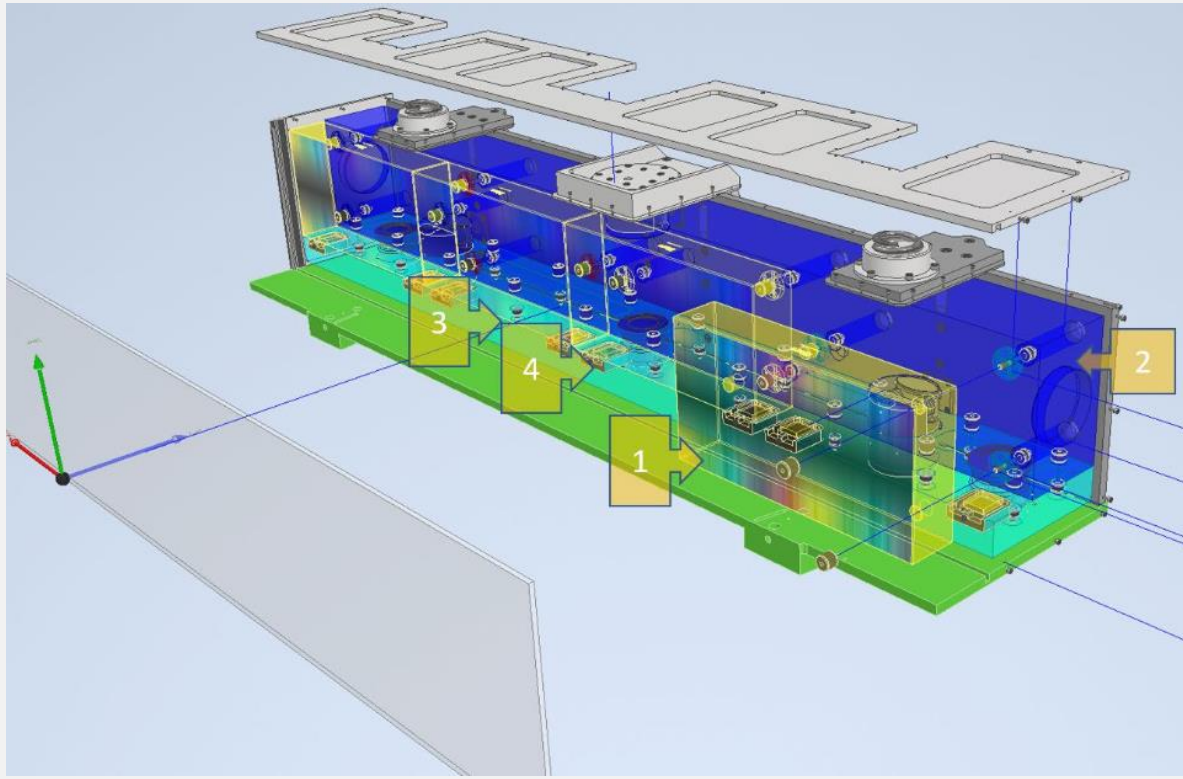
R = 100 000
λ ϵ [620, 960] nm

COUDÉ



Echelle gratings - VIS

In order to satisfy the requirements of a resolution of 100,000 and a light collecting area of ca. 1 square arcsec on the sky, a beam size of 400mm was chosen for the design of the Echelle spectrographs, which corresponds to a length of 1.6m for a R4 grating.
As the biggest astrophysical echelle grating in use is about 400mm long, a mosaic design of 4 gratings was adopted.



The only supplier is Newport Richardson grating lab.
There is a matching grating master available (425E, 41.59 l/mm, 76°, 204 x 410 mm) - Zerodur

Contact point:
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jweingrill@aip.de
obellido@aip.de

Echelle gratings - NIR

Description	Requirement	Notes
Environmental	Temperature 100 K, 20 C Pressure vacuum, 1 ATM	
Wavelength range	900 nm – 1800 nm 633 nm for testing	Y, J, and H bands Laser interferometer tests
Diffraction orders	68 – 127	192 – 194 for testing
Groove frequency	16 lines per mm	Tolerance to be discussed
Groove pitch	62.5 µm	Tolerance to be discussed
Random pitch error	< 5 nm	
Angle of incidence = groove blaze angle	76 degrees	0.9 degrees off Littrow
Peak efficiency	> 70 %	Apex angle to be optimised
Coating	Gold	
Substrate material	Low CTE e.g. Zerodur	
Dimensions Along grooves Across grooves	0.21 m 1.25 m	Size of mosaic parts to be discussed
Wavefront error	PV<120 nm, RMS<30 nm	

Contact point:
james.stevenson@stfc.ac.uk
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K: Canon, incl Au coating; estimate of in-order center-edge variation about ±5% (from RGL 53-*-182E grating (13l/mm) data) - Invar

Detectors

Science Focal Plane Detectors

for US & RS see E-AND-RU-TNO-00-00-001_RS_US_Detector_Selection_Trade-off at https://owncloud.ia2.inaf.it/index.php/f/172221680

U, B, V: 3x e2v CCD290-99-0-F82, 9k x 9k, 10 µm pixel, CH (Geneva)

R, IZ: 2x e2v CCD290-99-0-F24, 9k x 9k, 10 µm pixel, CH (Geneva)

Y, J, H: 3x H4RG, 4k x 4k, 15 µm pixel, CAN (Montreal)

K: 1x H4RG, 4k x 4k, 15 µm pixel (goal), D (MPIA)

SCAO

see E-AND-AO-DER-08-00-004_AOControlElectronicsDesignAndAnalysisReport at https://confluence-andes.atlassian.net/wiki/spaces/SE/pages/799310017/List+of+detectors#SCAO

SCAO WFS Camera: Andor OCAM2K hosting a CCD220

240 x 240 pix

CTE four9s5 (2.5% lost over 500 transfers)

QE 95% @ 650nm

SCAO Gain Camera: Andor Zyla 4.2

2048 x 2048 pix; 6.5 µm x 6.5 µm

well depth ~30,000

QE ~82%

SCAO Acquisition Camera: G1-2024 Allied Vision

FoV: 10" diam

SCAO Phasing sensor: C-RED2

640 x 512 pix; 15 µm x 15 µm InGaAs

900 - 1700 nm

QE ~70%

IFU viewer technical camera:

see E-AND-FL-DER-04-00-001_FLOpticalDesignAndAnalysisReport at https://owncloud.ia2.inaf.it/index.php/f/172173063

Teledyne NIRvana 640 (2D InGaAs FPA)

FoV = 4"x6" on 640 x 512; 20 µm x 20 µm pix

1" ⇒ ~100pix?? - note: yes, the scale on the IFU detector is 10 mas/pix, therefore its total FoV is > 6", sufficient to perform off axis observations on all the requested range (+/- 3")1" ⇒ ~100pix??

Spectral range: 900 - 1700 nm

QE~80%

FE SL arm guiding cameras

see E-AND-FE-DER-08-00-005_FE_Technical_Detectors at https://owncloud.ia2.inaf.it/index.php/f/171940120

Alignment & Viewer: Allied vision Alvium G1-234 (Sony IMX249 CMOS)

AIT and possible maintenance

Alvium configurator

1936 (H) × 1216 (V); 5.86 µm x 5.86 µm pix

300 to 1100 nm

40fps

well depth ~33000e-

FoV: 8.6 arcsec diameter (with a pupil mask)

Interface: GigE

UBV and RIZ guiding: Teledyne KURO 1200B (Back illuminated sCMOS)

https://www.teledynevisionsolutions.com/products/kuro/?model=KURO-1200B&vertical=tvs-princeton-instruments&segment=tvs

1200 (H) × 1200 (V); 11 µm x 11 µm pix

82fps / 12 bit, 41 fps / 16 bit

QE 40-90%

well depth ~80000e-

FoV: 6 arcsec diameter (defined/limited by guiding optical system)

Interface: USB

YJH guiding: NIRvana 640 (2D InGaAs FPA)

NIRvana 640 | Teledyne Vision Solutions

640 (H) x 512 (V); 20 µm x 20 µm pix

Spectral range: 900 - 1700 nm

110fps @ 10MHz

QE~80%

well depth ~45000e-

FoV: 6 arcsec diameter (defined/limited by guiding optical system)

Interface: GigE

K: Photon ZephIR 2.5 (MCT FPA)

ZephIR 2.5, SWIR, 850-2500 nm, infrared camera

320 (H) × 256 (V); 30 µm x 30 µm

Spectral range: 850 - 2500 nm

340 fps

QE ~80%

well depth ~160000e-

FoV: 6 arcsec diameter (defined/limited by guiding optical system)

Interface: USB


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