Widefield multi-object spectroscopy with the VLT

Mark Casali, Simon Ellis, Peter Gillingham, Andrew Hopkins, Will Saunders, Jon Lawrence (AAO)

Bernard Delabre (Airbus)

The New AAO: from 1 July 2018

AAO

Australia's Partnership for the Future

3 national nodes:

- Joint instrument calls
- Sharing of ideas, equipment, staff
- Coordination of expertise
- Unified national agenda
- 100+ available staff

AAO-Macquarie

MACQUARIE University

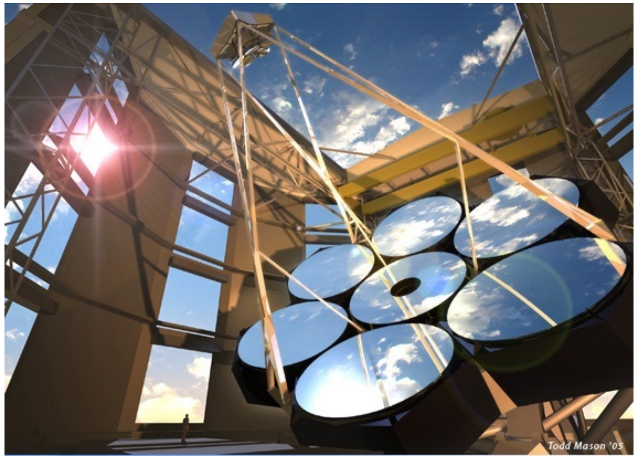
AAO-USydney

THE UNIVERSITY OF SYDNEY

AAO-Stromlo

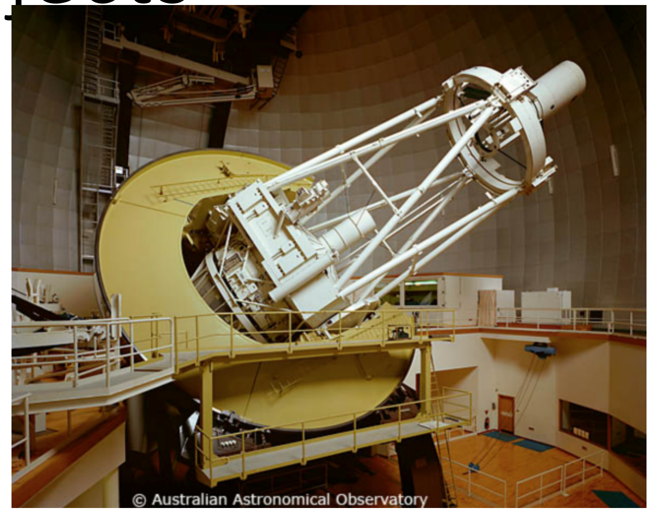
Australian National University

The AAO Consortium: Current Projects



GMT: GMTIFS, MANIFEST, Laser tomography

AST3: KISS



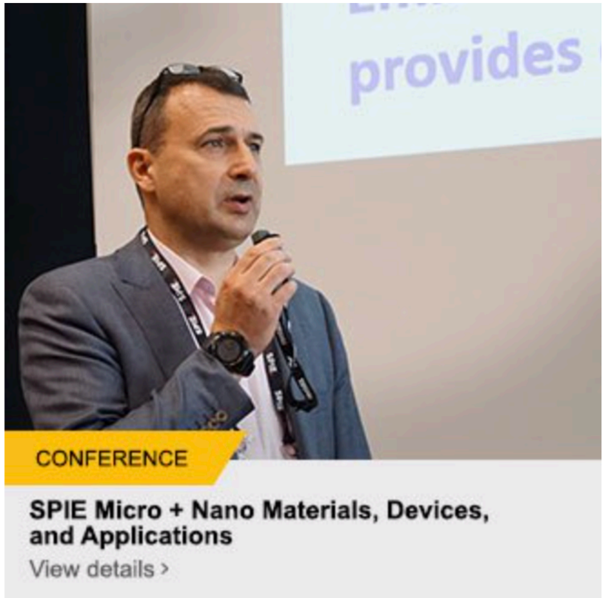
AAT: Hector, PRAXIS

Gemini: GHOST

VISTA&VLT: 4MOST, MAVIS

UKST: TAIPAN

Subaru: AO LGS, NBS



SPIE
ANZCOP

Melbourne
8-12 Dec 2019

Contact
Simon Ellis
simon.ellis@mq.edu.au

Large diameter High Multiplex Widefield spectroscopic facility

- ESO working group report (Ellis + 8)
- Canada Long Range Plan
- NOAO/LSST joint studies
- Australia Decadal Plan

A project has progressed as the Mauna Kea Spectroscopic Explorer (MSE: CFHT + Australia, China, India)

- Natural reference for 2030s

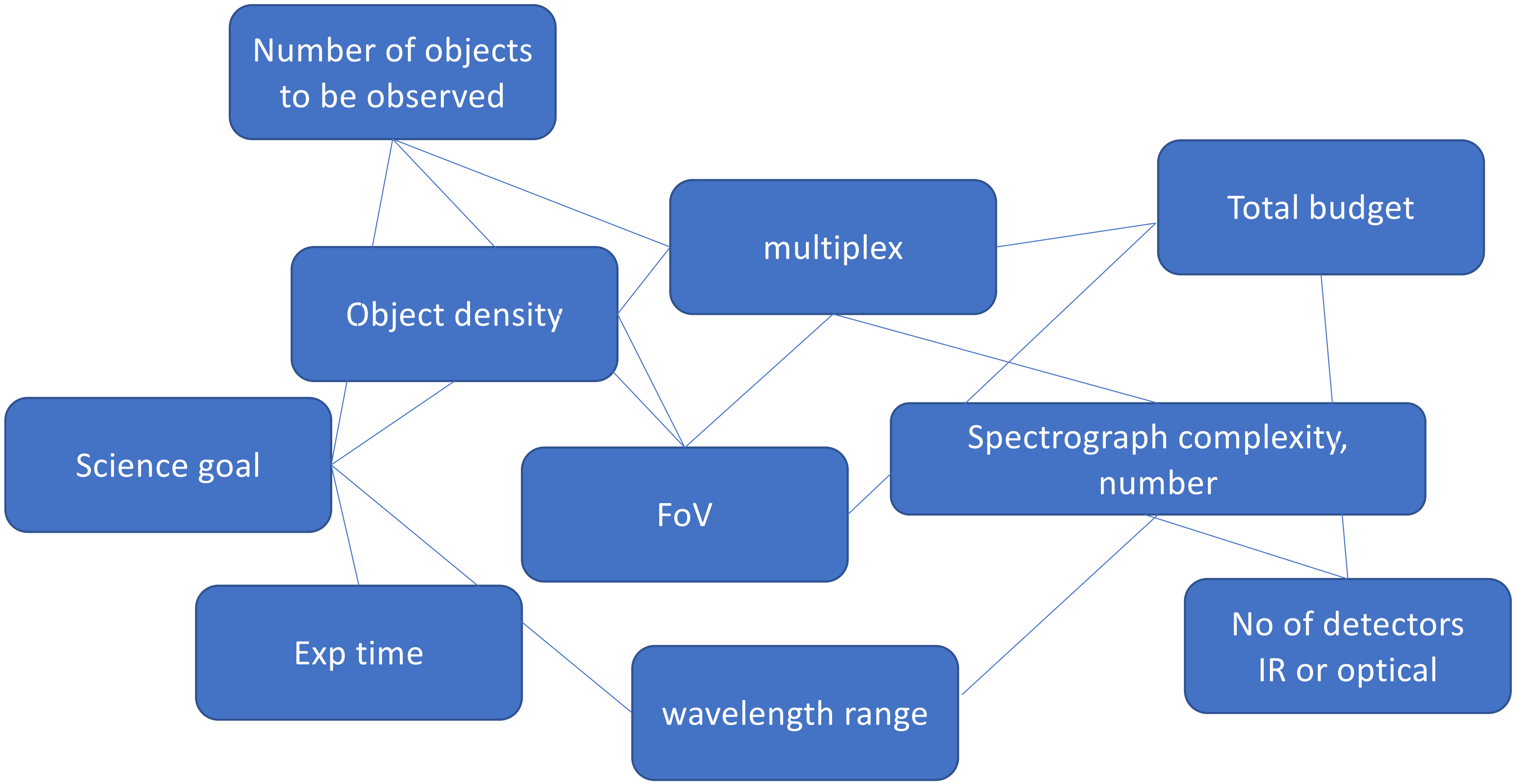
Spectroscopic survey science

Facility could address the same range of science as proposed by MSE, and potentially more.

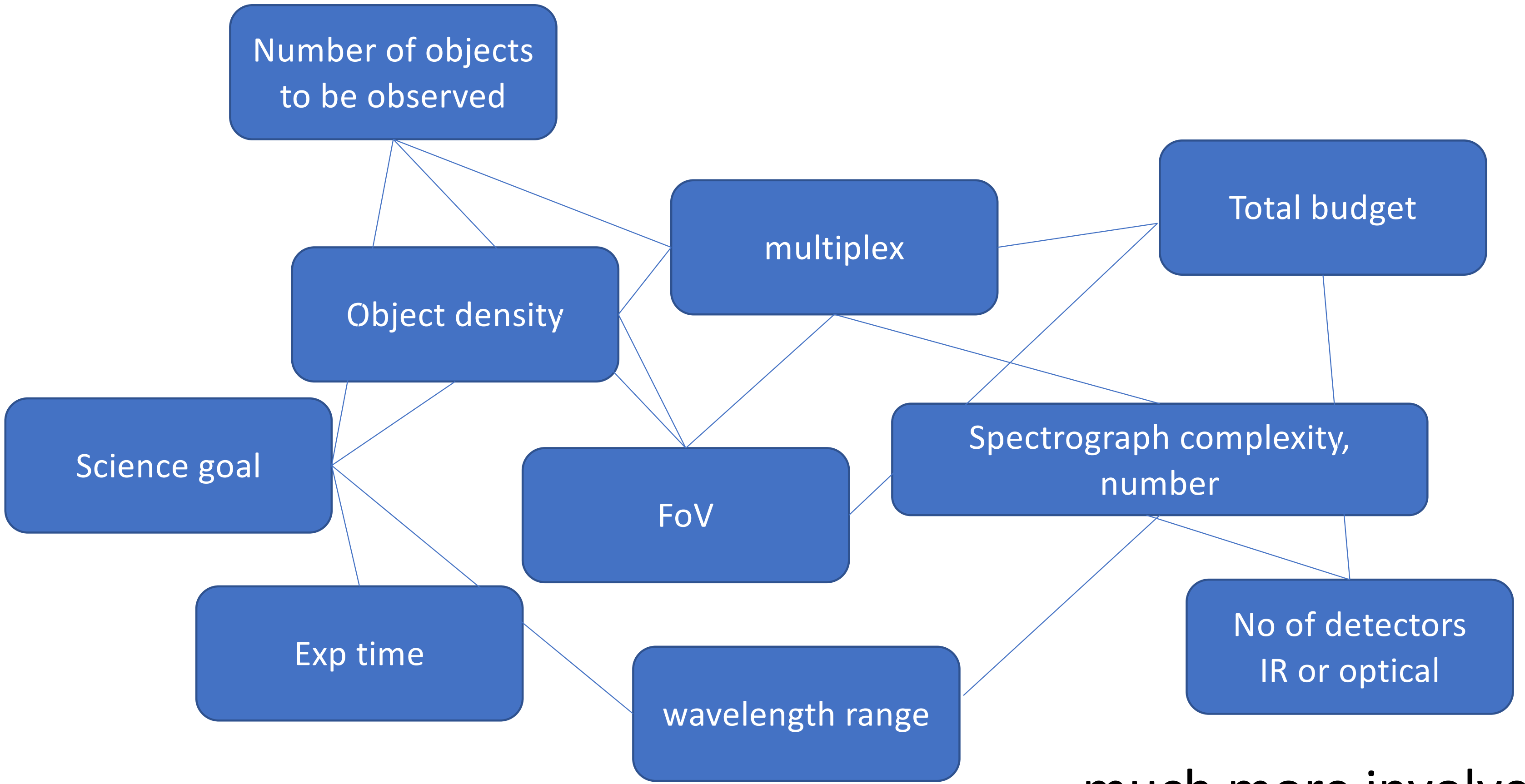
The MSE Science Case (arXiv:1904.04907, 300 pages) is extremely broad:

- Stellar astrophysics and exoplanets
- Chemical nucleosynthesis
- Milky Way and resolved stellar populations
- Astrophysical tests of dark matter
- Galaxy formation and evolution
- AGN and supermassive black holes
- Cosmology

MOS system analysis complexity



MOS system analysis complexity



…..much more involved than AΩ

Milky Way and resolved stellar populations

Goals include:

- Chemodynamical analysis of stars in all Galactic components [M].
- Definitive analysis of the metal-weak tail in the stellar halo [Ω].
- Chemodynamical measurements in Local Group dwarf galaxies (increasing by >10x number of stars for each system) [M/Ω].
- Full chemodynamical deconstruction of M31 and M33 across their entire spatial extent [M/Ω].
- 3D ISM mapping [M/Ω].

Galaxy formation and evolution

Goals are incredibly broad, spanning star formation/stellar assembly histories, to AGN coevolution, to properties of dwarf and giant galaxies at key redshifts. Some specifics:

- SDSS-like survey spanning $1<z<3$, with all associated science capability [M].
- Local universe wide-field survey, pushing mass function below $10^8 M_\odot$ [M/Ω].
- Large scale structure, halo-occupation, groups/clusters and low-density environments [M/Ω].

AGN and SMBHs

Goals include:

- Reverberation mapping to give 2000-3000 time lags, for >10x larger sample of BH masses than current campaigns [Ω].
- Large statistical samples of SMBH hosts spanning $0<z<3$, plus identification/confirmation of large sample of high-z ($z>7.5$) quasars [Ω].
- Measure cosmological density of galaxies hosting binary SMBHs, constraining rate of SMBH mergers [Ω]
- Understand AGN evolution, explaining trend from efficient accretion at high-z to low-efficiency at low-z [M/Ω].

Cosmology

Goals include:

- Discriminating between normal and inverted neutrino mass hierarchy, from tight limits on the summed mass constraint [M/Ω].
- Measuring the level of primordial non-Gaussianity, using power spectrum and bispectrum constraints to test slow-roll models [M/Ω].
- Resolving tension in Hubble parameter between measurements using SN and CMB+galaxy surveys, pushing consistency tests to redshifts where there are no current constraints [M/Ω].

Options for the ESO

- Don't participate in 8-12m widefield spectroscopic science
  - Impact on astrophysics
- Build a new telescope/instrument facility
- Participate in the MSE or other project
  - ESO funds could make it happen, but telescope = industrial procurement = full cash cost. Instrument = modest cash + GTO
- Modify an existing facility
  - 4MOST with VISTA – 2nd generation facility
  - Use one (or more) UTs – third generation facility. Idea already suggested 10 years ago at VLT conference.

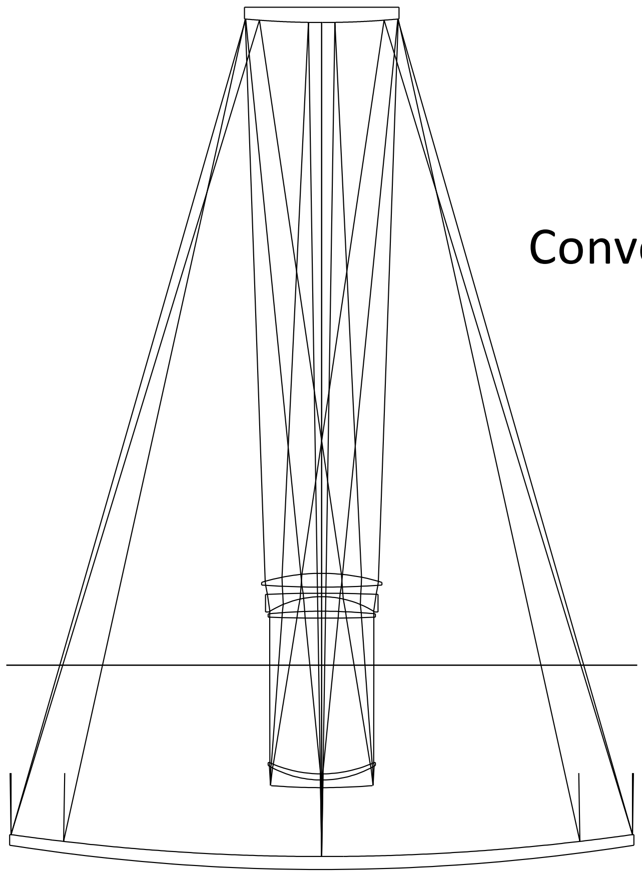
Questions

- Can a competitive field of view and multiplex be achieved on a UT ?
- What happens to the UT use in VLTI?
- How can such a facility be funded given ESO constraints until 2030?
- For a later first light (2035), what are the key science problems which should drive its capabilities?

Current Investigation

- Patchwork of ideas and investigations to clarify feasibility put together over 4 weeks
- Requirement on keeping VLTI capability in a modified UT
  - Major constraint
- AAO team closely involved with MSE

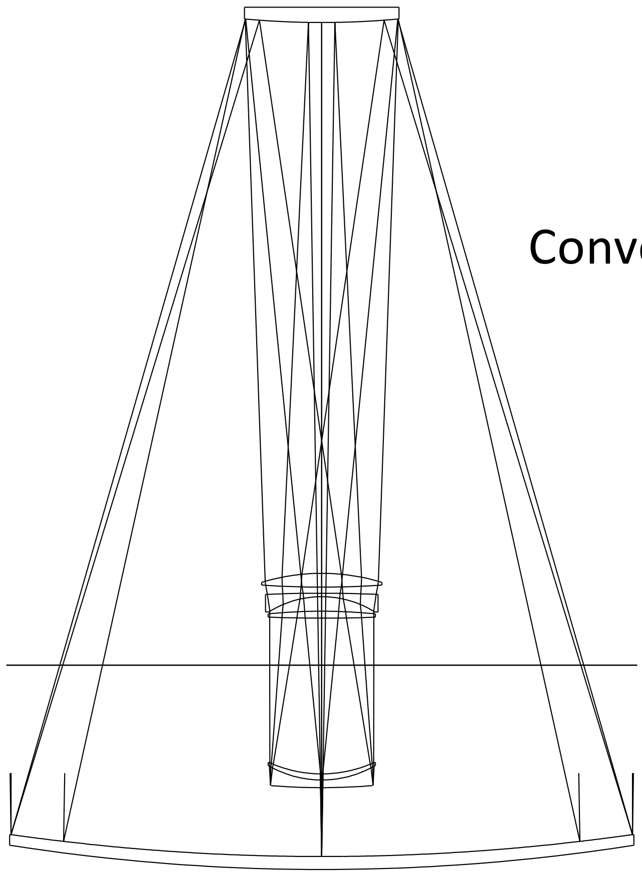
1.82 deg Option (2.6 sq.deg. 1.7xMSE)



New M2
2m diameter

Conventional M1, M2 + corrector.

1.82 deg Option (2.6 sq.deg. 1.7xMSE)

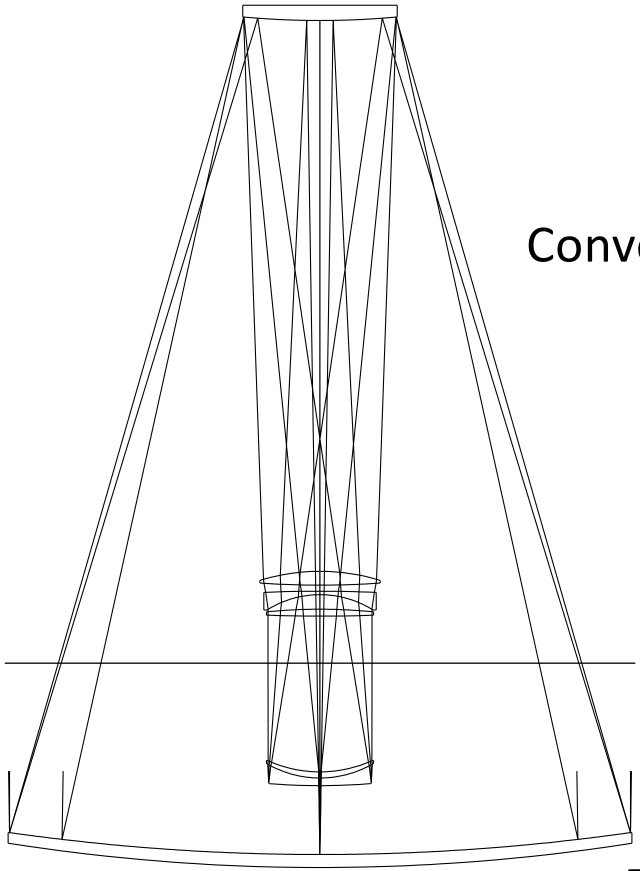


New M2
2m diameter

Conventional M1, M2 + corrector.

- Few true widefield telescope optical designs (Schmidt)
- Others are f-ratio + corrector (4m history, F changes)
- Same as MSE shortlisted architecture

1.82 deg Option (2.6 sq.deg. 1.7xMSE)



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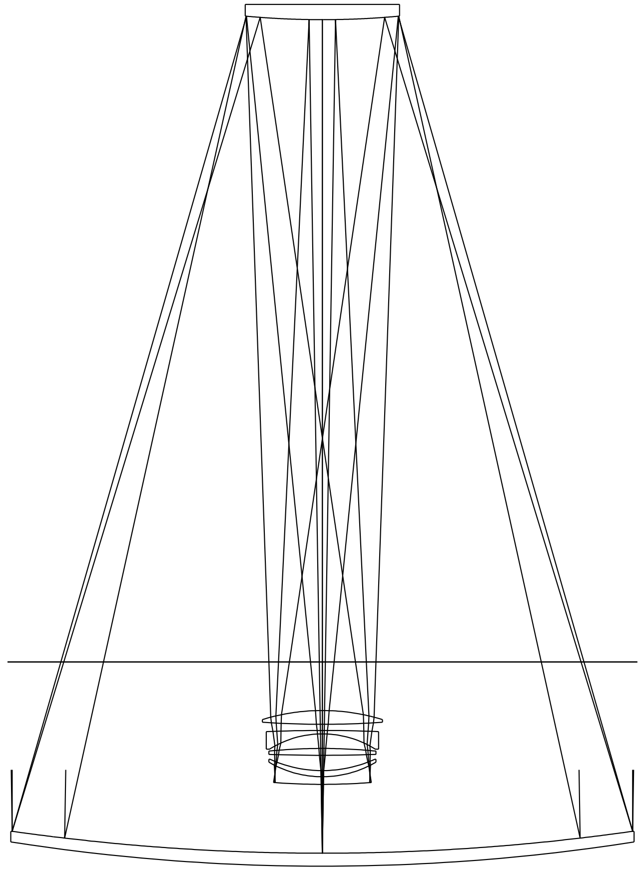


Corrector retracted
Fiber positioner does not move

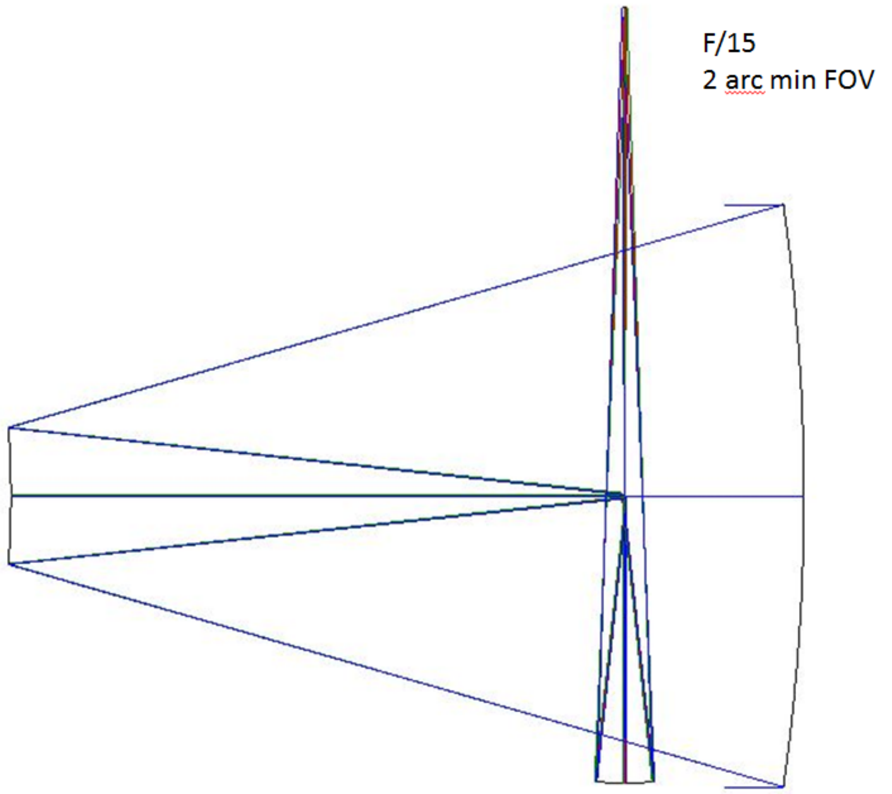
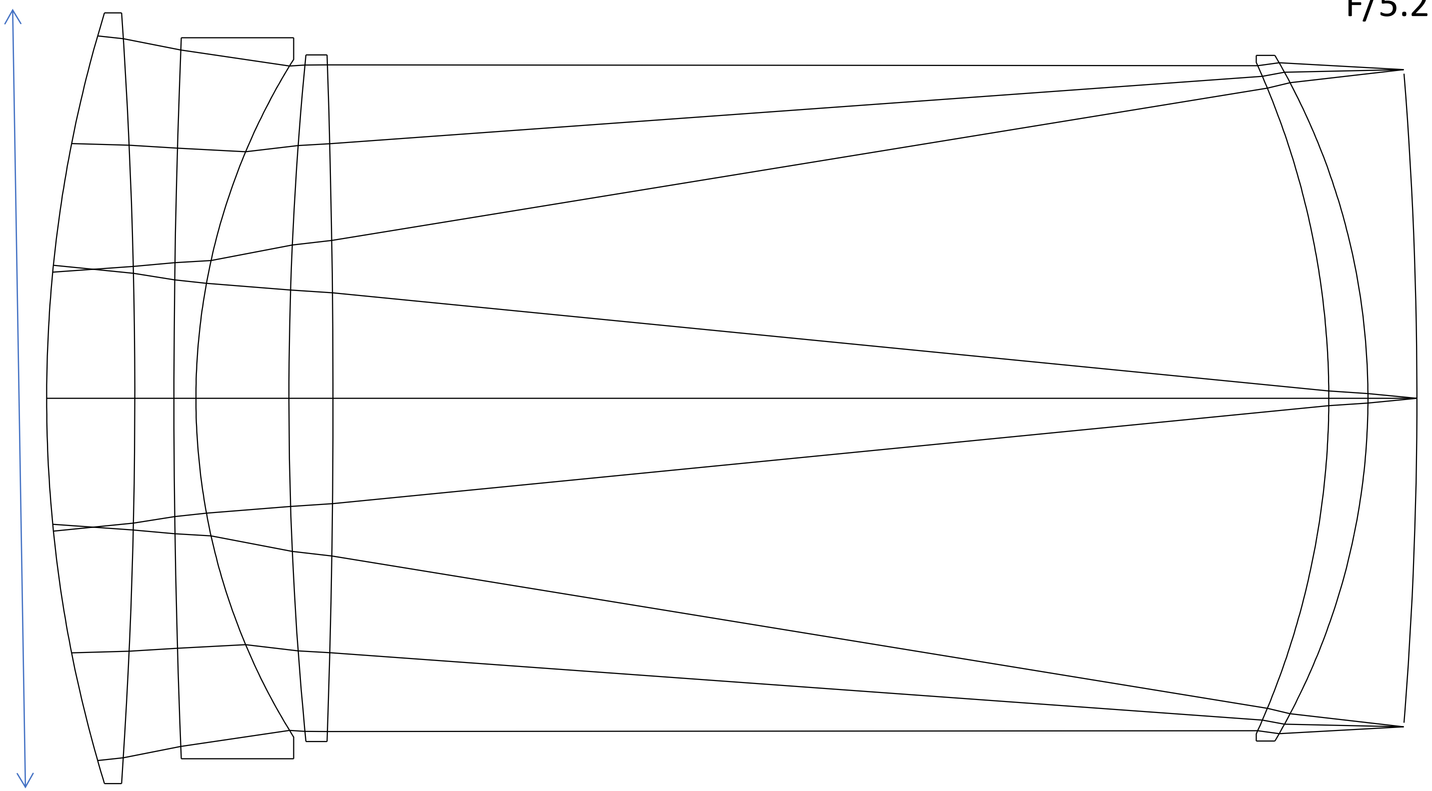


Figure. Bernard's figure showing the alternative light path to the Nasmyth focus and coude feed for interferometry. It requires that any WFC component above the elevation axis be moved.

Field of view : 1.82^{o} diameter

F/5.2

1550 mm



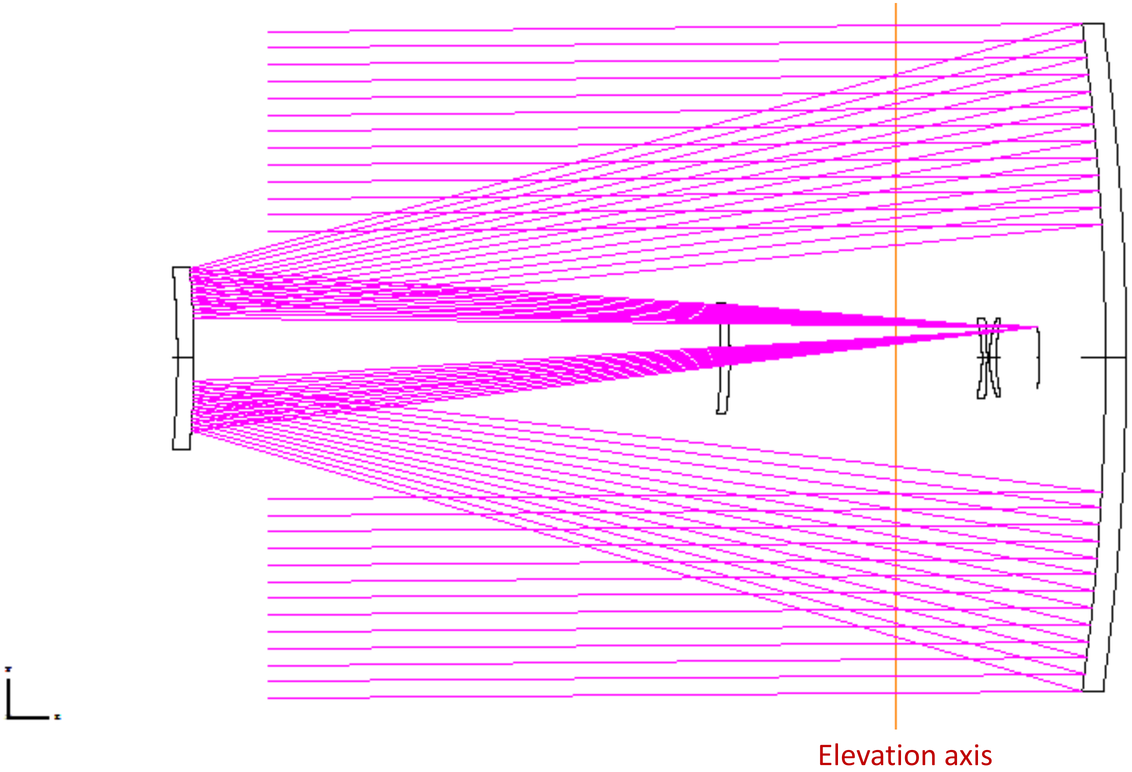
CORRECTOR (including ADC)

Single material : Fused Silica

All surfaces are spherical

1 deg option

Figure. Ray trace at edge of field for ADC at zenith setting. The outside diameters of M2, L1, L2, and L3 are 2194, 1334, 956, and 944 mm respectively with 25 mm radial allowances for cells and the field diameter is 736 mm. The vertex of the focal surface, which has a radius of curvature of 10.51 m, is 800 mm ahead of the M1 vertex. The three WFC elements, from left to right, weigh 327, 130, and 98 kg.
The final focal ratio is ~f/5.24.



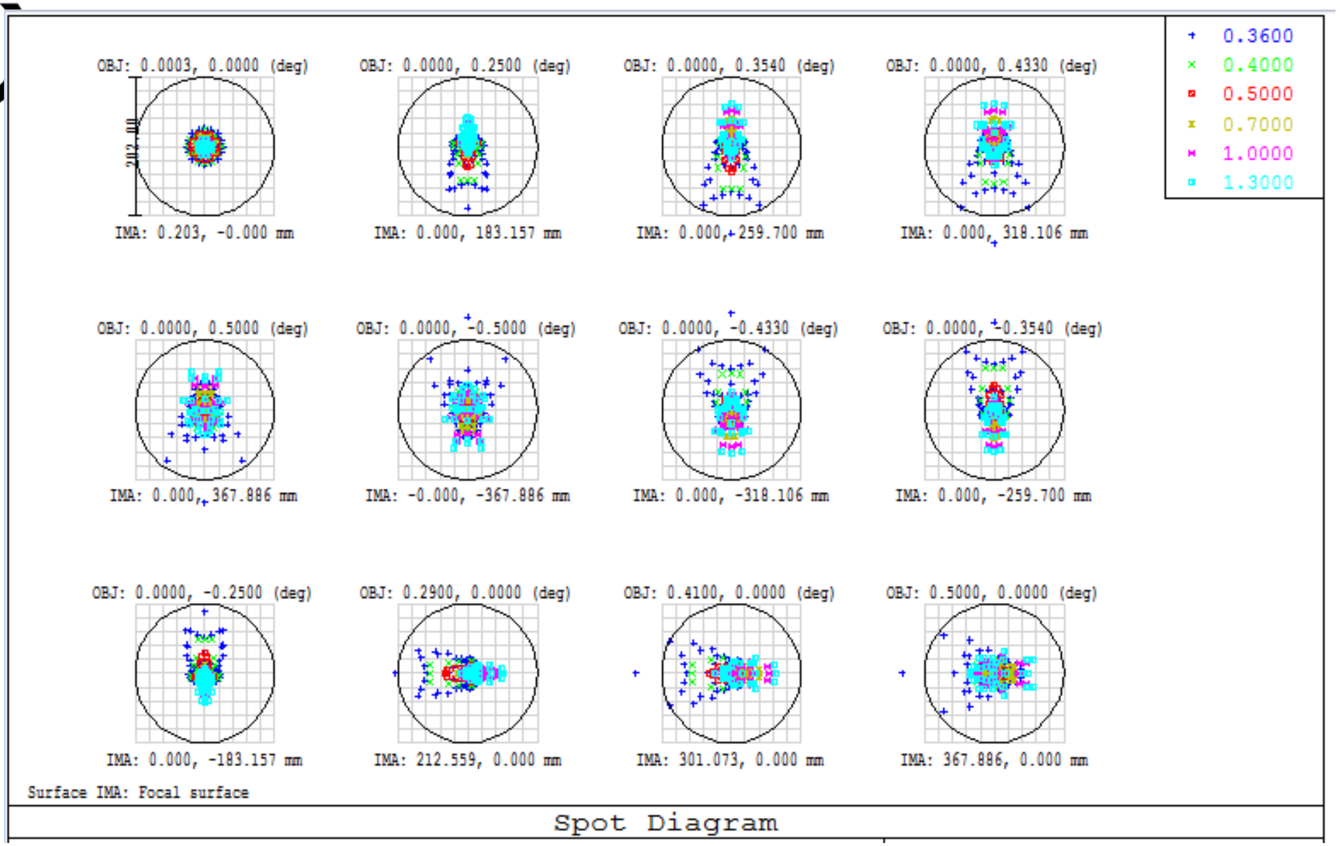


Figure. Spot diagrams for ZD 0. The circle diameters are equivalent to 1 arcsec.

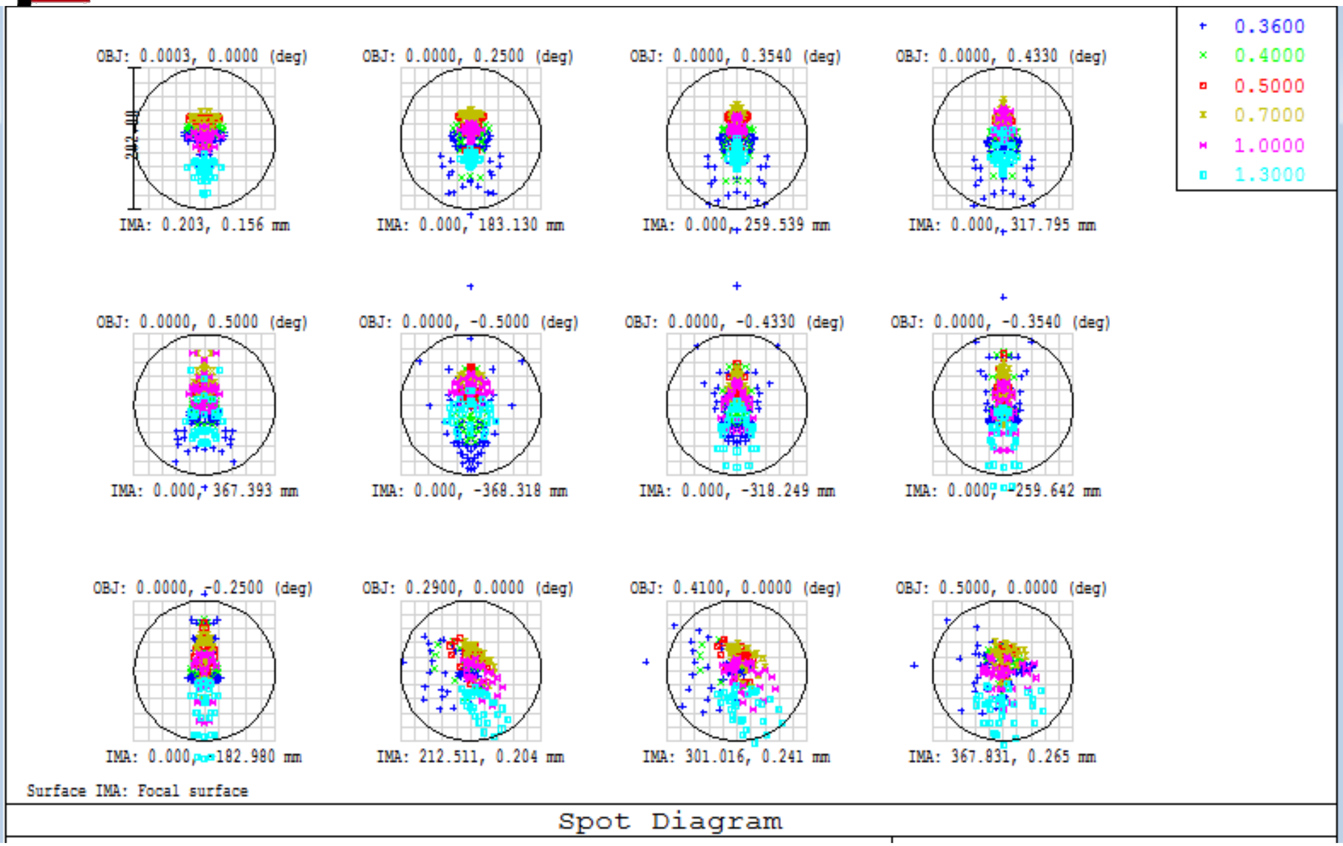


Figure. Spot diagrams for ZD 55^o with ADC correction. . The circle diameters are equivalent to 1 arcsec.

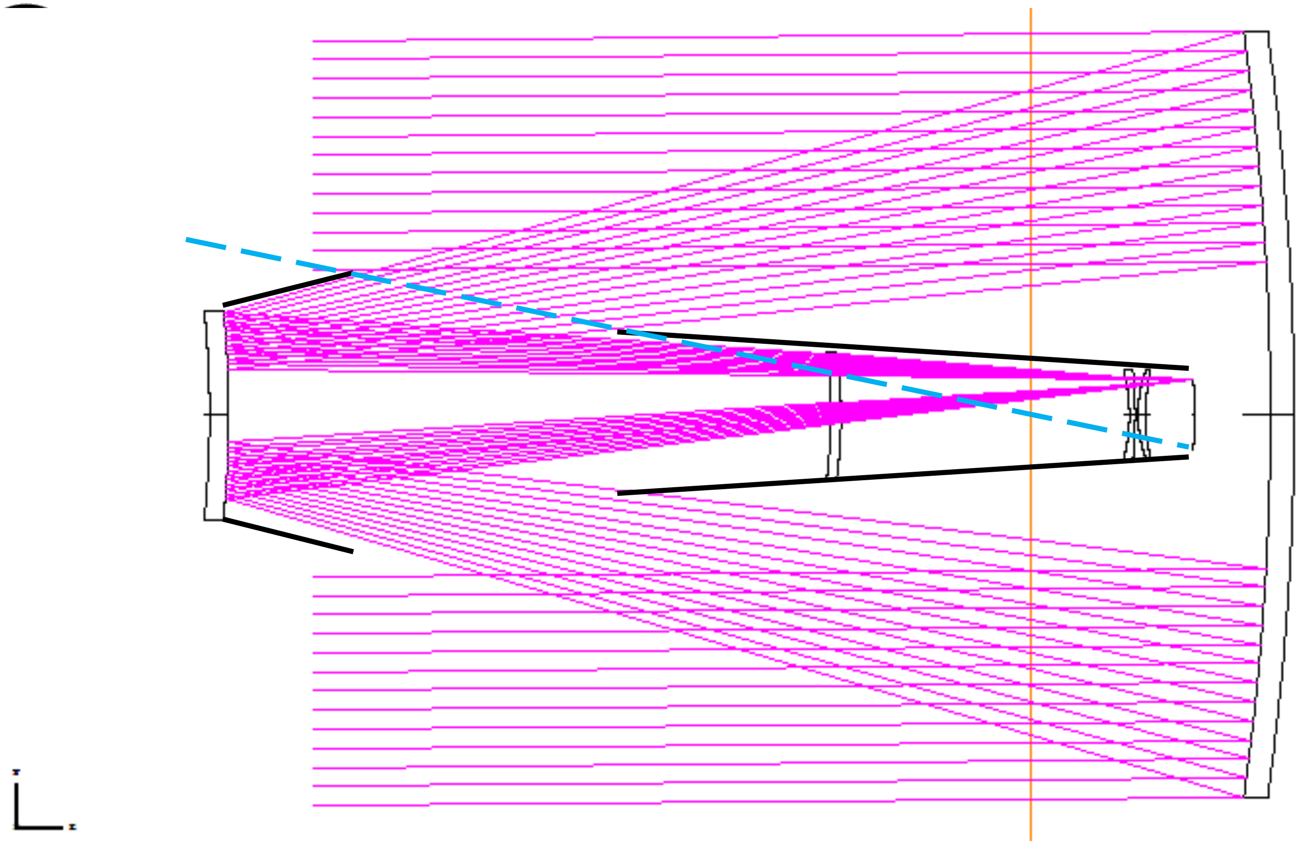
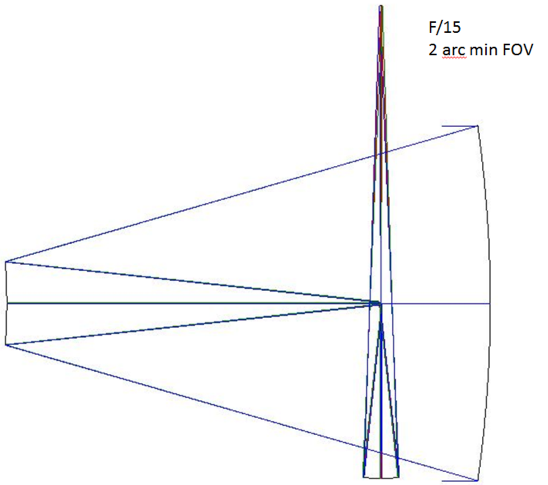
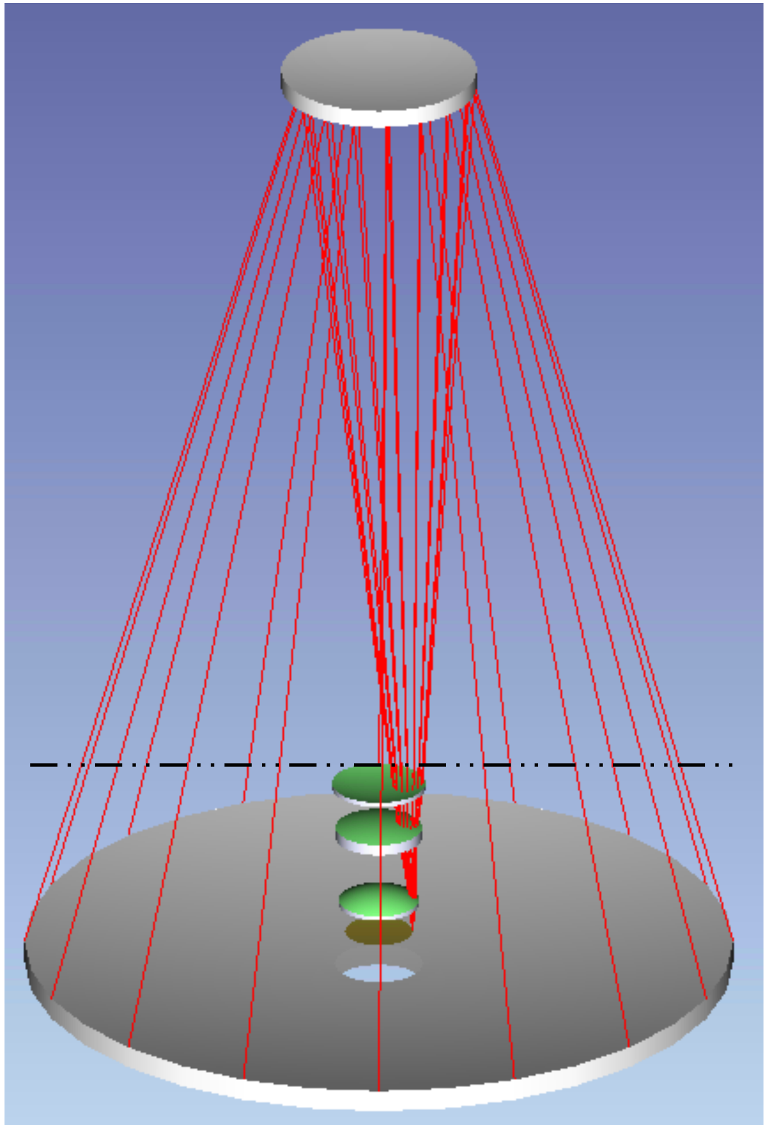


Figure 9. Rough illustration of how the focal surface could be shielded from extraneous radiation with baffles at the secondary and at the WFC.

Static corrector option

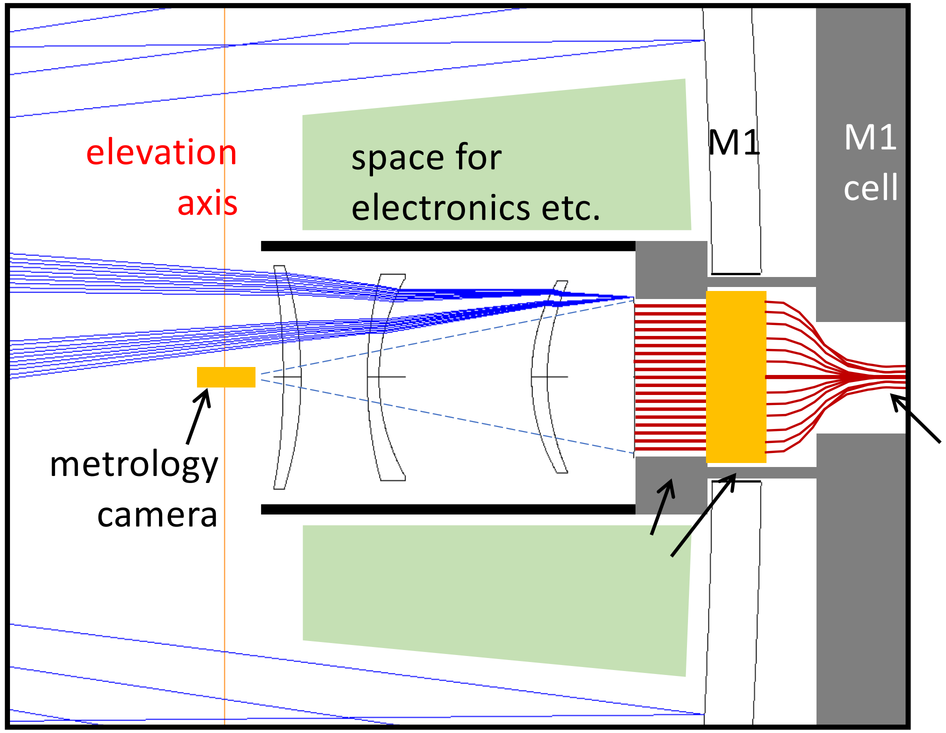




Instrument concept

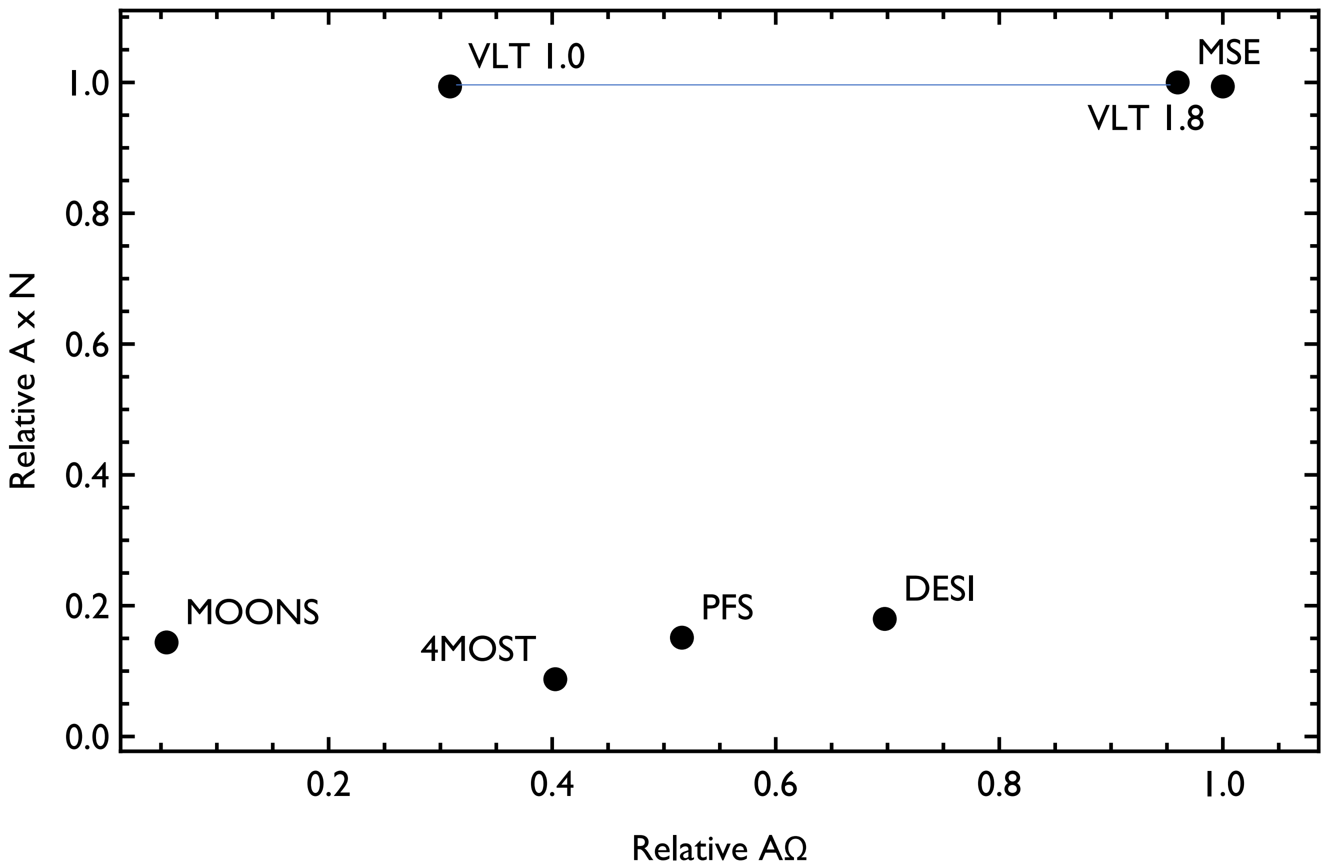
Rough layout of 7000 fibre positioner with spines ~400 mm long, 1 m dia. hole in M1 and 0.5 m hole in its cell.

For the VLTI option, a small 45° mirror replaces the metrology camera.



Or something else entirely, eg. IFUs !

VLT widefield performance

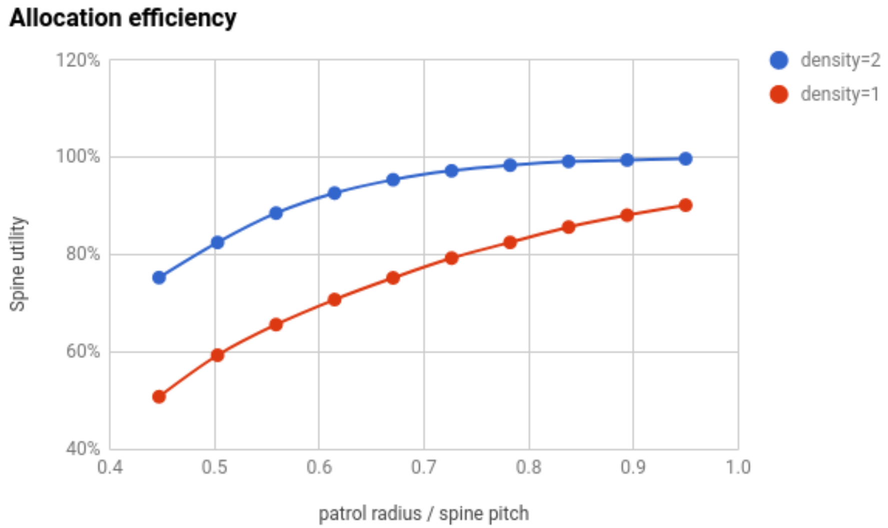


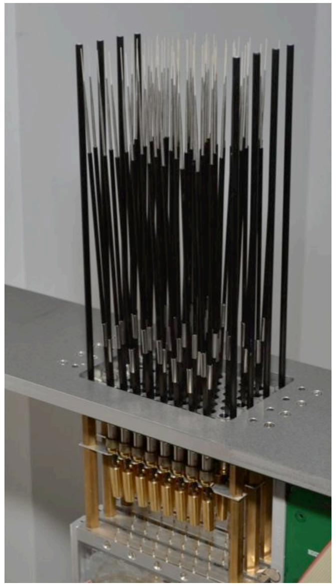
New technologies for performance

- Conventional instrument project approach unsuitable
- Long timescale to facility completion invites an aggressive programme of focussed technology development to maximise performance/cost before any trade-offs and final specifications developed.

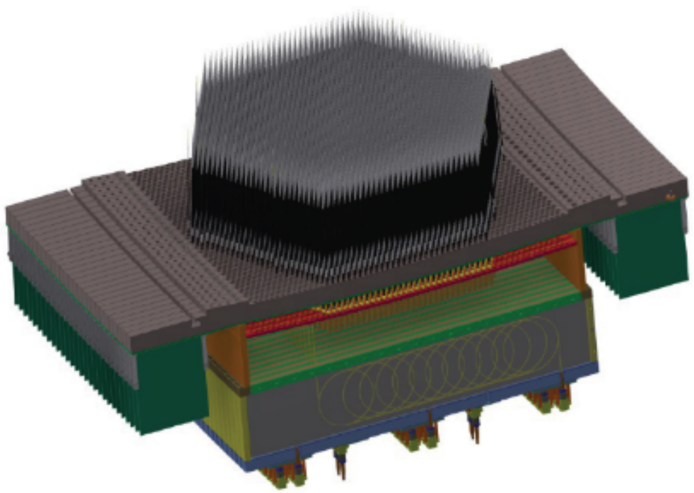
Fibre positioners

- "Echidna" spines
- Patrol radius of 10 mm = 48 arcsec
- Approx 10% more efficient coverage than theta-phi



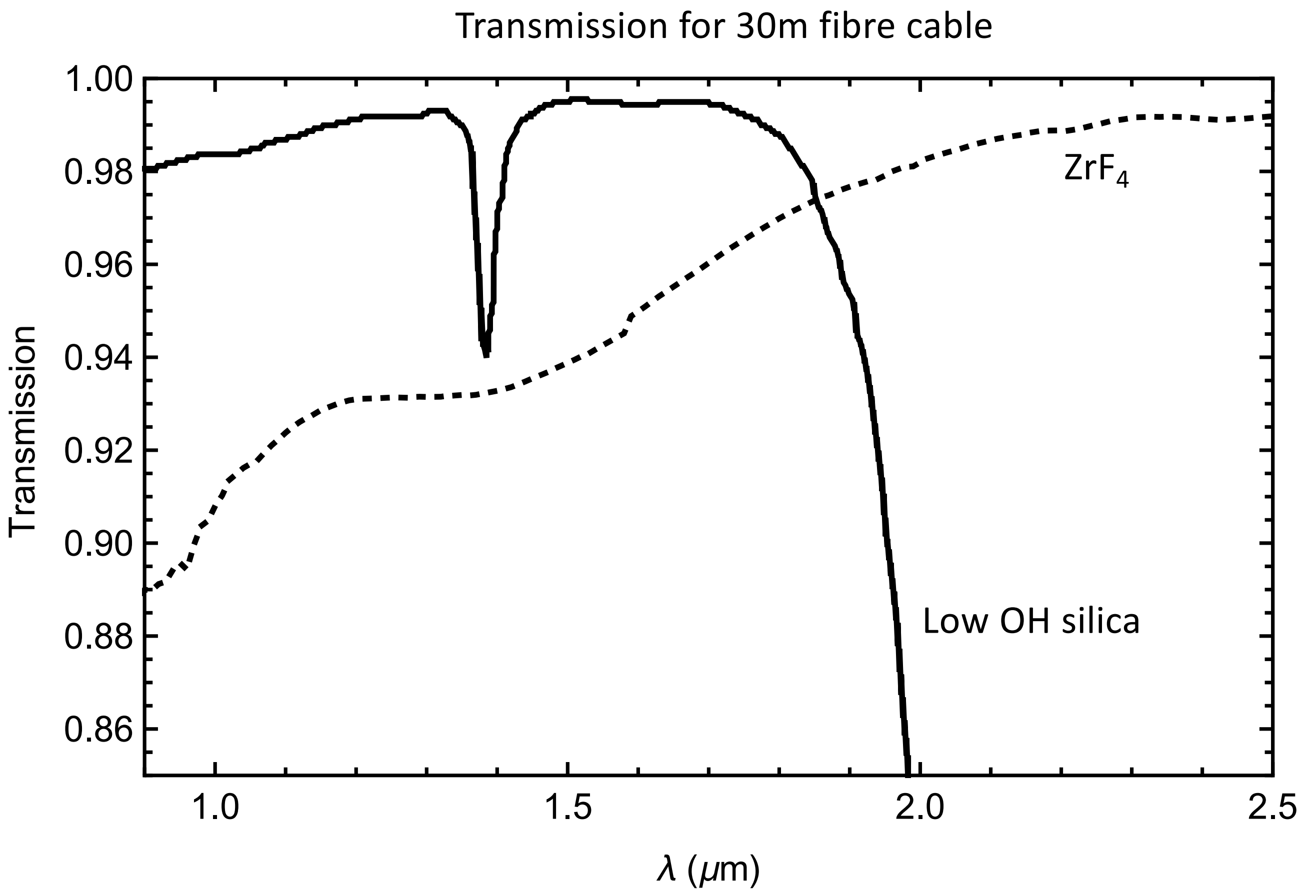


4MOST positioner

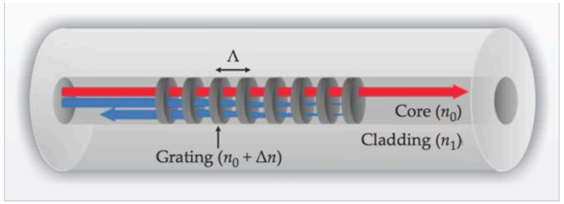


ZBLAN fibres

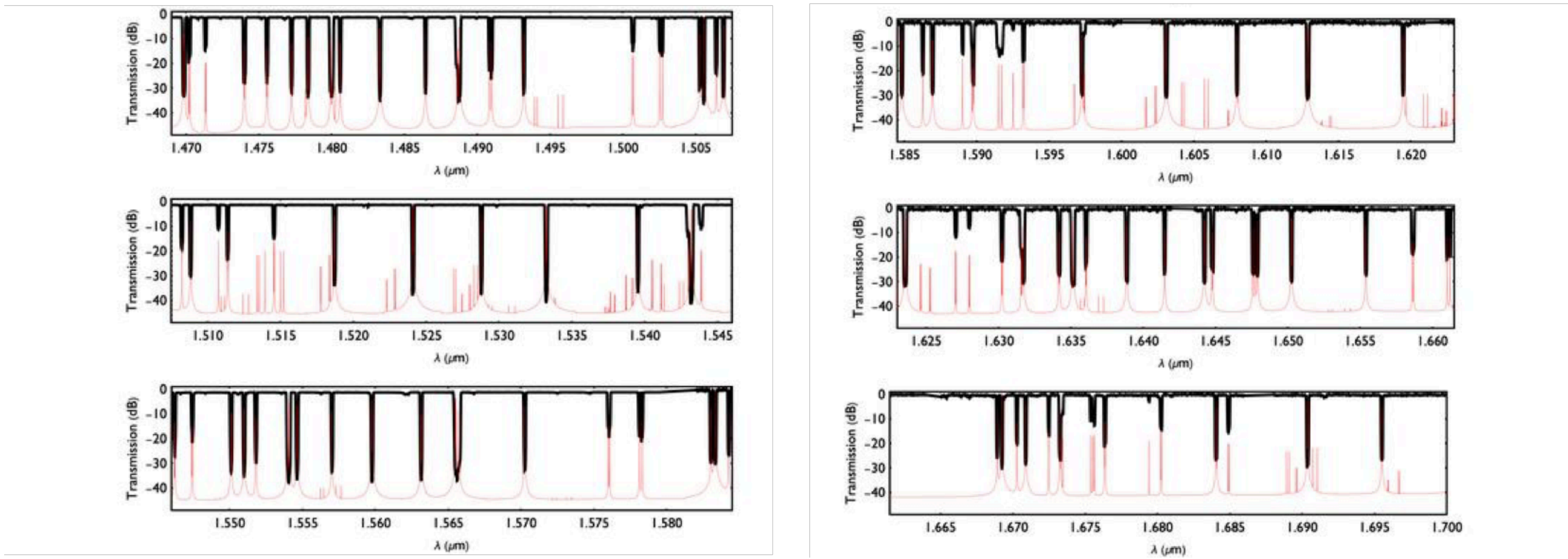
- Flouride (ZBLAN fibre is now available with excellent transmission
- Used by Spirou, OHANA and GRAVITY
- Further tests on FRD and polishing necessary



OH suppression using Fibre-bragg gratings



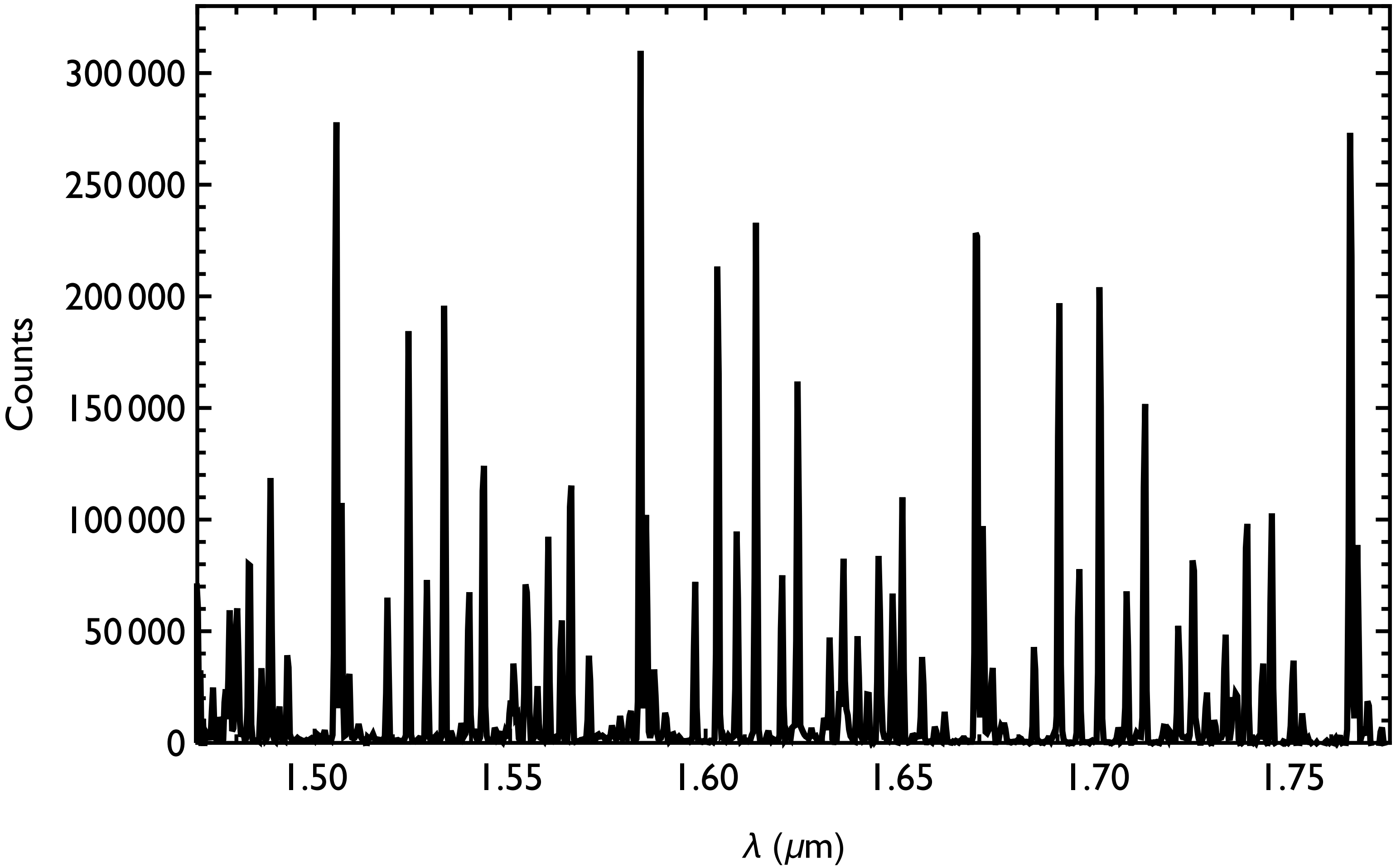
- has been tested on AAT
- See poster by Simon Ellis



Transmission of FBGs – filters 103 brightest OH doublets between 1.47 – 1.7µm by ~30 dB

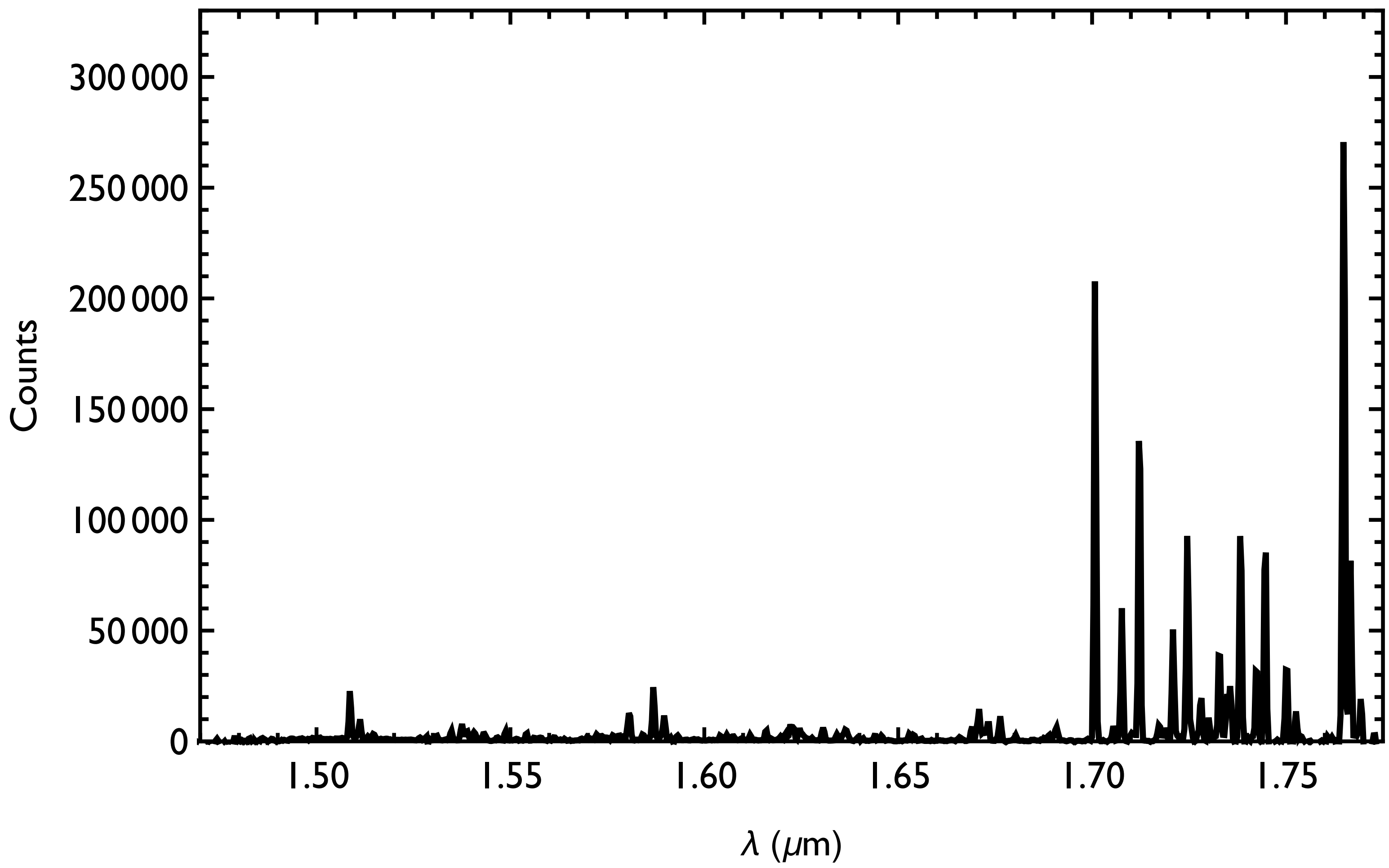
OH suppression

- has been tested on AAT
- See poster by Simon Ellis



OH suppression

- has been tested on AAT
- See poster by Simon Ellis
- Background reduced by x9

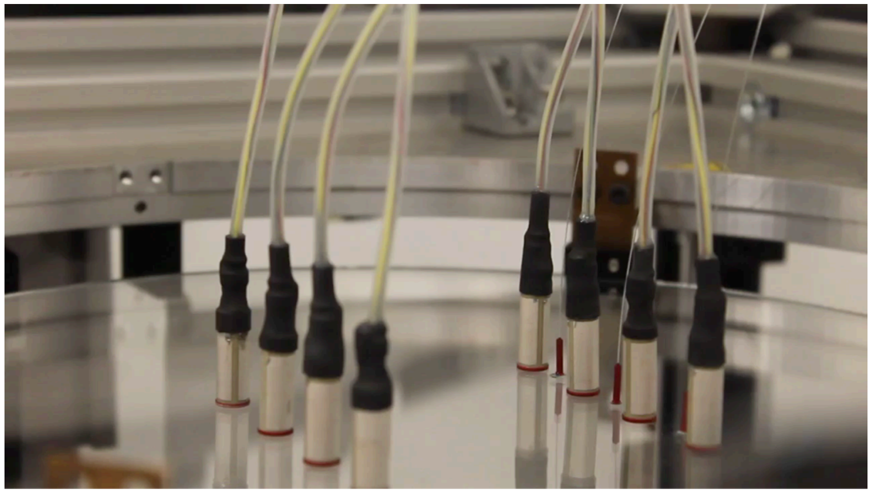


Eg. NIR spectroscopy

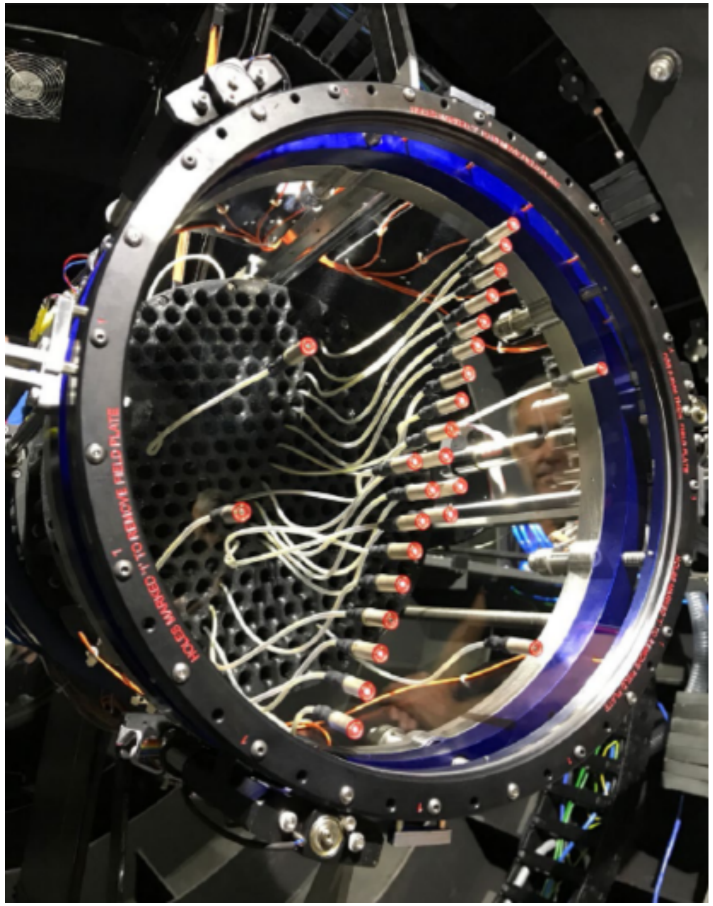
- 6912 fibres
  - 35,000 spatial pixels on the detector
  - 4k detector needs 9 spectrographs
- R=5000 to see between OH lines
  - Two arm spectrograph J,H and K
- R=1000 with OH suppression
  - J,H,K within 2k pixels
  - Can stack spectra side by side and reduce number of spectrographs by factor 2
  - Requires R&D to extend OH suppression to J and possibly K

Fibre positioners - starbugs

- Can carry larger payloads, e.g. IFUs
- Simultaneous reconfiguration < 5 min



TAIPAN



Conclusion regarding feasibility

- An MSE-class facility using a UT can probably be designed and built
- More than one concept exists which allows VLTI feed
- competitiveness rests not only with field of view but with the instrument performance and scale of multiplex

ROM Cost

Telescope mods + Instrument

Telescope mods

- Compared to MSE values
- 2m M2 at 12M

€25M

Instrument

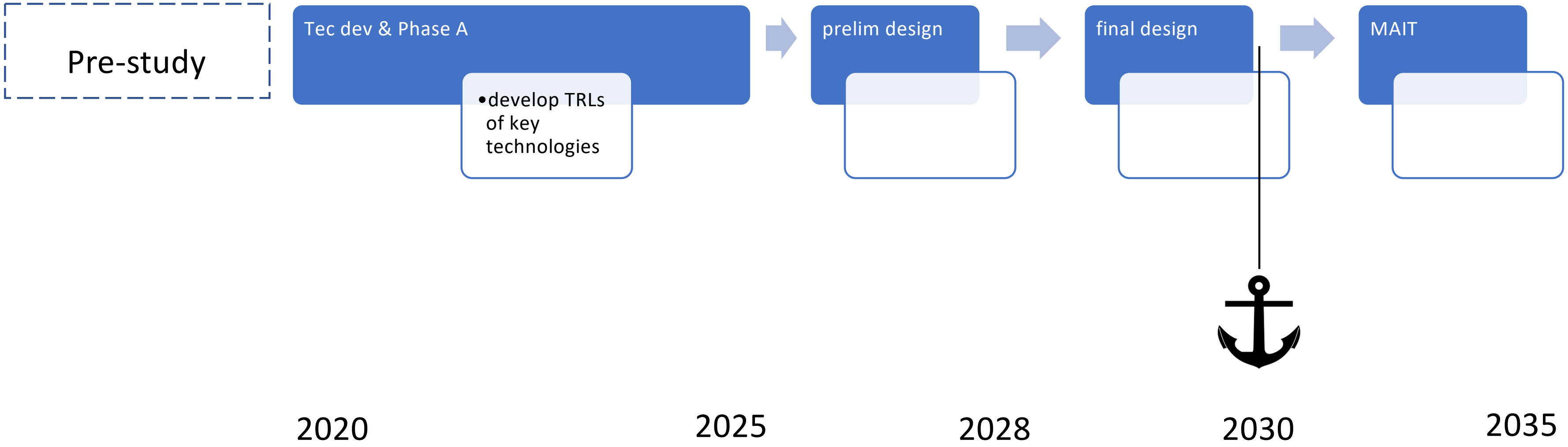
- 7000 multiplex
- 12 spectrographs
- High and low resolution

€50M +FTEs(GTO)

MSE ~ $400M

Schedule – includes technology phase

- anchor FDR at 2030 to allow funding or procurements



Significant ESO staff involvement not necessary till 2028

NEXT

- Concept needs more elaboration and detail before serious review and consideration
- If ESO interested next step would be a pre-phase A study with a small international team to
  - establish true feasibility and multiple design options
  - Discuss 2030+ science topics as guide to identifying key performance technologies for development
  - 4 FTEs AND 1-2 years

END