WEAVE: The next-generation wide field spectroscopy facility for the WHT

Gavin Dalton (RALSpace & Oxford)

La Palma 2/3/15

Project to-date:

2010: Community push for new spectroscopic capabilities matched to Gaia and LOFAR surveys

Phase A study KO at SPIE in 2010 ☺

Preliminary Design Phase, 9/2011-3/2012 ☺

Data Flow PDR 12/6/2014 ☺

Optics FDRs 7/2013 (Prime), 1/2014(Spectrograph) ☺

POS FDR 1/15 ☺

SPE FDR 3/15

Data Flow FDR 4/15

Now approaching end of Final Design Phase

The WEAVE Design Reference Surveys

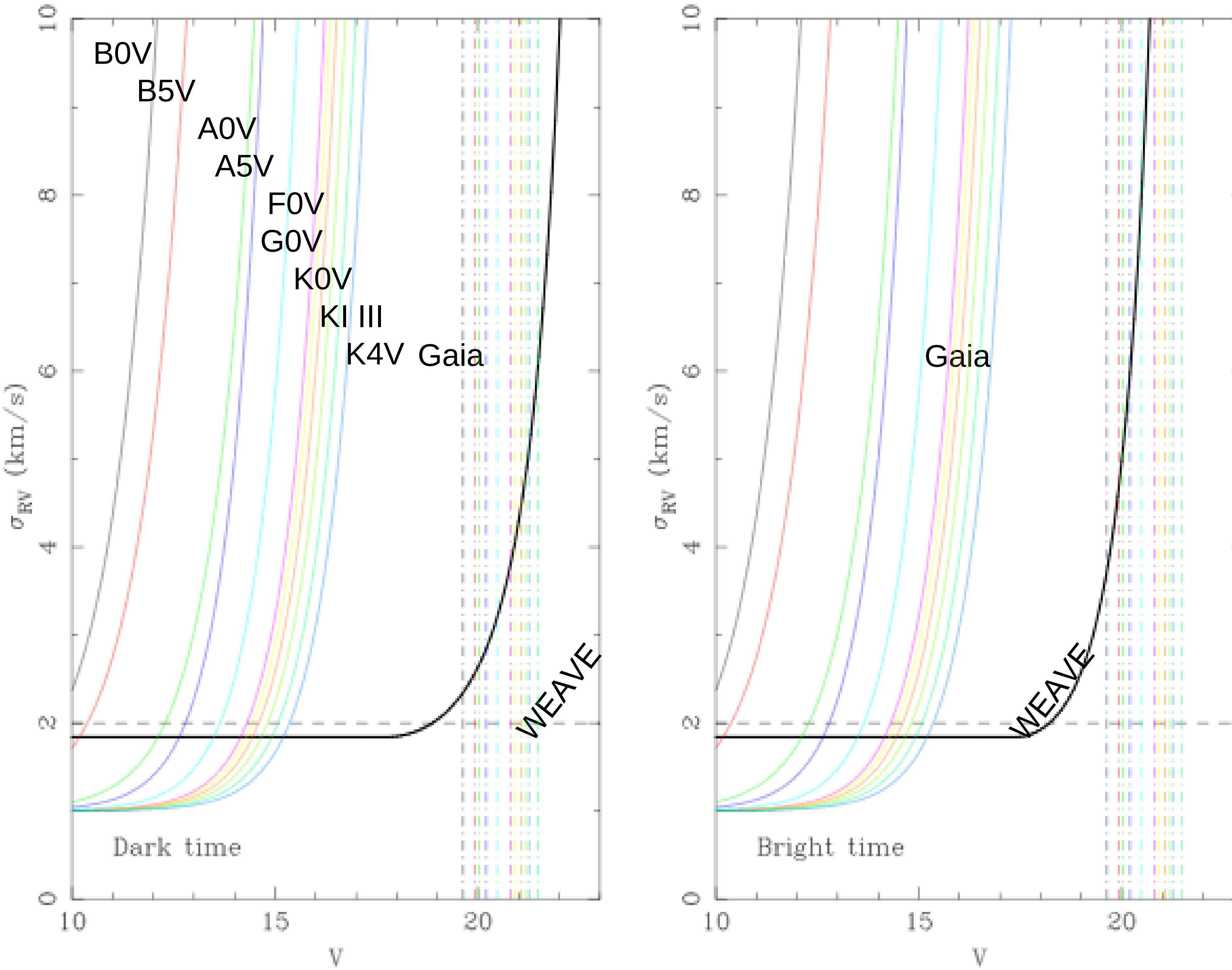
- Three “design reference surveys” were used to determine the requirements for the WEAVE design:
  - Galactic Archaeology
    - The Halo
    - Dynamics of the disk
    - Chemical Labelling
    - Open Clusters
  - Galaxy Evolution
    - LOFAR
    - Galaxy Clusters
    - Populations and dynamics
  - Cosmology
    - Unbiased large-scale structure surveys
    - Gravitation and infall

WEAVE at R=5000

WEAVE will measure radial velocities to σ(v_r)<3 km/s at V=20 in 1hr of dark time (V=19 in bright time), *closely matching the Gaia photometric limits*

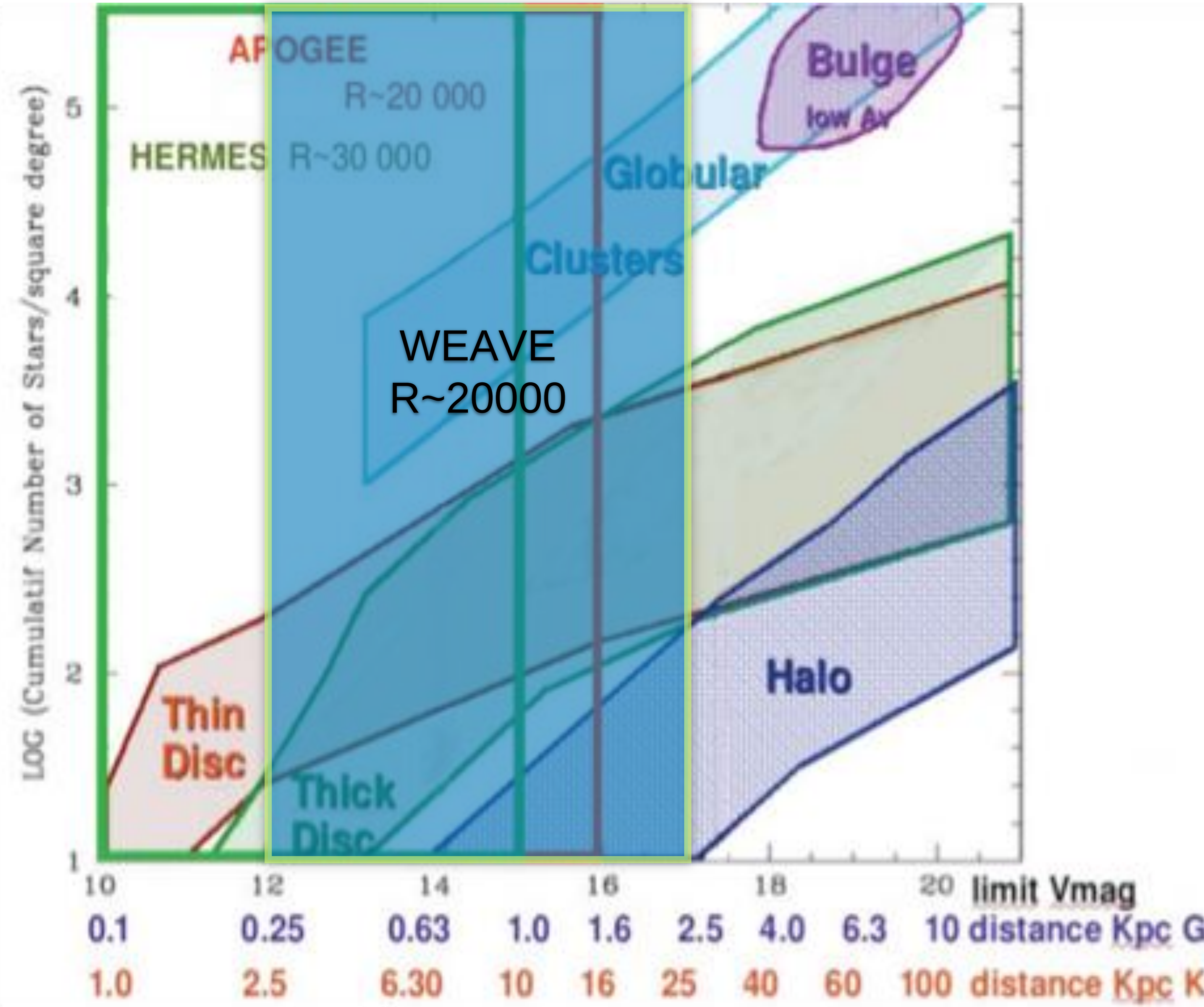
WEAVE will be able to determine the radial velocities of *any* of the ~10^9 Gaia stars that RVS won't!

Abundances to ~0.2dex, [Fe/H] ~0.1



WEAVE at R=20000

- Abundances of individual elements to ~0.1 dex accuracy will allow us to chemically label stars
- WEAVE will reach V~17 in ~2 hours at S/N=50/resolution element at R=20000



Galactic archaeology design reference surveys

	log(N)	Area (deg^2)	R	Depth
Halo	6	6500	5000	V≤20
Disks	6,7	2000	5000	V≤20
Chemical labeling	4.7 (disk) 5.7 (halo)	2000 2500	20000	V≤17
Open clusters	4,7	150	20000	V≤17

Galaxy Evolution

C L U S T E R S

Layer 1: Tracing the evolution of dwarf galaxies in clusters

>10^4 cluster dwarfs at R=5000 down to M_r<-16 with MOS mode + 10^3 cluster dwarfs with **mIFUs** to derive *spatially-resolved properties*

Layer 2: The infall regime

10^4 galaxies in 10 large superstructures at z~0.1–0.2 at R=5000 to R<21 in **MOS** mode

Layer 3: The evolution of cluster galaxies at z<0.5

150 cluster cores with **LIFU** mode

F I E L D

Galaxy evolution doesn't occur just in clusters, of course!

How have field galaxies managed to build up the *red sequence* by a factor of two in mass since z~0.8?

Archeological studies required to probe massive-galaxy evolution

WEAVE will collect high S/N spectra for stellar population analysis – age-dating and chemical abundances – of 10^5 galaxies with $M>10^{10.5}\,M_\odot$ at $0.2<z<0.8$ over 70 sq. deg. in **MOS** mode

Galaxy evolution and cosmology

WEAVE can obtain redshifts for ~4×10^6 emission-line galaxies detected by LOFAR at z<1.3 (OII) and z>2.3 (Lyα)

- Radio continuum fluxes + redshifts = unbiased star-formation rates over large range of cosmic time!
- Spectra will often give metallicities and even stellar velocity dispersions: chemical evolution and stellar masses
- Black hole accretion mechanism can be determined for radio AGN: evolution of BH accretion rate and stellar-BH co-evolution
- Useful unbiassed sample for studies of infall and BAO, similar in sensitivity to the Euclid redshift survey
- Useful photo-z calibrators for Euclid, J-PAS etc.
- High resolution observations of bright QSOs will provide Lyα forest measurements with excellent continuum determination, in parallel with the MW halo survey.

Galaxy evolution and dynamics

Layered complement to APERTIF:

Tier 1: 10^4 galaxies, half over 10^4 deg^2, half over 500 deg^2 with **mIFU** at R=5000 to probe star-formation quenching and the fueling of the blue cloud

Tier 2: 50 LSB galaxies with **LIFU** at R=10000 to determine masses of their dark and luminous matter using disk kinematics (+150 HSB galaxies if time permits)

Tier 3: 10 nearby large disk galaxies with **LIFU** to determine the impact of secular evolution on their gas and stars

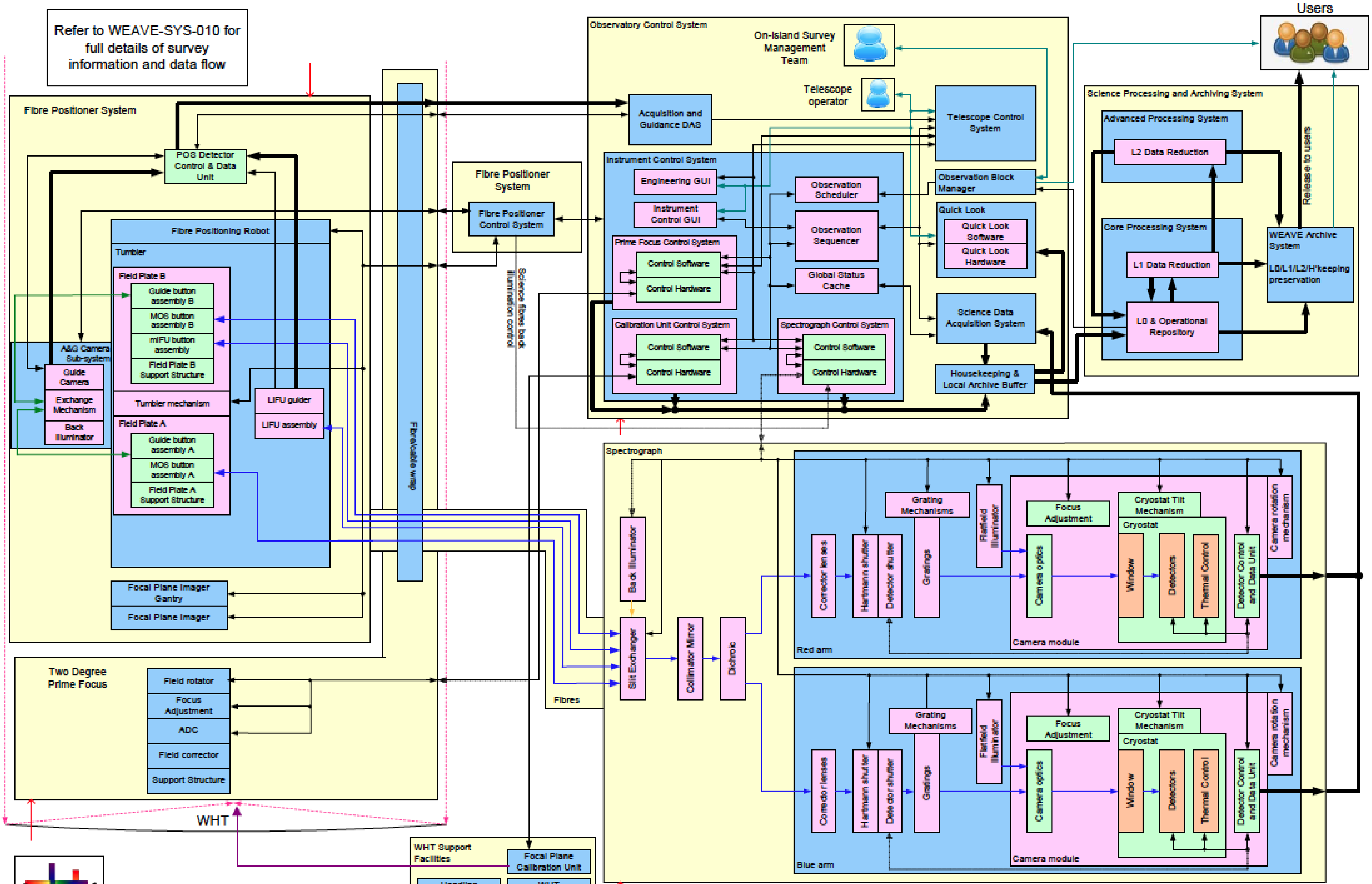
Derived requirements for instrument concept

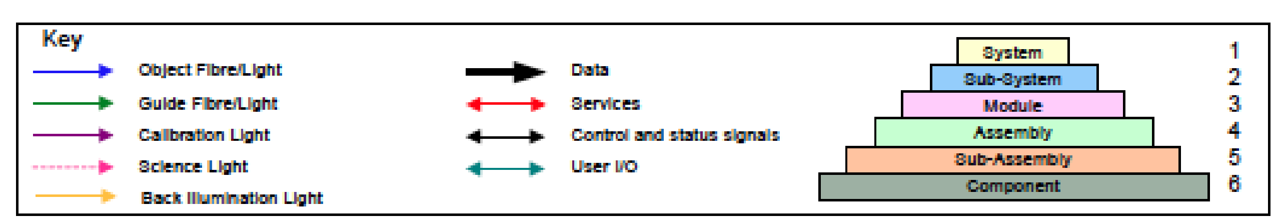
Gaia	R=5000 for radial velocities at $17 \le V \le 20$ R=20000 for stellar abundances at $12 \le V \le 17$ $\sim 10^7$ stars over 10^4 degrees^2
LOFAR	λ370–960nm and $V \le 21.5$ at S/N=5 (continuum) for redshifts ~few x 10^6 galaxies over 10^4 degrees^2
Apertif	Mini-IFUs and Large IFU for 2D spectra of gas-rich galaxies $\sim 10^4$ galaxies over 10^4 degrees^2
Clusters + Field	MOS, mini-IFUs, and large IFU $\sim 10^4$ galaxies over 10^2 degrees^2

Instrument top level specifications

Telescope, diameter	WHT, 4.2m
Field of view	2º ∅
Number of fibers	~~1000~~ 960/940
Fiber size	1.3″
Number of small IFUs, size	20 x 11″x12″ (1.3″ spaxels)
LIFU size	1.3′x1.5′ (2.6″ spaxels)
Low-resolution mode resolution	5750 (4000–7250)
Low-resolution mode wavelength coverage (Å)	3660–9590
High-resolution mode resolution	20000 (15000–25000)
High-resolution mode wavelength coverage (Å)	4040–4650, 4730–5450 5950–6850

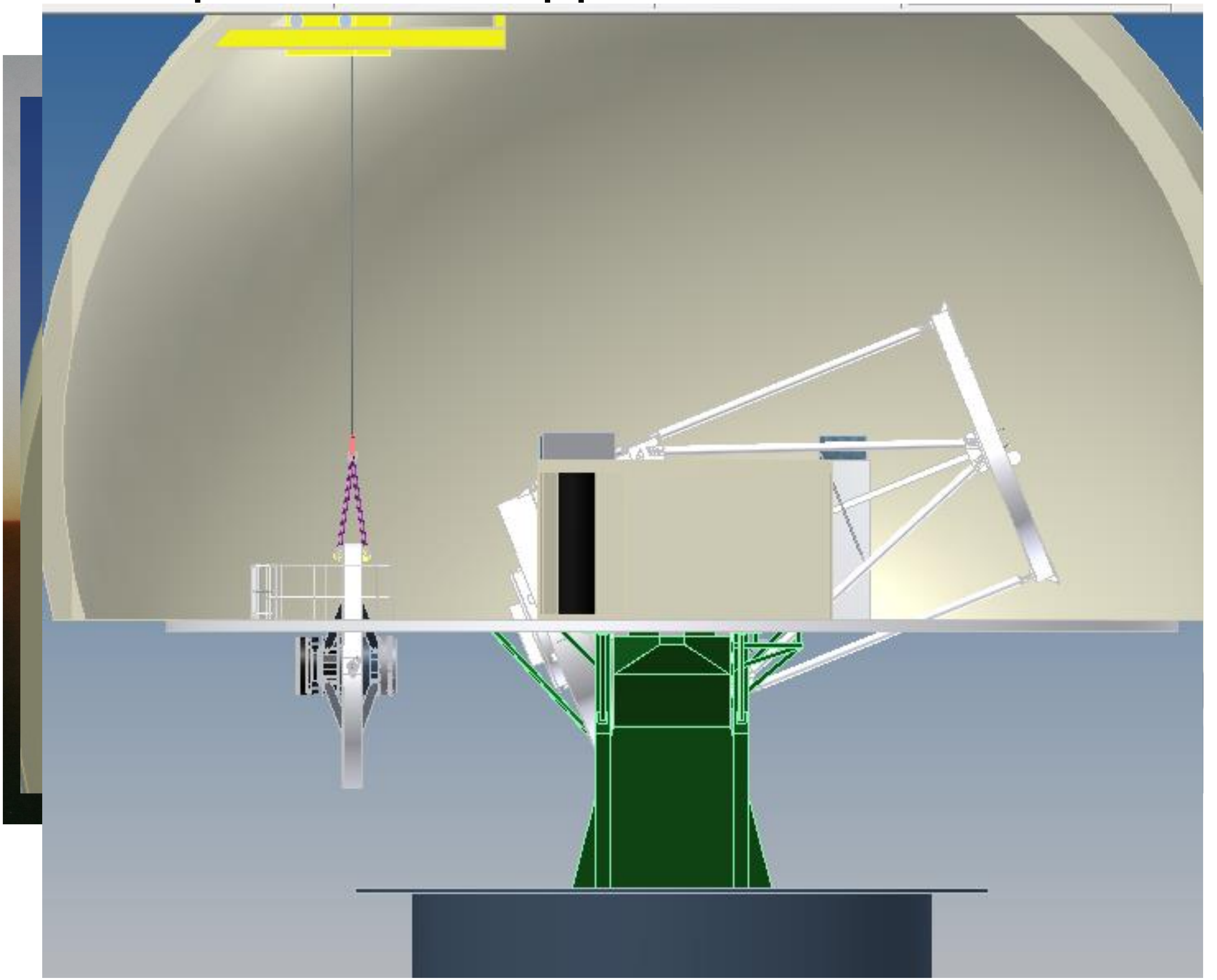
Facility instrument that will integrate fully with ING instrumentation model

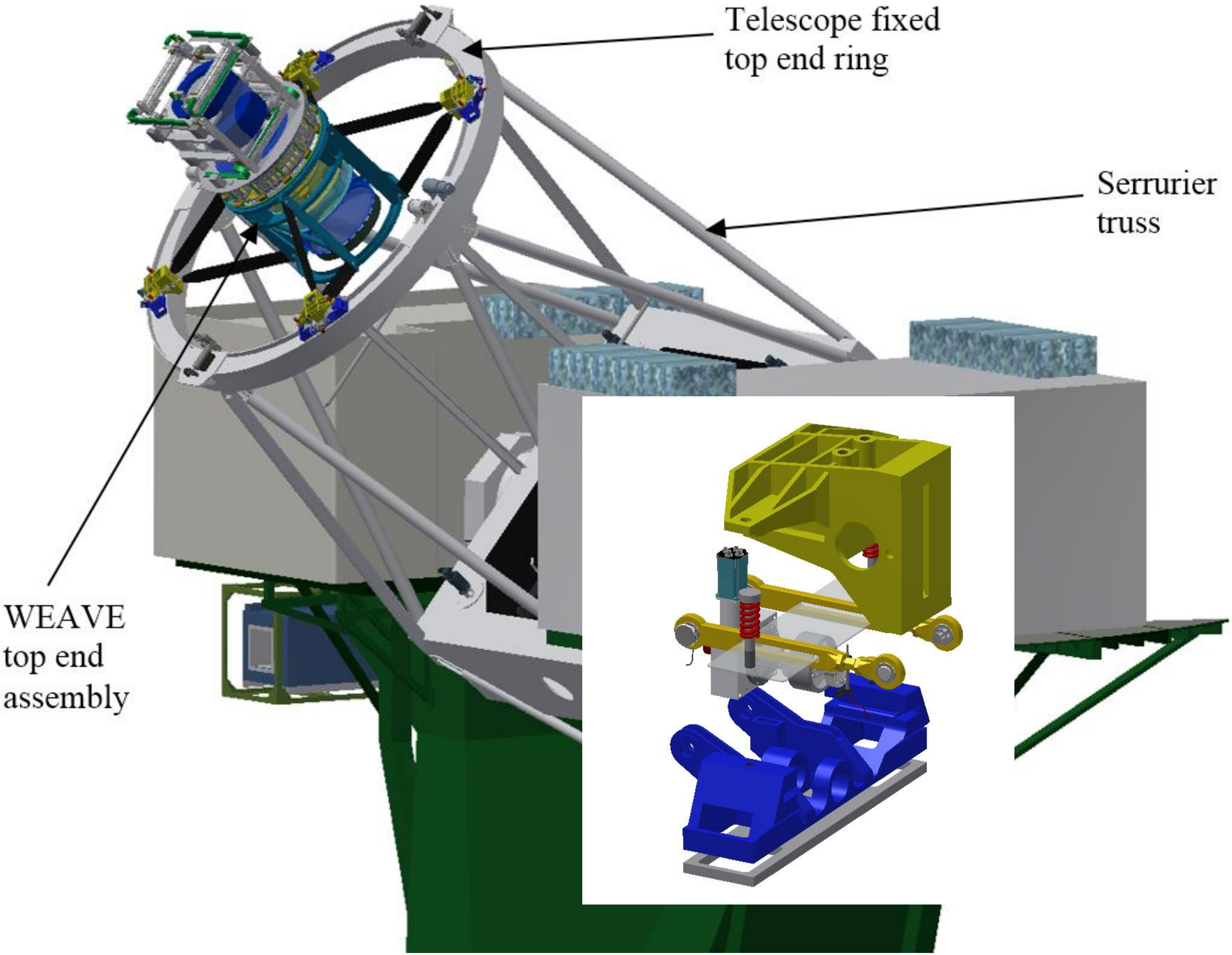




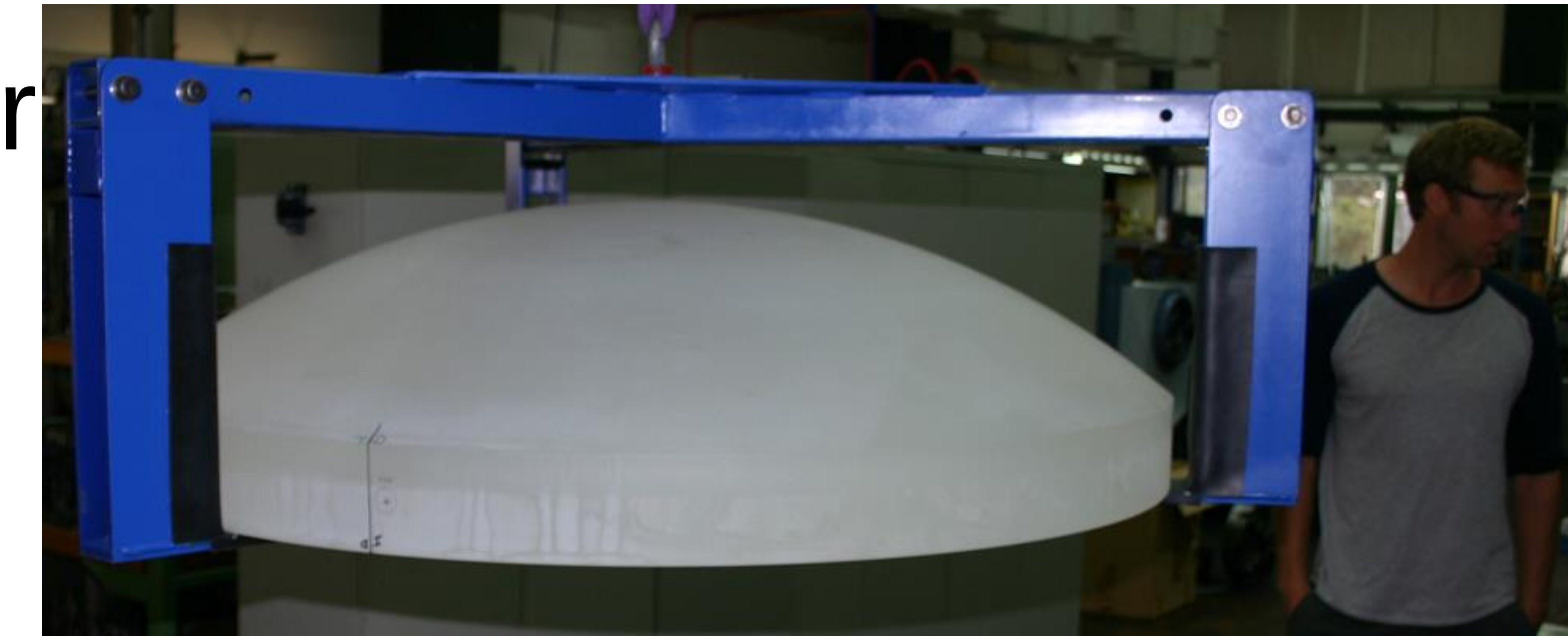
Drawn by	Kevin Middleton			Project	WEAVE
Date	25 Nov 14	Doc No	WEAVE-MAN-013	Title	Instrument Block Diagram by System
Version	1.6	Size	A3	Location	http://www.ing.iac.es/bscw/bscw.cgi/236162

New top end and support structure for WHT




Telescope fixed top end ring
Serrurier truss
WEAVE top end assembly

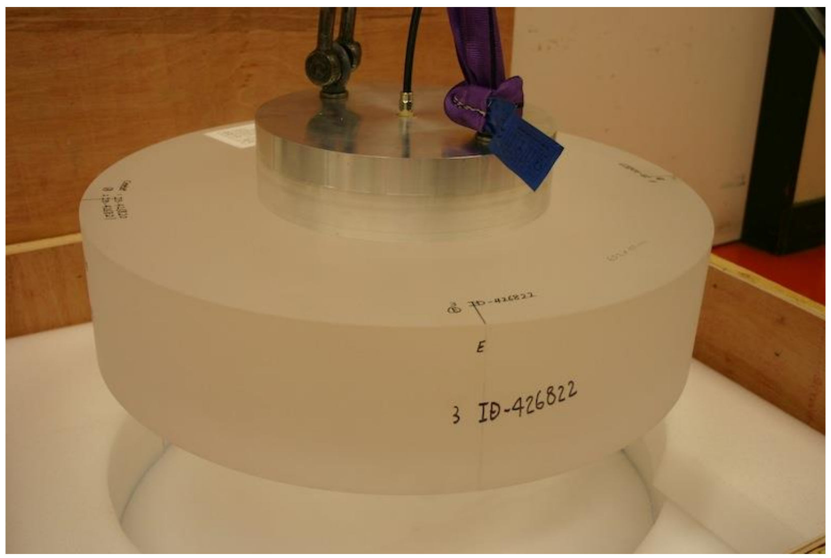
Prime focus corrector

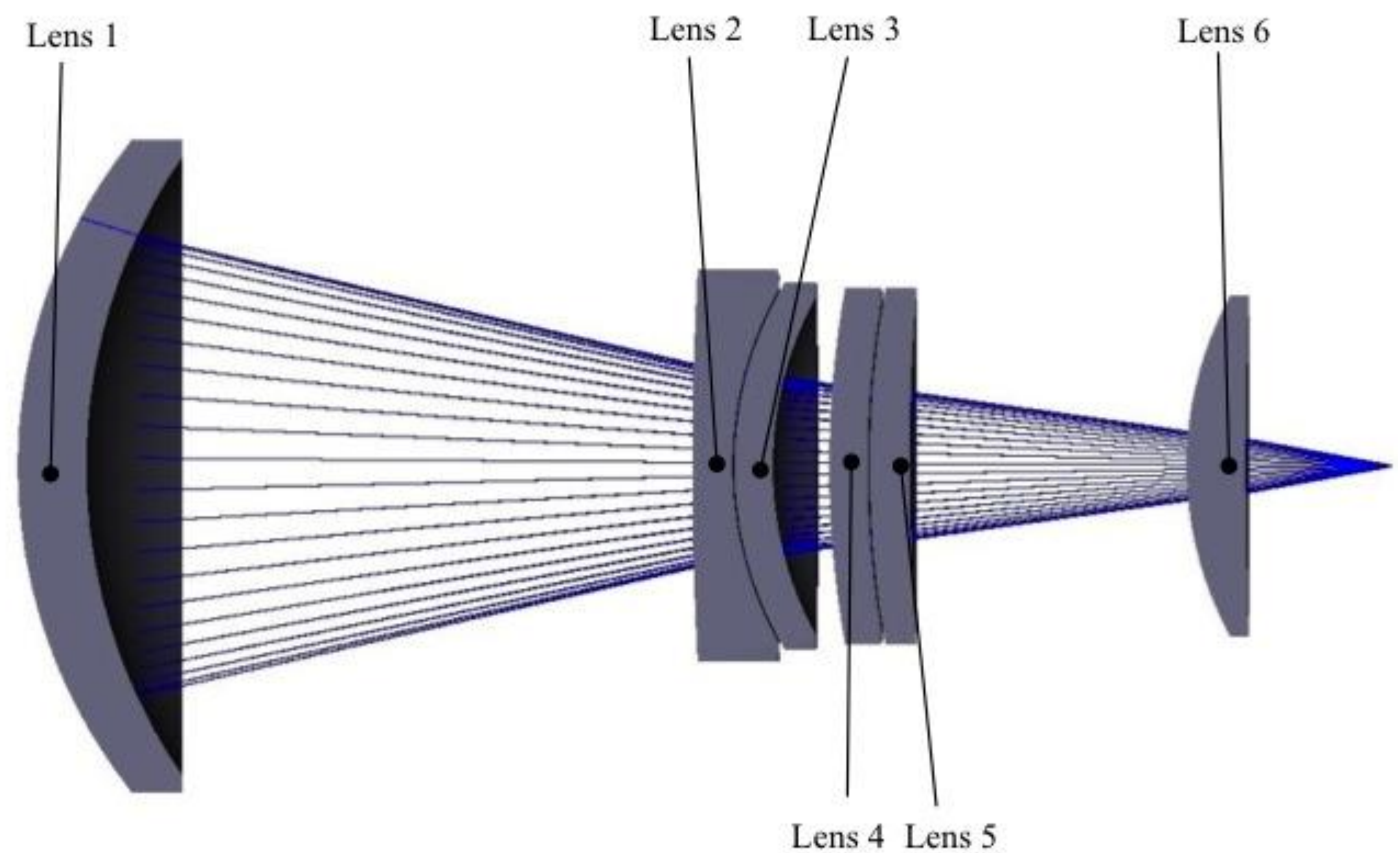


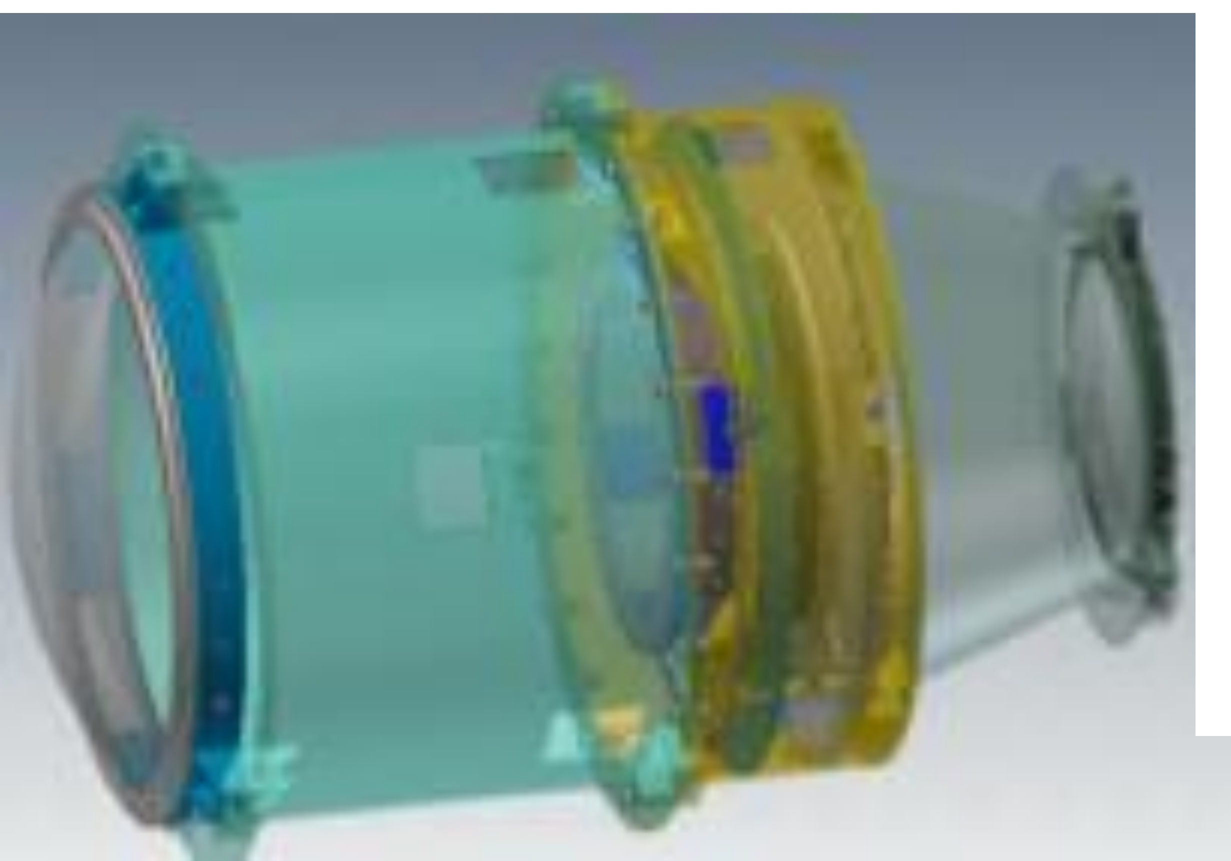
6 Lenses with ADC (L2–L5)

Lens 1 is 1100 mm

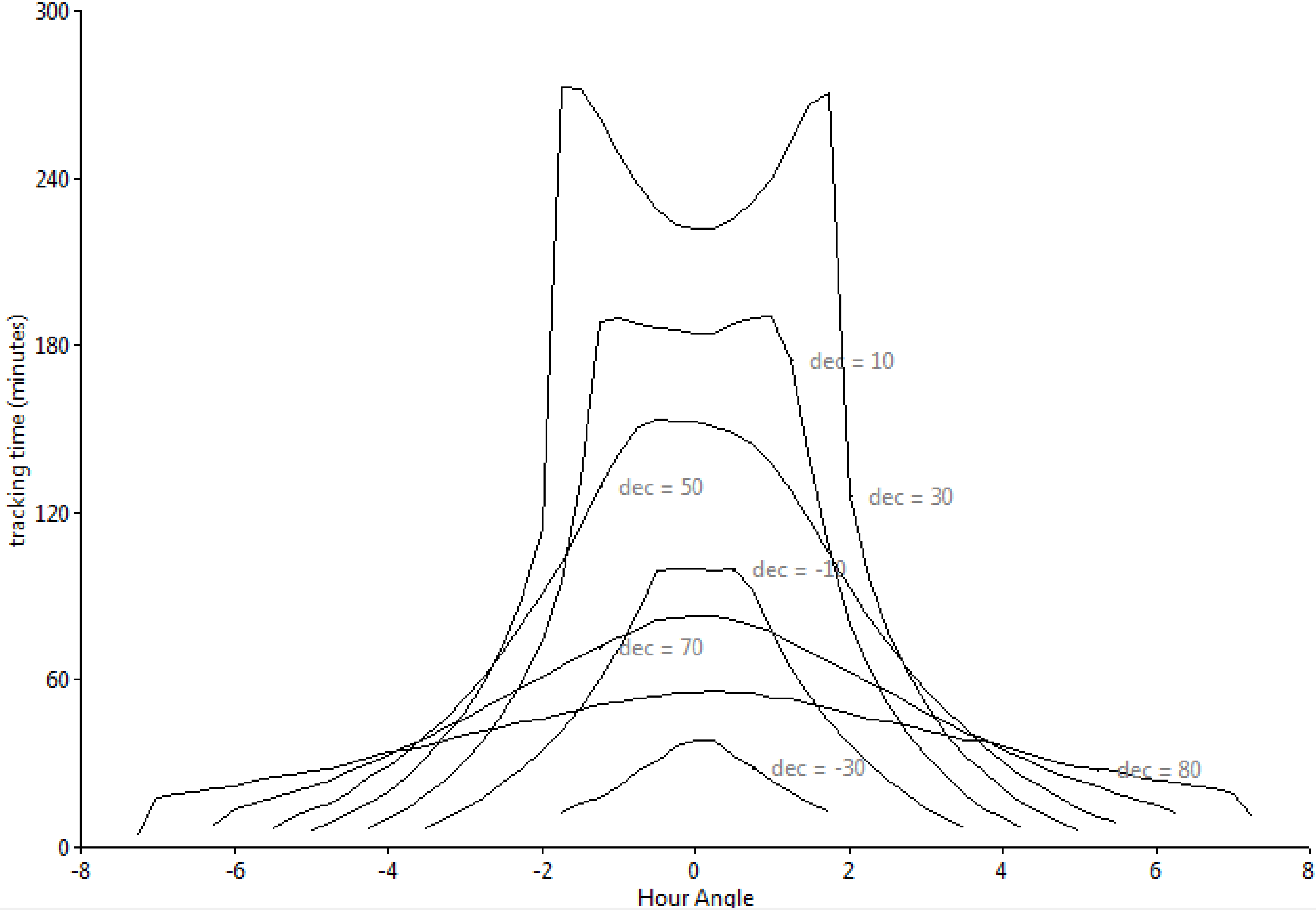
4 blanks delivered, 2 slightly delayed.
Polishing in process at Kiwistar



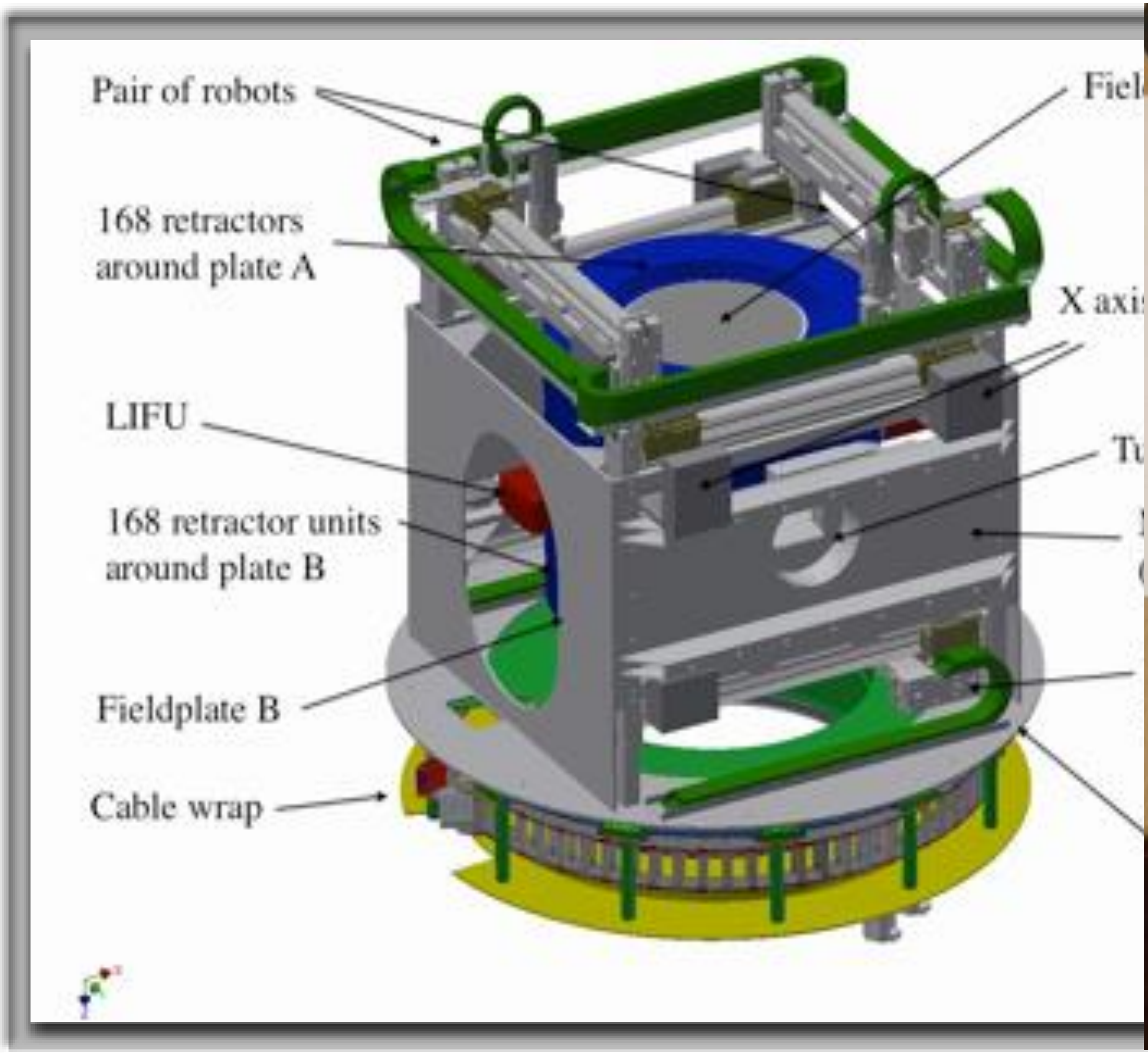


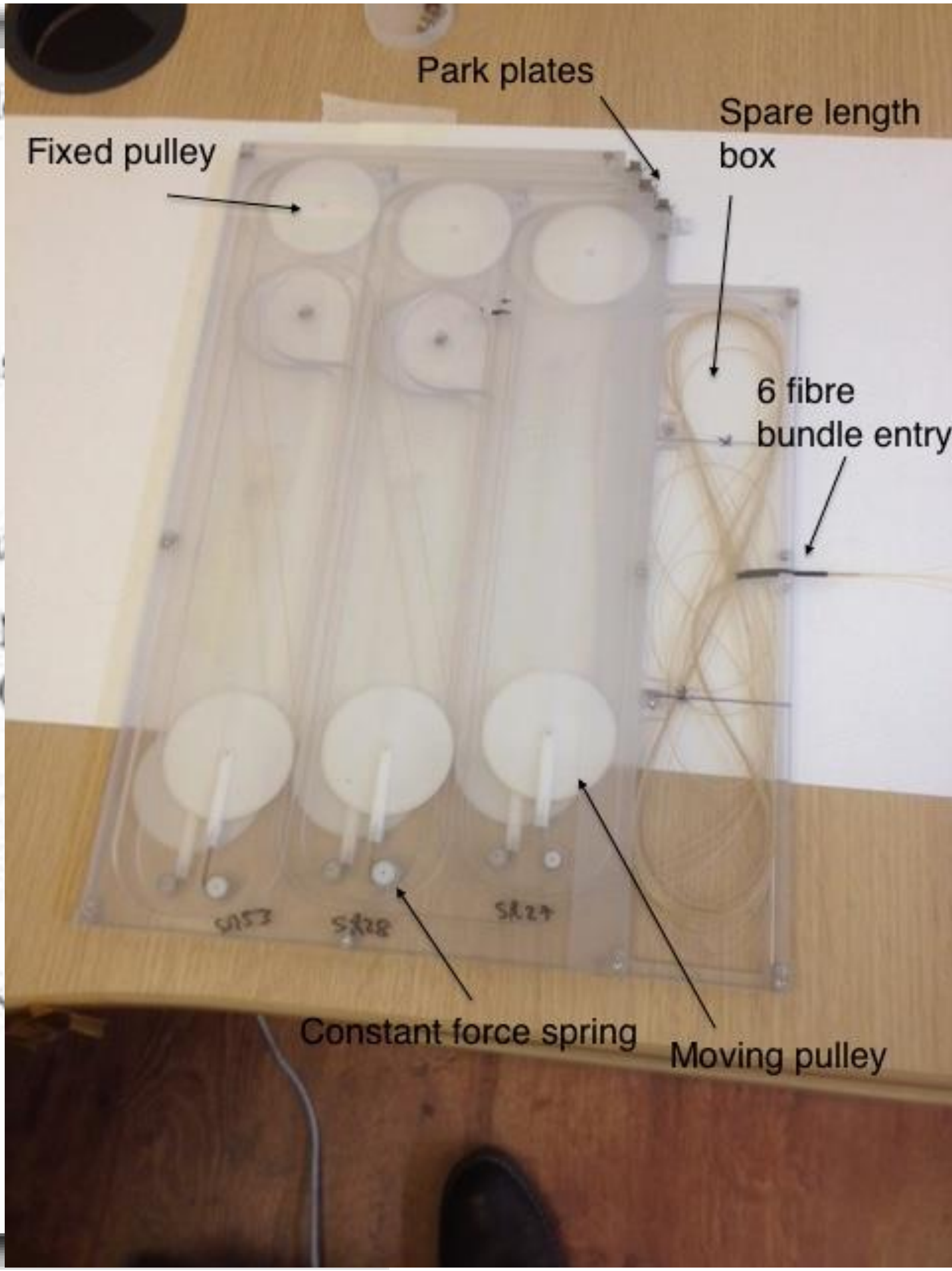


Effect of differential refraction on the astrometric distortion of the focal plane



Fibre positioner system





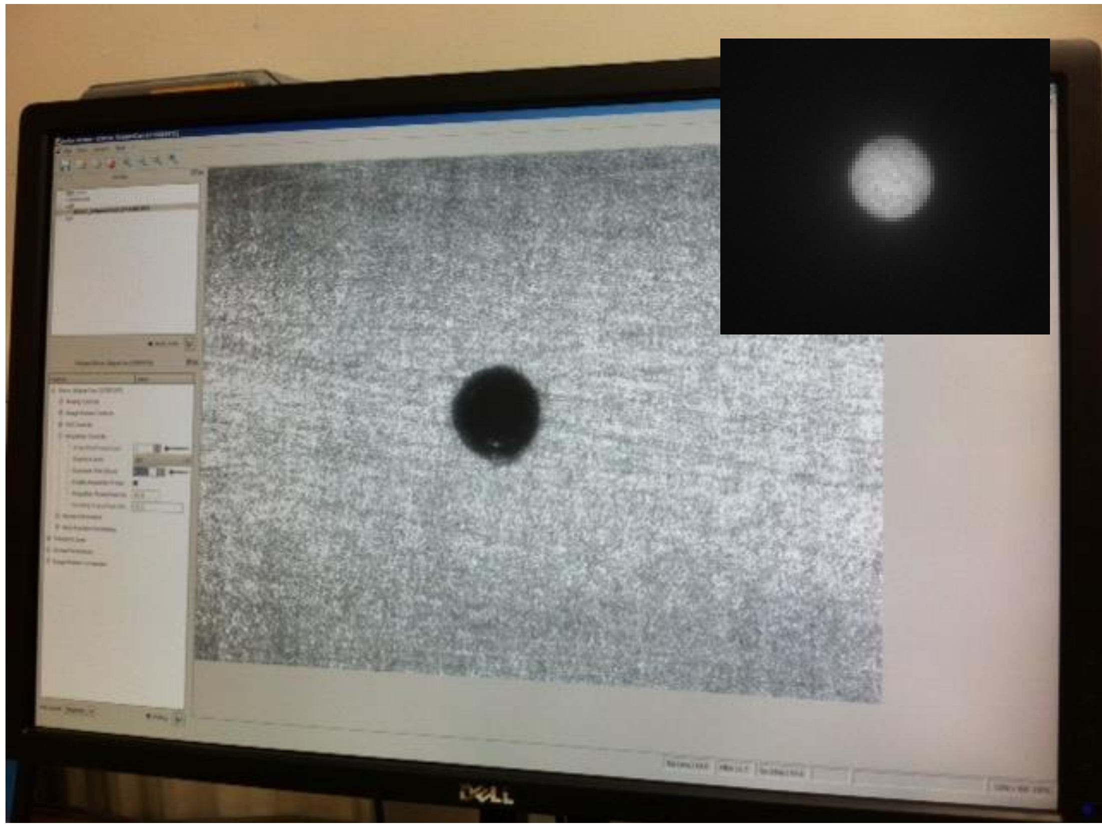
2dF-style tumbler, two robots – ~940 fibres/plate (plus 20 mini-IFUs on one plate)
Large IFU in red box

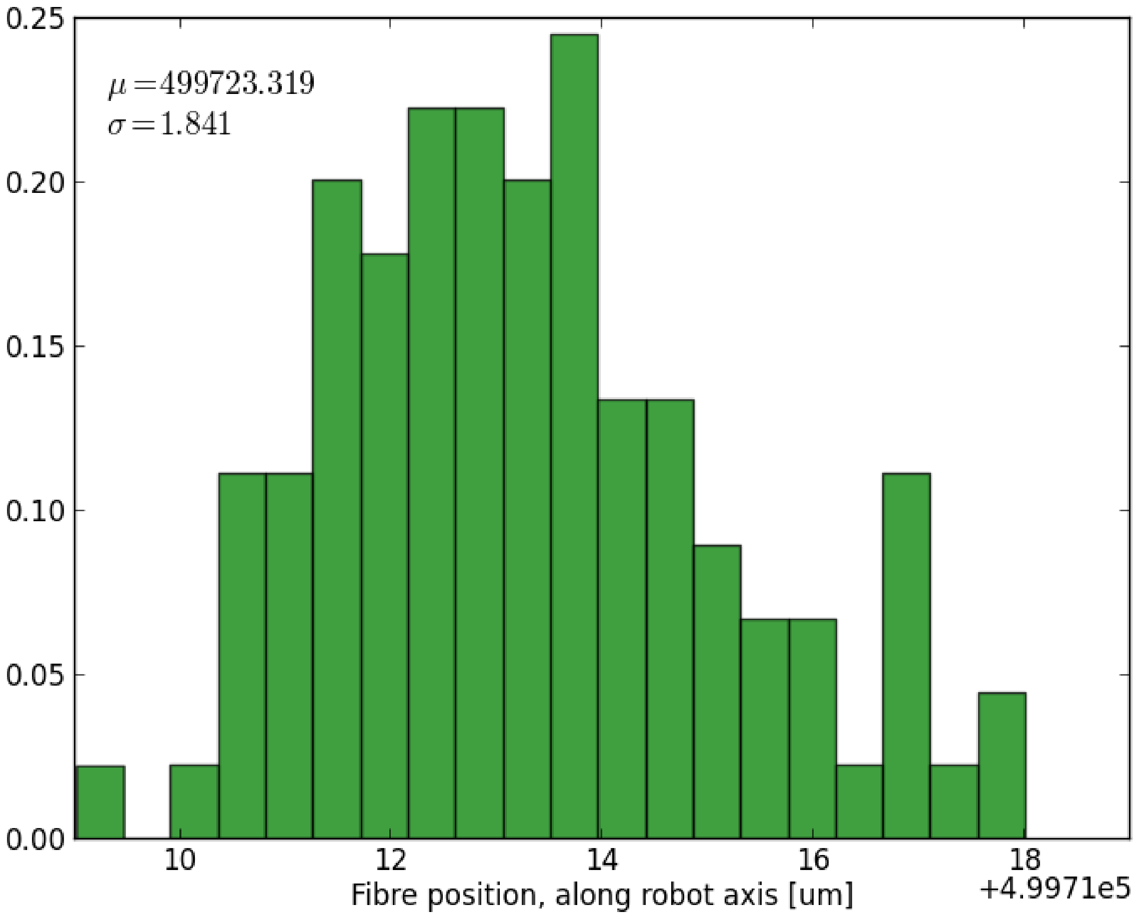
More details in the poster…

Positioner prototype

Single y,z,θ with gripper unit and imaging camera

Testing of fibre retractors
Development of low level control software
Confirmation of gantry flexure calculations





Fibre placement

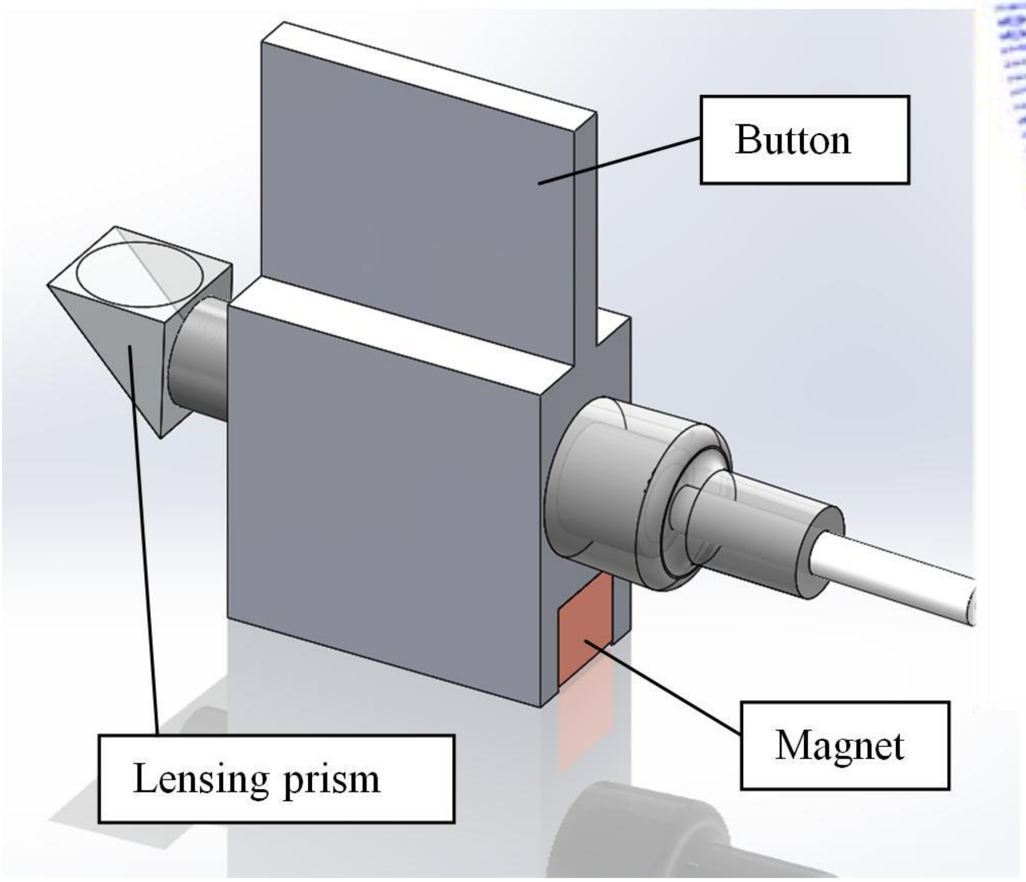
97% of fibres placed in test simulations

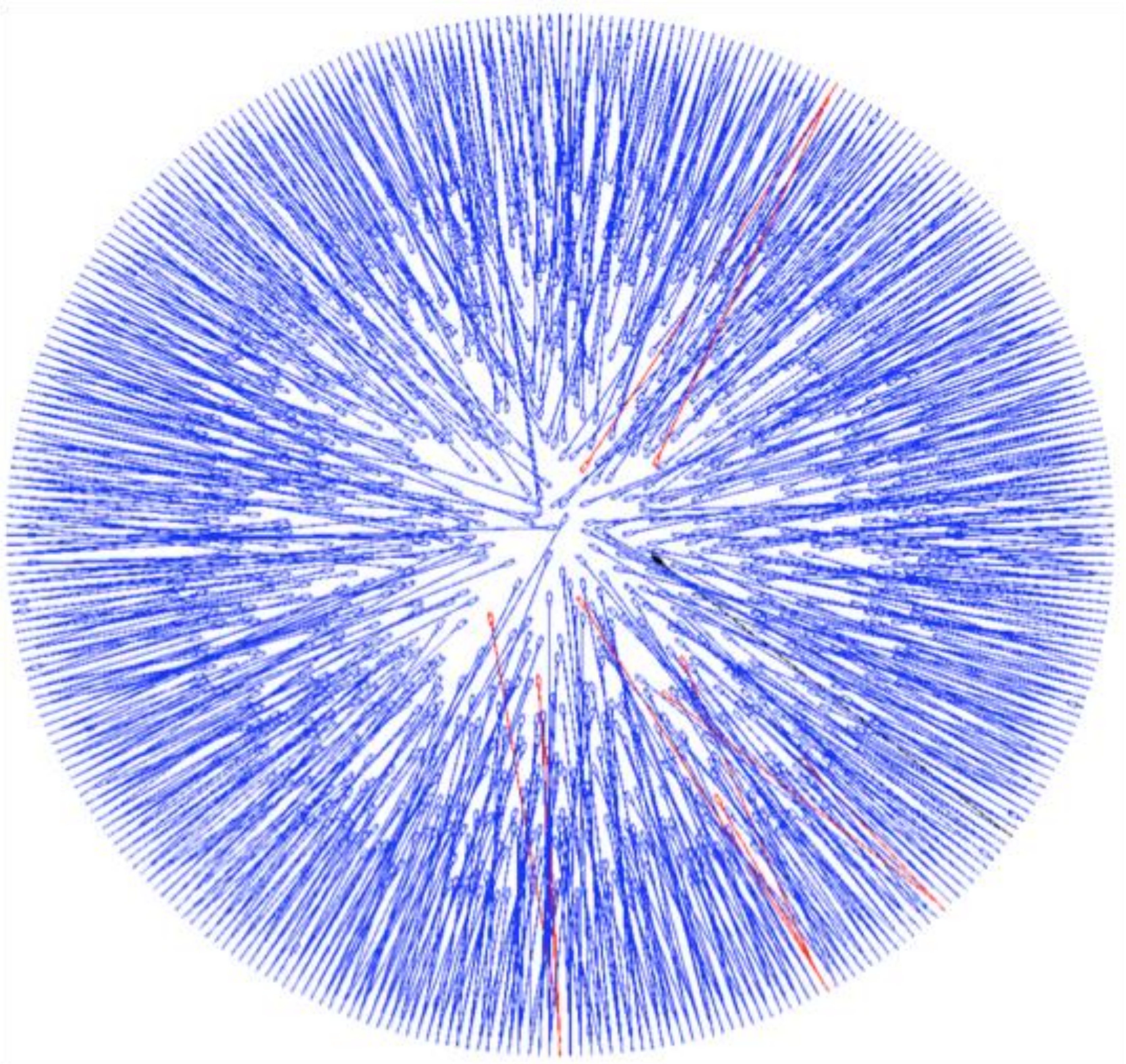
1.8x oversampling

~8500 fibre crossings(!)

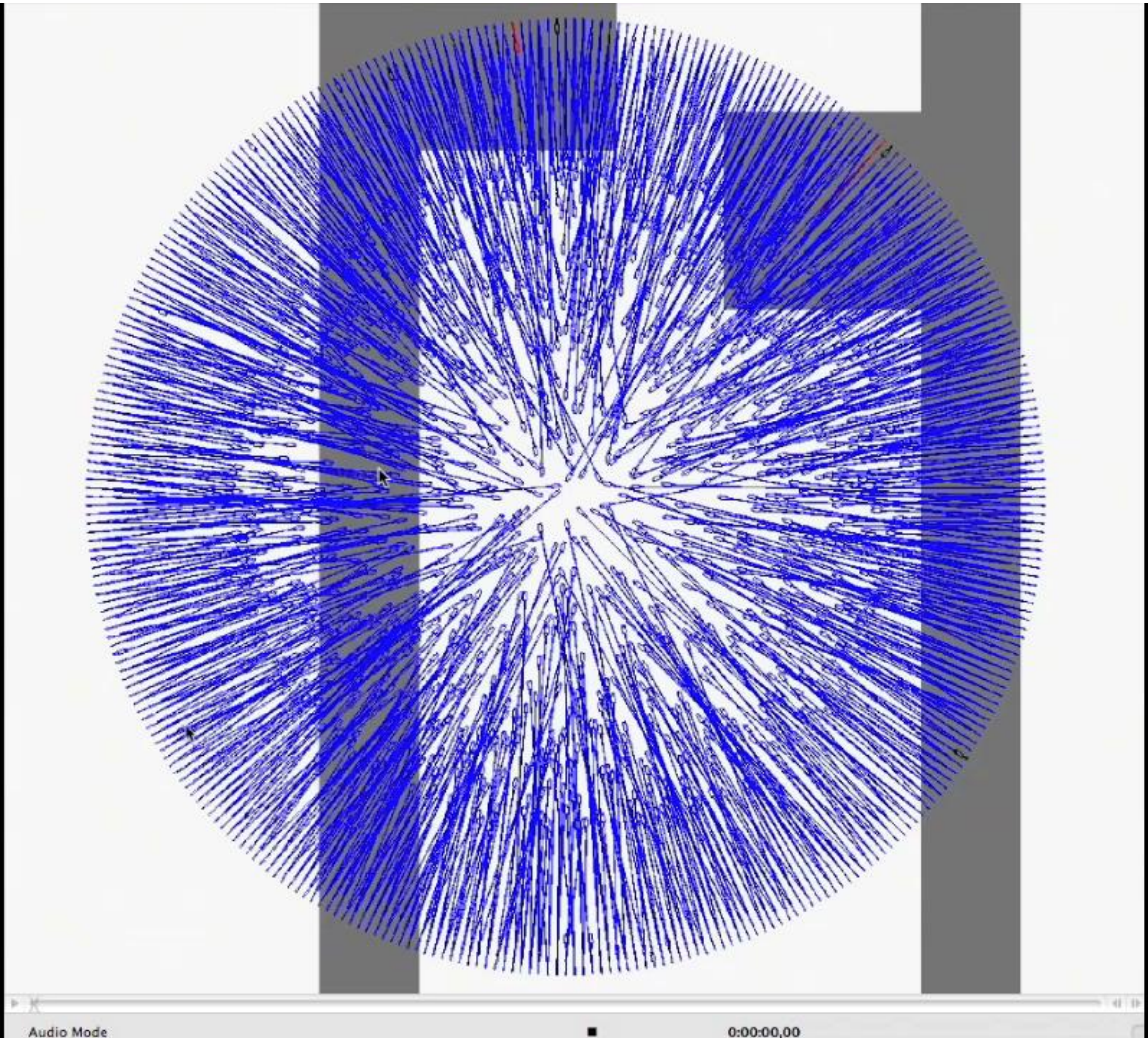
~1800 moves in ~55 minutes with two robots

8 coherent guide fibre bundles (5″ø). Desired guiding location tracked within the bundle for each star.

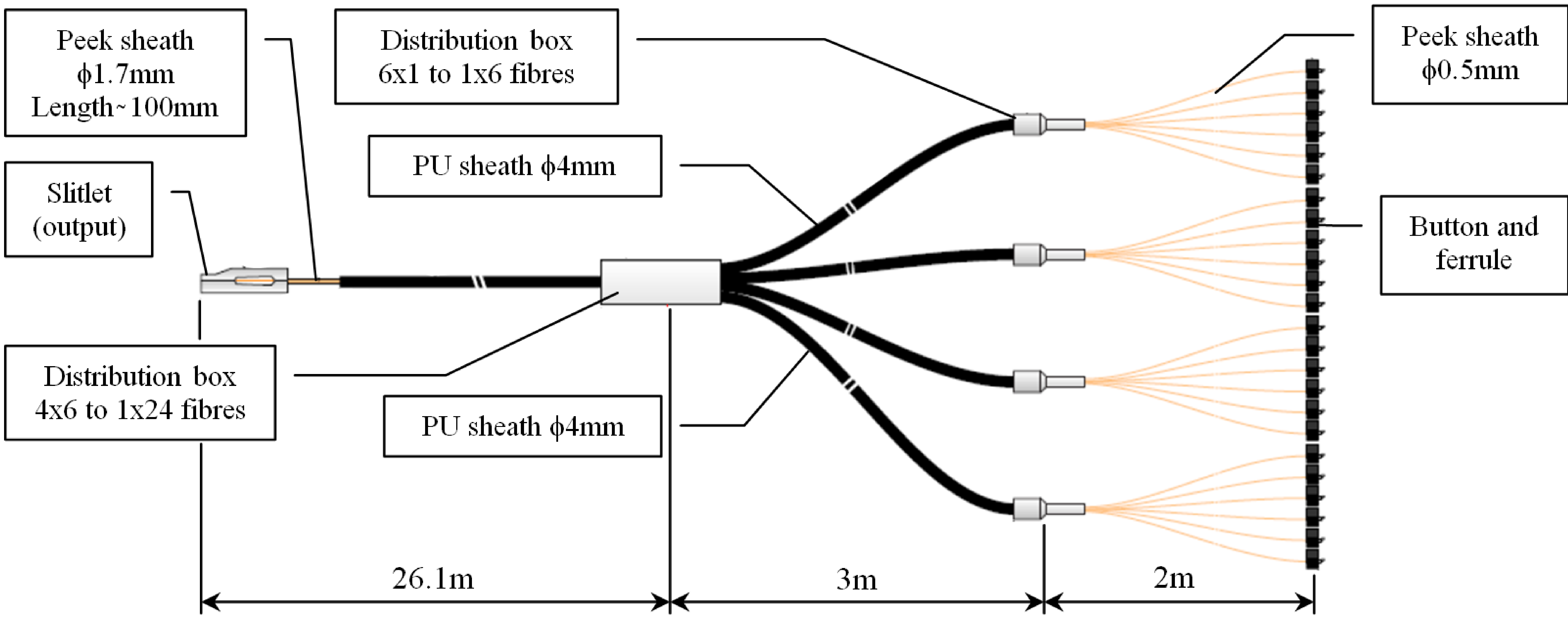


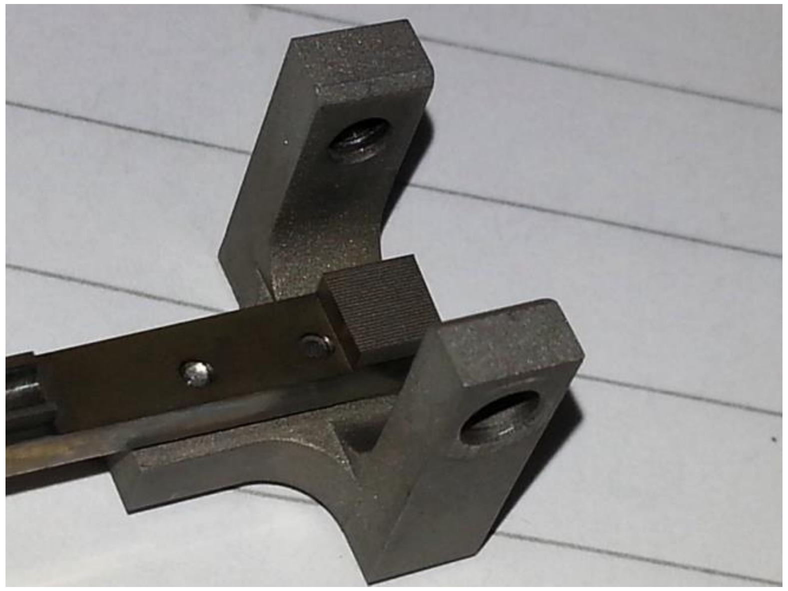


Field-Field configuration



Fibre cable modularity



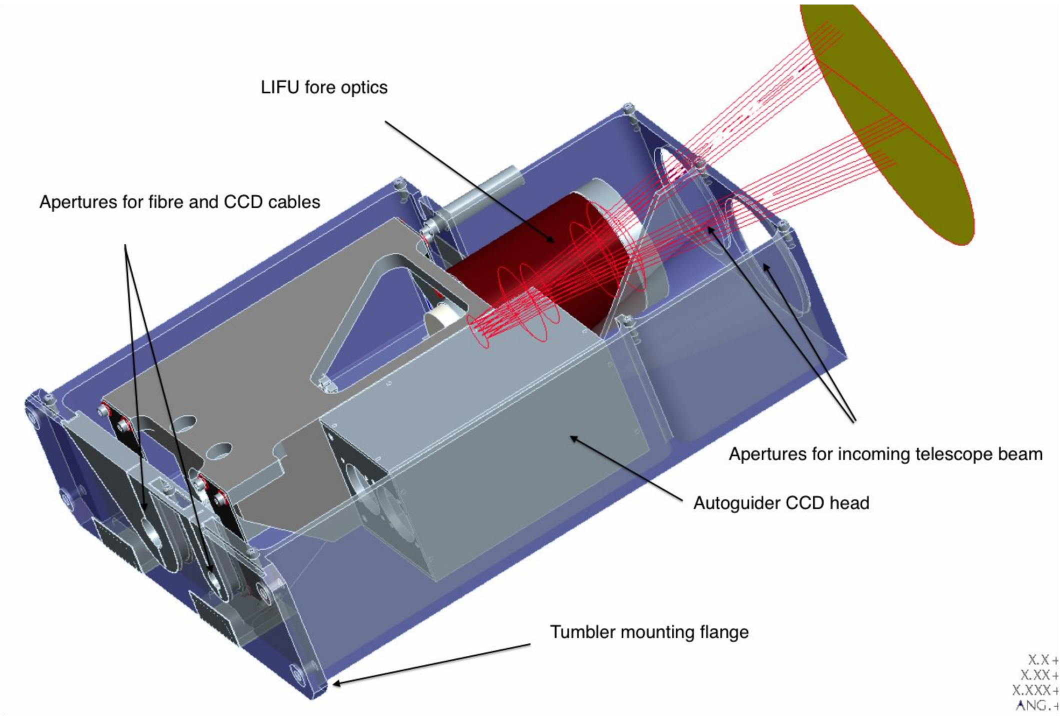


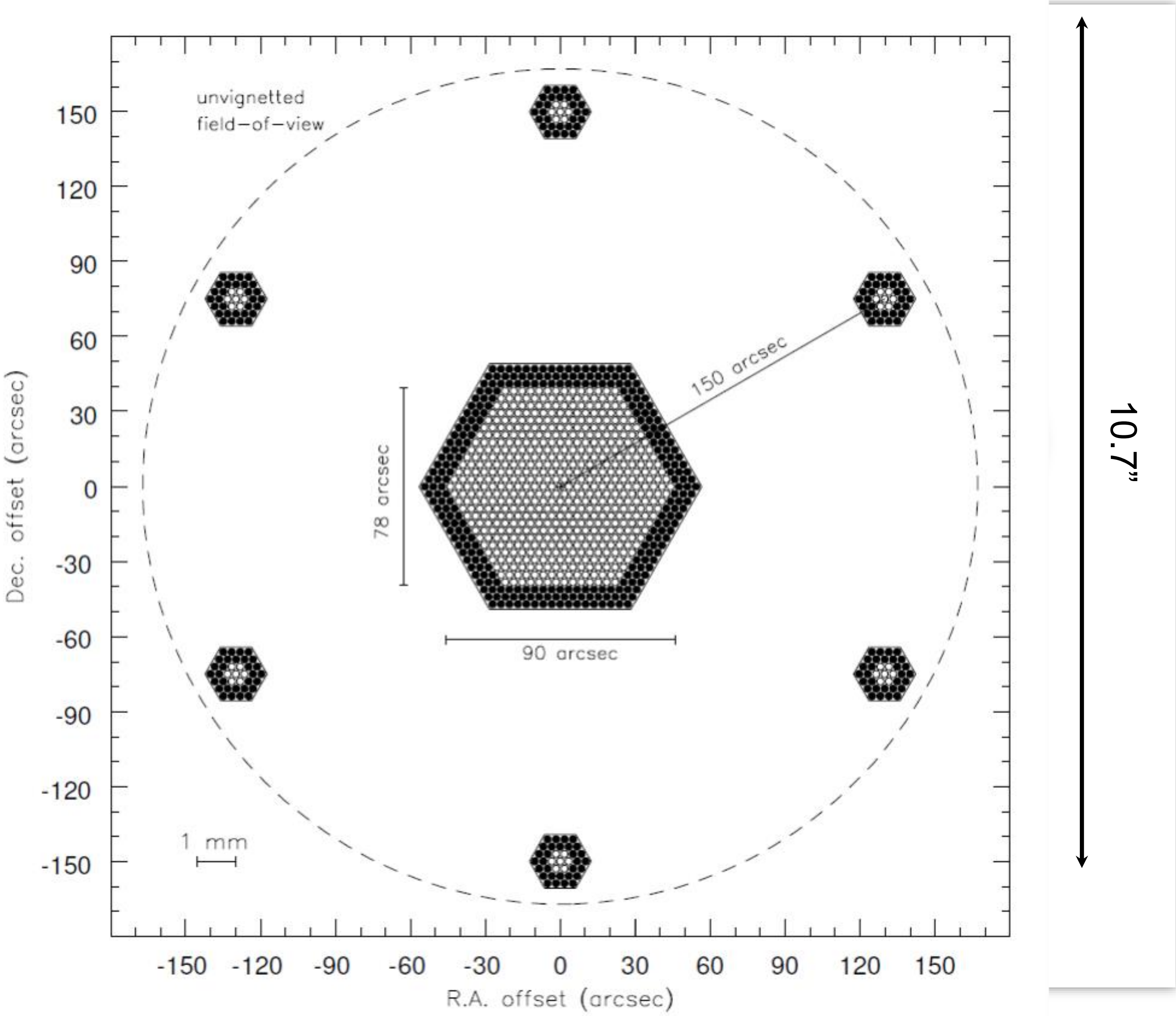
24-fibre slitlet similar in principle to that used by MANGA.

IFUs

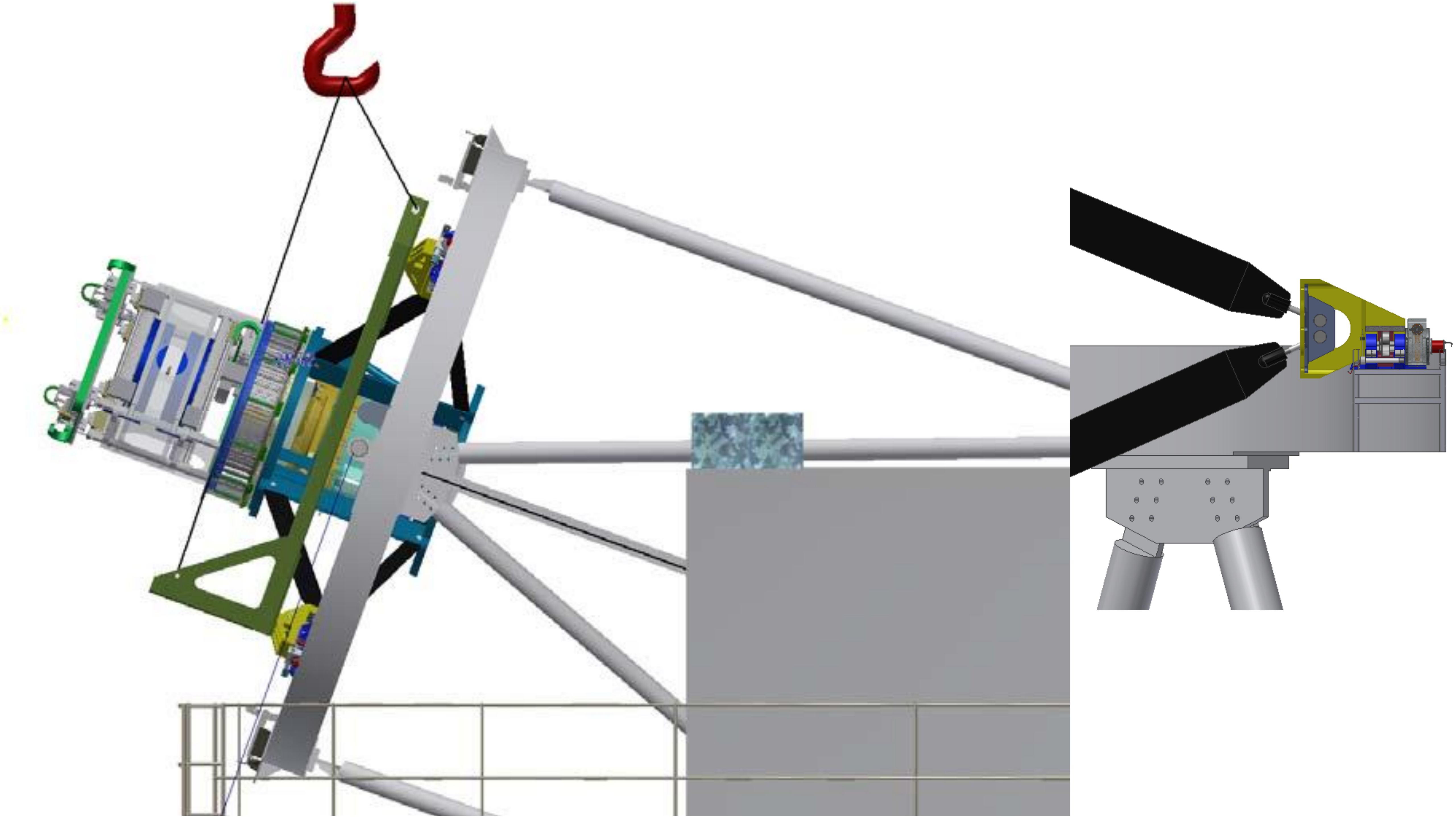
mIFU cables 37 fibres in a single PU sheath
mIFU cable inside the retractor has similar bend radius to a single MOS fibr
e.

- 20 miniIFUs on one positioner plate
  - ~11″×12″
- Large IFU between plates
  - 1.3′×1.5′
- IFU modes cannot be used simultaneously with MOS fibres



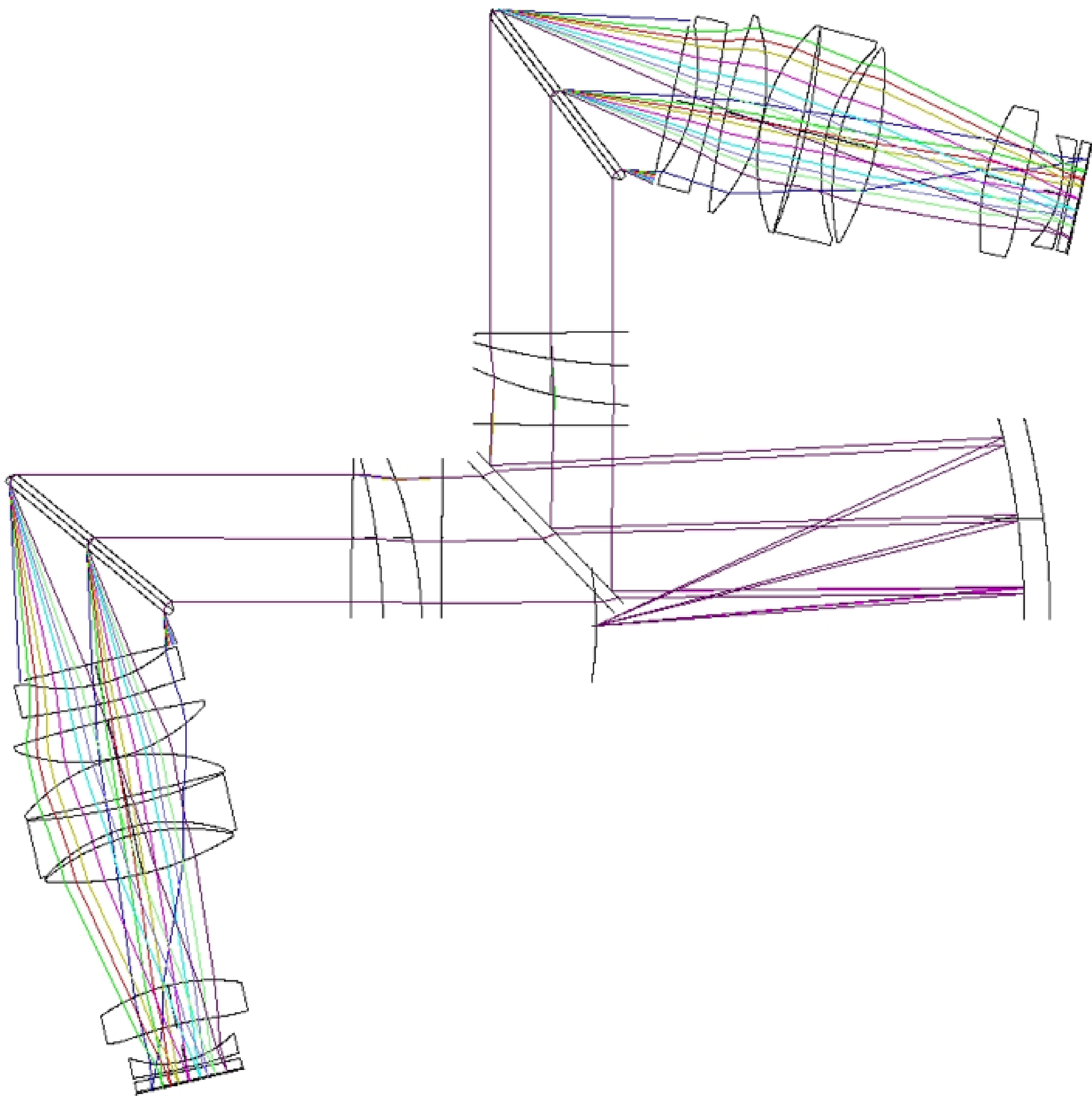


Top end mounting strategy

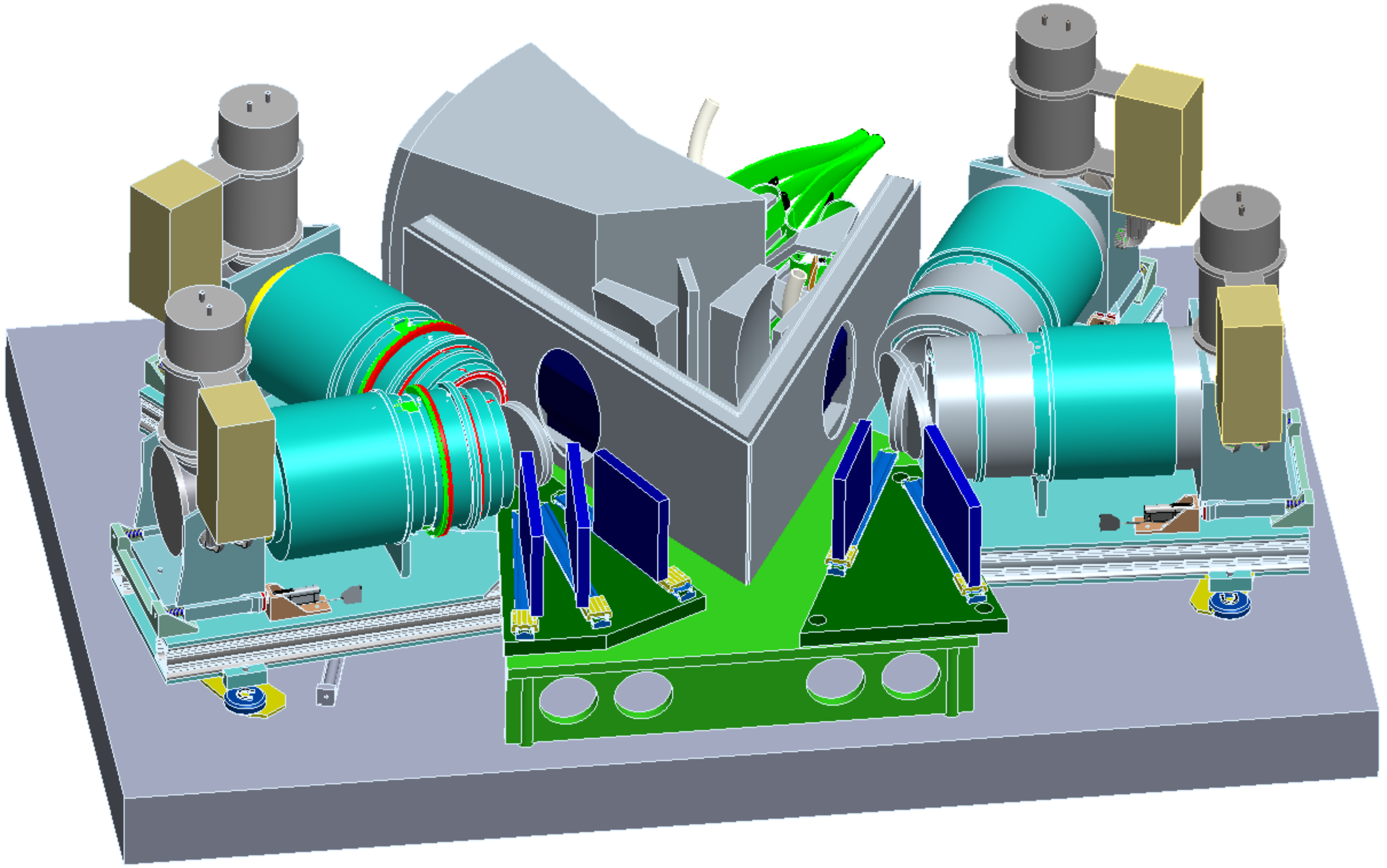


Spectrograph

Two arms split at 595 nm
Switchable from low- to high-resolution



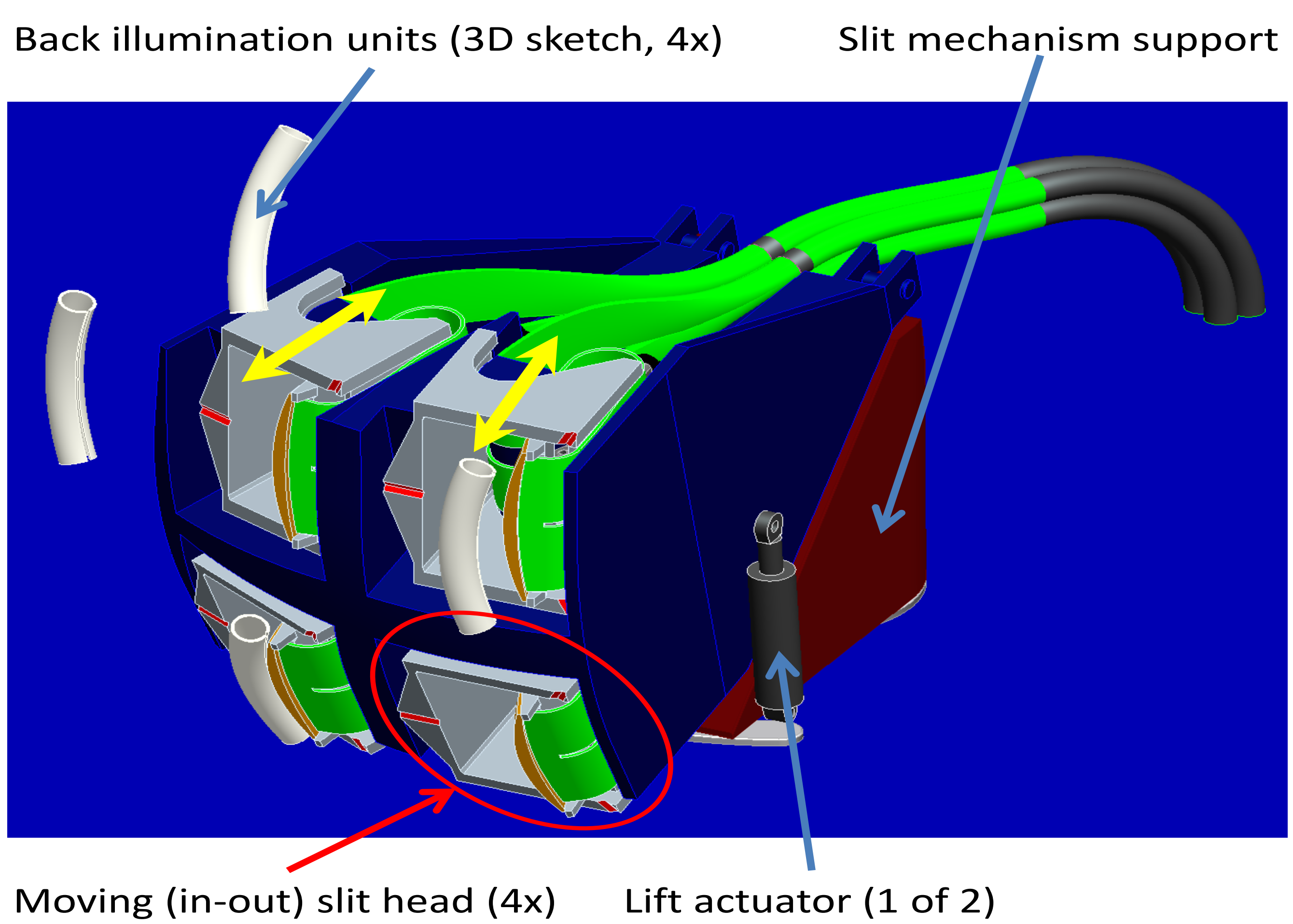
Spectrogaph mechanics



Mechanisms mostly pneumatic
Translations into kinematic locations

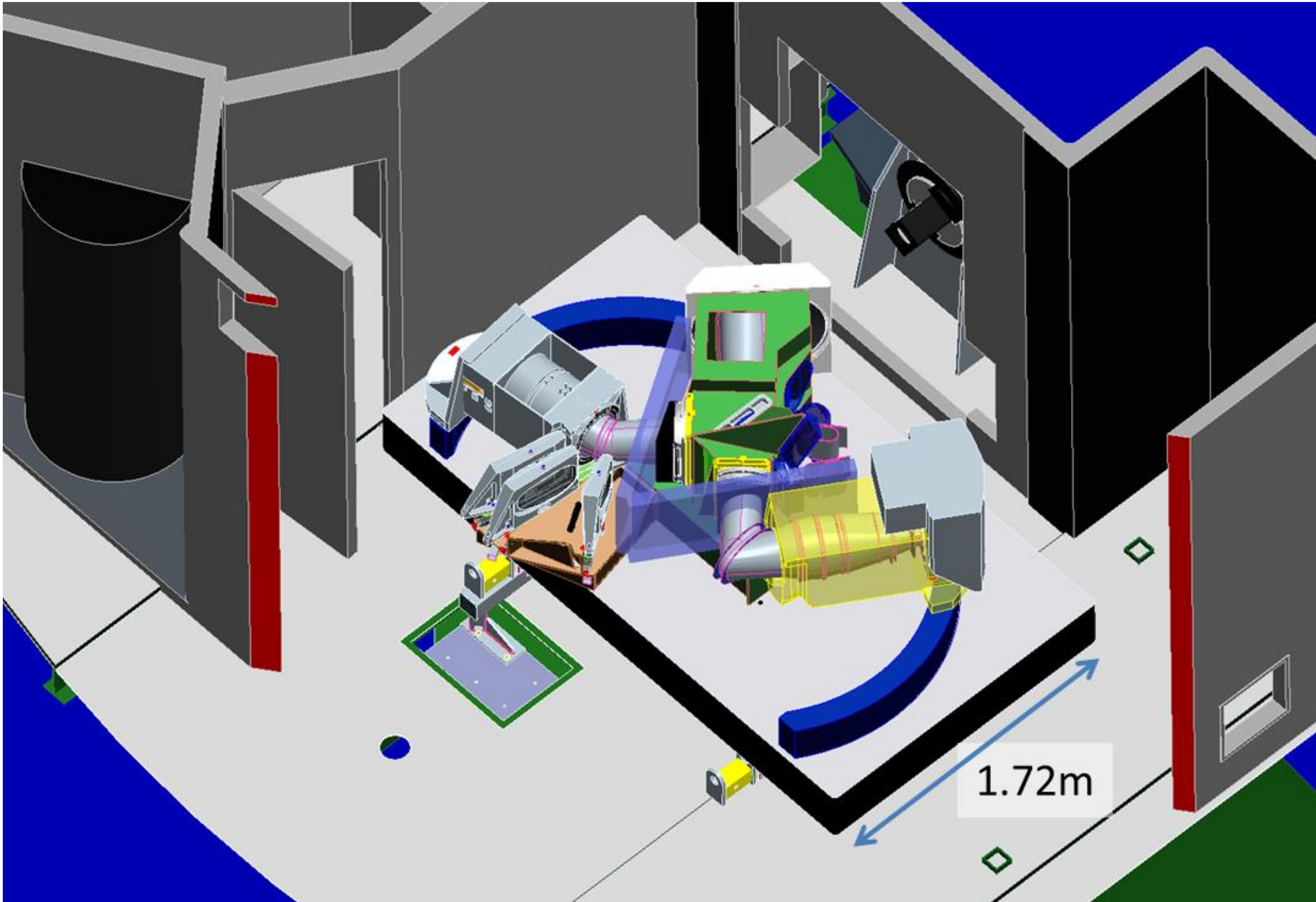
ING standard controllers based on ARC GenIII

Shutters located close to pupil

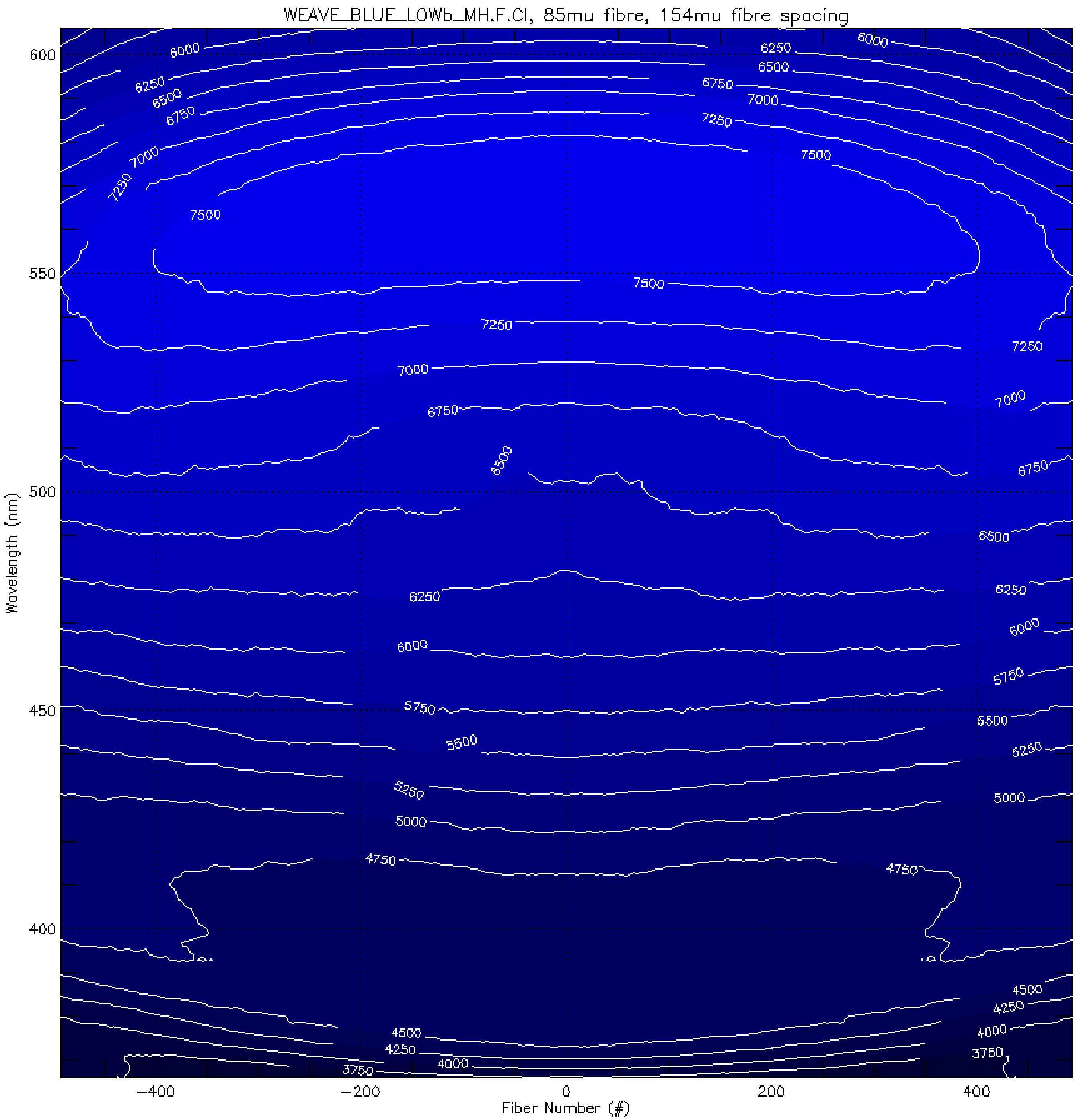


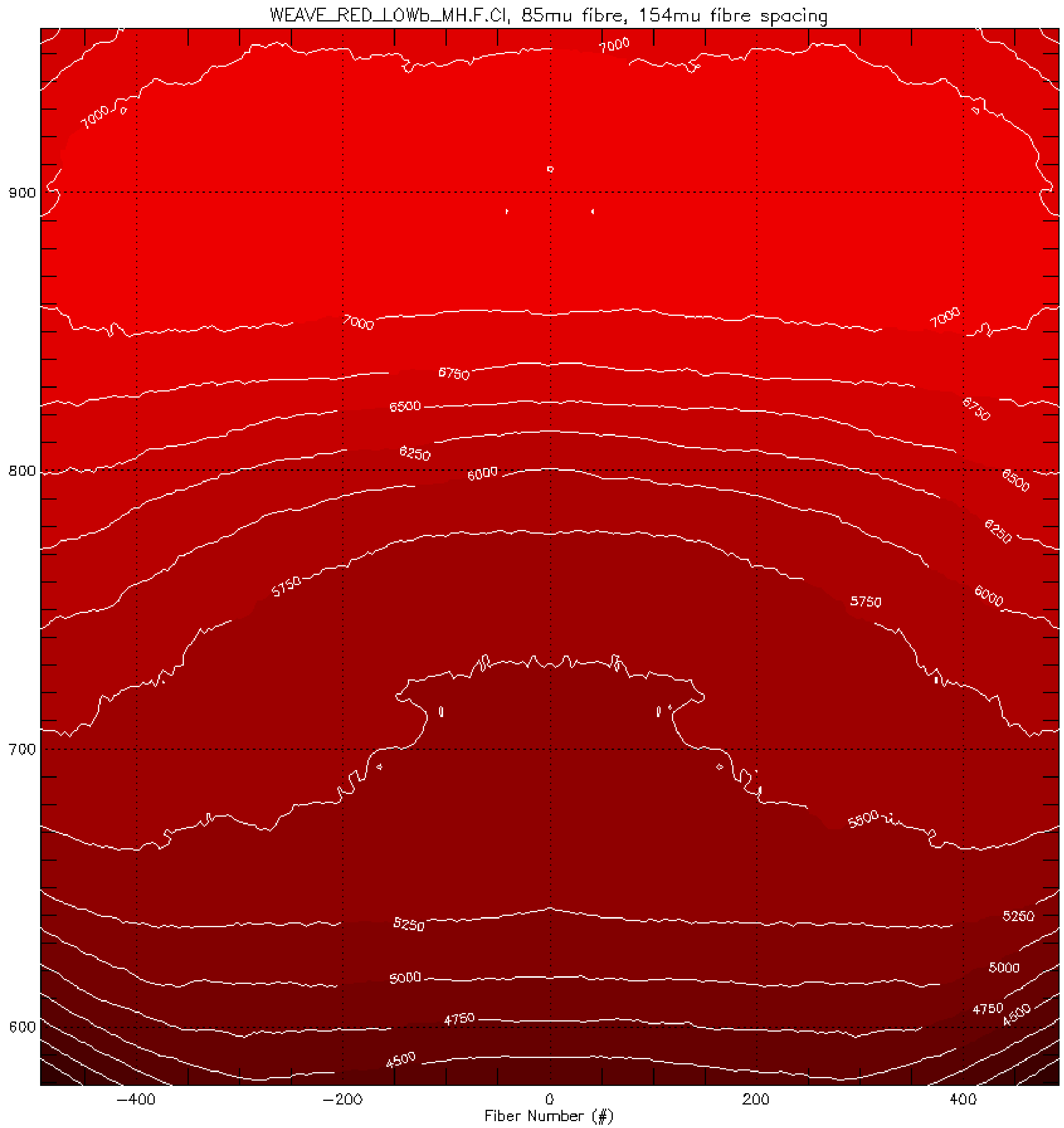
Posters 9147-232 & 242 tonight

Complete spectrograph located inside the GHRIL enclosure

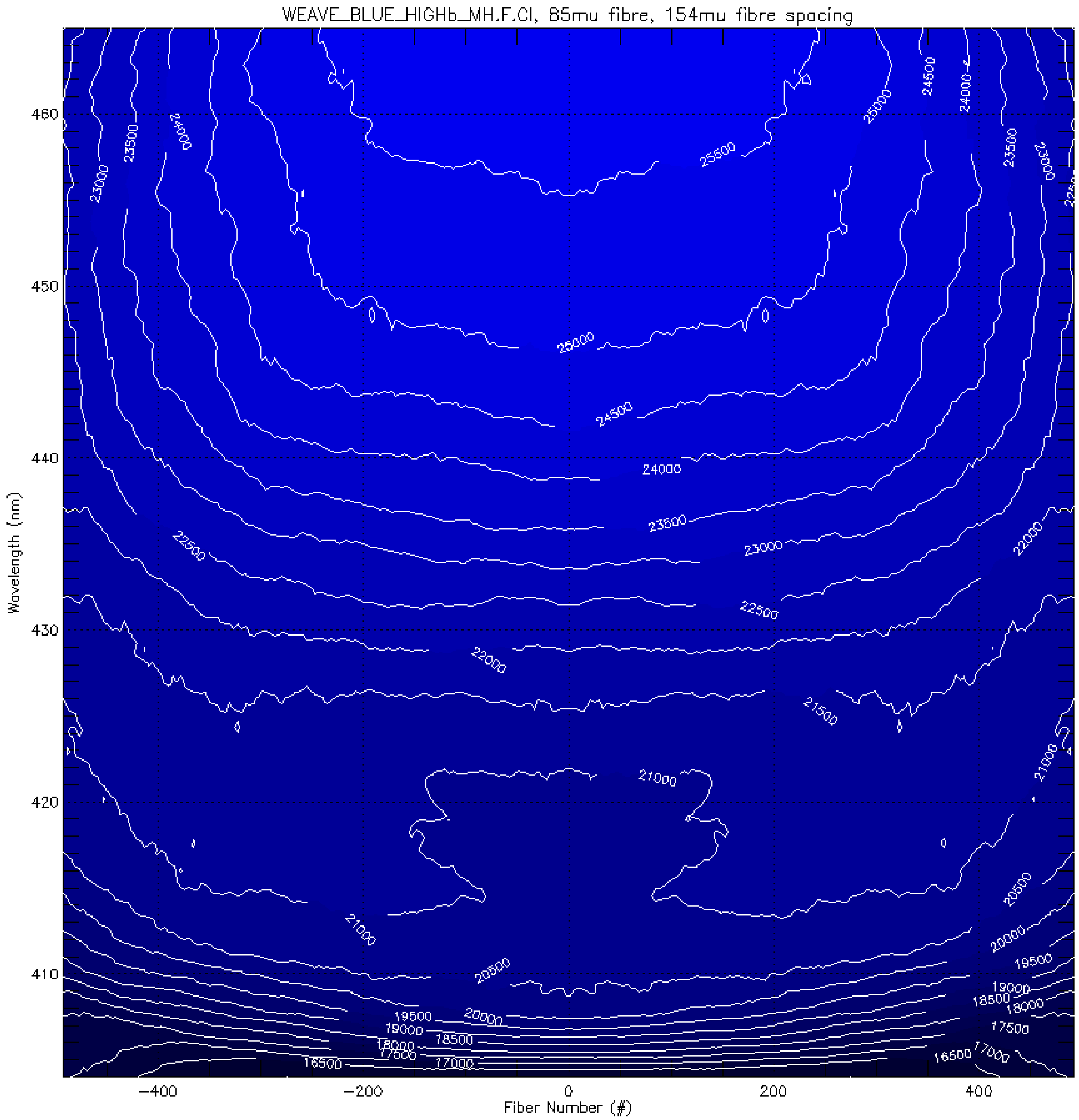


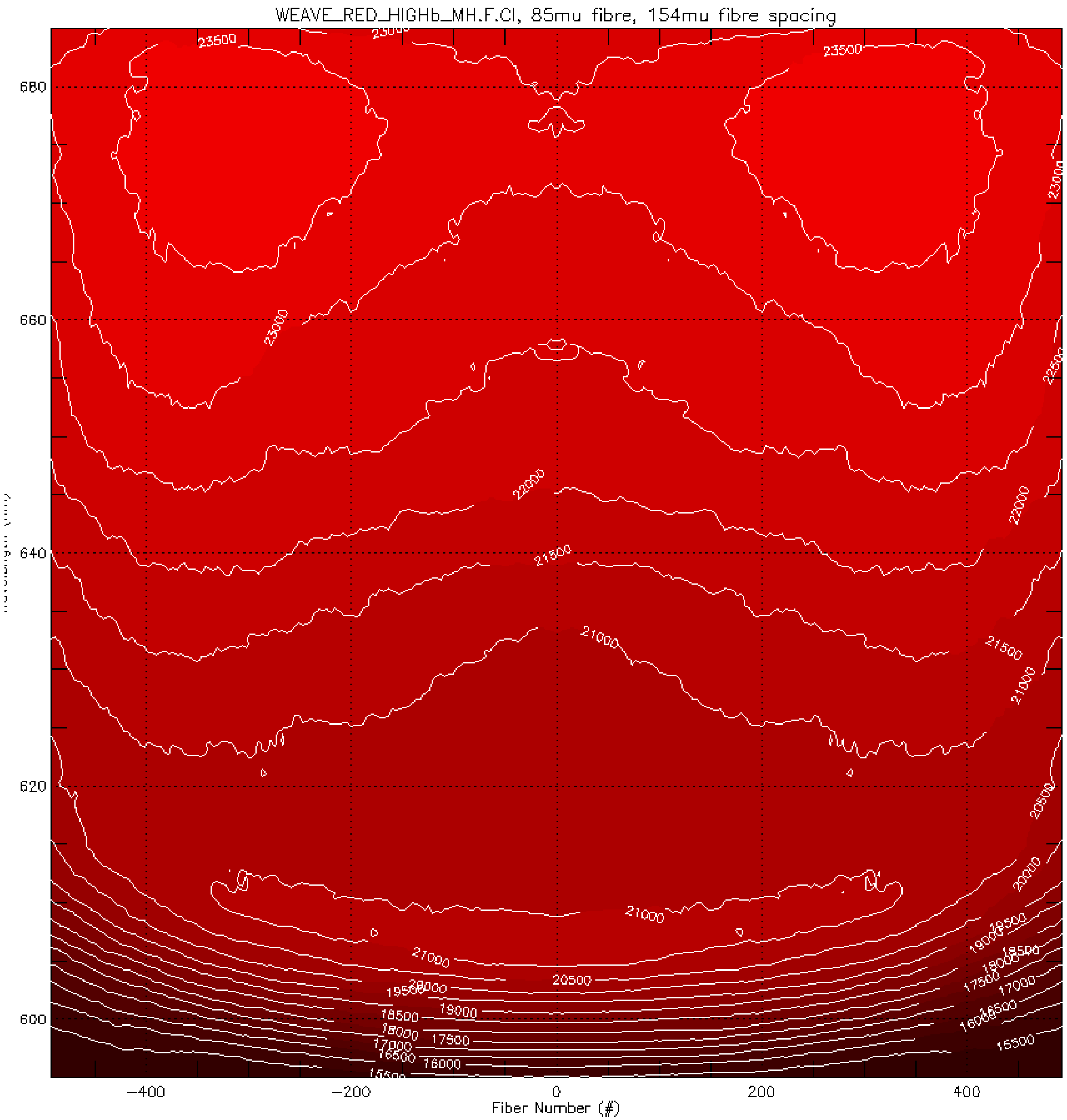
Detailed modelling of recovered resolution

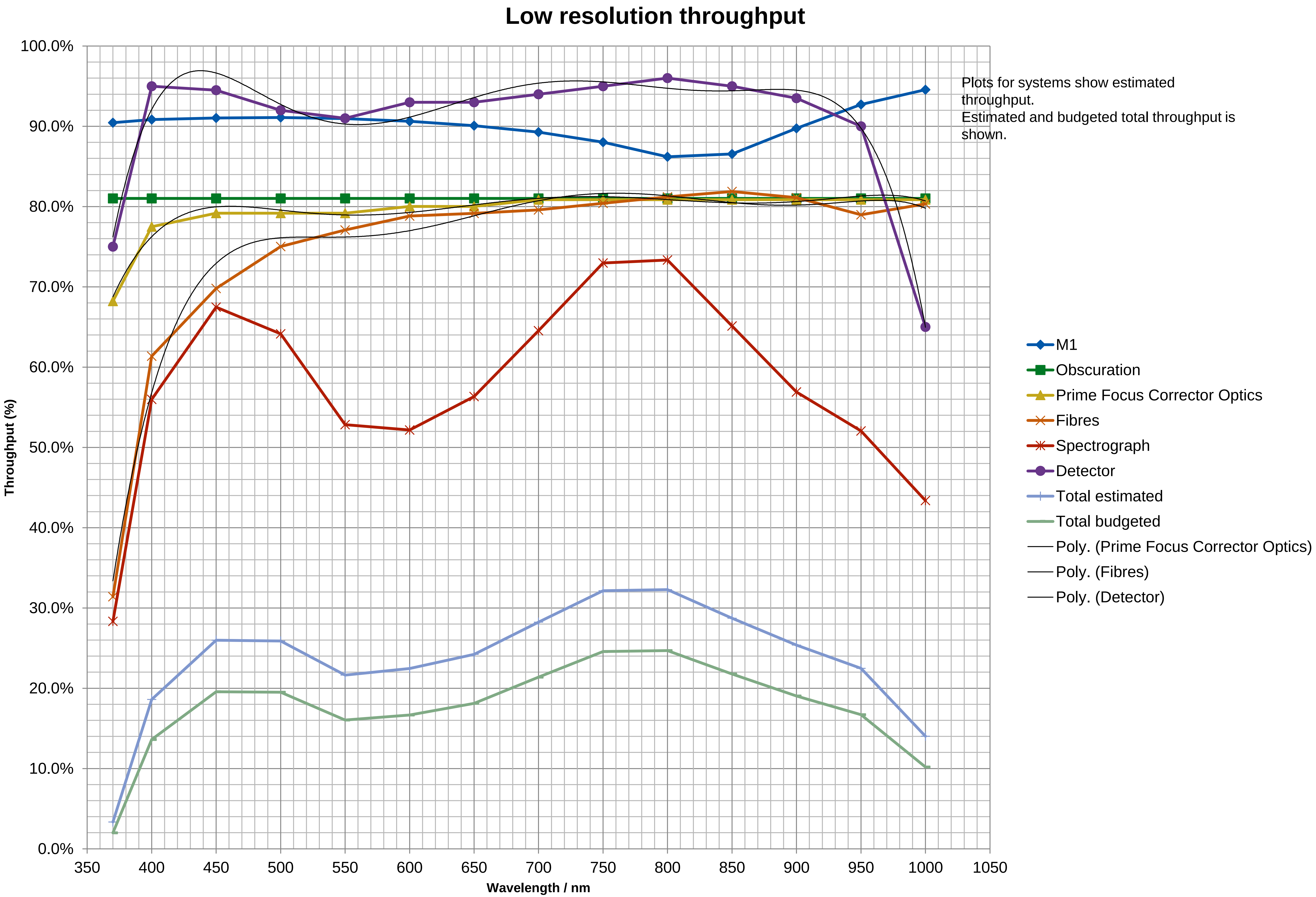




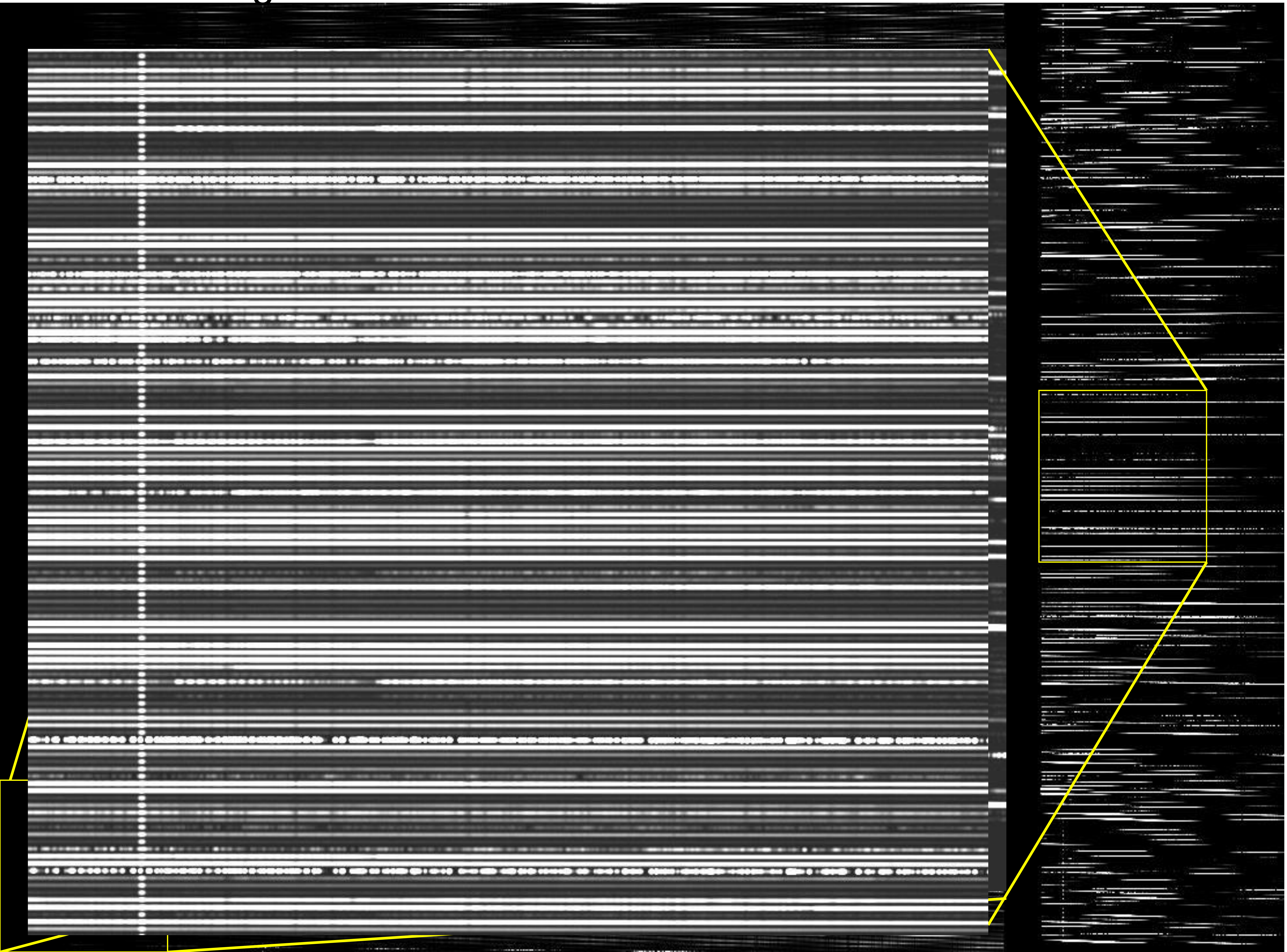
Detailed modelling of recovered resolution



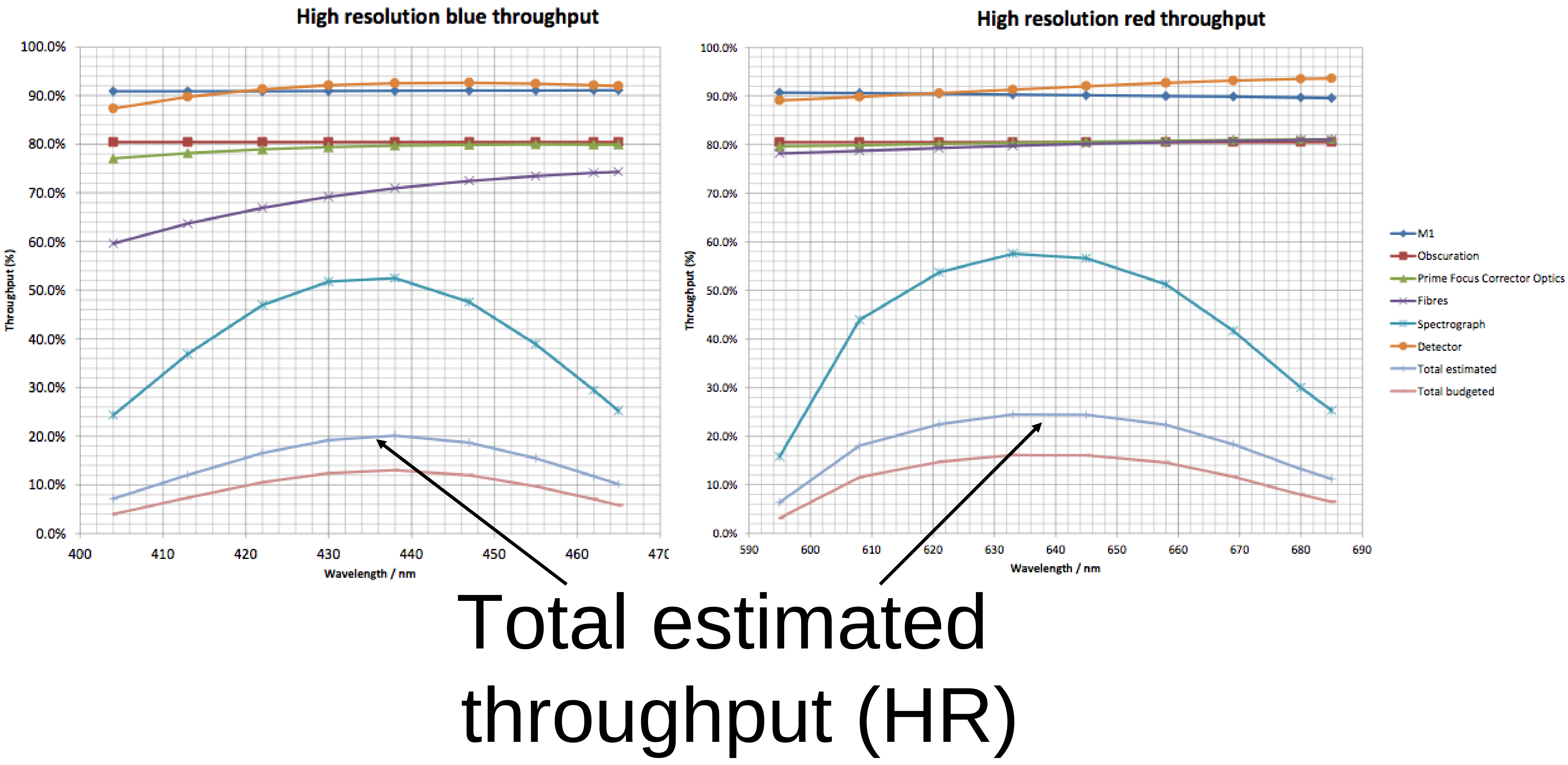



Low resolution throughput
Throughput (%)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
Wavelength / nm
Plots for systems show estimated throughput.
Estimated and budgeted total throughput is shown.
M1
Obscuration
Prime Focus Corrector Optics
Fibres
Spectrograph
Detector
Total estimated
Total budgeted
Poly. (Prime Focus Corrector Optics)
Poly. (Fibres)
Poly. (Detector)

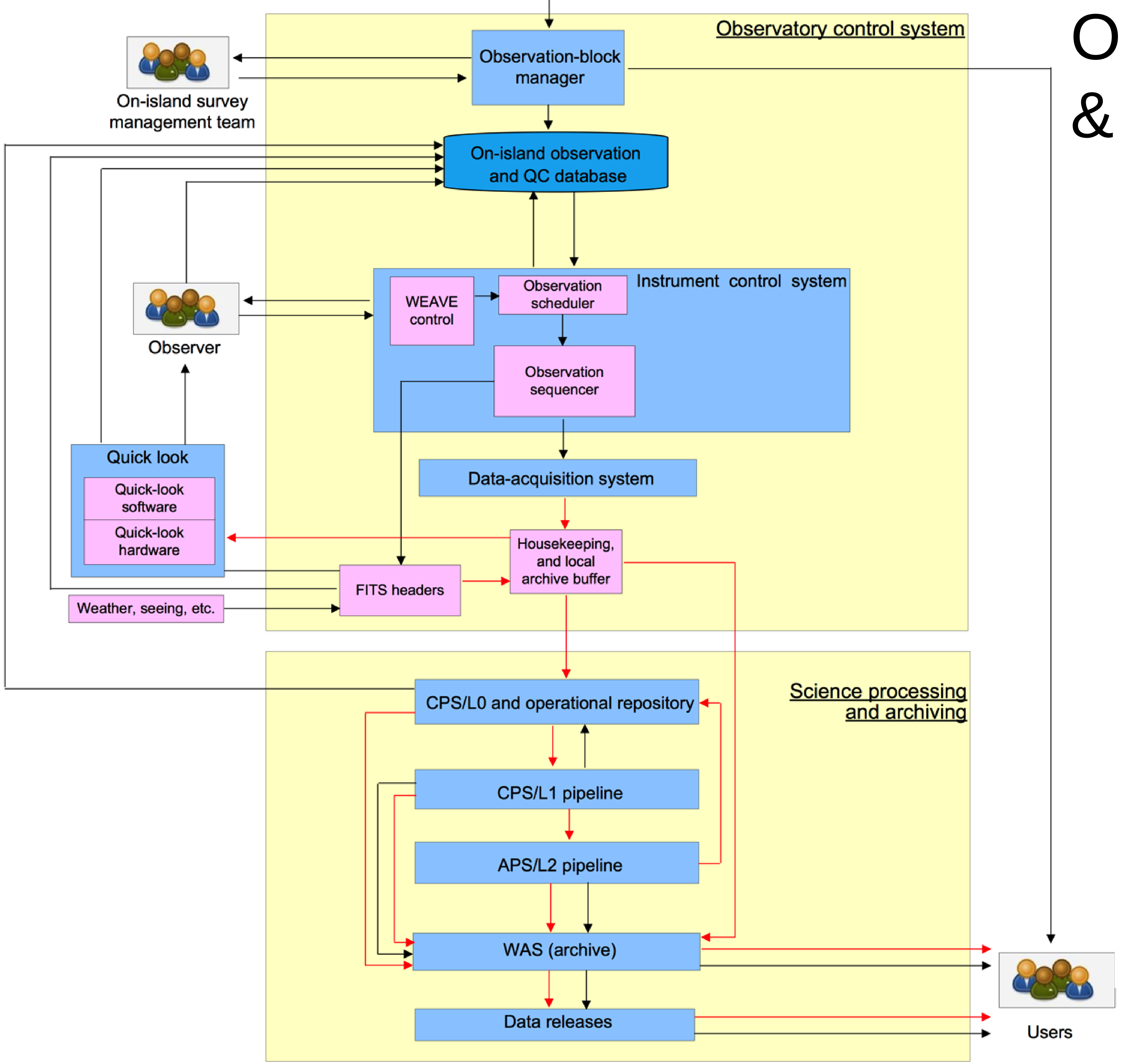
End-end image simulation - LR Blue camera



HR Throughput



Operations & Data Flow



Timeline

- Detailed survey strategy planning starts in May 2015
- Strategy review complete by November 2015
- Target lists to be ready <nominally> by end of 2016
- Construction complete: Q2/2017
- Assembly and integration at WHT complete: Q3/2017
- First light: Q4/2017
- Surveys begin: Q1/2018
    - Detailed survey planning from now to first light.
    - Initial survey programme for 5 years at 70% of total available nights