4MOST: 4-meter Multi-Object Spectroscopic Telescope

A design study for an ESO spectroscopic follow-up facility for Gaia, eROSITA, and other all-hemisphere surveys

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Conceptual Design Study for ESO

- Now: Conceptual Design study, completed by Feb 2013
- Selection: 4MOST/MOONS decided May 2013
- Goal: start all-sky *public* surveys early 2018
- Telescope: 4m-class telescope, either on VISTA or NTT (TBD May 2012)
- Science: space mission follow-up: Gaia, eROSITA, Euclid
- Data: yearly public data releases with higher level data products

- Goal specs:
  - Very high multiplex: ~3000 fibers
  - Full optical wavelength coverage: 390-1000 nm
  - Large field-of-view: ⌀=3°
- 4MOST provides in a 5 year survey
  - $>20 \times 10^6$ spectra @ R~5000 to m_V~20 mag at S/N=20
  - $> 1 \times 10^6$ spectra @ R~20,000 to m_V~16 mag at S/N=50

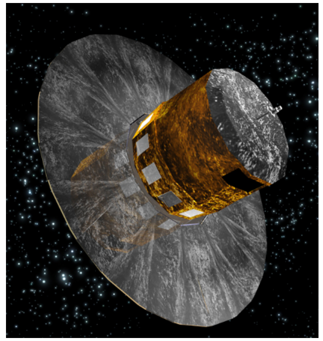
One size fits all, all the time

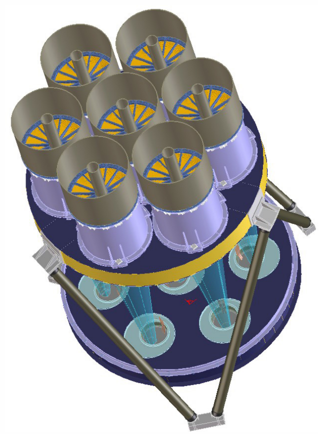
4MOST can do many science cases at the same time

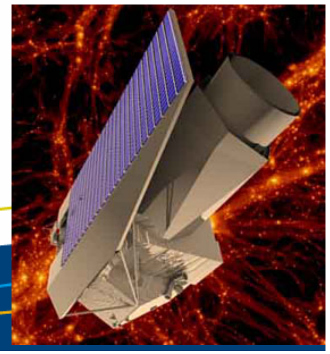
- Large Field-of-View of 3-6 □° enables all-sky surveys
  - 20,000□° / 6□° =~3300 pointings
  - 7 pointings/night x 300 nights/year = ~1.5 years
- Large multiplex of >1500 (goal 3000) enables massive surveys and repeats
- 4MOST combine 3 spectral regimes in one facility
  - R~1000-2000, S/N>5 for redshift surveys of faint objects
  - R~5000, S/N>25 for radial velocities, [Fe/H], and [α/Fe]
  - R>20,000, S/N>50 for abundances
- Doing all at the same time, all the time creates opportunities otherwise not possible
  - Targeting object densities <1-100s / degree^2 all-sky

Science drivers

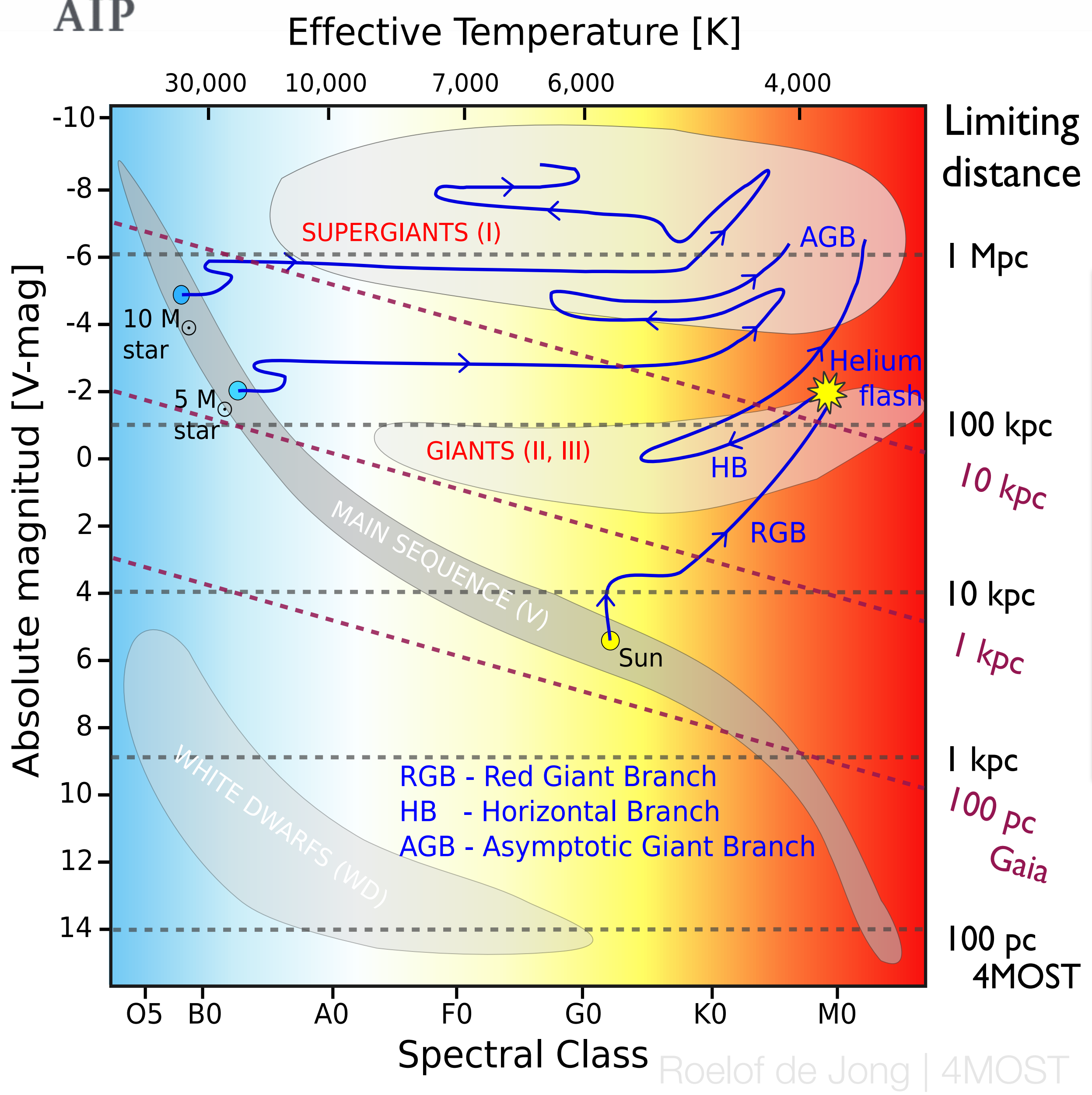
- **Gaia** follow-up:
  - Stellar radial velocities, parameters and abundances ($15 < m_G < 20$ mag)
  - Chemical tagging ($m_G <$ ~16 mag)
- **eROSITA** follow-up:
  - Cosmology with x-ray clusters of galaxies ($z <$ ~0.6, $r < 22.5$ mag)
  - X-ray AGN/galaxy evolution to z~5
  - Galactic X-ray sources, resolving the Galactic edge
- **Euclid/LSST/SKA** (and other surveys) follow-up:
  - Dark Energy from BAO
  - Galaxy evolution

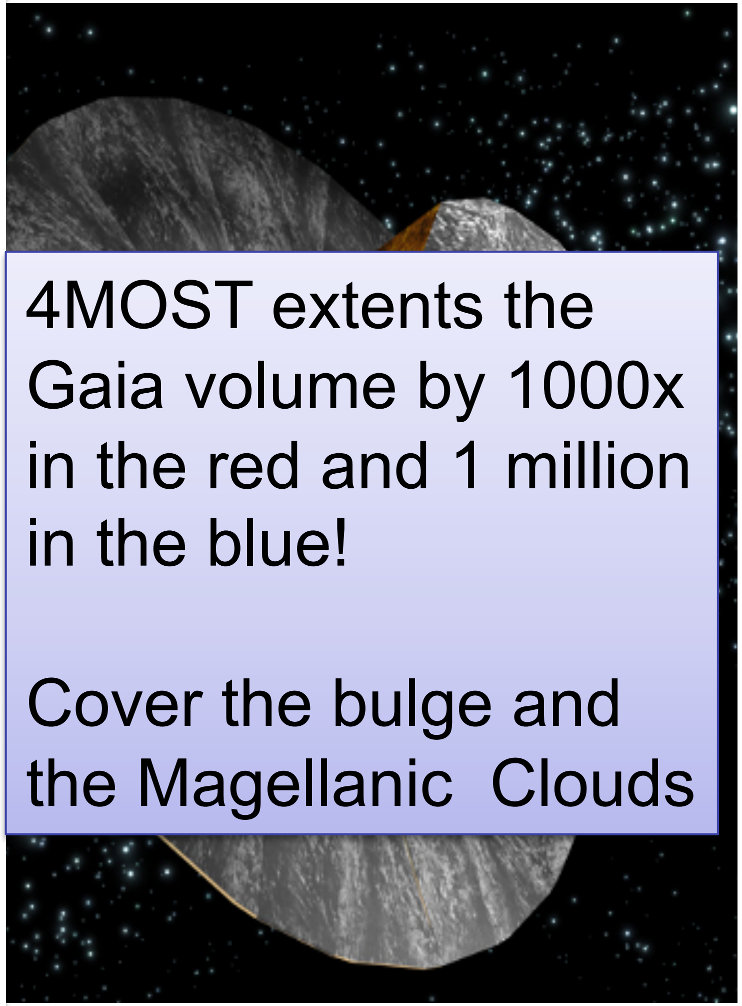






Gaia needs spectroscopic follow-up to achieve its full potential



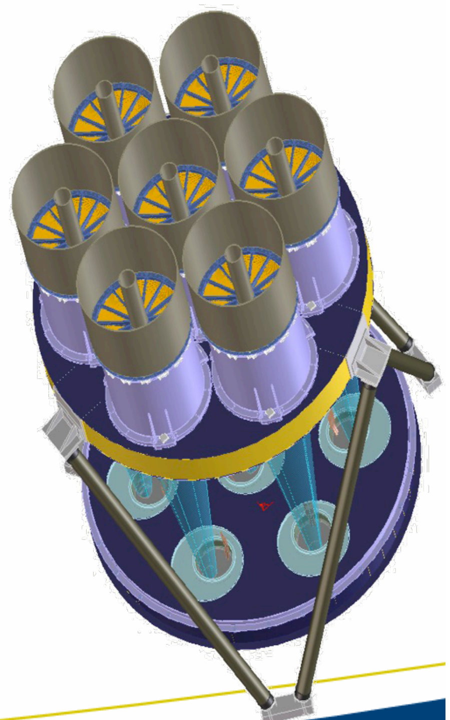


4MOST extents the Gaia volume by 1000x in the red and 1 million in the blue!

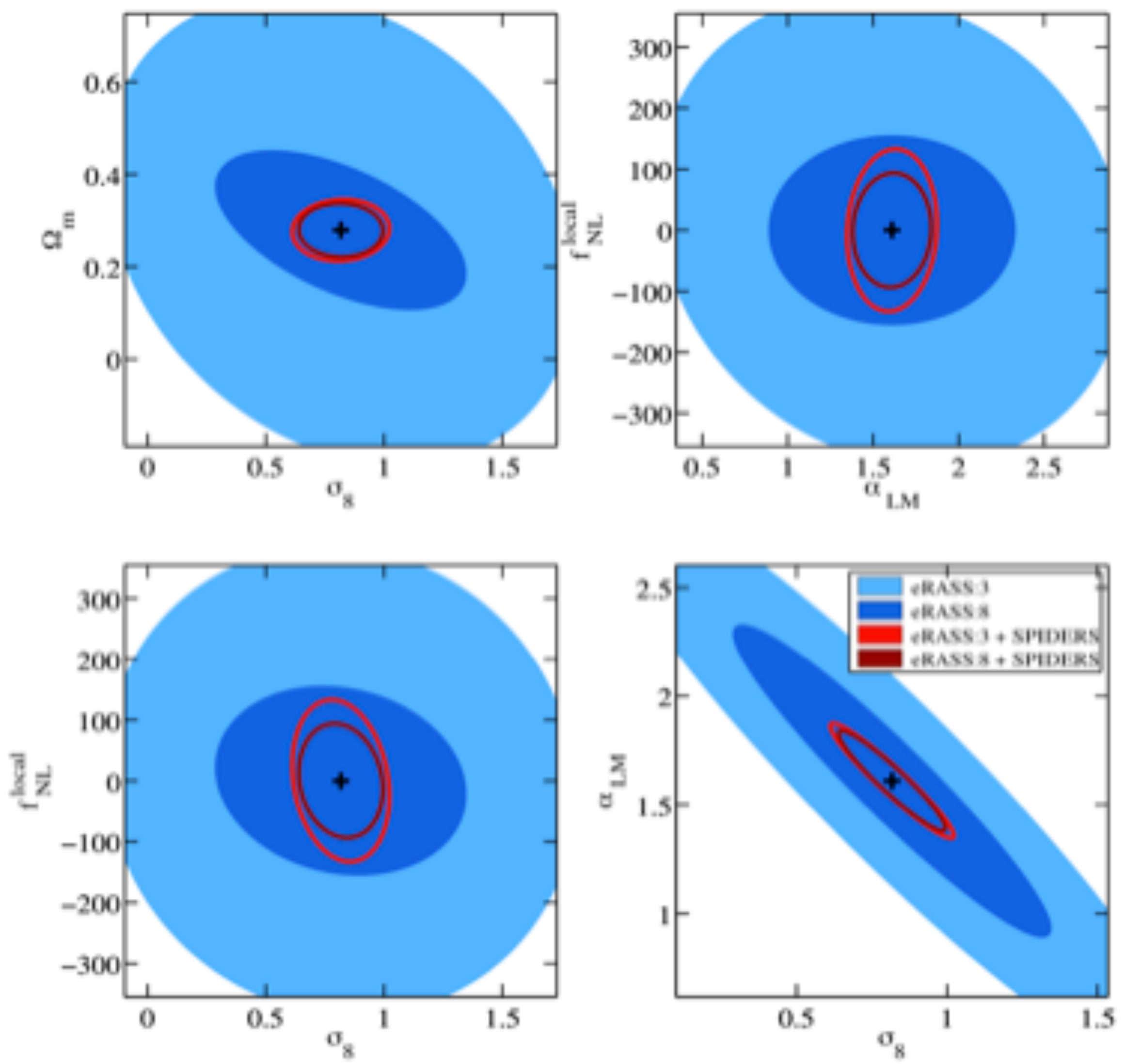
Cover the bulge and the Magellanic Clouds

eROSITA follow-up

- German - Russian mission
- 0.3-4.5 keV, beam ~25”
- 8x all sky survey (4 year) + 3 years pointed observations
- Sky divided in two, German and Russian half
- Launch end 2012
- Mission goals:
  - Dark Matter and Energy, growth of structure
  - X-ray detection of 100000 galaxy clusters
  - X-ray detection of 3 million point sources (AGN and Galactic)
- Spectroscopic follow-up needed!



Cosmological constraints by obtaining redshifts of clusters



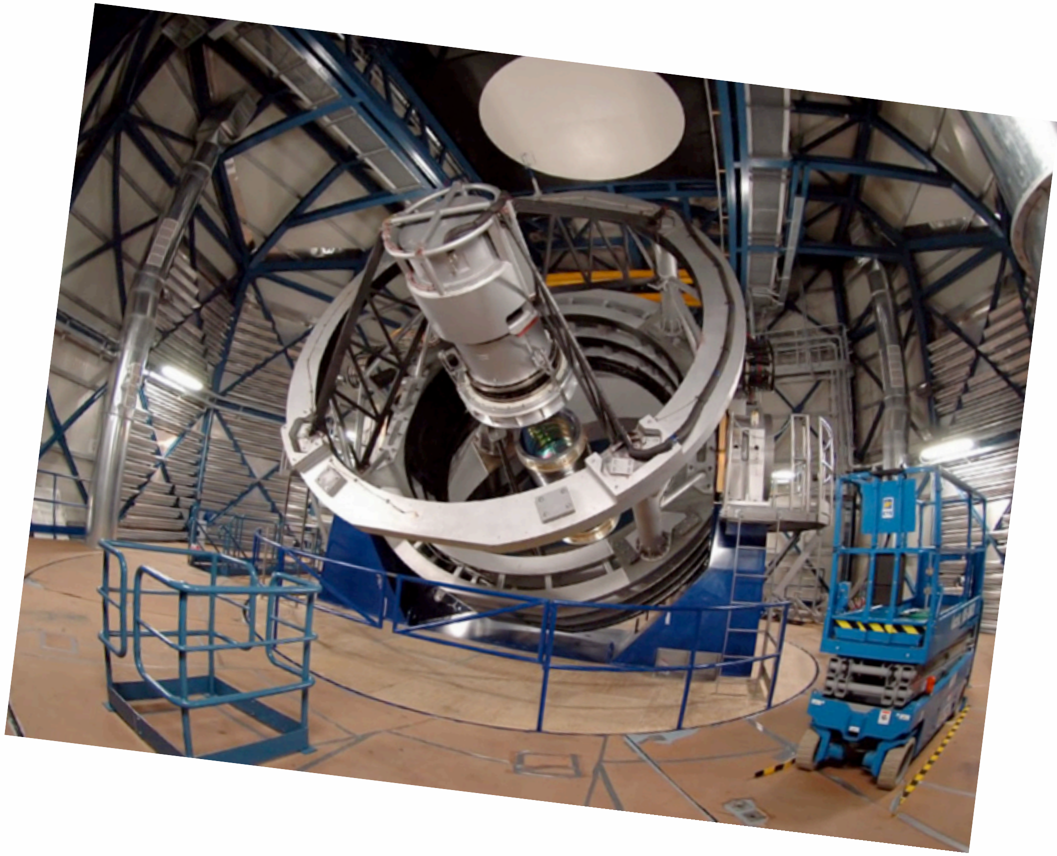
- Using both cluster abundance and clustering, but no additional constraints
- Blue: no redshifts
- Red: with redshifts

- This is for 8000 clusters, goal for 4MOST is 50,000 clusters

Instrument Specification

Specification	Baseline	Goal
Field-of-View (hexagon)	3 degree^2	**>5 degree^2**
Multiplex fiber positioner	1500	>3000
Low Resolution Spectrographs	R~5000	R~5000
Passband	400-900 nm	390-1000 nm
High Resolution Spectrograph (10-20% of all fibers)	R~20,000	R~20,000
Passband	395-456.5 & 587-673 nm	390-459 & 585-676 nm
# of fibers in ⌀=2' circle	>3	>7
Area (5 year survey)	2h x 15,000 deg^2	**>2h x ~20,000 deg^2**
Objects (5 year survey)	6x10^6	**>20x10^6**
Start operations		end 2017

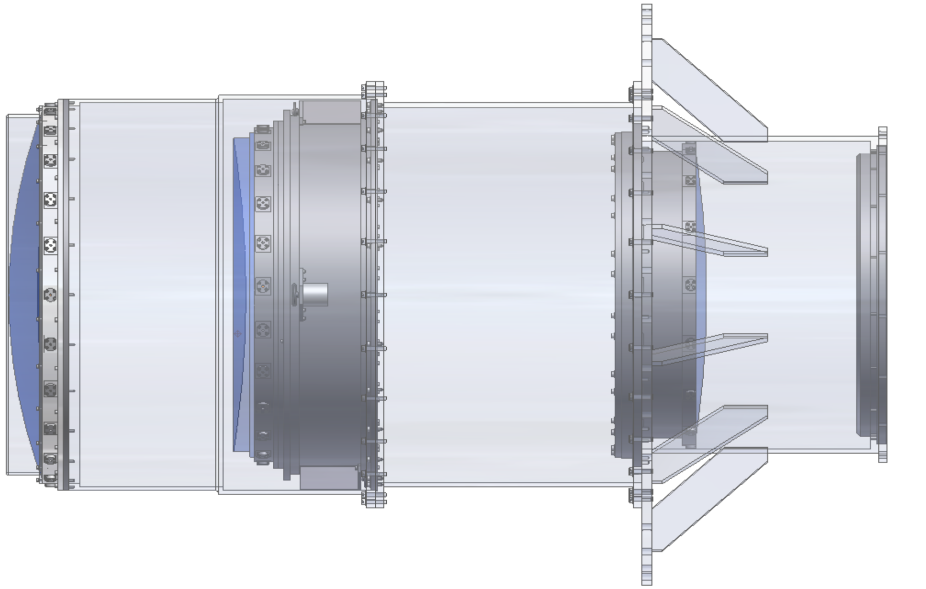
Telescope choice between NTT and VISTA

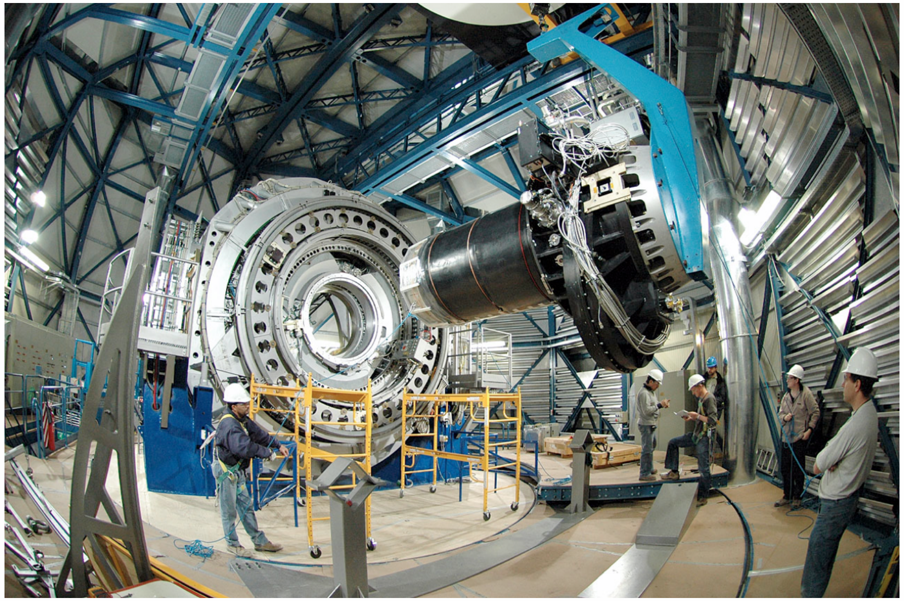


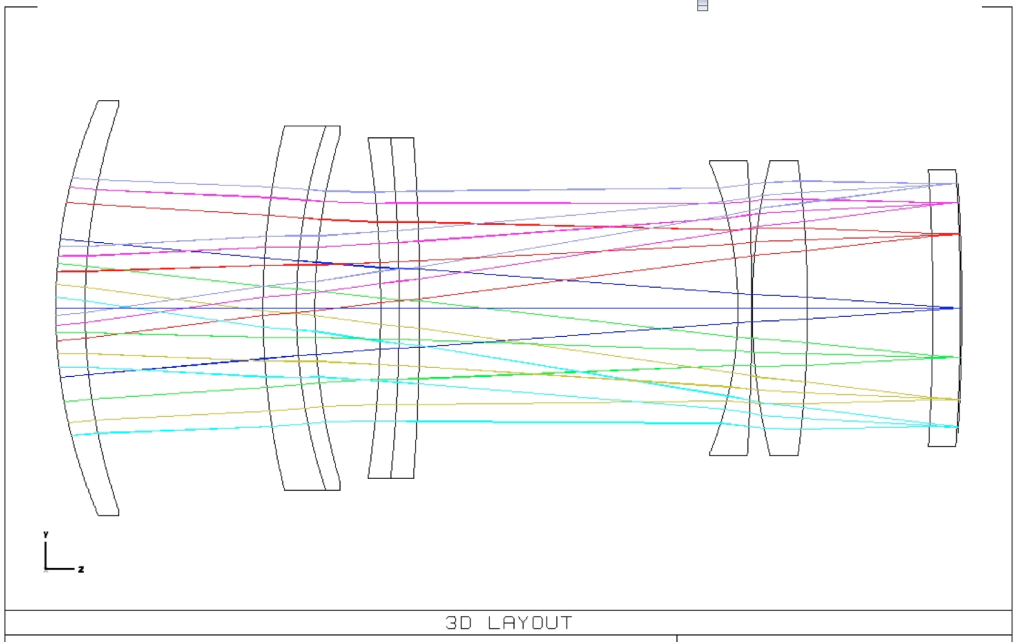
- Policy decision by ESO, our report due in 3 weeks

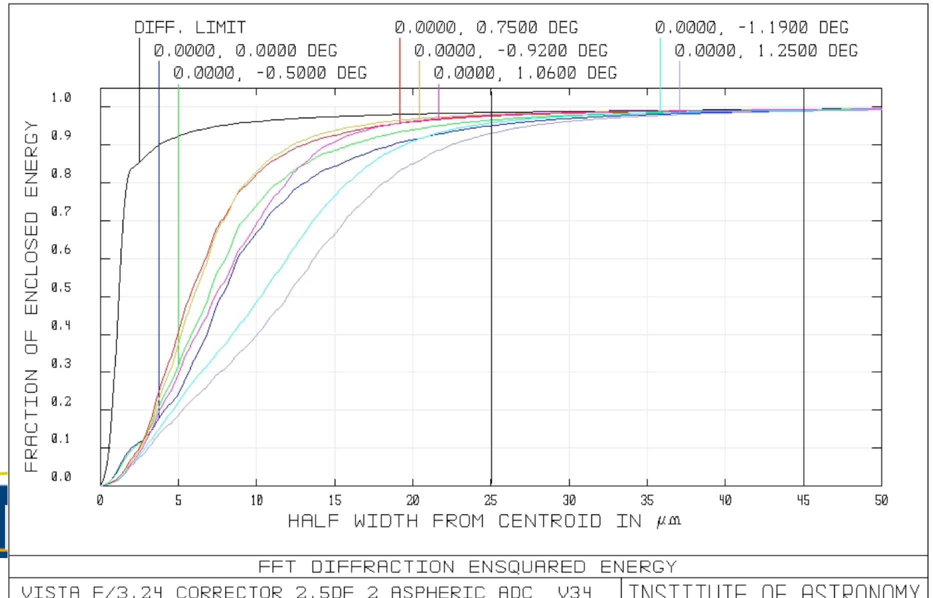
Wide-field corrector VISTA

Wide-field corrector VISTA ⌀=3°

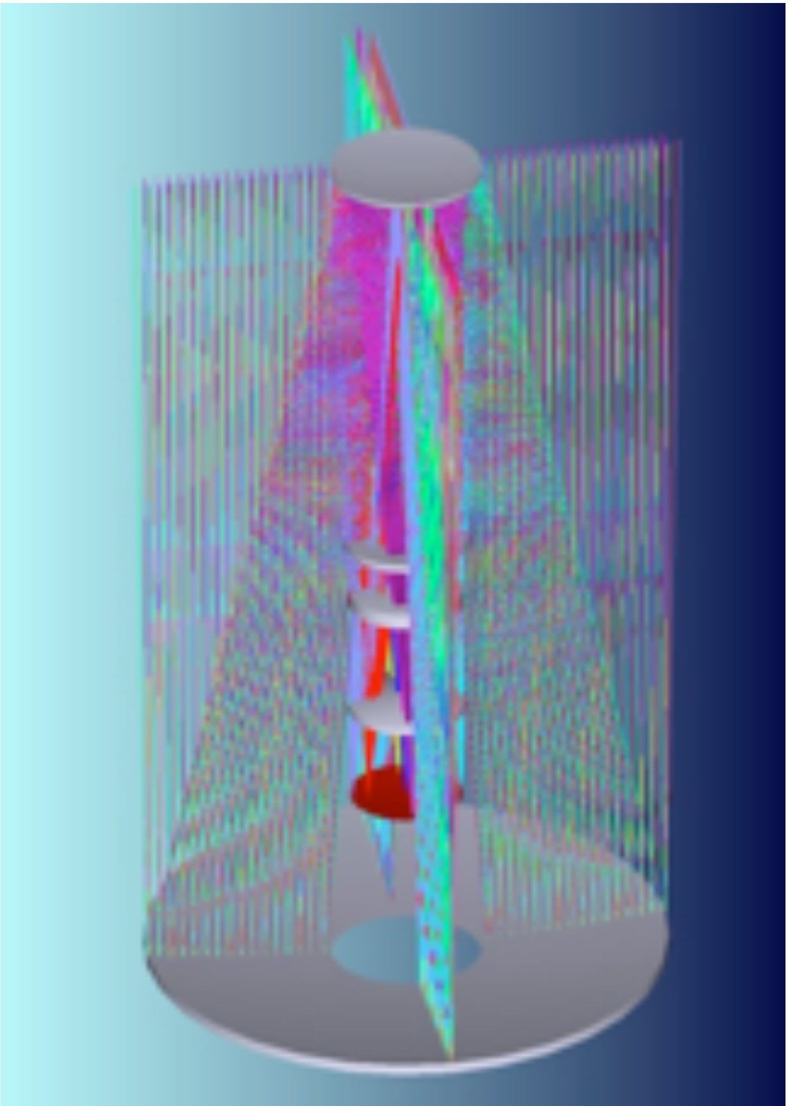




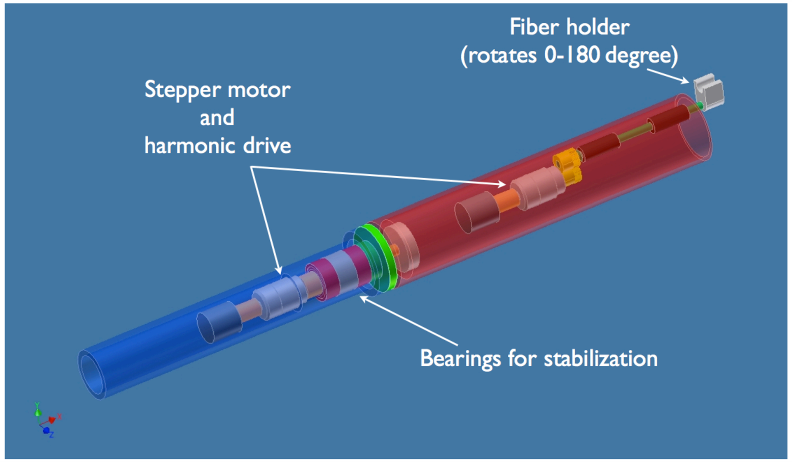


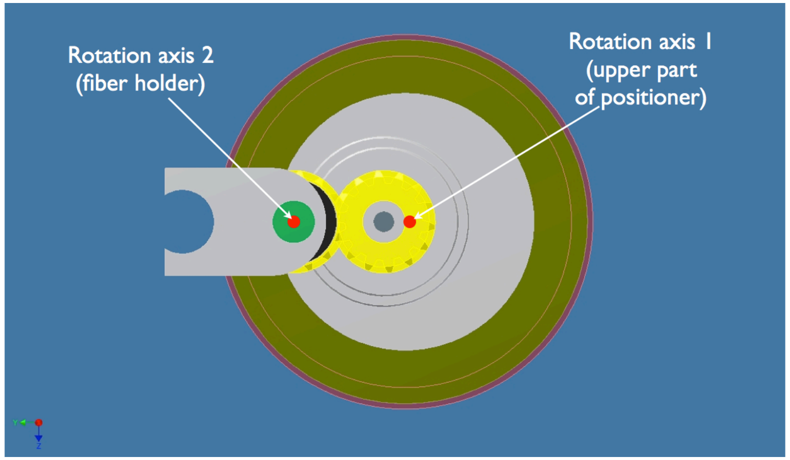


NTT corrector design ⌀=2.5°



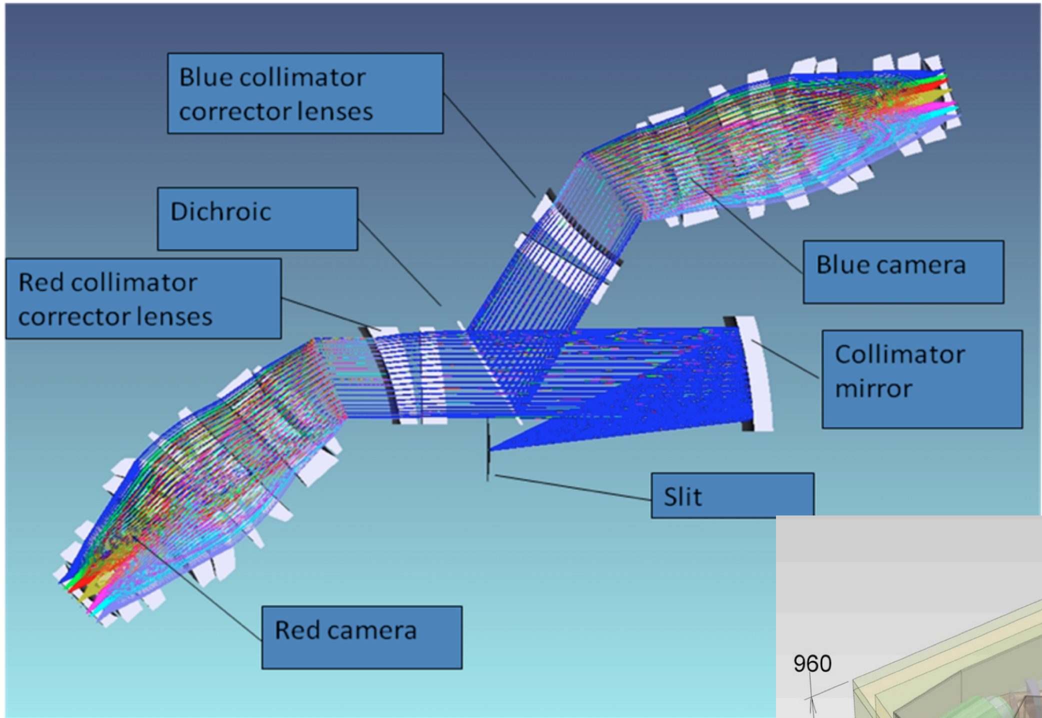
Phi-Theta and Echidna-style positioner being prototyped

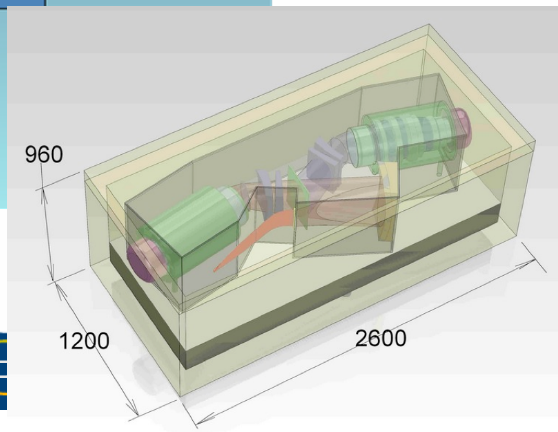


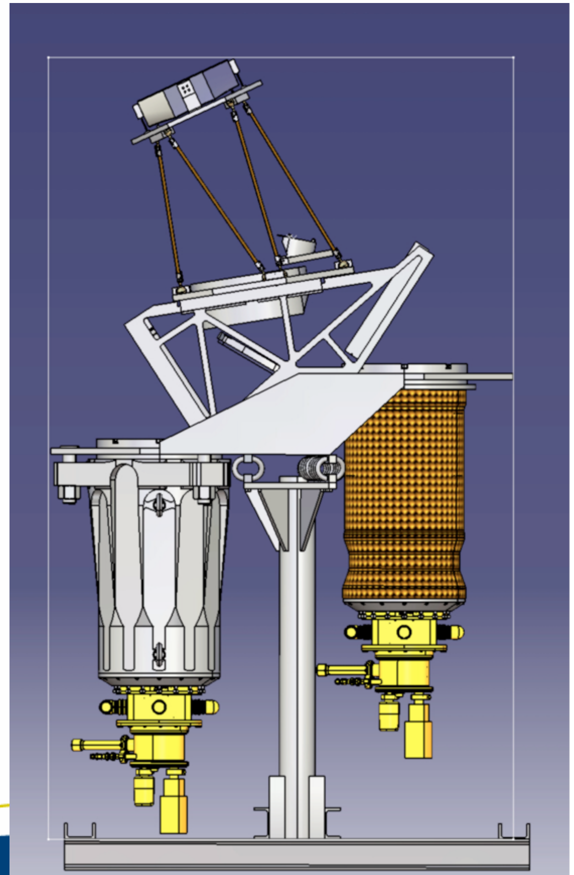


Low and High Res Spectrographs

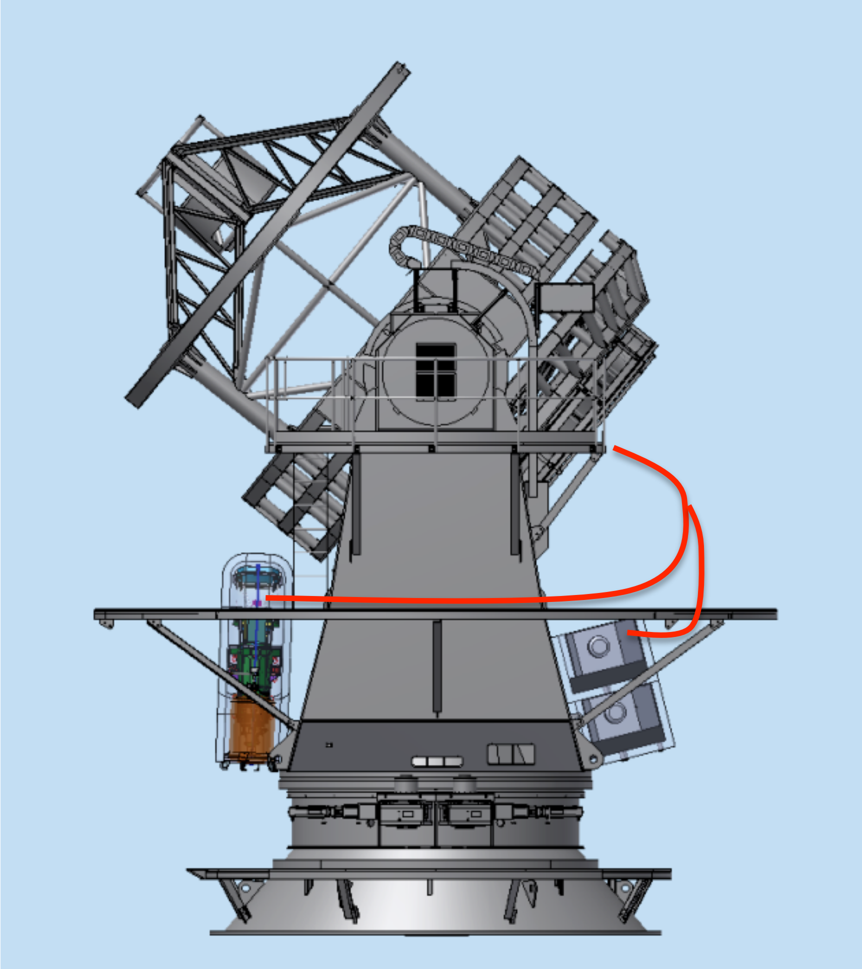
- Single configuration spectrographs, high throughput with VPH gratings
- Replicate R~5000 spectrographs to fiber count of positioner Dedicated R~20,000 spectrograph for ~10-30% fibers

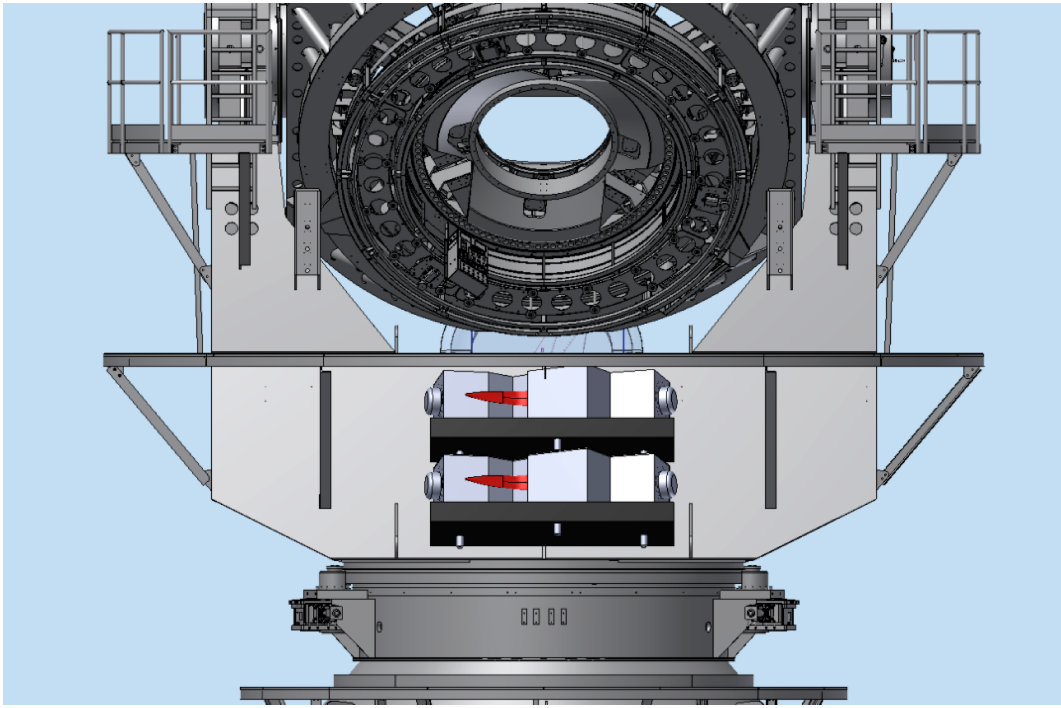






Spectrograph location (VISTA)

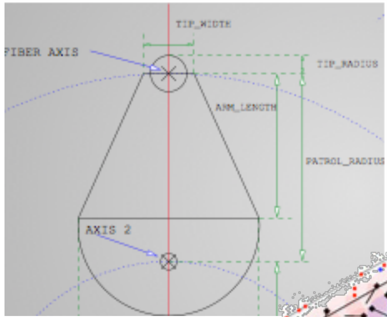


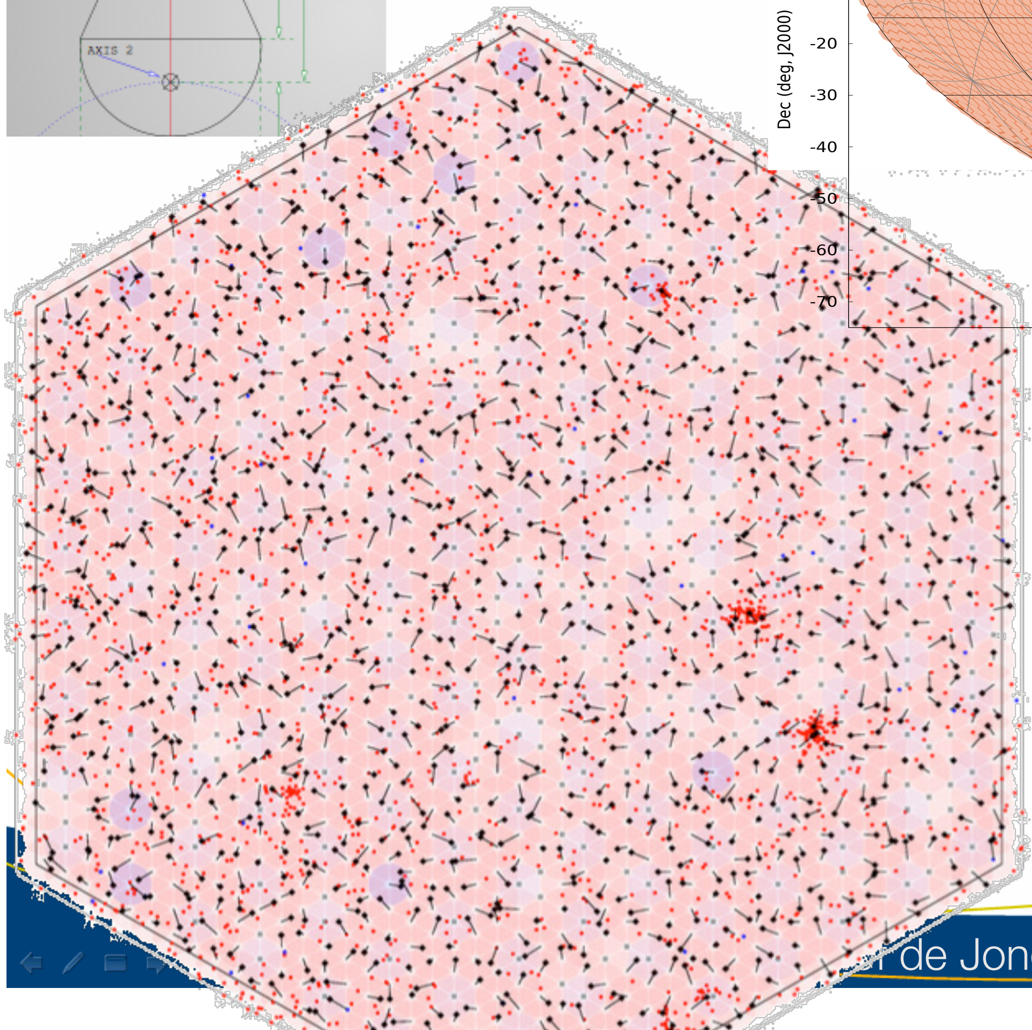


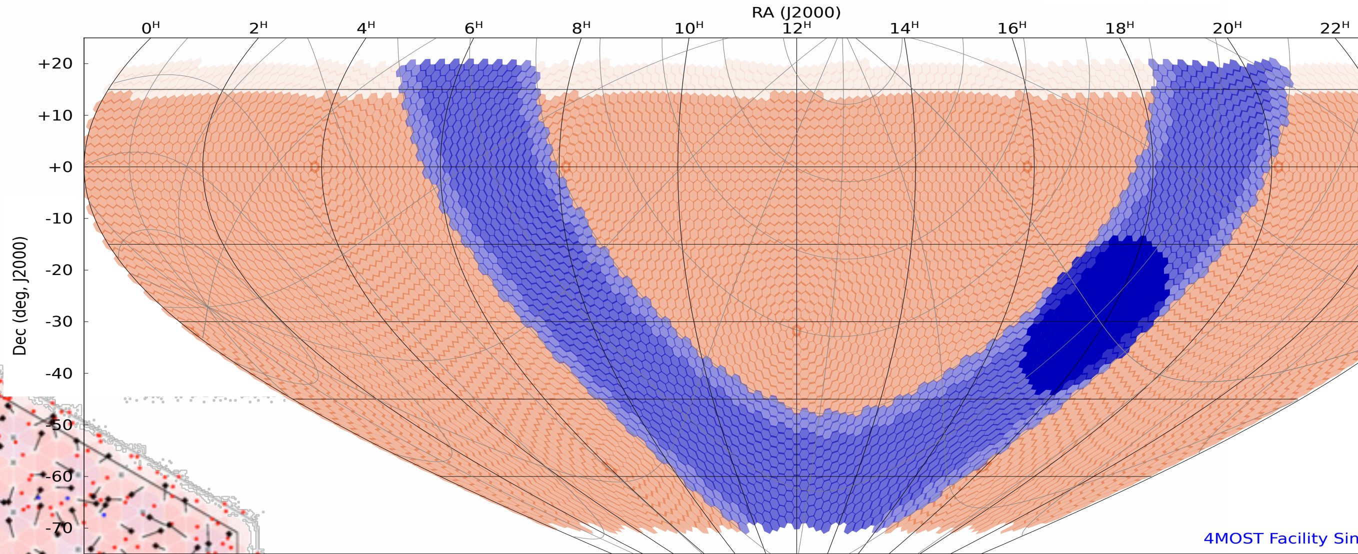
Science verification with full 4MOST simulator: Design Reference Surveys

- Milky Way halo R>5000 (~2M objects)
  - Chemo-dynamics streams: large area, accurate velocities, faint stars, LMC & SMC low DEC
- Milky Way halo R>20,000 (~ 0.2M objects)
  - Chemical evolution of accreted components: wavelength coverage and resolution for abundances, large area to get enough stars in metal distribution function tails
- Milky Way disks/bulge R>5000 (~10M objects)
  - Chemo-dynamics of bulge/disks: wavelength resolution to get abundances to separate MW components, large number of targets along the full MW mid-plane
- Milky Way disks/bulge R>20,000 (~1.5M objects)
  - Chemical evolution in situ components: wavelength coverage/resolution for abundance measurements of metal-rich stars, large number of targets for metal DF
- eROSITA galaxy clusters (~50,000 clusters, ~2.5M objects)
  - Dark Energy and galaxy evolutions: high source densities at ~2 arcmin scales, large area, redshifts of faint targets drives efficiency and fibre size at dark time
- eROSITA AGN (~1M objects)
  - Evolution of AGN and the connection to their host galaxies: high completeness and large area coverage for statistical studies, faint objects
- BAO survey (~10M objects)
  - Luminous red galaxies survey: large number of objects, large contiguous area, faint objects

Simulate throughput, fibre assignment, survey strategy and verify total survey quality







- Trade-off configurations:
  - Field-of-View
  - Fibre count
  - Positioner concepts
  - High/low resolution
  - Exposure time/overhead
  - Survey strategy

AIP

Telescopes pros and cons

	VISTA	NTT
Primary mirror diameter	3.8m	3.5m
Telescope site	Paranal ++	La Silla +
Corrector FoV	⌀=3°	⌀=2.5°
Modern survey telescope	++	-
Easy access focus	++	--
Thermal control in Focal Surface	+	-
M2, rotator, cable wrap	+	-
Space for spectrographs	++	++
Community reluctance	- ?	+

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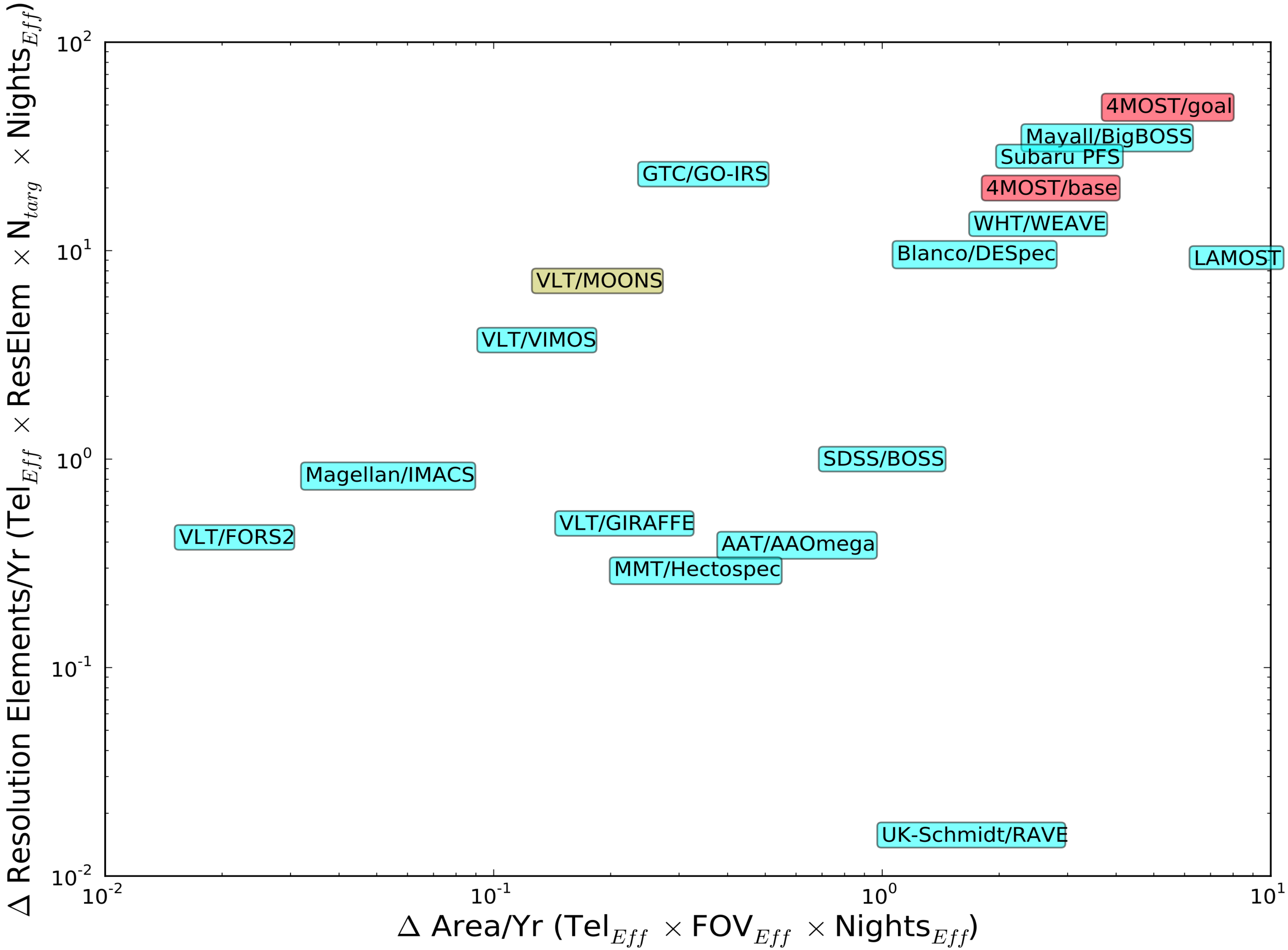
- Your input welcome at this stage!

Survey speed comparison



Design reference surveys performance