A very versatile, large A-omega, fibre-fed spectrograph design

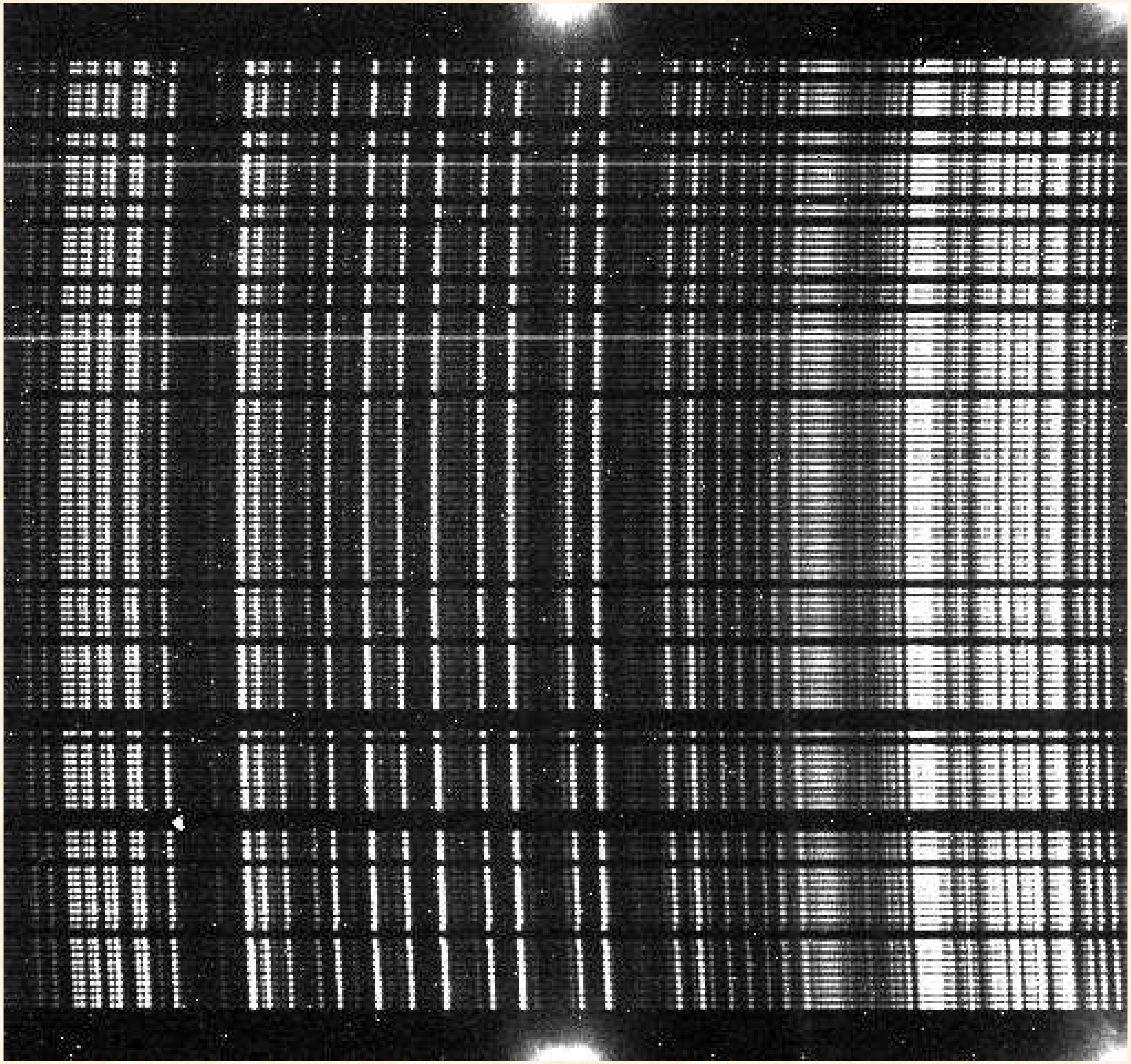
Ian Parry

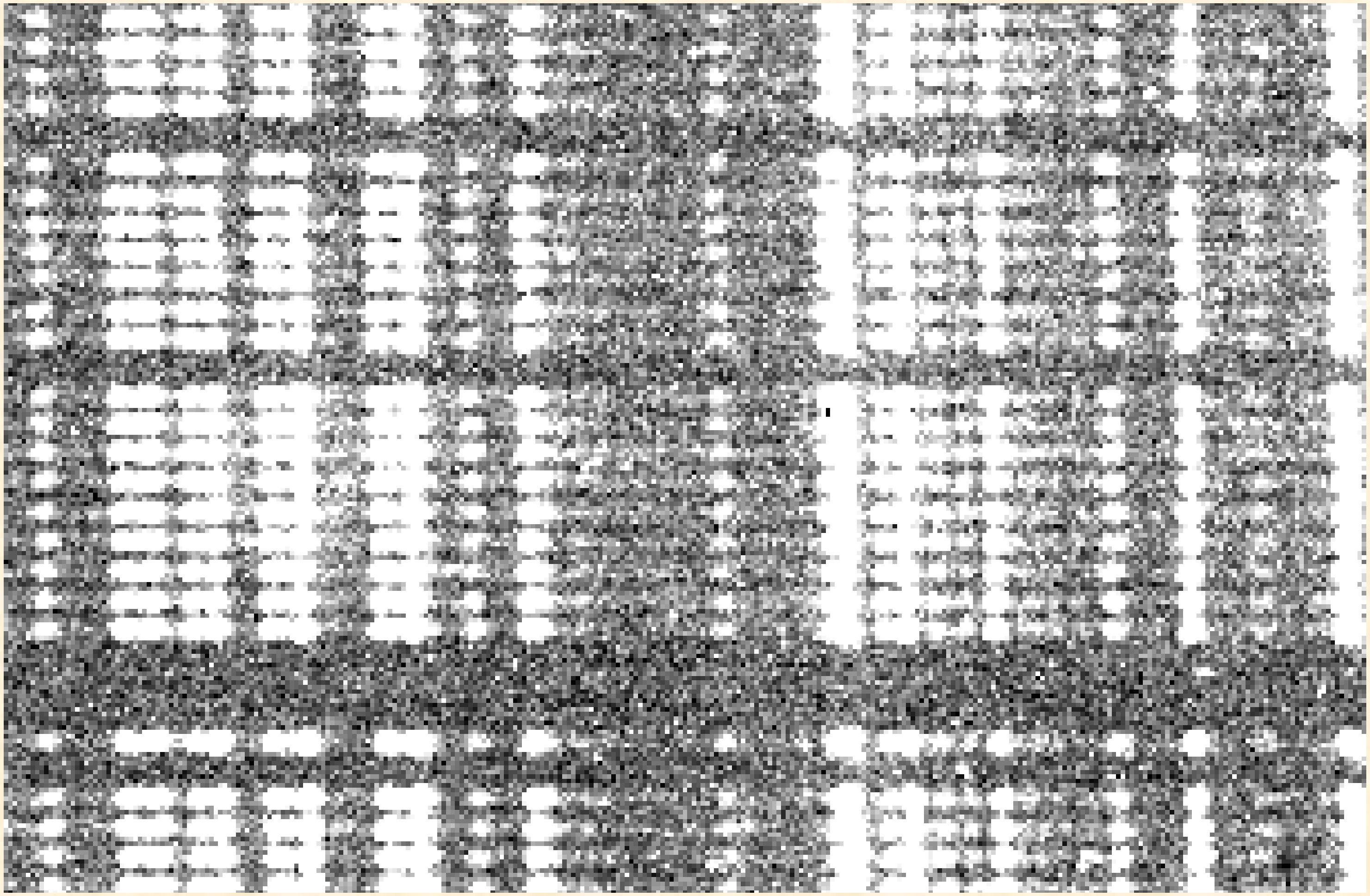
IoA, Cambridge

But first a quick diversion to support Alvio's case

- NIR multi-object spectroscopy with fibres works!
- CIRPASS was used in this mode with R~4000 on the AAT in Oct 2002.
- Sky subtraction (via beam-switching) worked perfectly – there were no systematic errors and the S/N was as expected from read-noise, shot-noise and the inter-OH sky background.

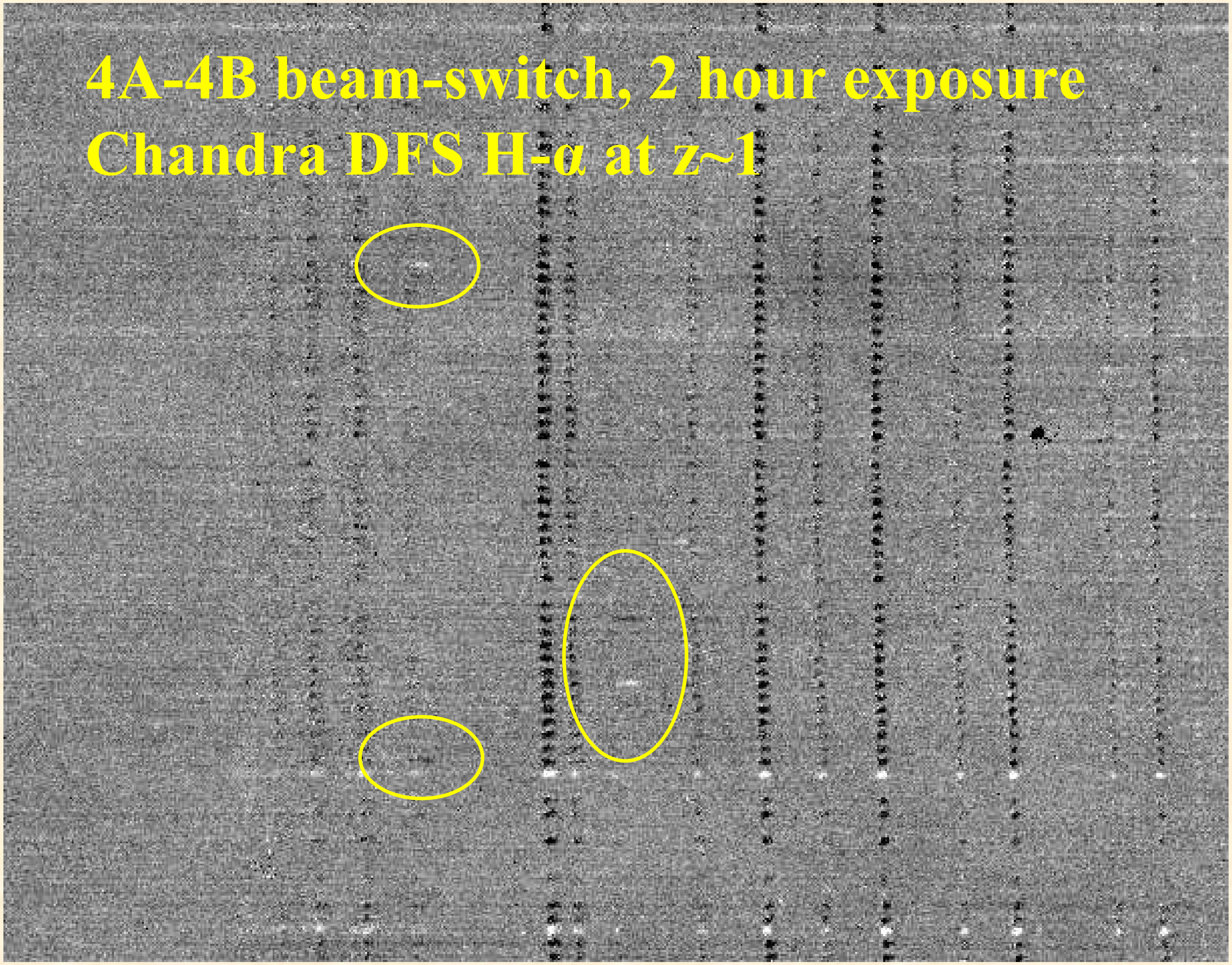
CIRPASS MOS A raw data frame. 1k detector





Faint inter-line sky ~ 2×Maihara value

Perfect sky subtraction in between the OH lines!



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Talk Summary

- Discuss the WFMOS design study challenge:
  - **Enormous information gathering power**, need spectrographs with a large number of spectral resolution elements (4.1 million SREs).
  - **Resolving power range** (from R~500 to R~30000)
  - **Trade SREs per spectrum versus multiplex gain.**

- A possible solution
  - Optical design (1.4 million SREs per spectrograph).
  - Mechanical design
  - Performance

The WFMOS Design Study

- Wide-field Fibre-Fed Multi-Object Spectrograph – 2 competing teams (IoA in JPL-led Team 1).
- A proposed facility funded by the Gemini Observatories.
- Similar in concept to Sloan and 2dF but with greater multiplex, higher spectral resolution and on an 8m telescope. DE and GA science.
- 1.5 deg diameter prime focus of Subaru.
- Classical multi-object spectroscopy at optical wavelengths using several thousand optical fibres. [one fibre per galaxy or star]

WFMOS Science Requirements

	DELZ	DEHZ	GALR		GAHR
			Blue	Red	
Min λ(nm)	630	420	480	818	480
Max λ(nm)	970	670	544	885	680
Resolving power	3500	1500	5000	5000	20000
Fibre core (arcseconds)	1.2	1.2	1.2	1.2	1.2
Number of fibres	2400	2400	2400	2400	600

The A-Omega for GAHR and DELZ are the ~same ⇒ same detector area. Even though the number of fibres and spectral resolutions are very different between surveys they can be done with one very versatile design.

A-omega of the IoA spectrograph design

- ~3.4 × one BOSS spectrograph
- ~5.1 × a single MUSE spectrograph
- ~ 15 × Flames + Giraffe spectrograph

Comparisons are for one spectrograph measured at the detector – for WFMOS we require three spectrographs

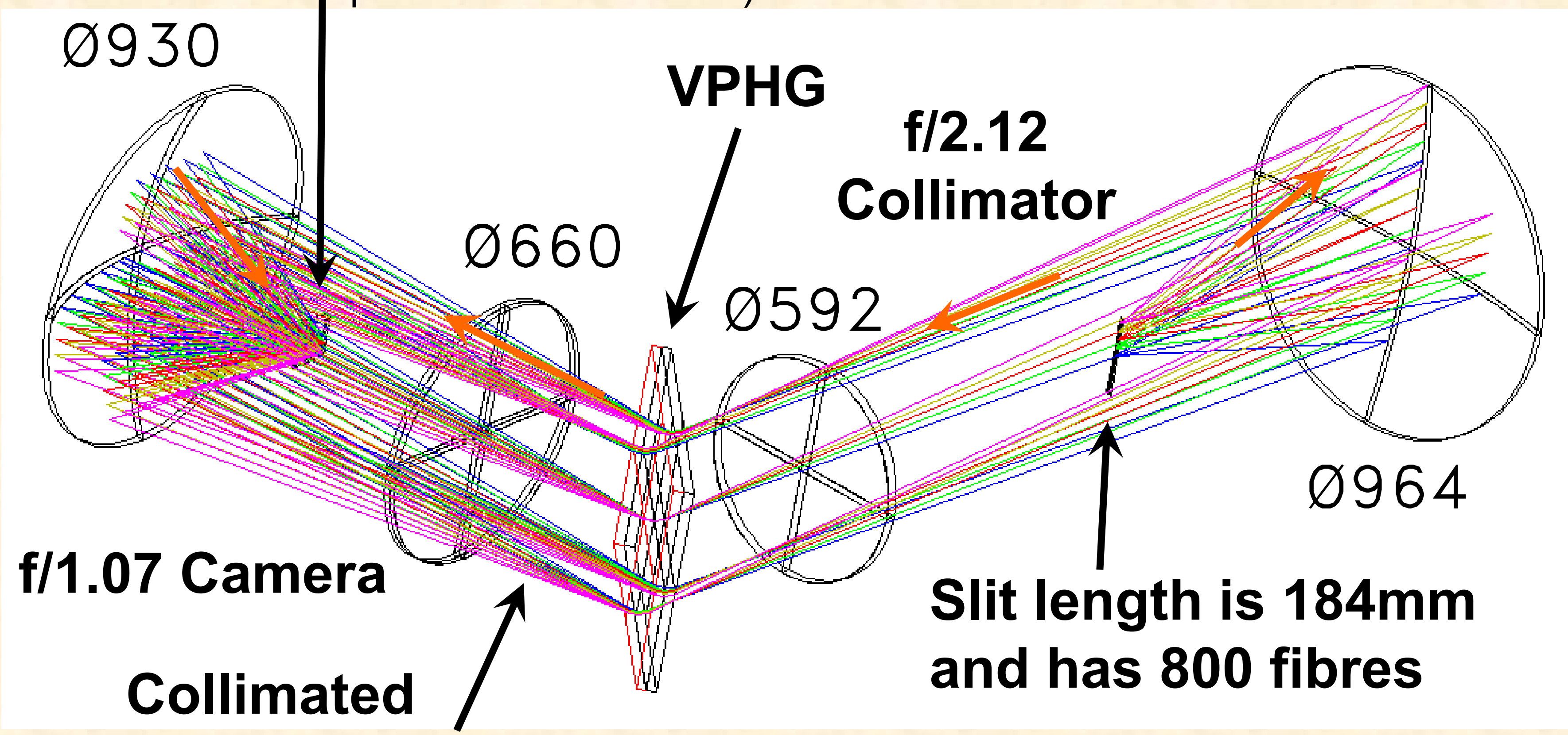
Solutions to the design challenges

- **High resolution** is achieved by having a **large collimated beam diameter** (to give a large optical path difference across the grating).
- **Large resolution range** is achieved by having a **variable geometry** that goes from small to large optical path differences
- **Re-deployment of SREs** is achieved by using **cross-dispersion**.
- **Large A-omega** is achieved by using **Schmidt optics**.

Optical Design

Spectrograph shown in R=20,000 mode

Detector
93mm x 93mm
(LBL 5812×5812 16μm pixel custom devices)

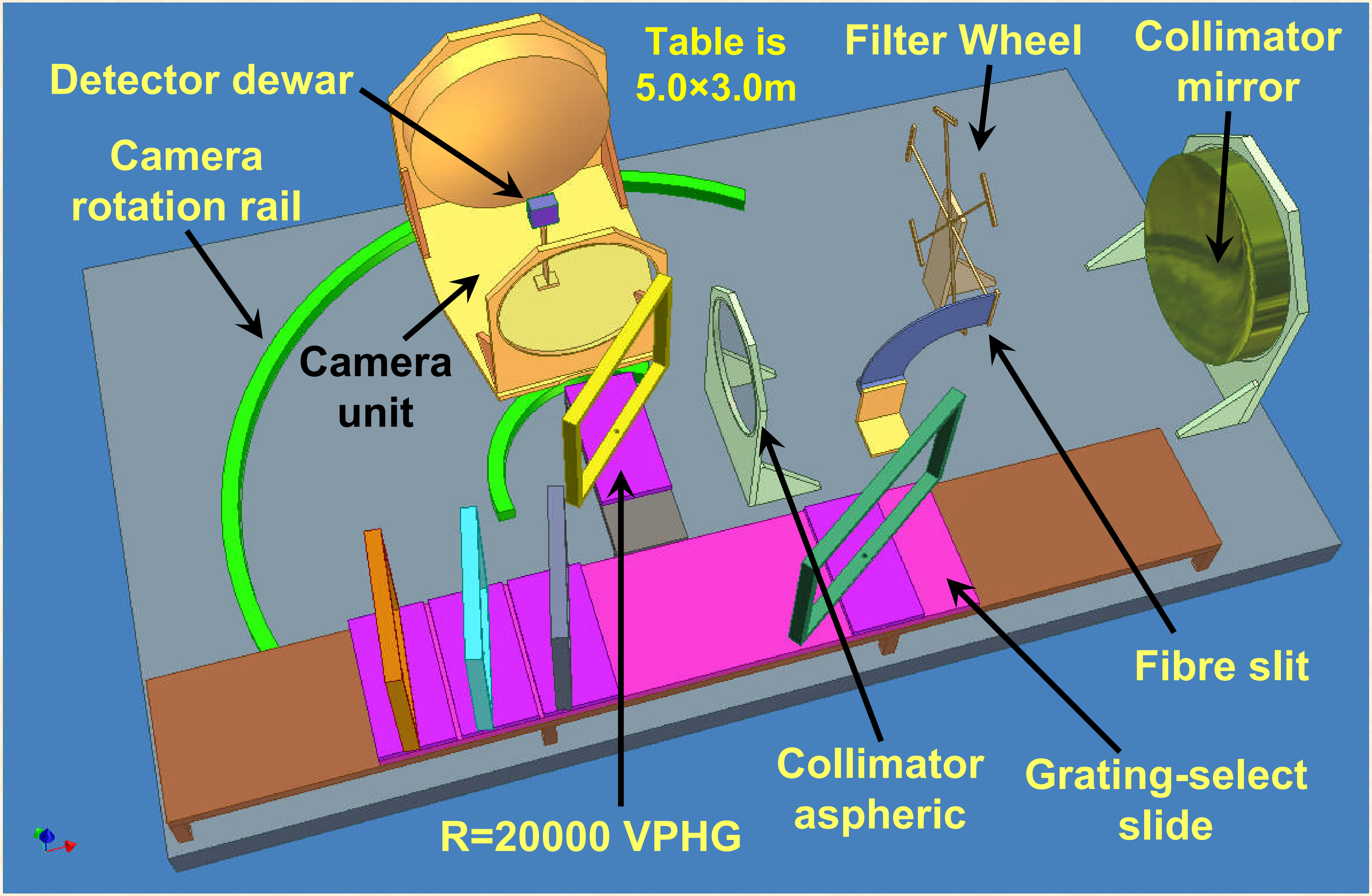


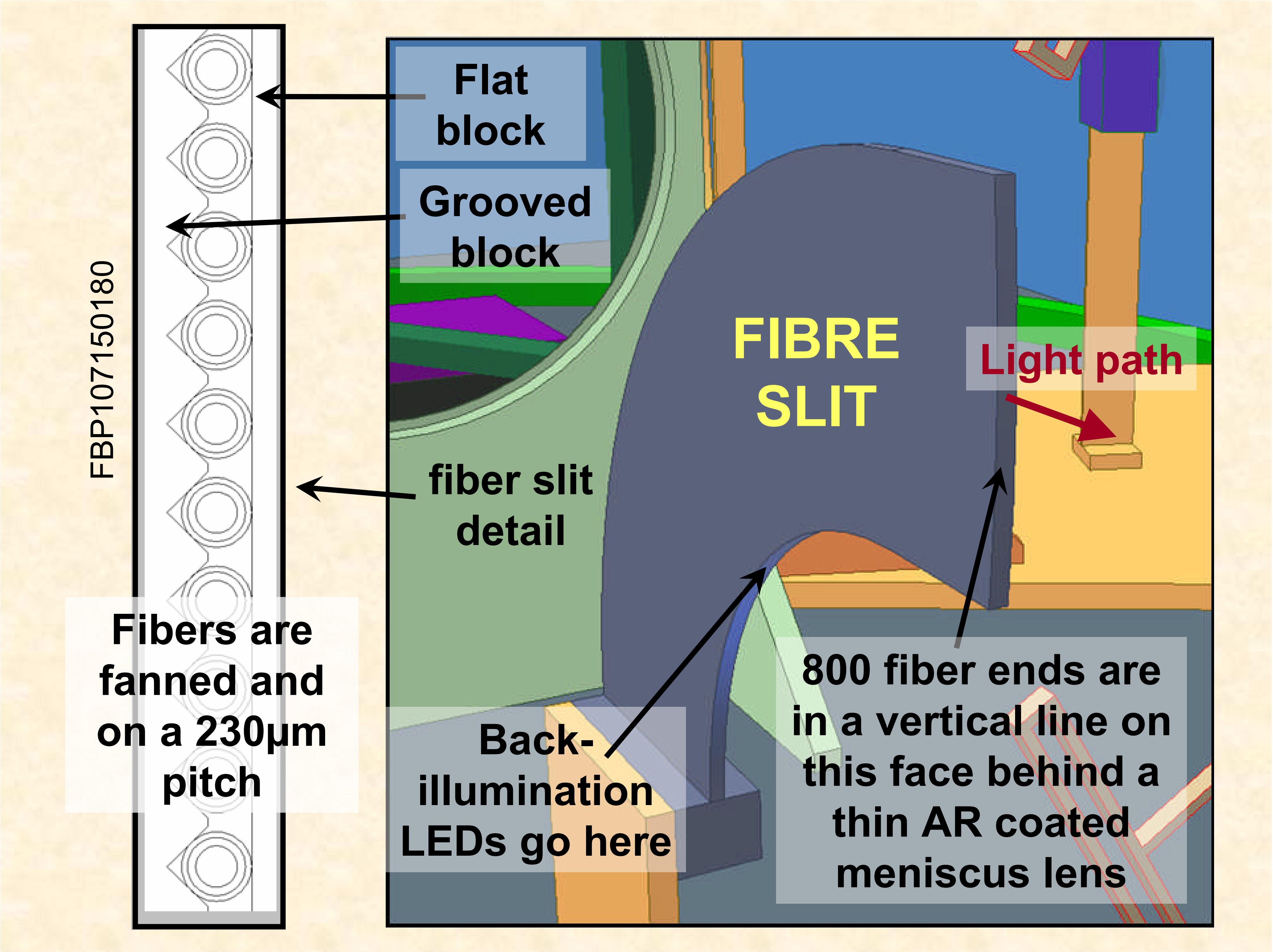
Collimated beam is 500mm in diameter

1. Schmidt systems offer the most A-omega per euro.
2. Slower f-ratio off-axis Schmidt collimator for a Cass/Nasmyth feed is simple.

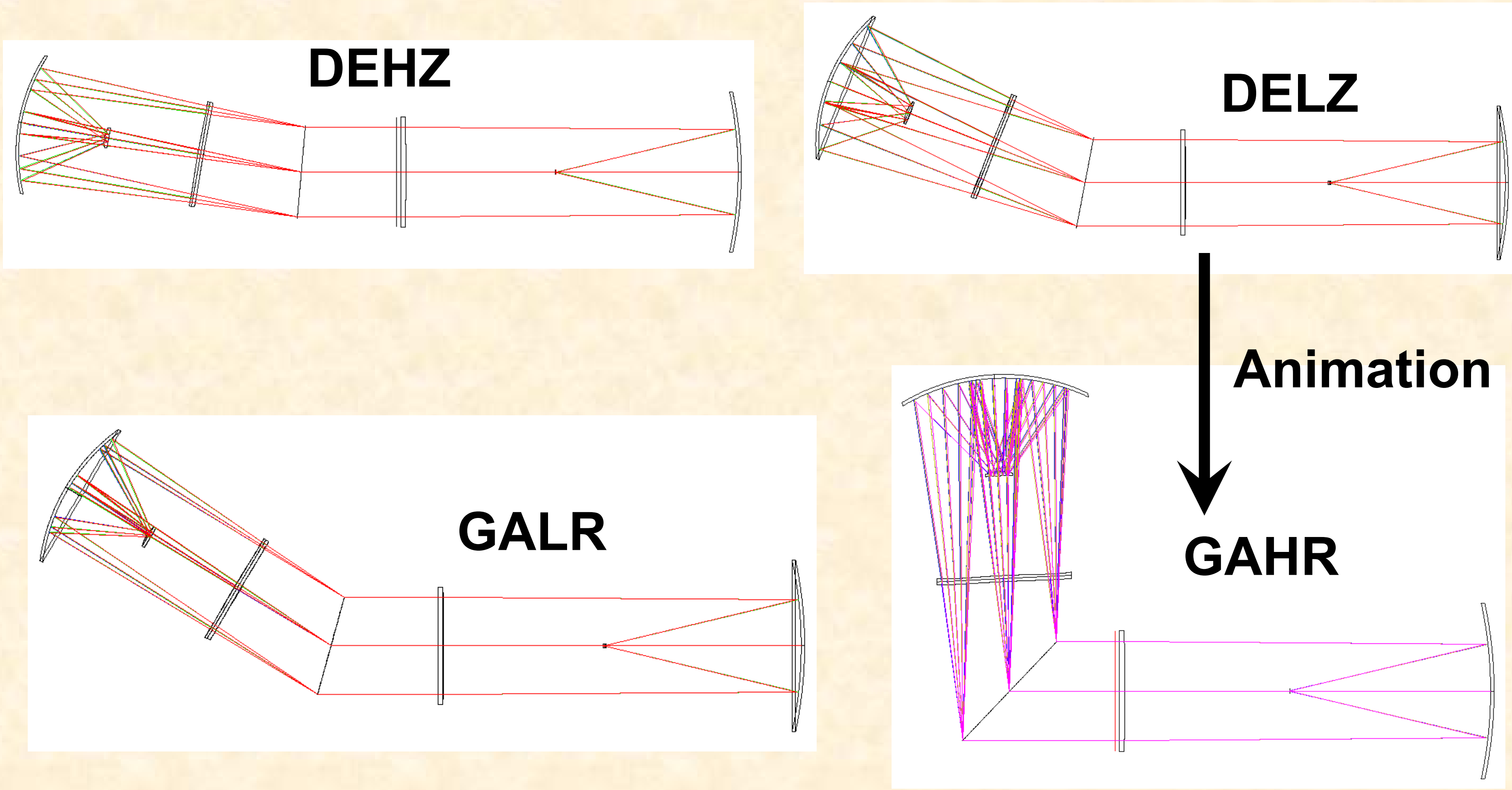
Mechanical Design

The spectrograph set up for R=20,000

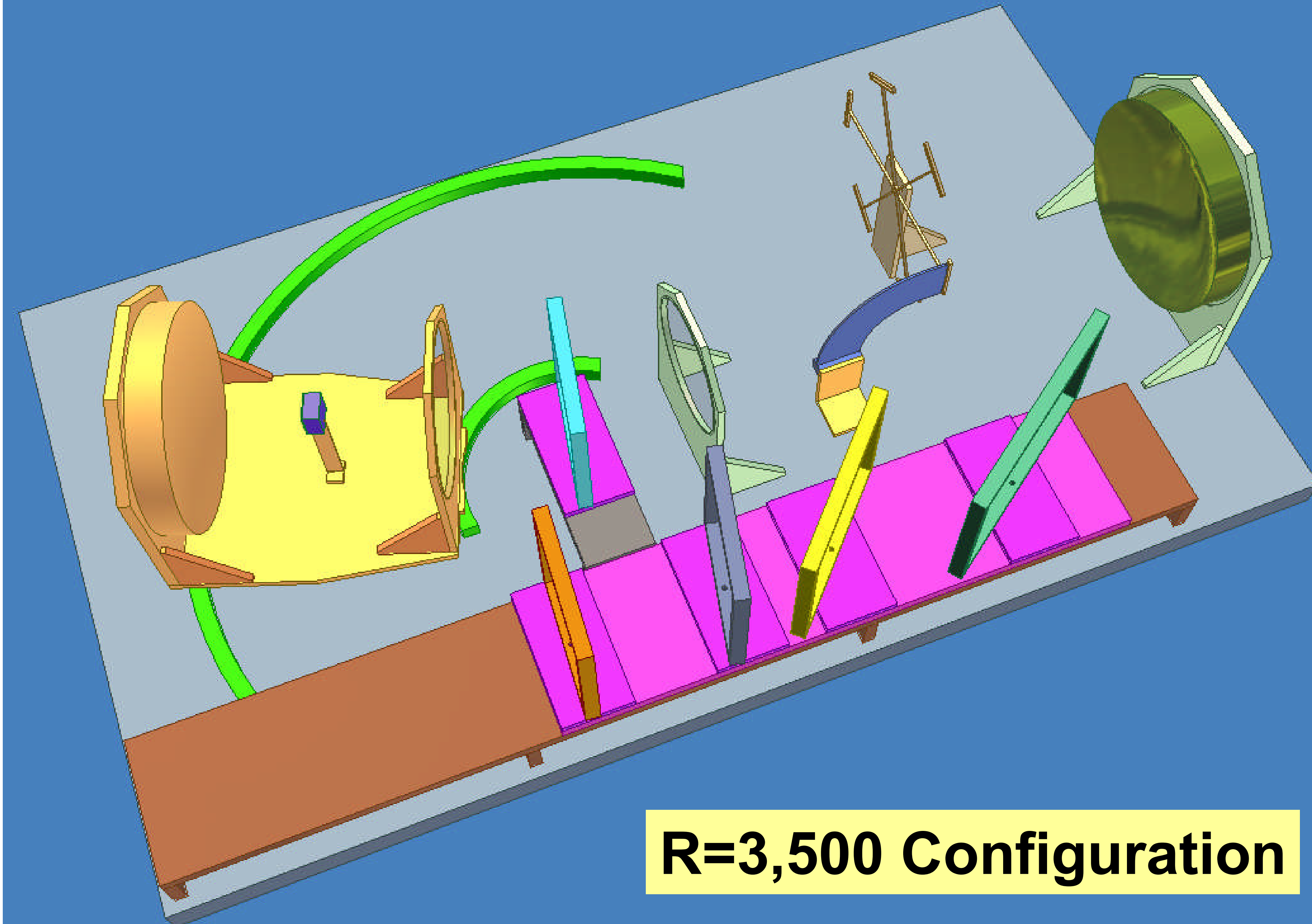




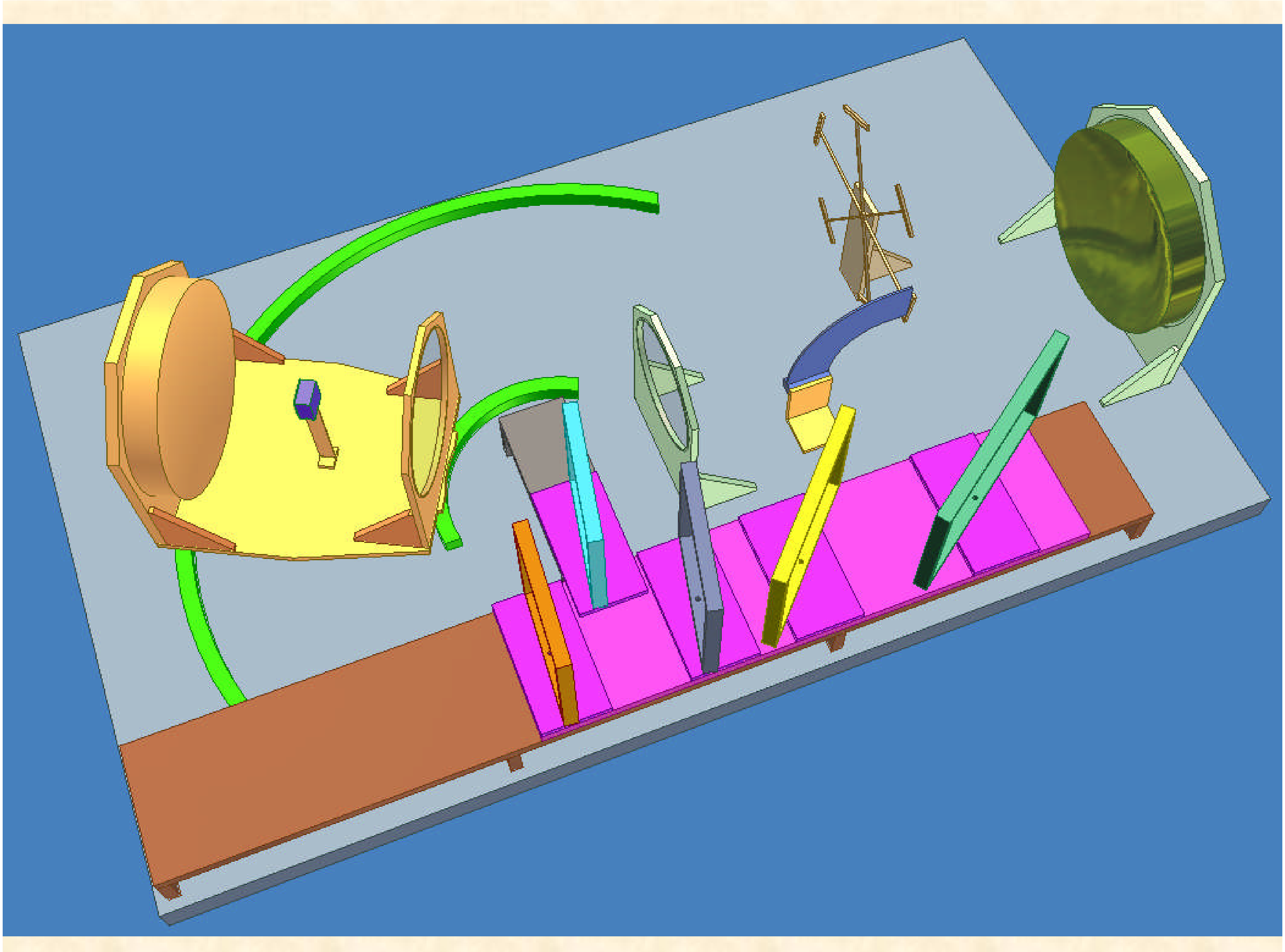
FBP107150180
Flat block
Grooved block
fiber slit detail
Fibers are fanned and on a 230µm pitch
FIBRE SLIT
Light path
Back-illumination LEDs go here
800 fiber ends are in a vertical line on this face behind a thin AR coated meniscus lens

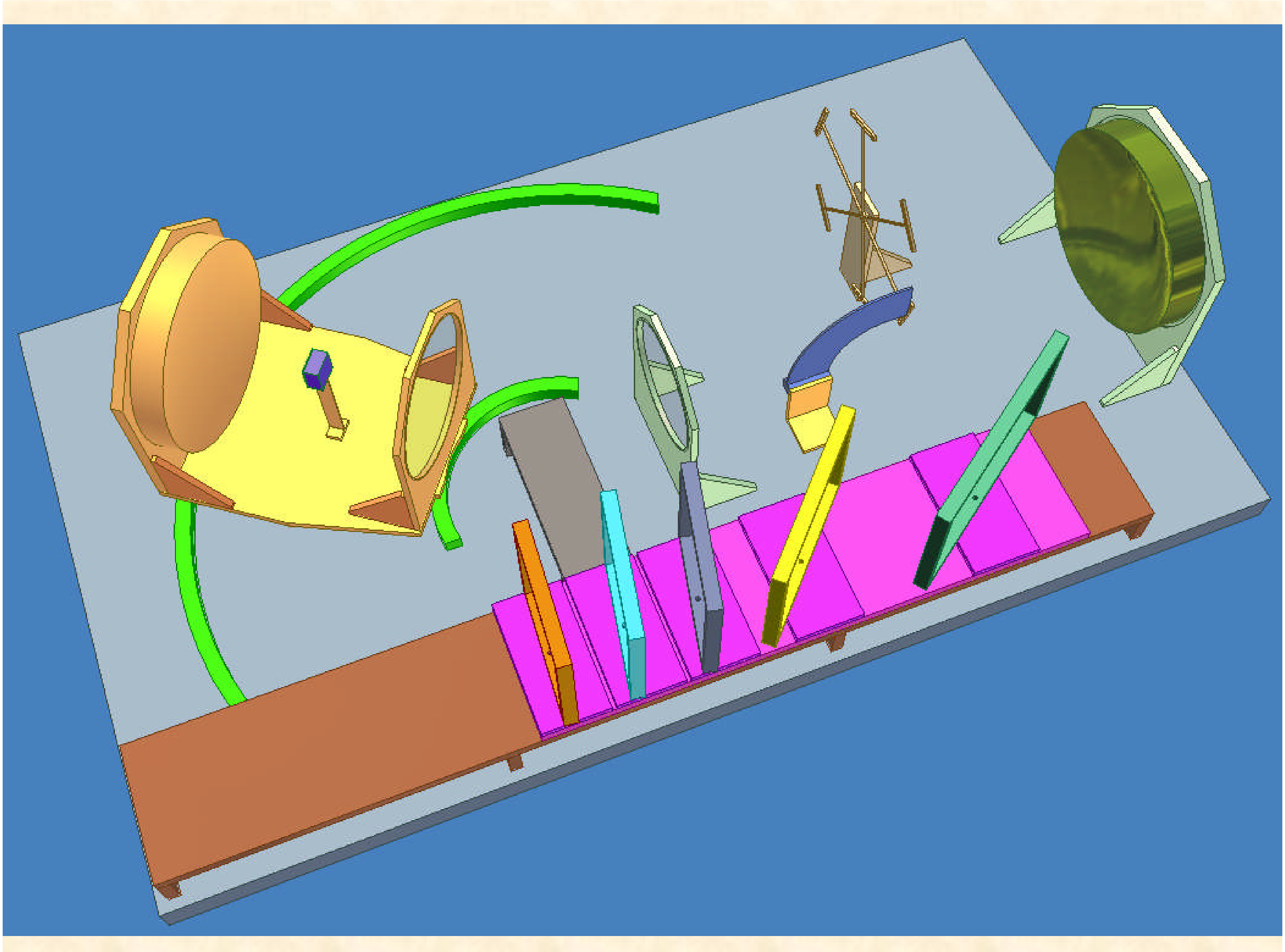


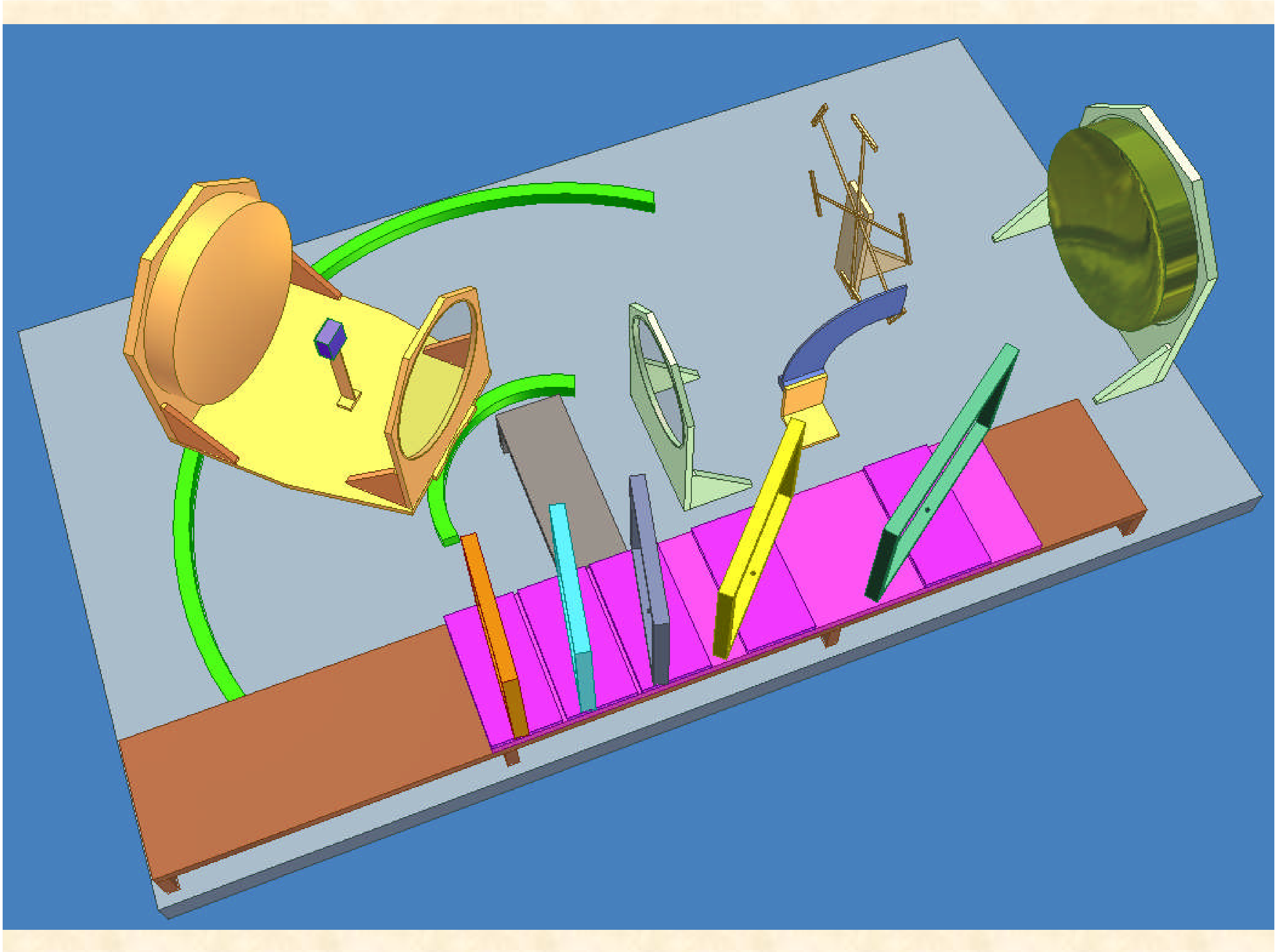
To change between survey modes we change: 1) the camera-collimator angle, 2) the VPHG and 3) the band-pass-filter.

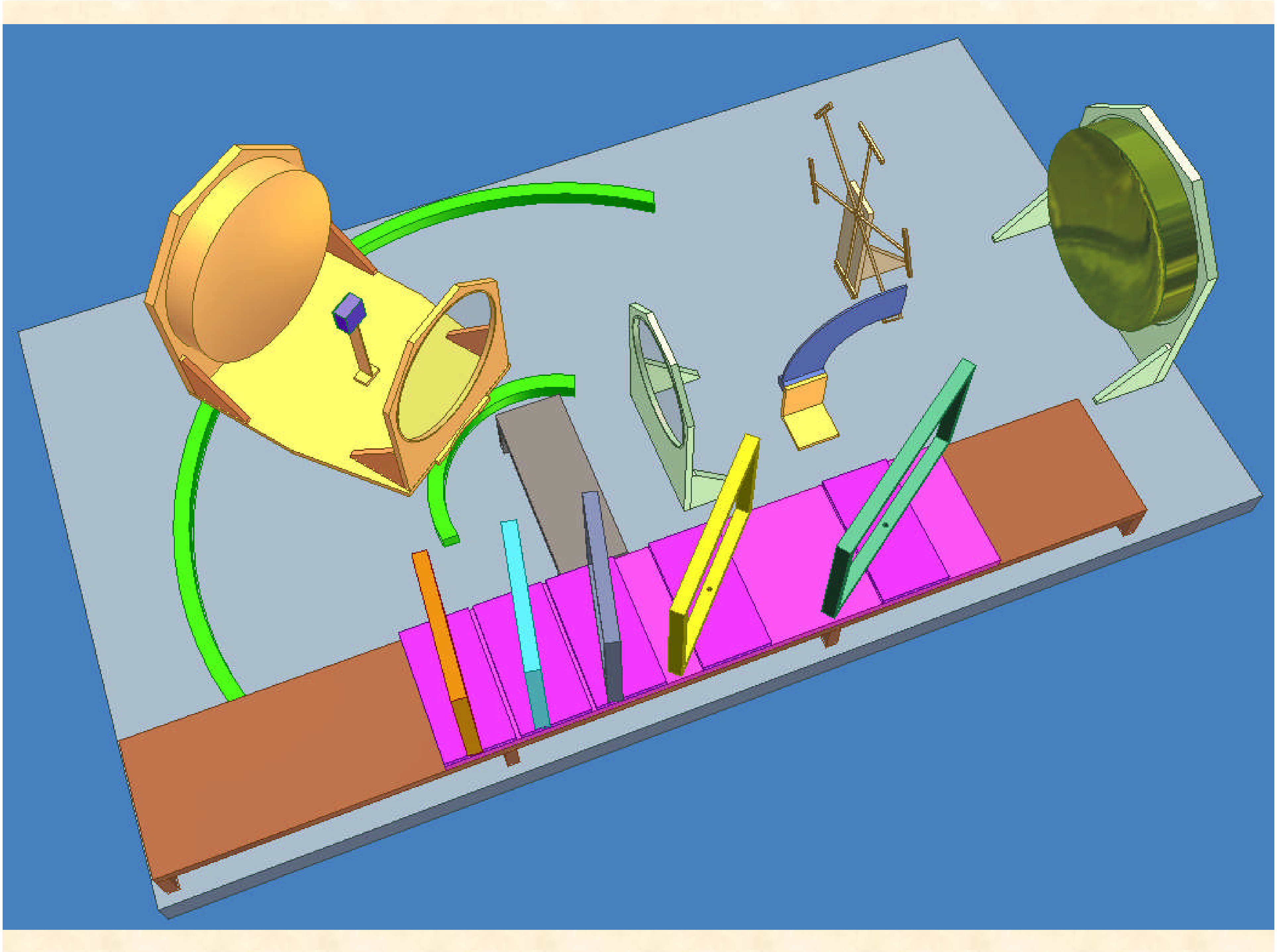


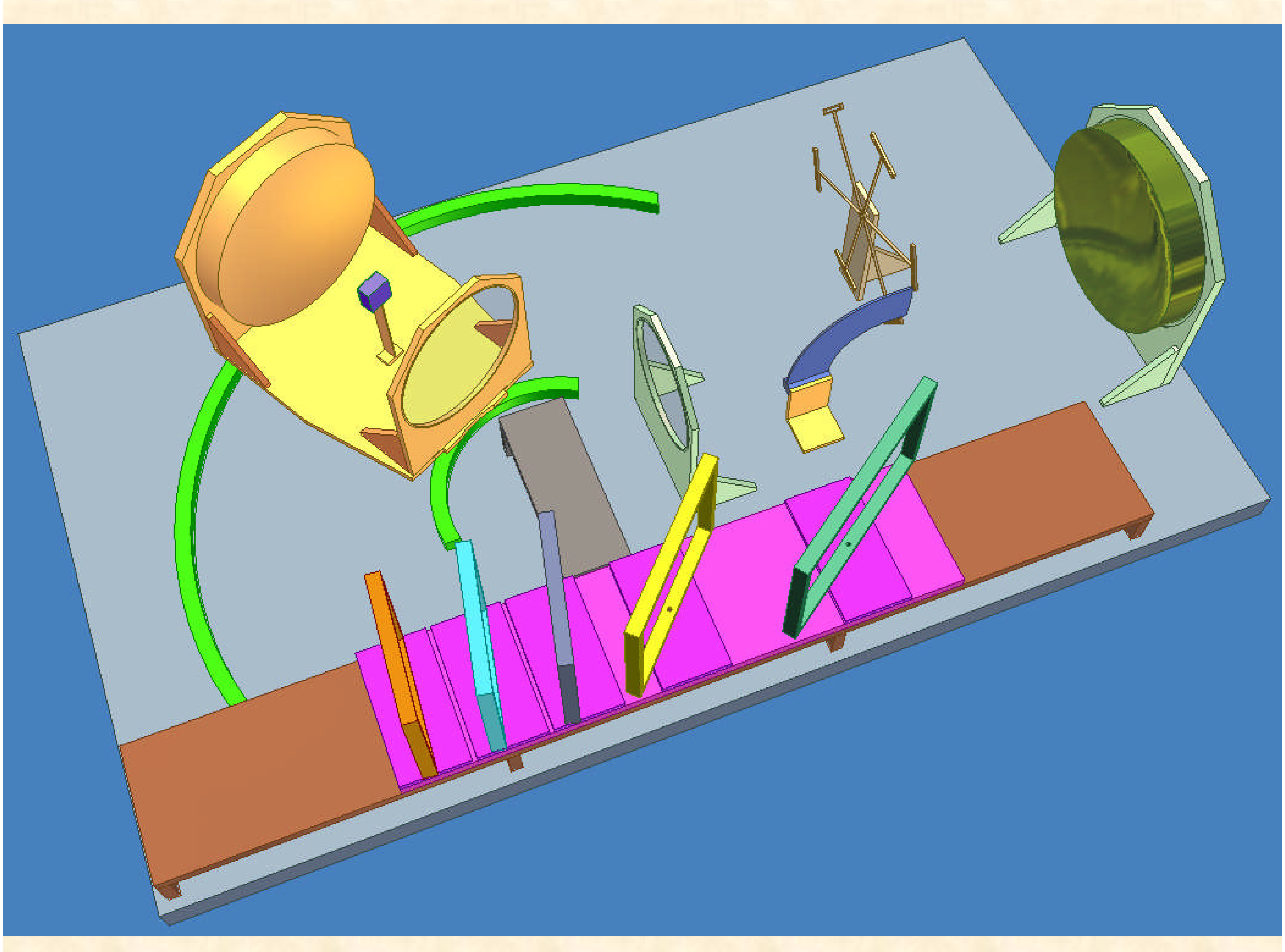
R=3,500 Configuration

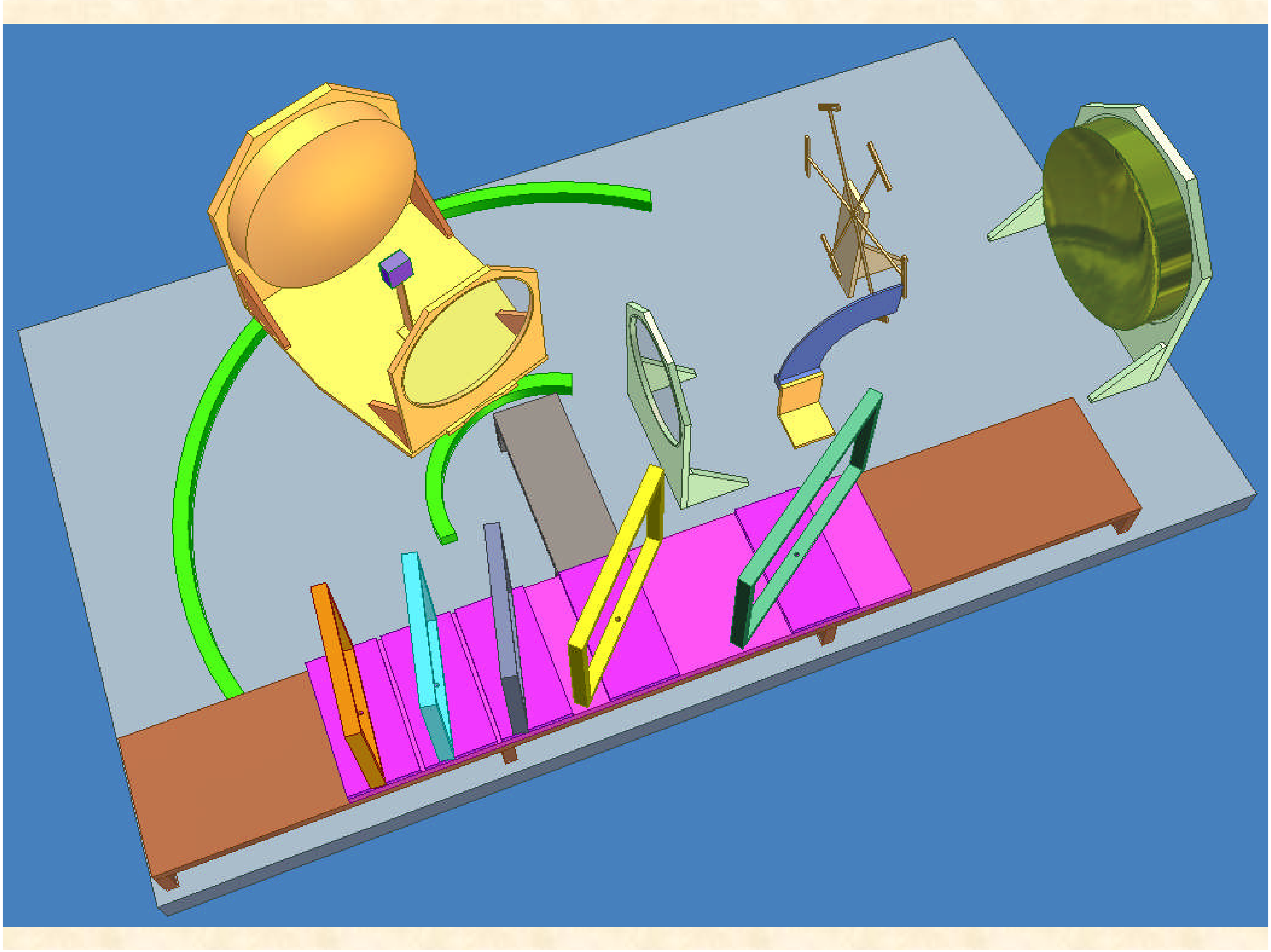


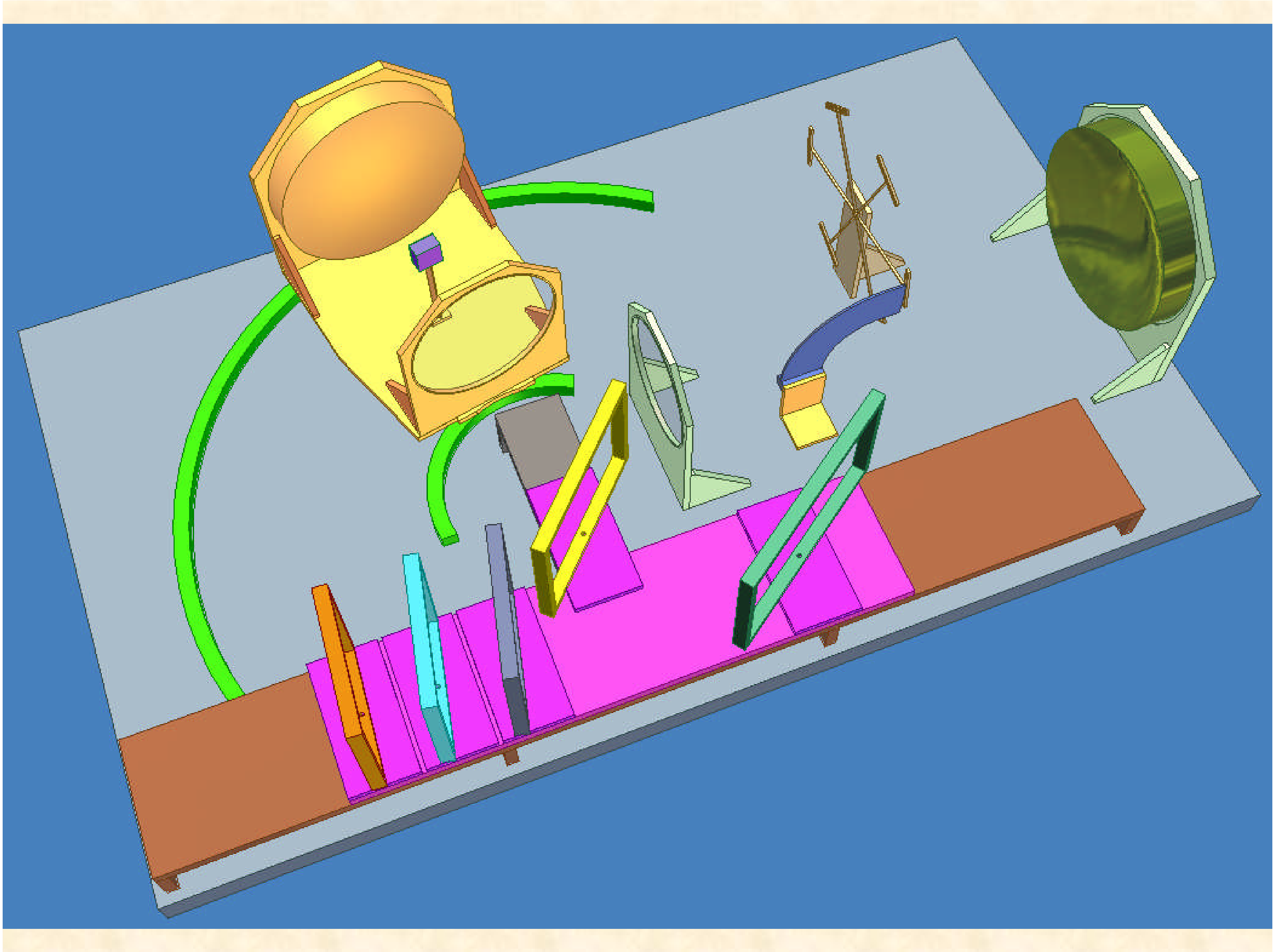


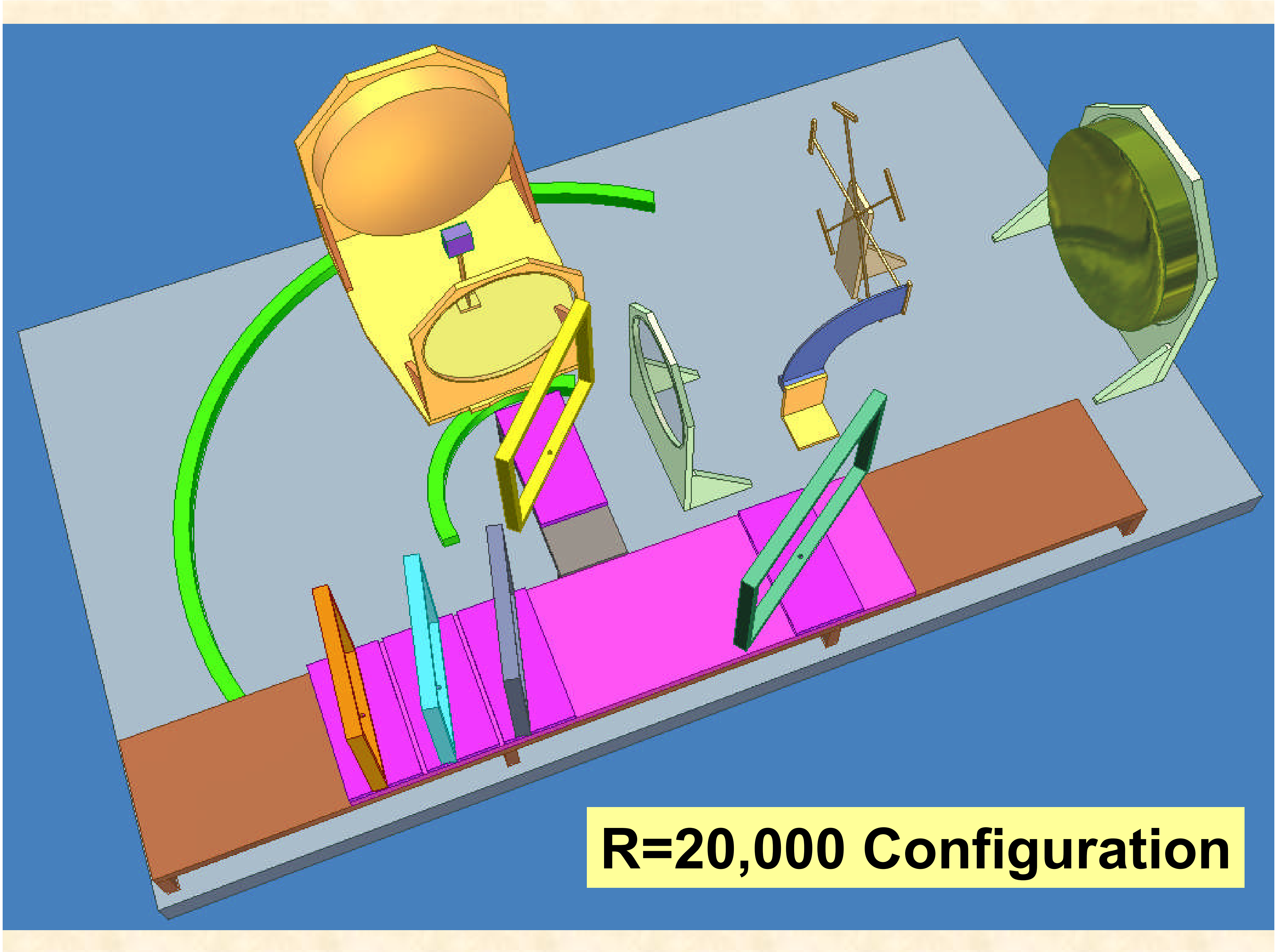










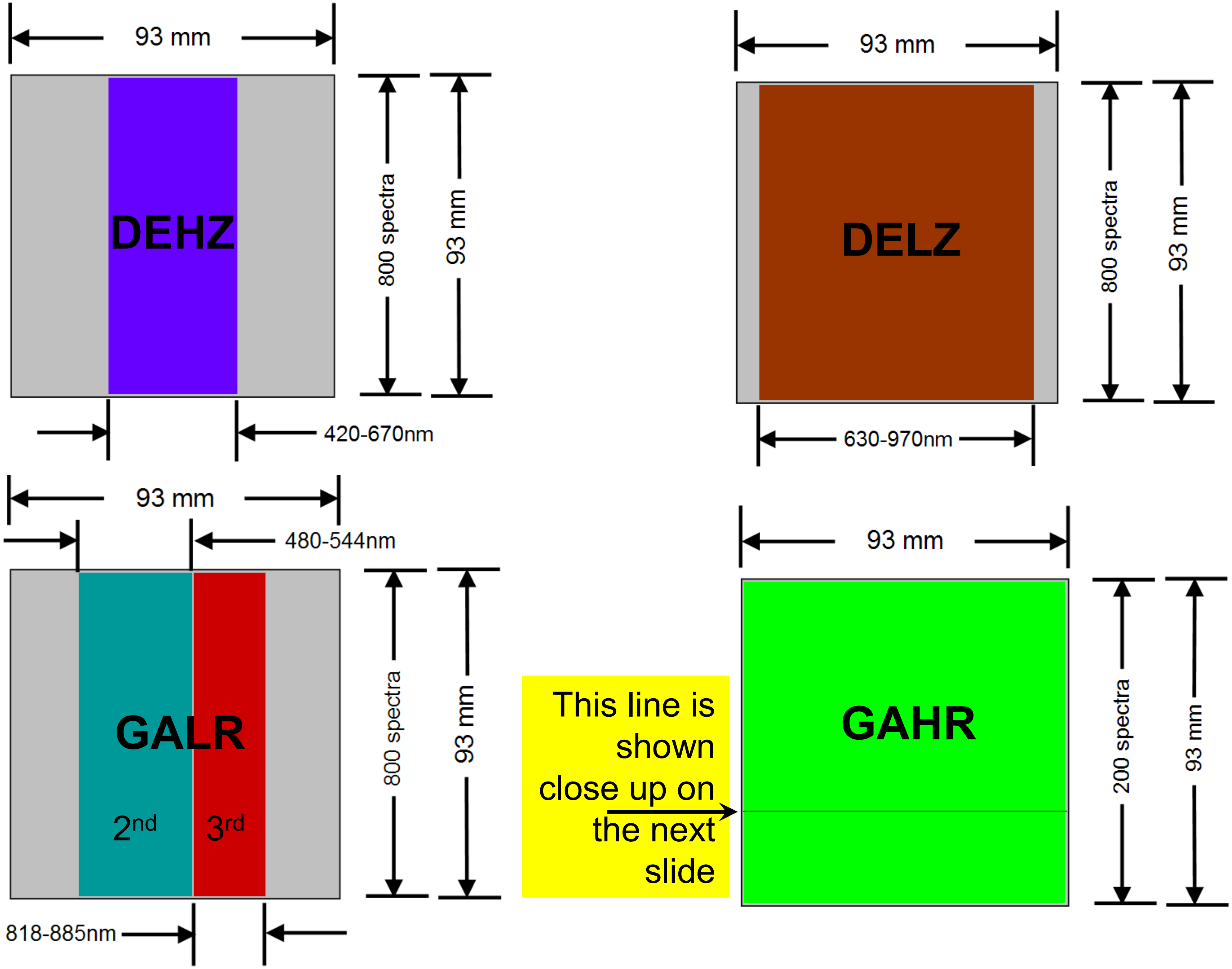

R=20,000 Configuration

Spectrograph Enclosure

- The spectrograph(s) will rest on anti-vibration mounts inside a temperature-controlled enclosure, controlled to 20°C.
- The system electronics and control computers will also reside in the same enclosure.
- The heat generated inside the enclosure will be dumped in to the telescope glycol system.
- The enclosure wall insulation will be substantial enough to ensure minimal heat transfer to the ambient air (<50W: FPRD).

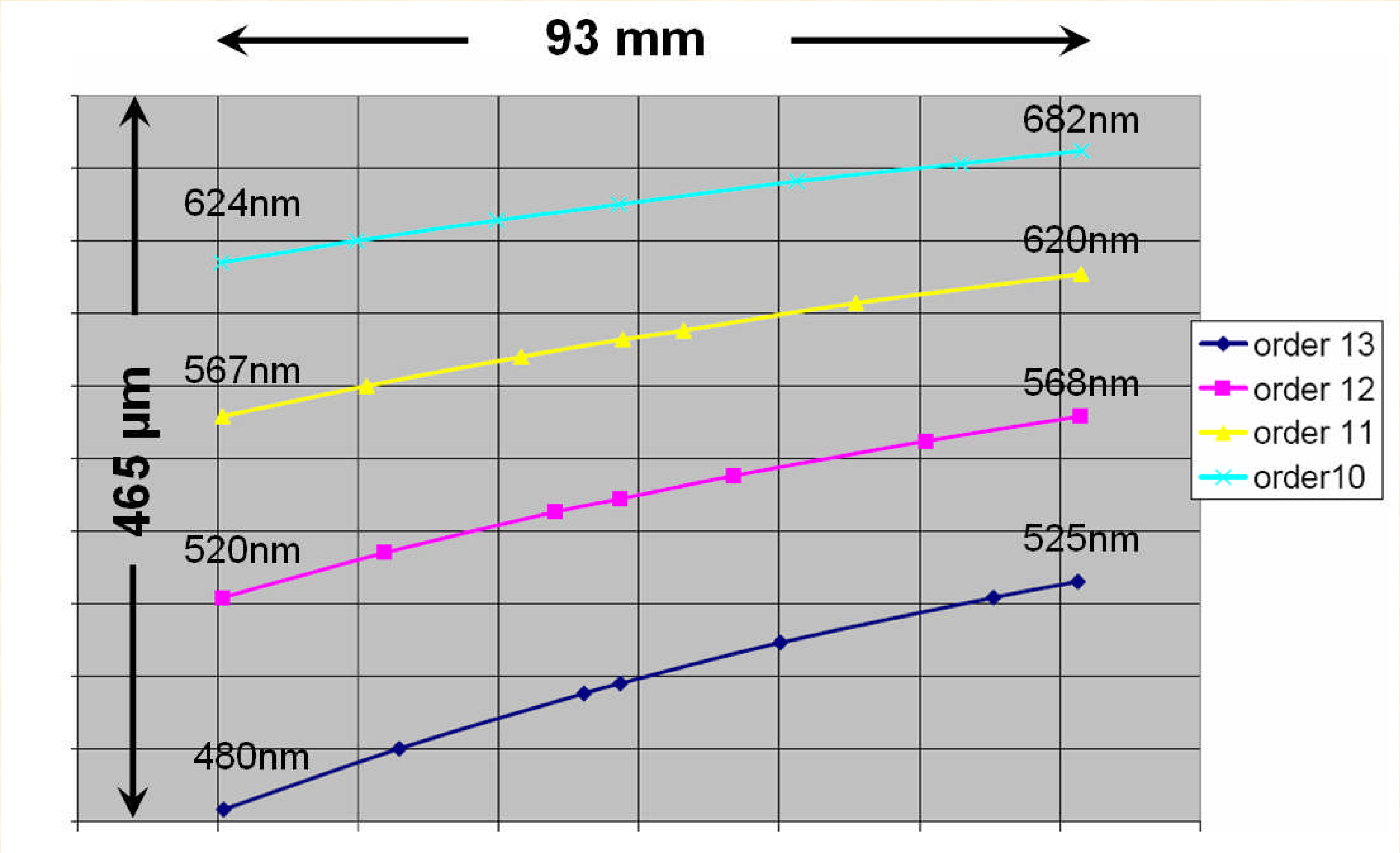
Performance

Data format on one detector for the various surveys



Data format for <u>one fibre</u> in the GAHR mode.

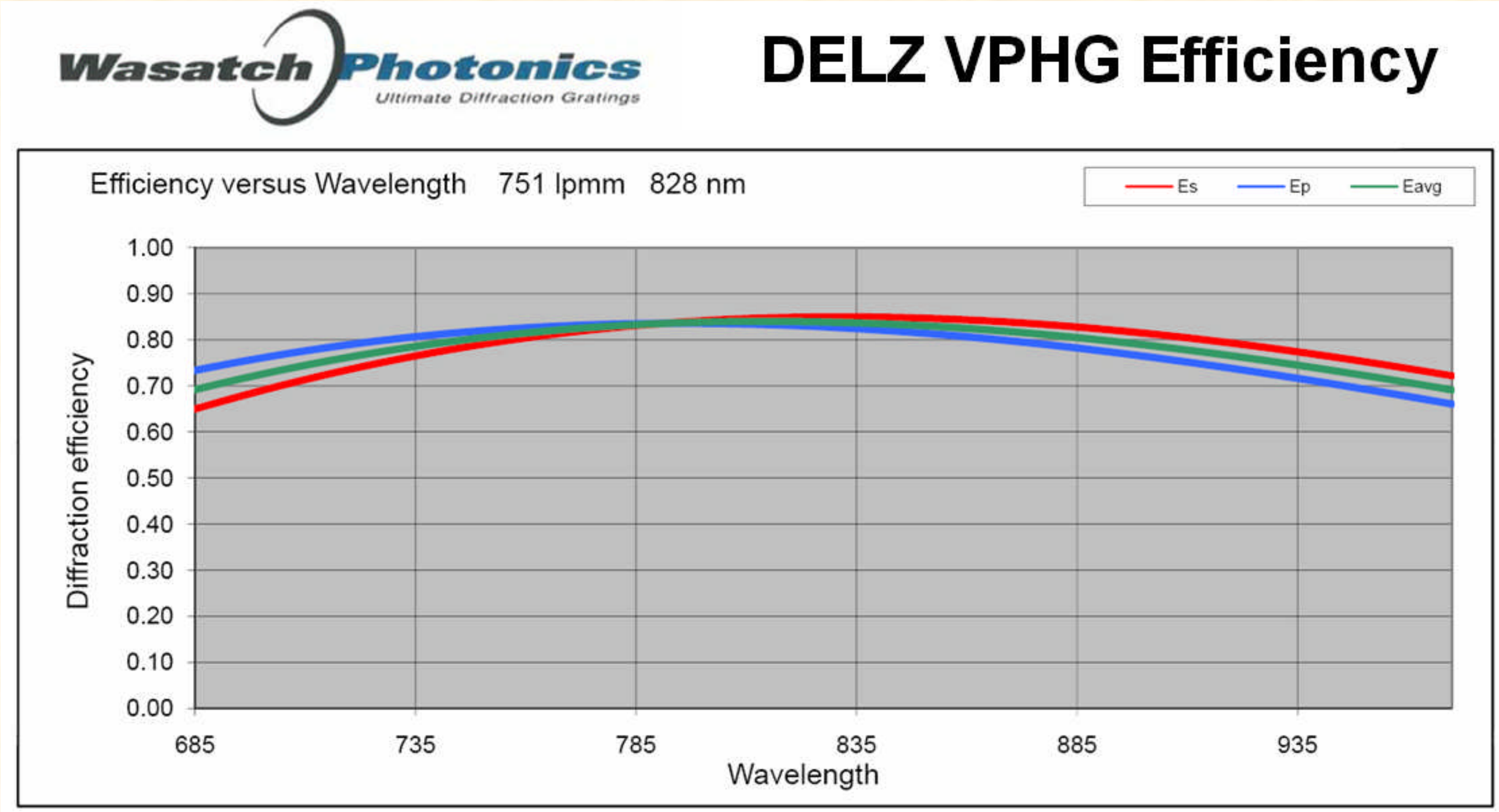
The area shown is the full width of the detector but only 1/200th of its height



Cross dispersion comes from a prism. Main dispersion comes from a VPHG.

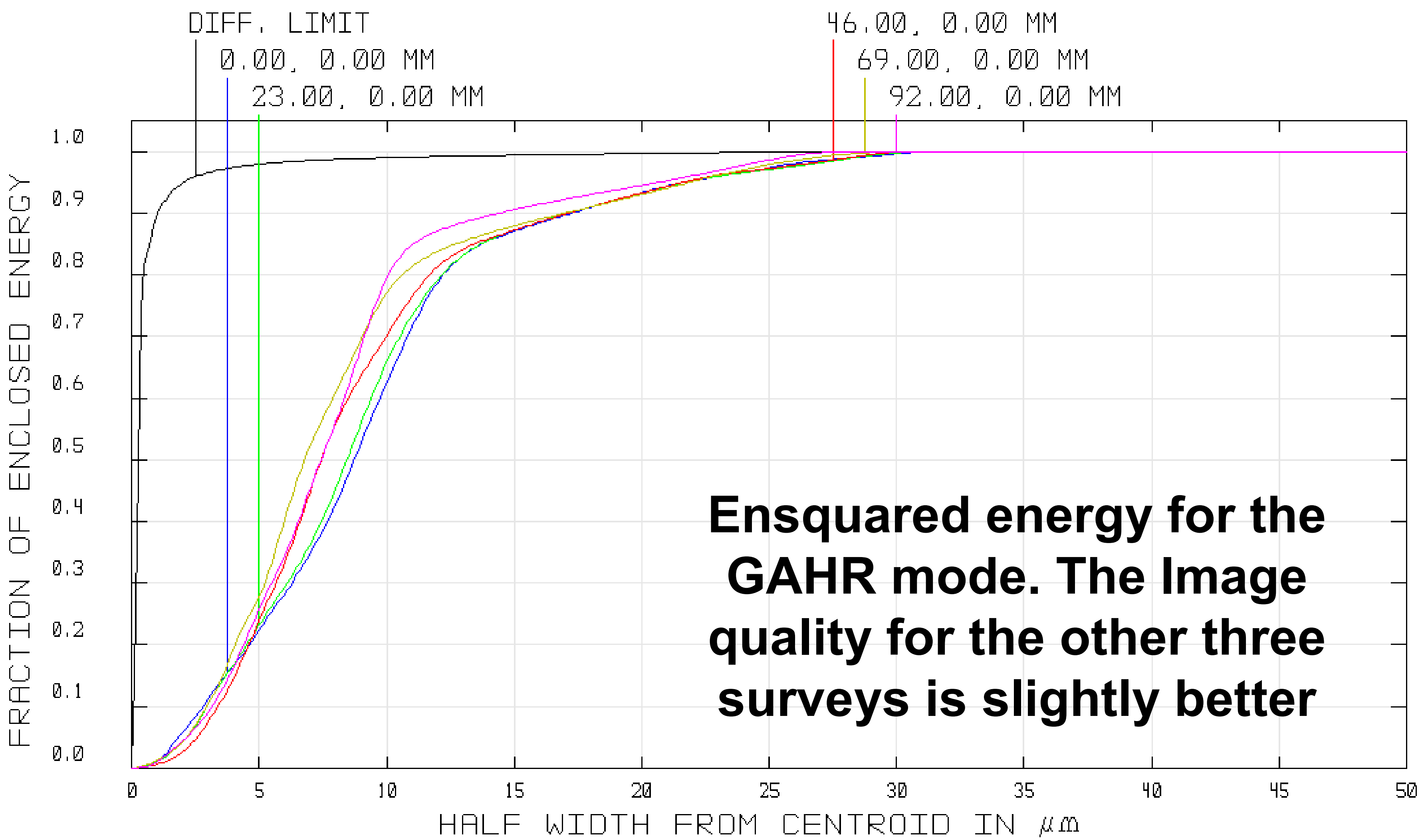
The volume phase holographic gratings (VPHG)

Survey	Central Wavelength	Orders	Lines Per mm	Camera-Collimator angle (deg)	Height	Width	R
	nm				mm	mm	
DEHZ	545	1	272	8.5	550	555	1500
DELZ	800	1	423	19.5	550	560	3500
GALR	850 & 515	2 & 3	282	26.4	550	570	5000
GAHR	580	10-13	211	87.1	550	750	20000
MAXR	550	1	2979	110.0	550	940	29707



Throughput example (DELZ)

Fibre end loss	98%
Filter	98%
Collimator optical surfaces	96%
VPHG	85%
Camera optical surfaces	96%
Combined camera and collimator obstructions	91%
Total	69%

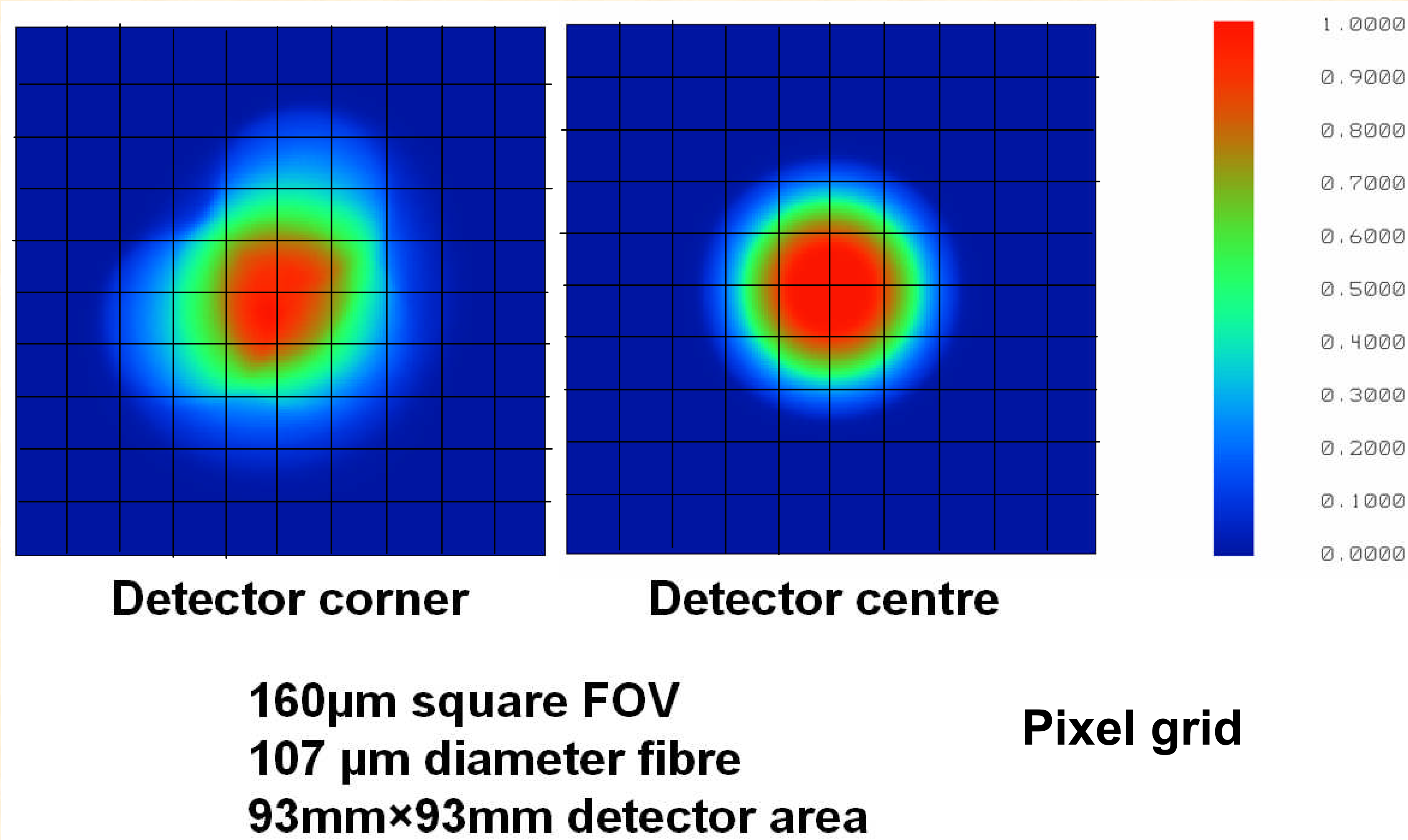


Ensquared energy for the GAHR mode. The Image quality for the other three surveys is slightly better

FFT DIFFRACTION ENSQUARED ENERGY

MON NOV 17 2008
WAVELENGTH: 0.532000 µm
SURFACE: IMAGE (DETECTOR)

GAHR-12TH-ORDER.ZMX
CONFIGURATION 1 OF 1



Images of a monochromatically illuminated fibre at the detector corner (worst case) and the field centre (best case). The FWHMs are in the range 54 – 64μm over the whole detector. We therefore achieve our required spectral resolutions.

Conclusions

- We have a spectrograph design with a very **large A-omega** which is well matched to 8m class telescopes.
- The design is very **efficient** which minimises the time taken to carry out large surveys.
- The design is very **versatile** and will allow astronomers to carry out a large range of science programs (most of the ones presented at this workshop).

Fin