

Multi-purpose toroidal optical view AEA21 using CXRS Immersion Tube.

Idea Proposal for OP2.1/2.2?

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CXRS Immersion tube AEA21

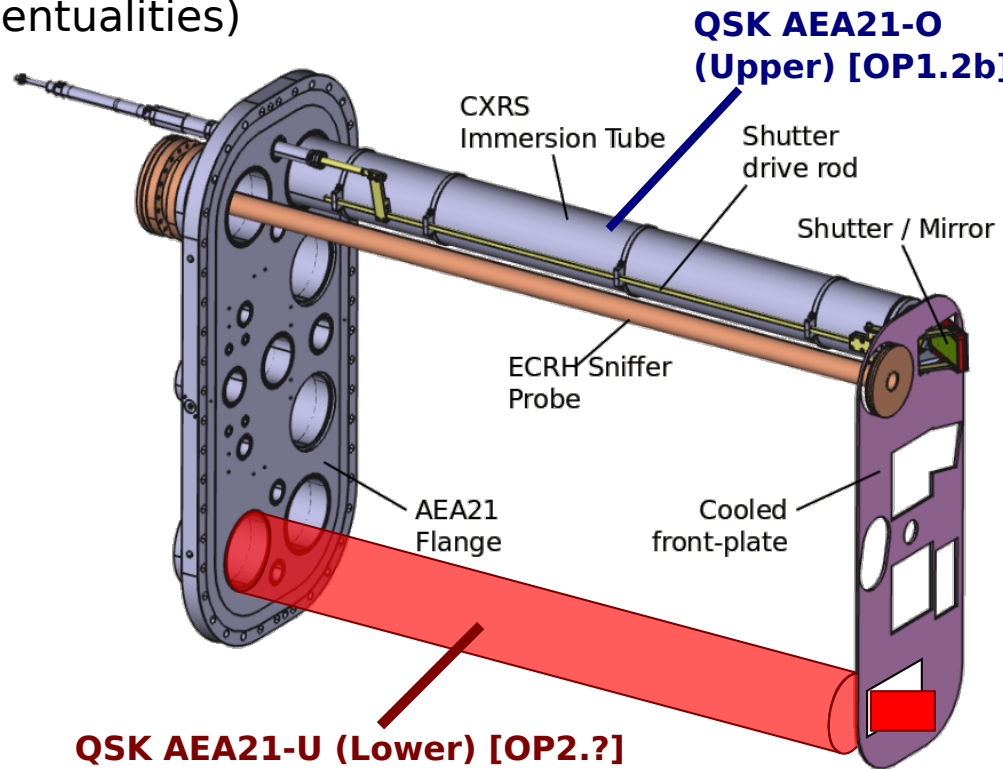
- Several diagnostics require a high-étendue toroidal plasma view:
 - E3/QSK: CXRS on NBI for NI20
 - E4/QRI: Doppler CIS
 - E4/Q??: Fast Video (system??) (E4)
 - E3/QST: Motional Stark Effect
 - E5/Q??: Fluctuation Beam Emission Spectroscopy (US Collaboration??)
- } AEA21 in OP1, which may need replacement with pinhole.

Proposal: Build 2nd immersion tube for CXRS.

- Vacuum interface components could be ready for OP2.1 (<15k€):
 - 9.3k€, repeat existing orders. (+5k€ eventualities)
 - One small TD Auftrag.
 - Minimal workload for E3-DIA, PK, QM.
 - Zero workload for DE, AS or CoDAC.

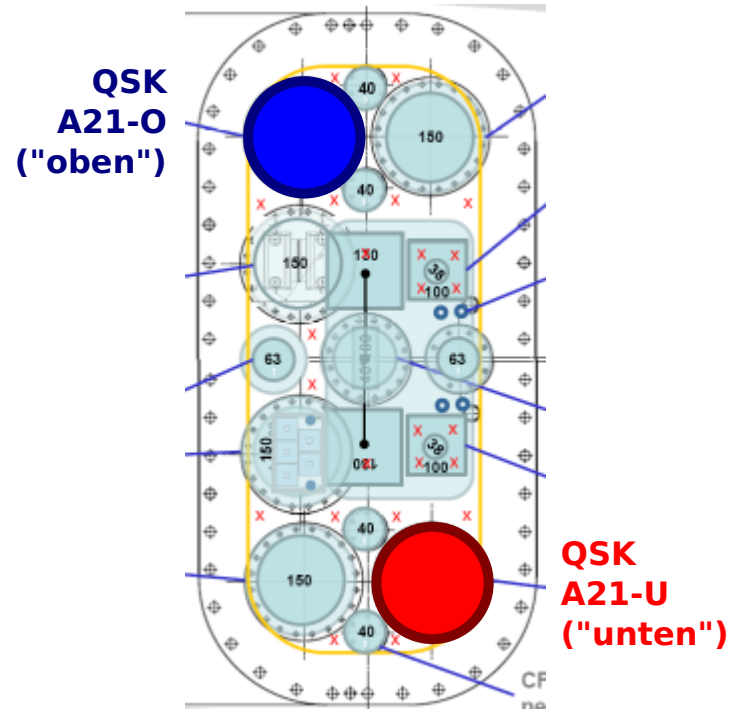
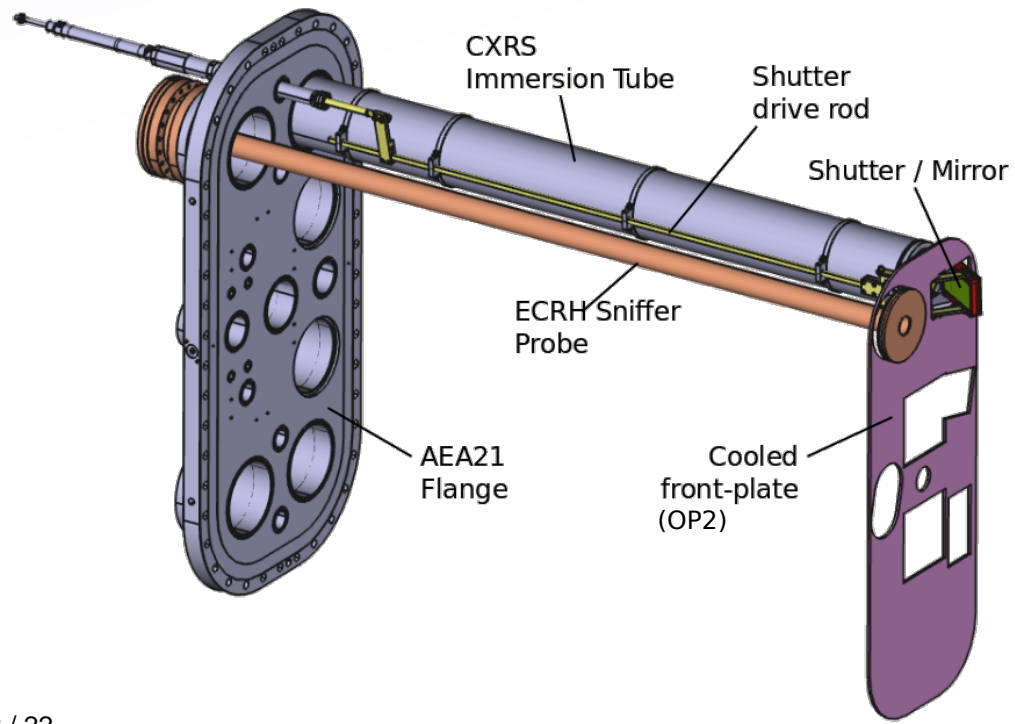
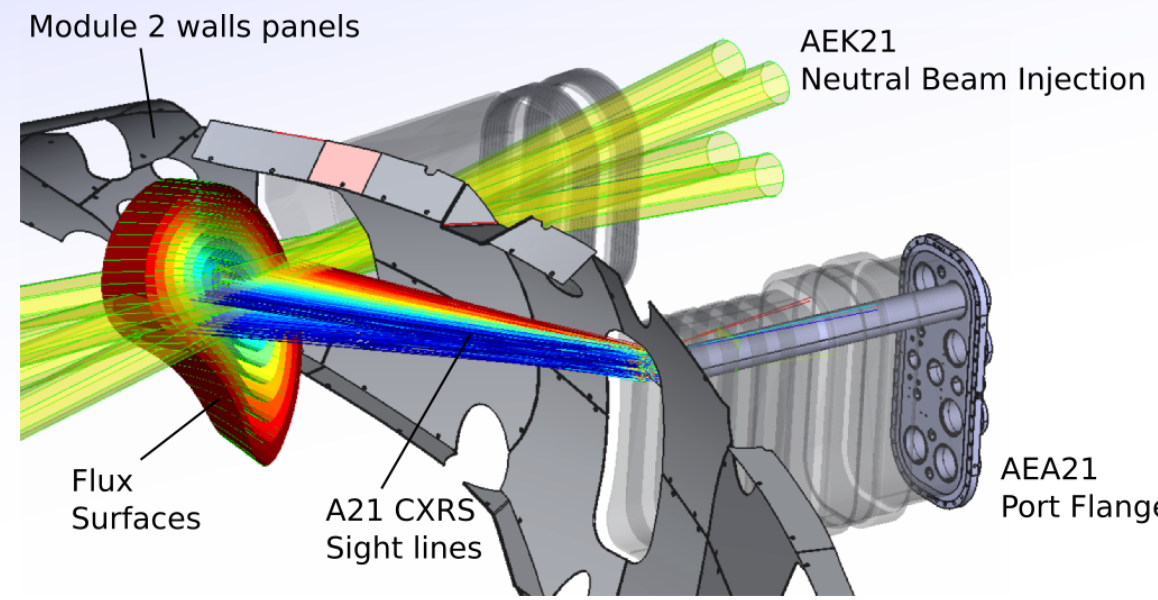
Disadvantages:

- Limited measurement period in 10MW long-pulse operation (~10secs)
- Optics need to be designed and built.



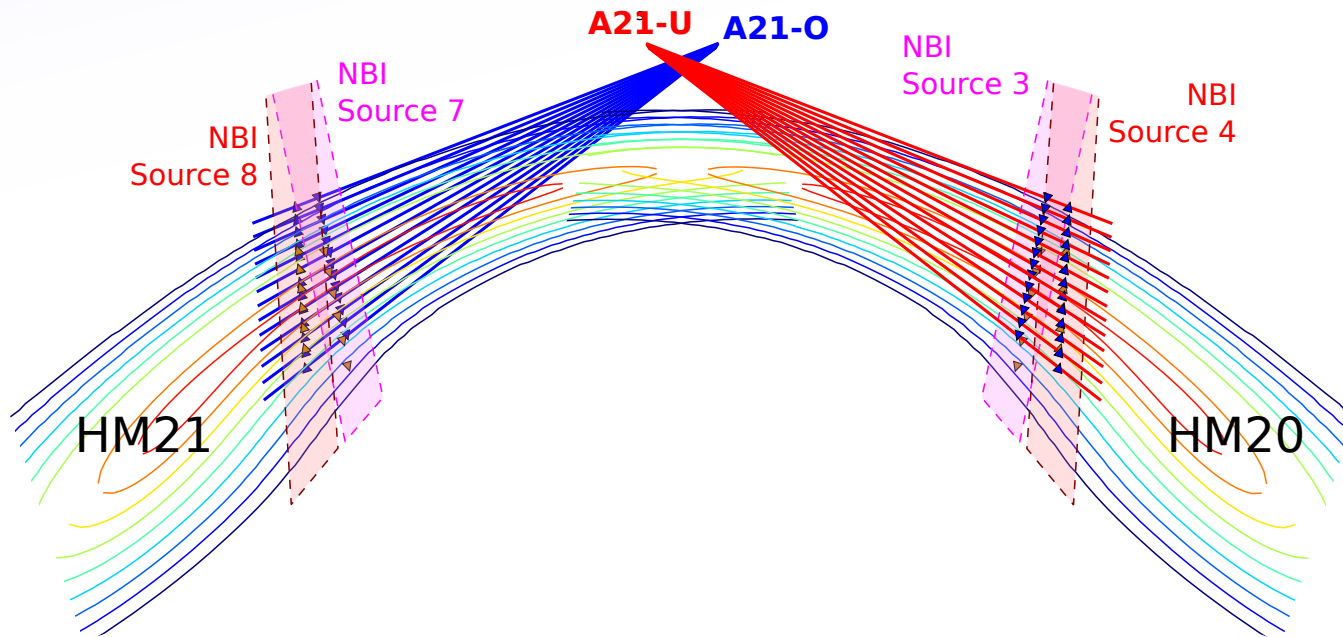
CXRS Immersion tube AEA21

- AEA21 plug-in tube viewing M21 installed and operated in OP1.2b.
- Daughter-flange was reserved for possible opposite system viewing M20.



Approximate view (CXRS optics)

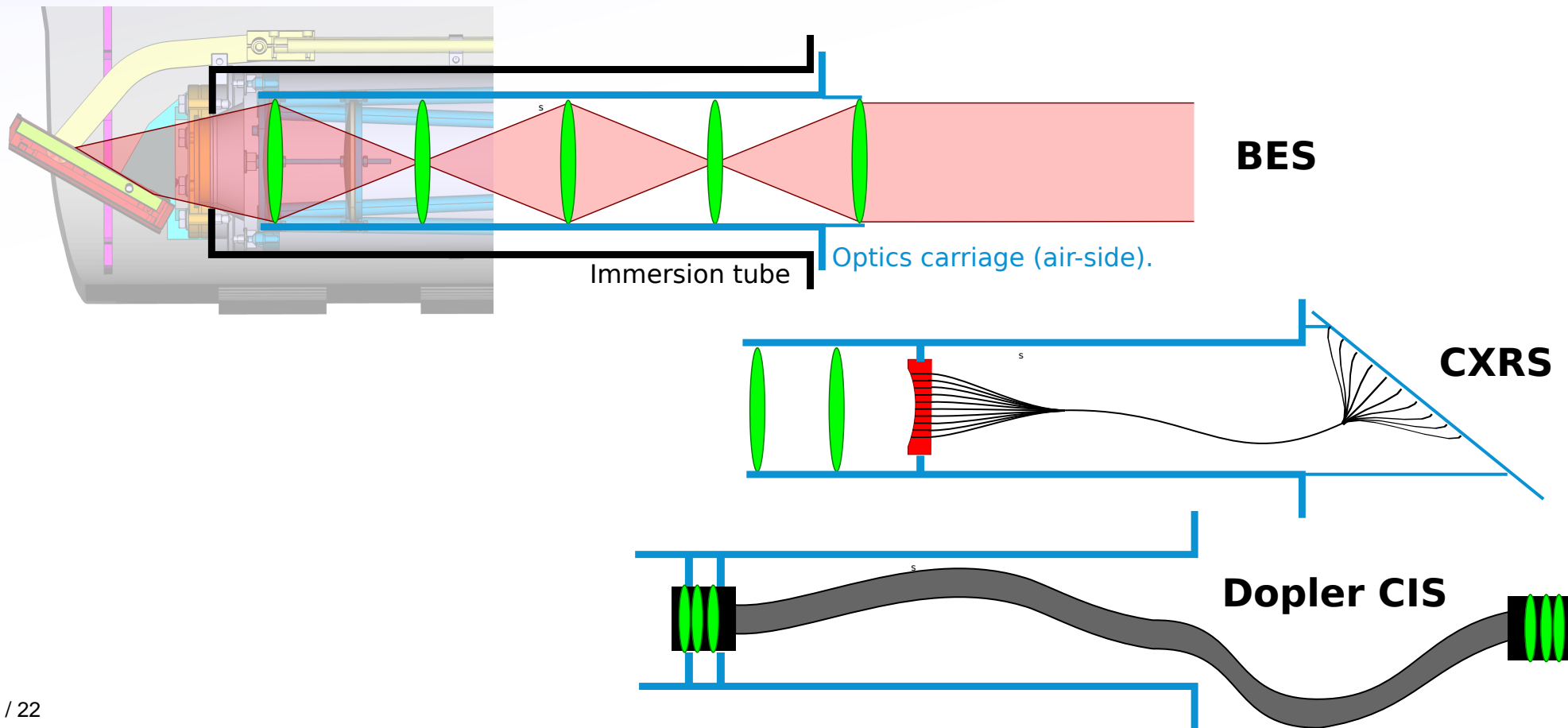
- System uses a in-vacuum mirror to view toroidally.
- Mirror can only be opened for ~ 10 s periods at 10MW - **not steady state capable!**
(This is the design safe estimate. Can probably be increased with some calculations)
- Shutter and tube cooling under development for OP2.1.
Whatever the solution is, can be repeated for A21-L (budgeted 5k€ here).



Optics / Usage

- Optics not covered in 15k€, but would need a redesign required anyway.
- Optics can be completed later (not vacuum-side).
- Could E4, E5, US or Hungary contribute optics?

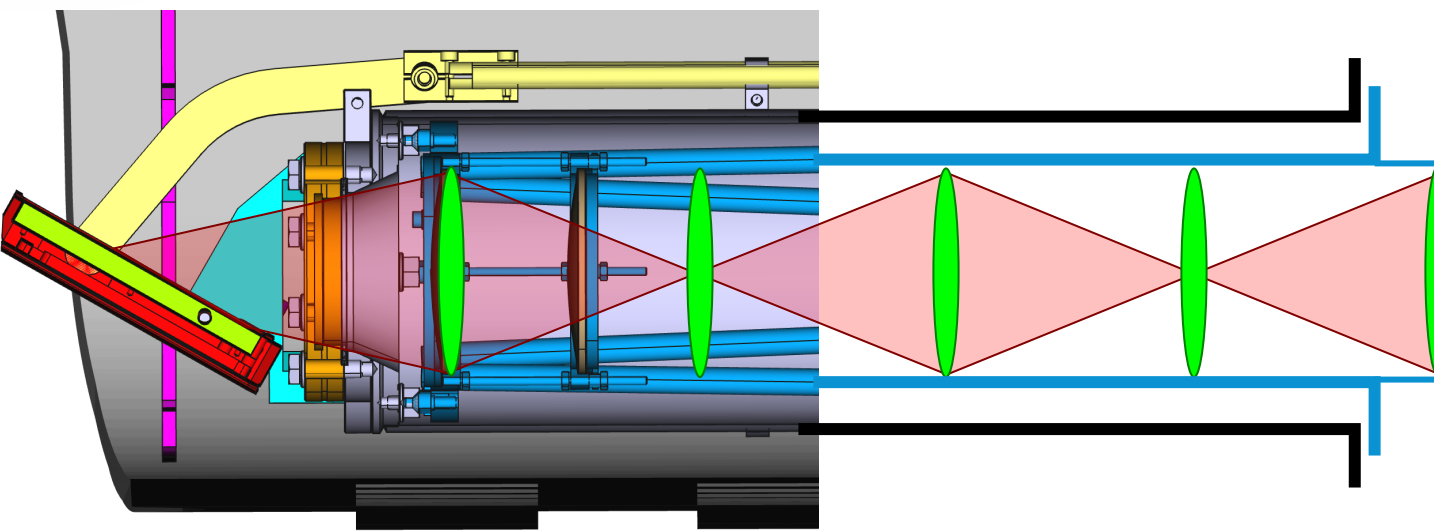
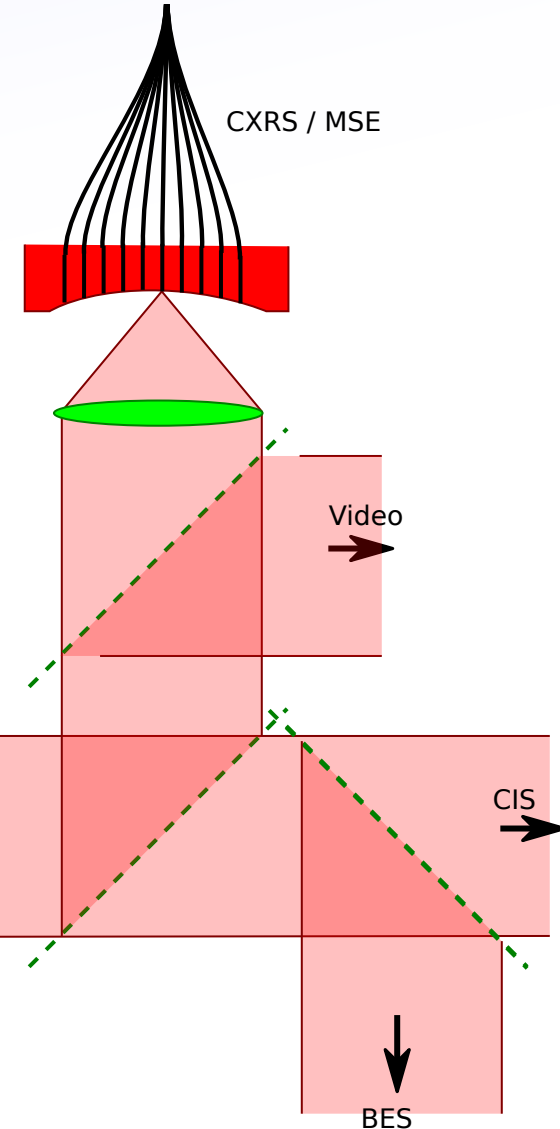
Concept 1: Separate optic carriage for each diagnostic:
Preliminary, simple mechanical designs.
Time-share diagnostic port through-out campaigns.



Optics / Usage

Concept 2: Image transfer and beam splitters.

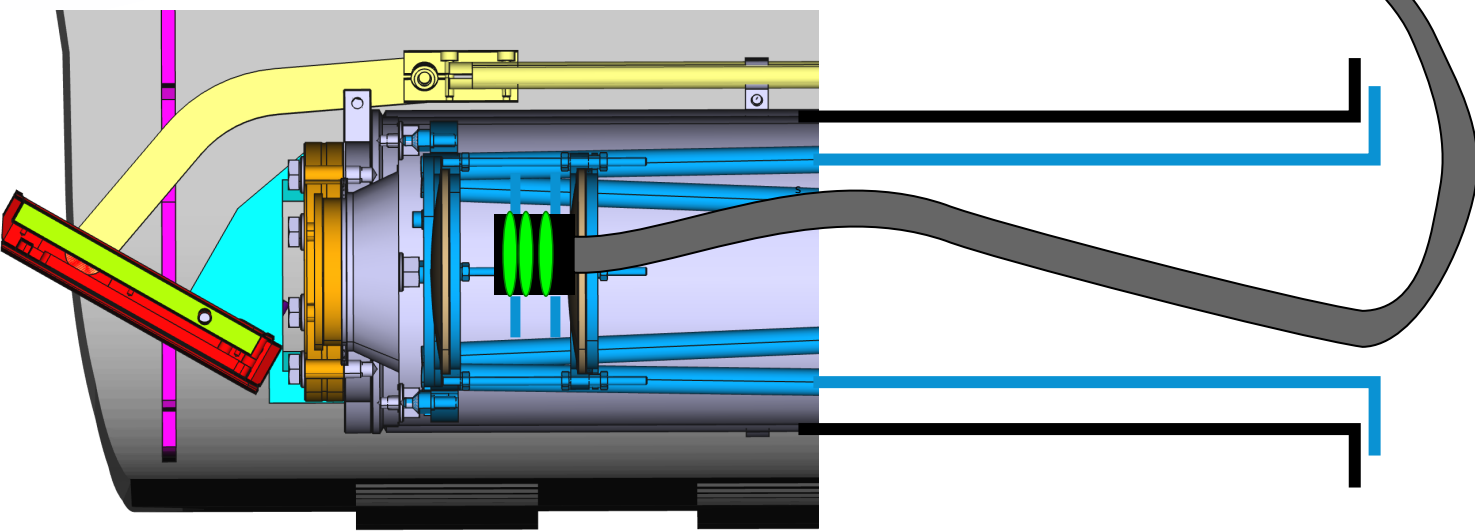
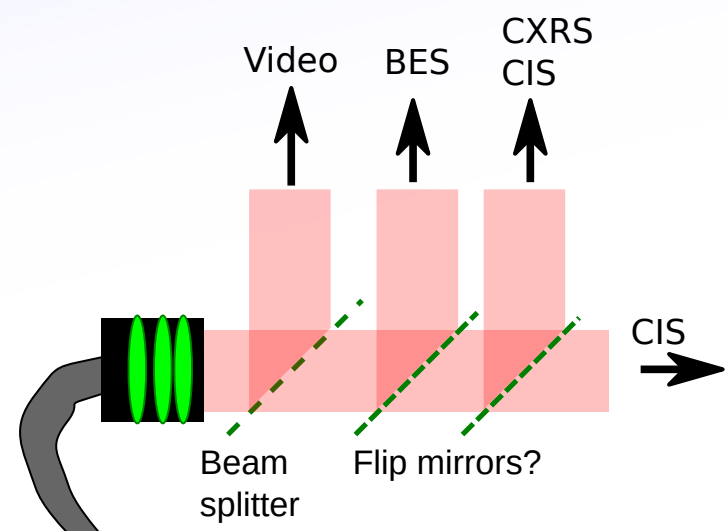
- Requires complex detailed optics design.
- Compromise FOV vs etendue between diagnostics.
- No fibre bundle --> Significant upgrade in etendue for CIS.
- Possibly motorised mirrors for full-etendue time-share?
- Could feasibly hi-jack CIS for iMSE and iCXRS studies.



Optics / Usage

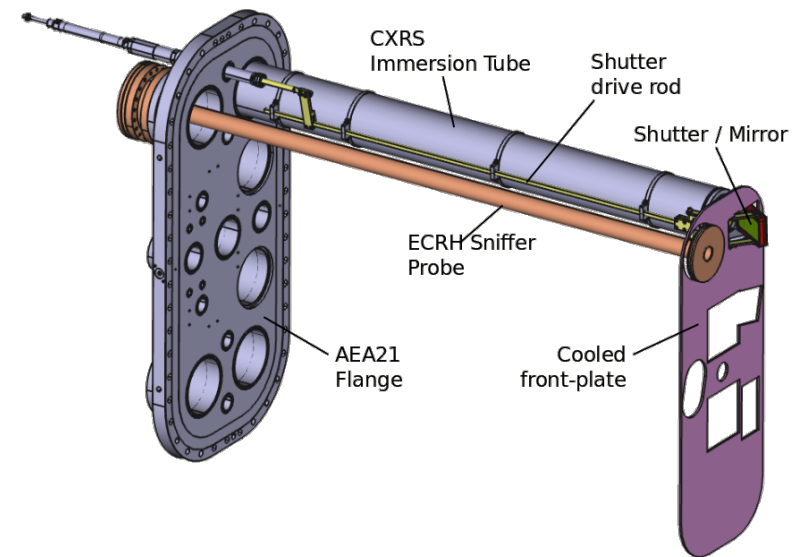
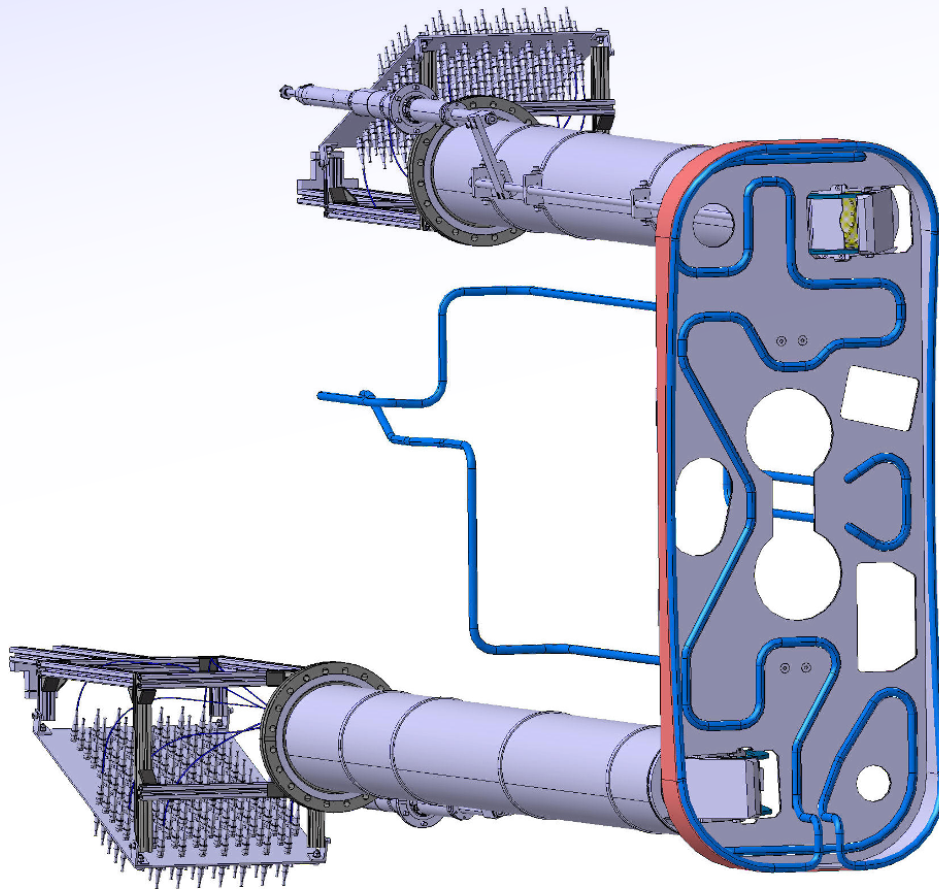
Concept 3: Image fibre bundle and beam splitters or flippable mirrors.

- Time and/or light share?



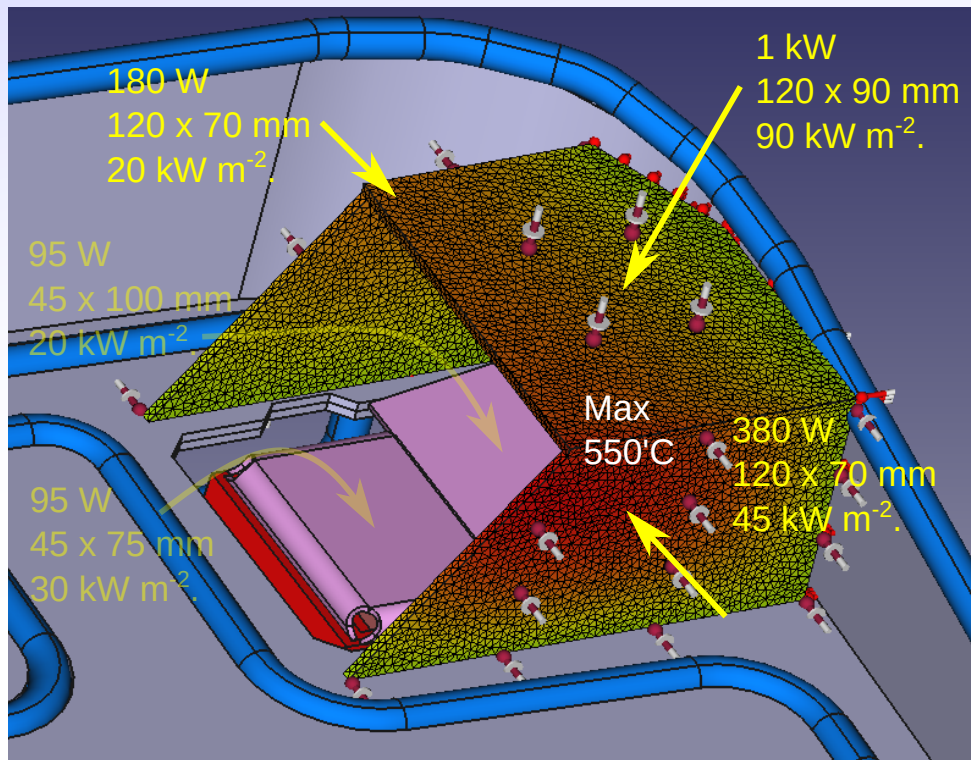
Frontplate

Front plate cooling as part of AEA21 common to multiple diagnostics.
Already near complete design:



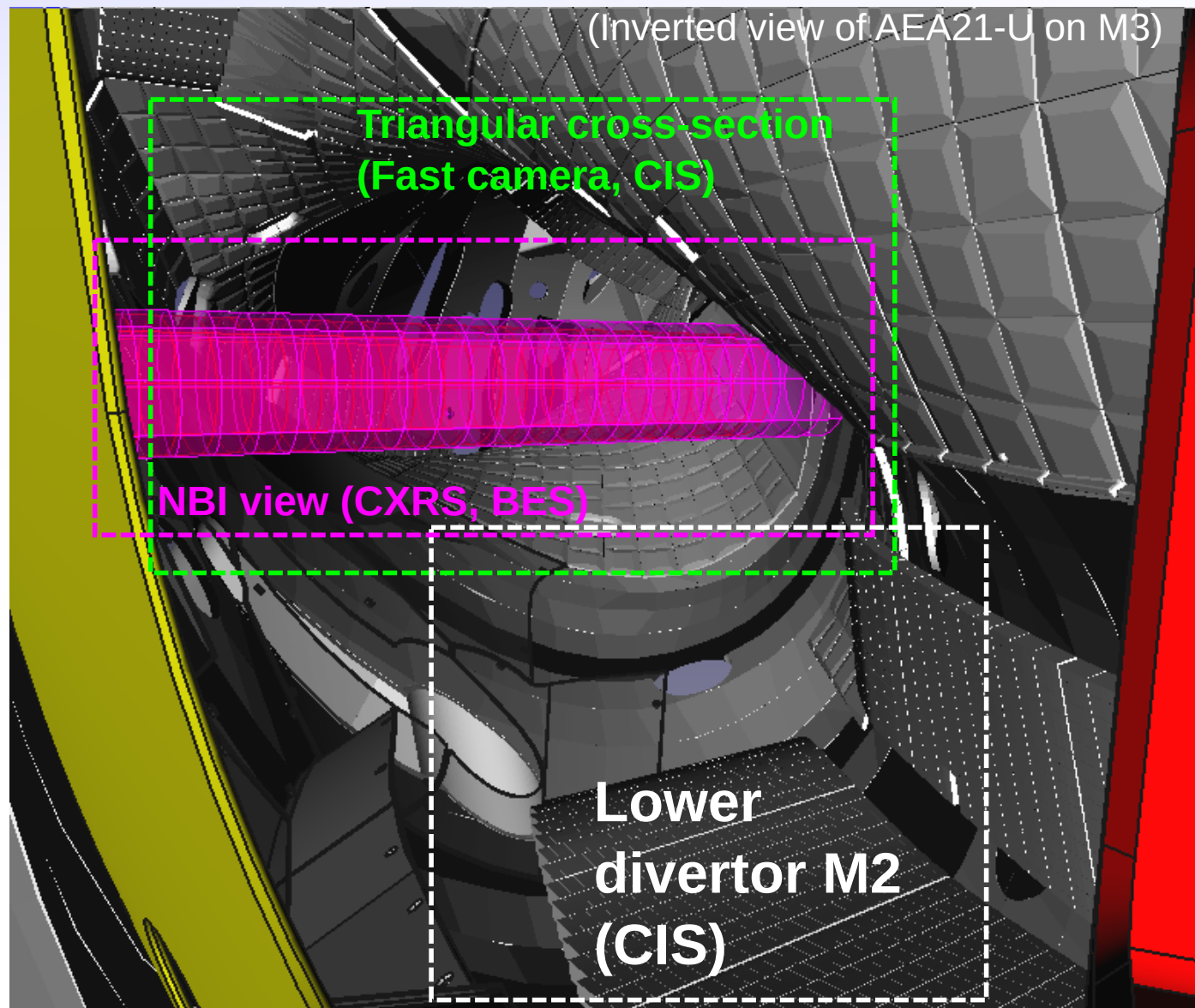
AEA21 - Outer Cover

Outer cover is required as part of OP2 cooling upgrade to QSK-AEA21-U/O systems.
Barely limits view from mirror.



AEA21-U - view

View from AEA21-U:



AEA21-U - CXRS fibres

The image fibre bundle is:

10mm x 8mm at $\sim F/0.85$

The front end lens will be a $\sim 17\text{mm}/0.95$ lens.

To extend the conventional CXRS system, we can reimage the fibre bundle on to the normal CXRS transfer fibres:

$NA=0.22 \rightarrow F/2.3$, 400 μm core, min 0.5mm spacing

Max $\times 2.3$ magnification to fill $F/2.3$ from $F/1$ image guide.

0.5mm spacing becomes 0.2 spot, 0.25mm spacing on bundle.

$f=17\text{mm}$, $v=2\text{m}$ distance to beam $\rightarrow u=17.1\text{mm}$ focal dist

\rightarrow spot size on beam = 23mm

channel spacing on beam = 29mm

This is about 2.5x worse than the AEA21-O CXRS system and would allow ~ 13 channels across the radius.

Stacked and with the HFS one could add a AUG-type spectrometer:

Transfer fibres: 12k€

Spectrometer:

CCD: 40k€

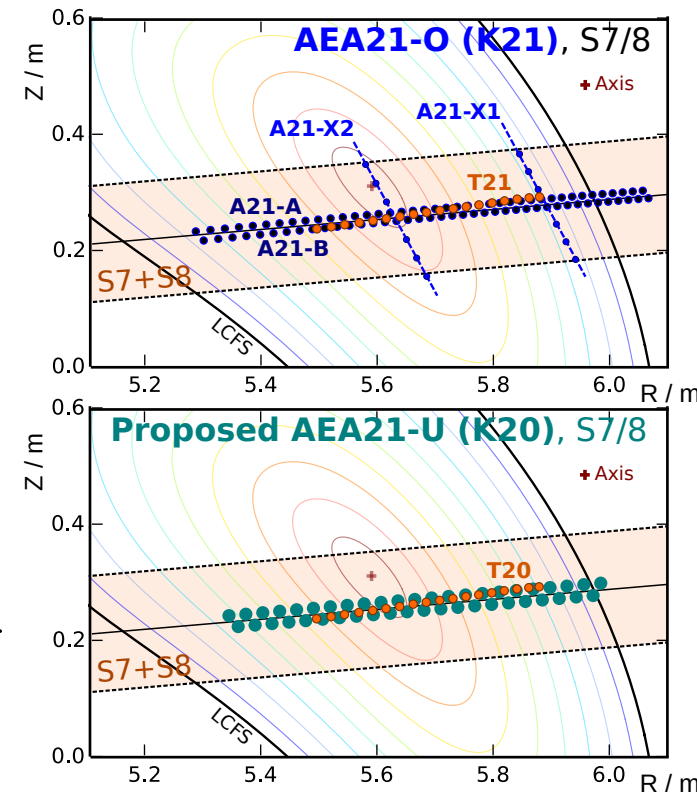
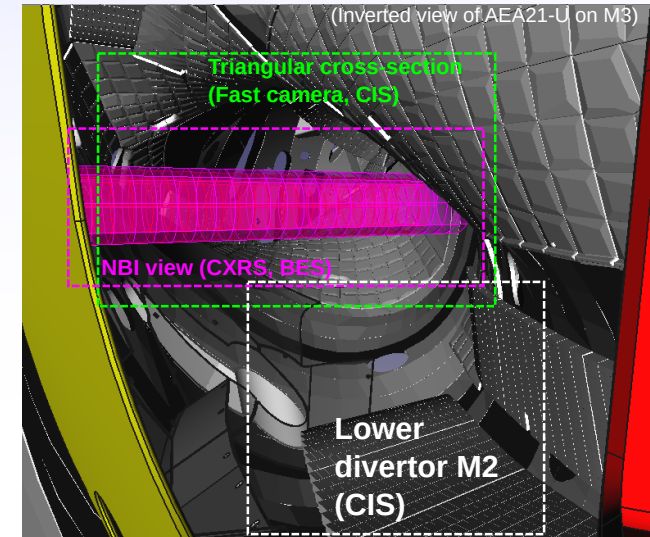
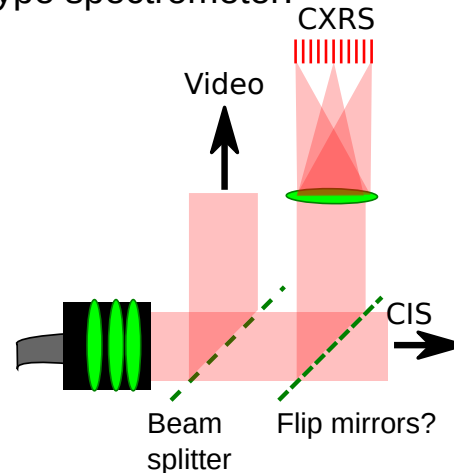
Opto-mech: 10k€

Lenses: 8k€

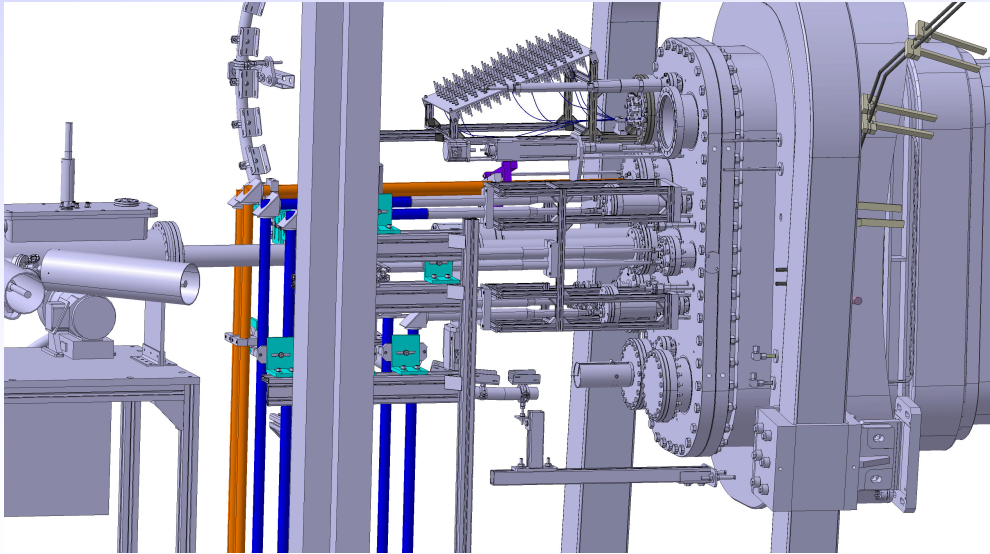
Grating: 0€ (Use old SPEX-M)

Head fibres: 0€ (Technician)

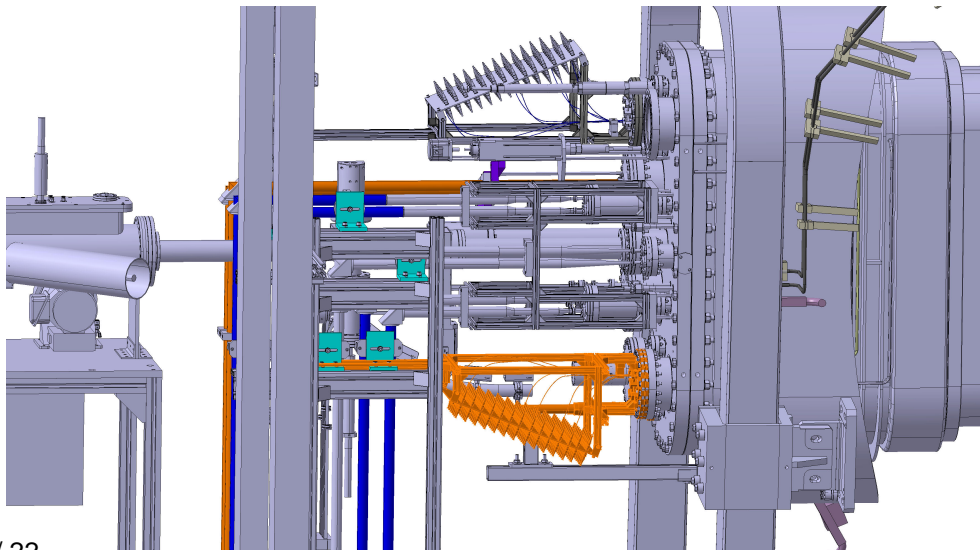
= 70k€ for 45 channels @ 1/2 S/N, $\Delta r = 2.5\text{cm}$



CXRS Immersion tube AEA21

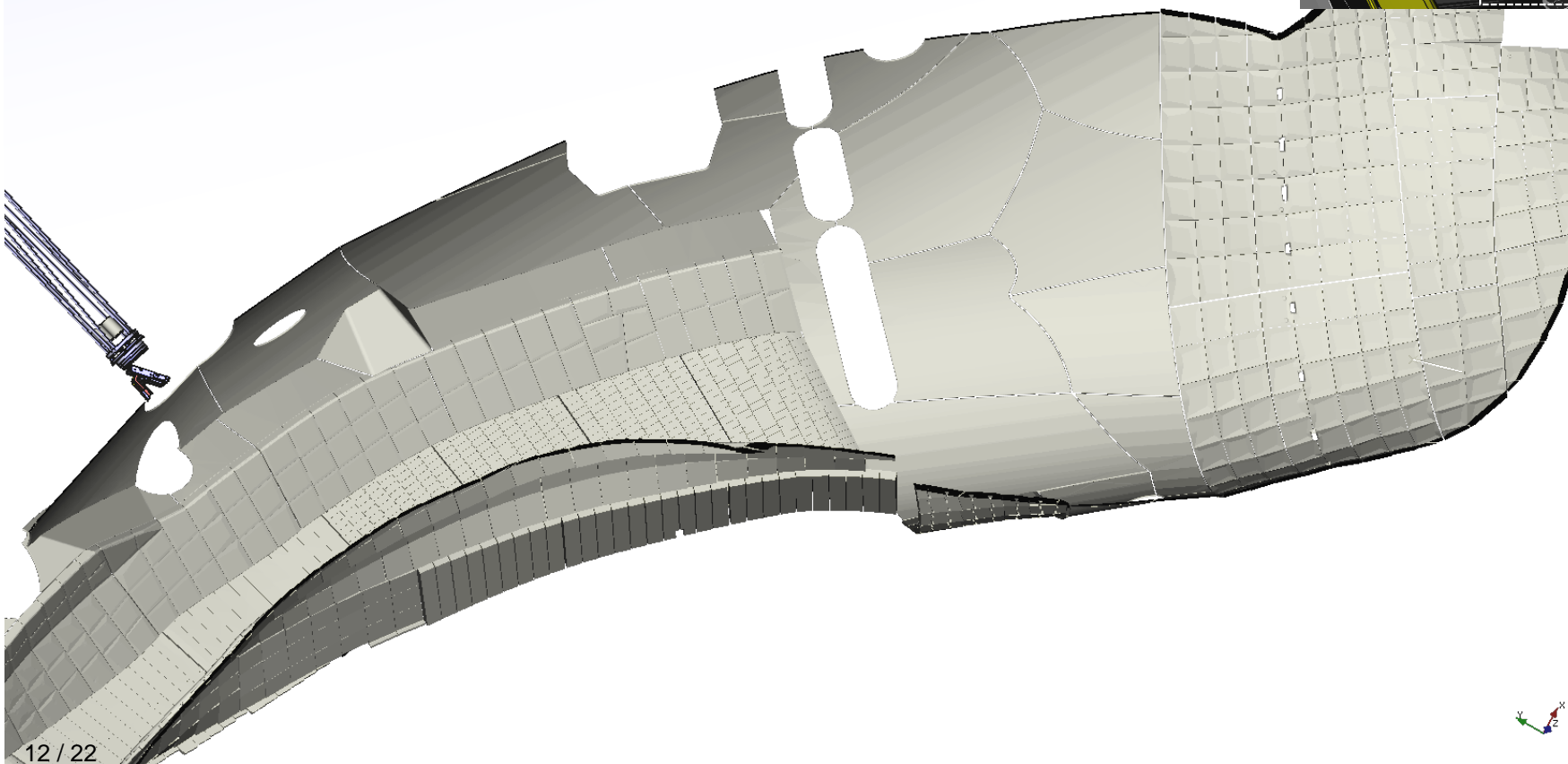
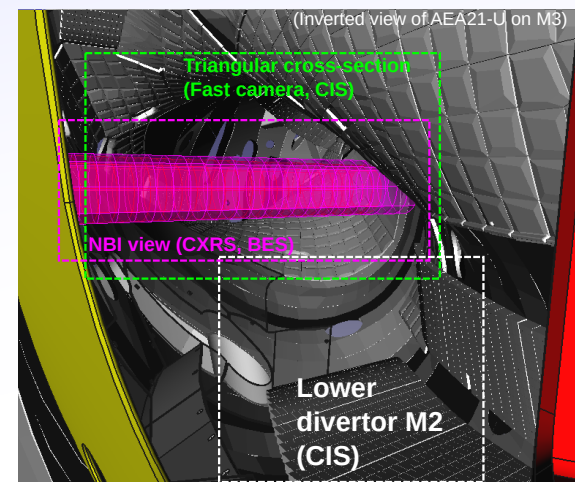


- Need to check space behind port for optical design.
- Currently insufficient space to install/remove existing optics carriage and patch panel as AEA21-O due to waveguide supports.
- Waveguides and supports can be modified?





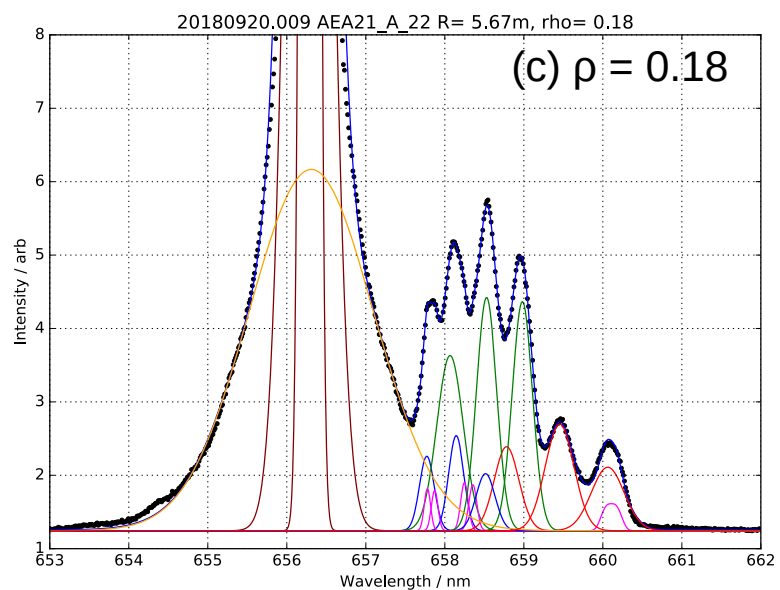
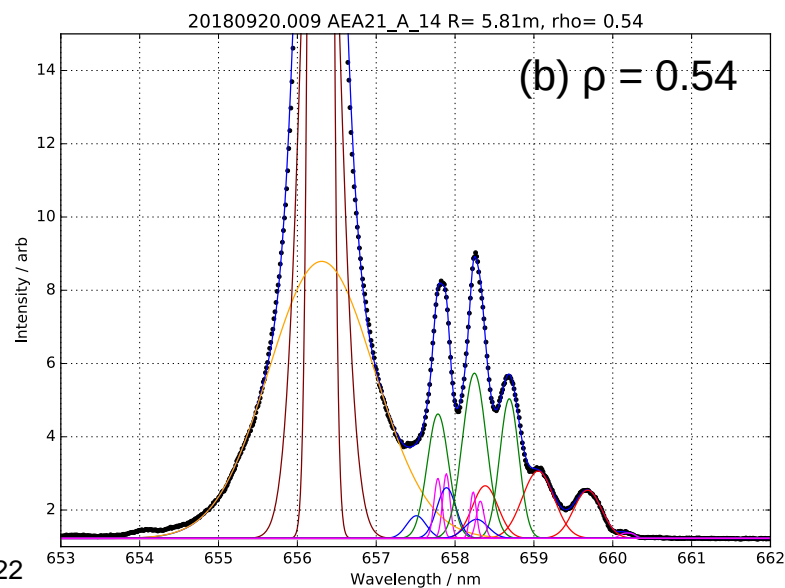
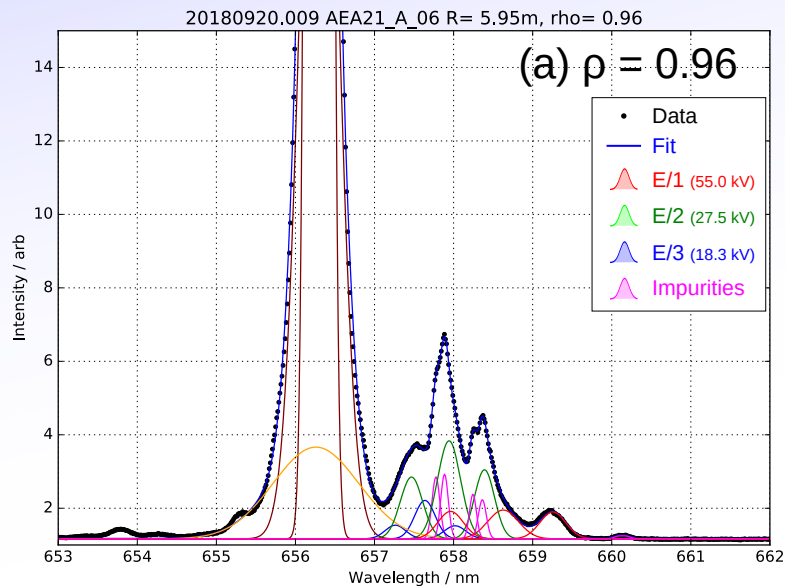
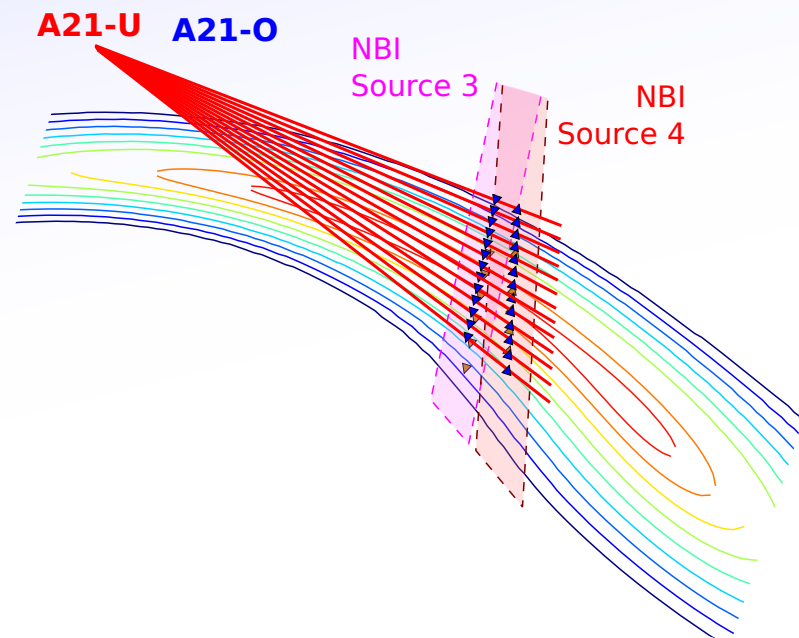
AEA21-U - view





BES Spectra

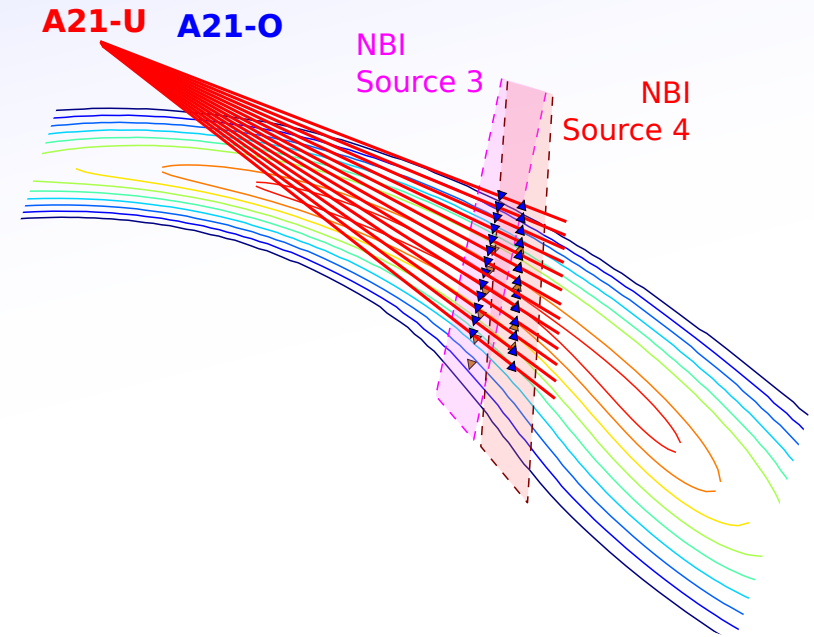
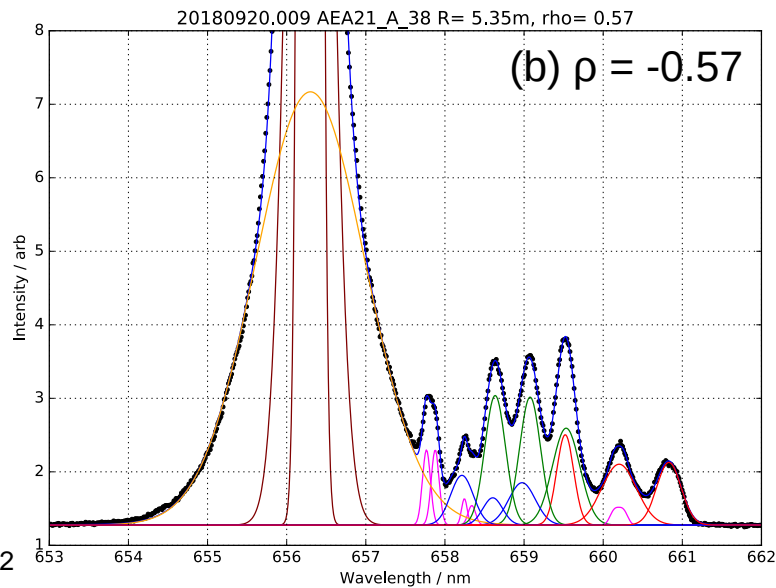
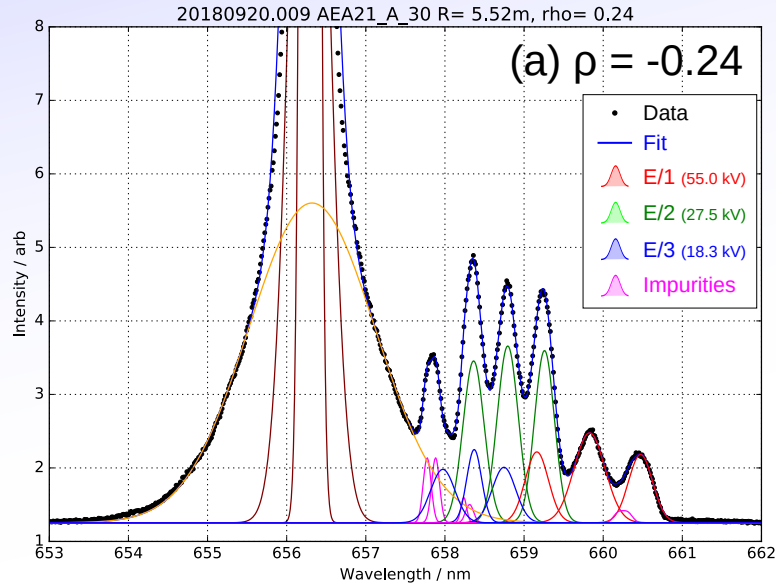
Fitted BES spectra from AEA21-o during OP1.2b:
From source 8 (or 4).





BES Spectra

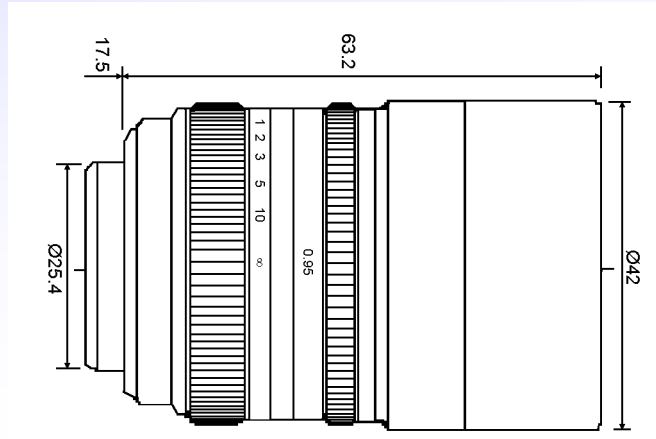
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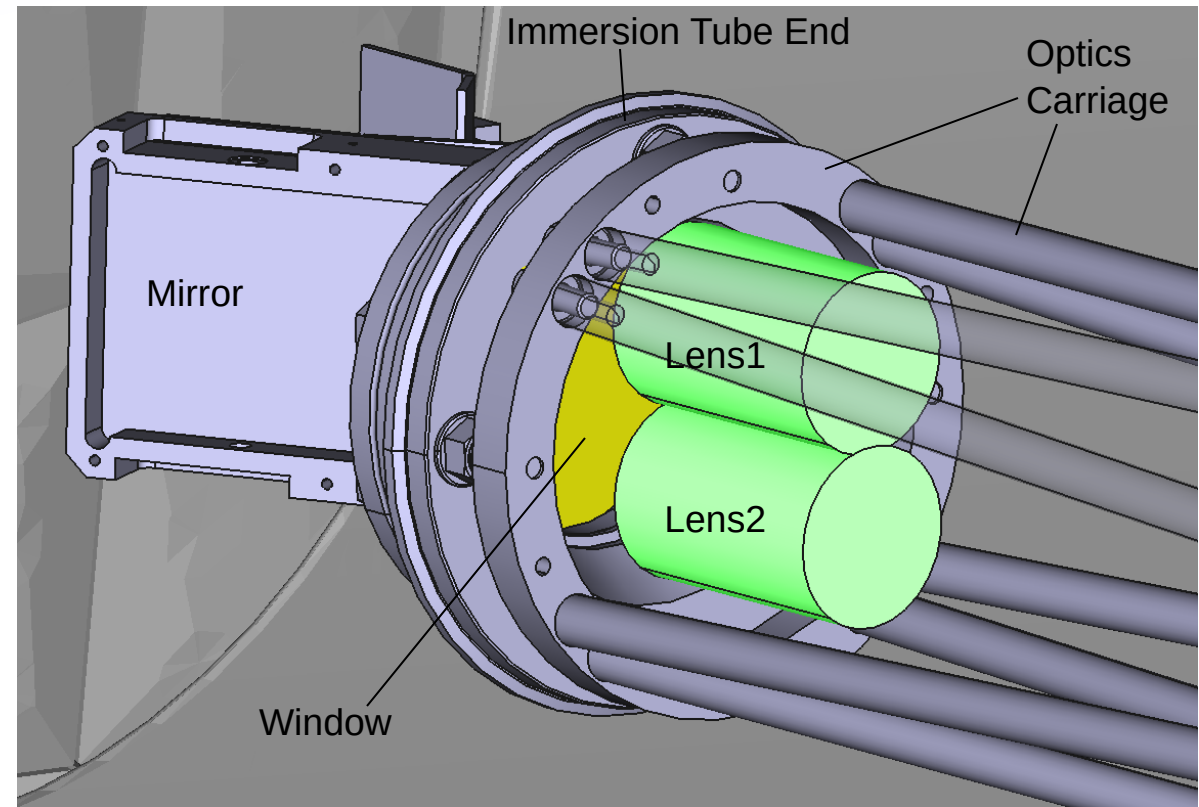
AEA21-U - Optics

Is it possible to put two lenses and fibre bundles in AEA21-U optics carriage??

Proposed lens from QRI/QSV: Navitar DO-1795 17mm F/0.95:

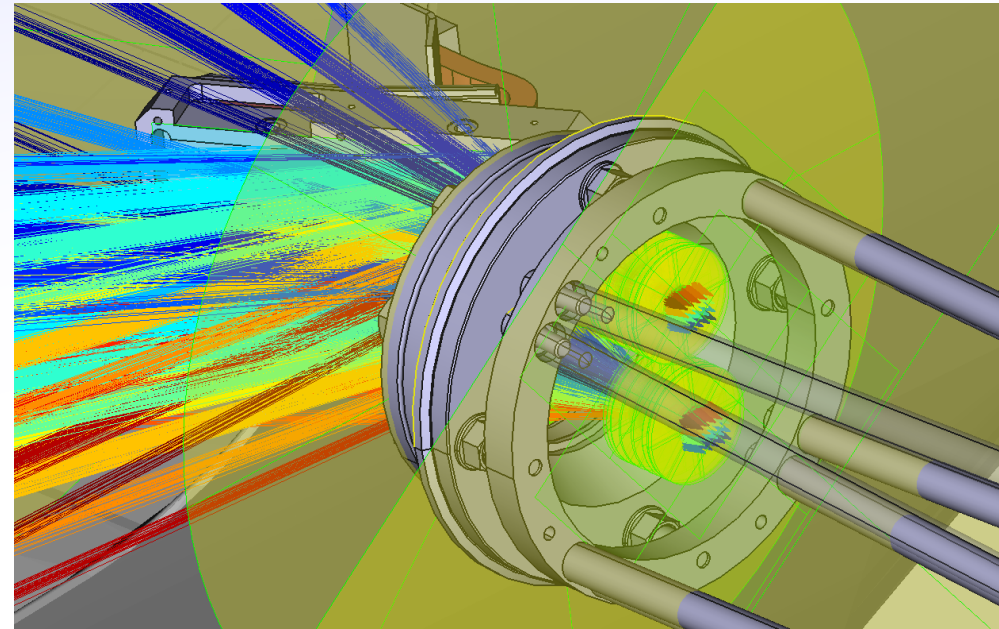
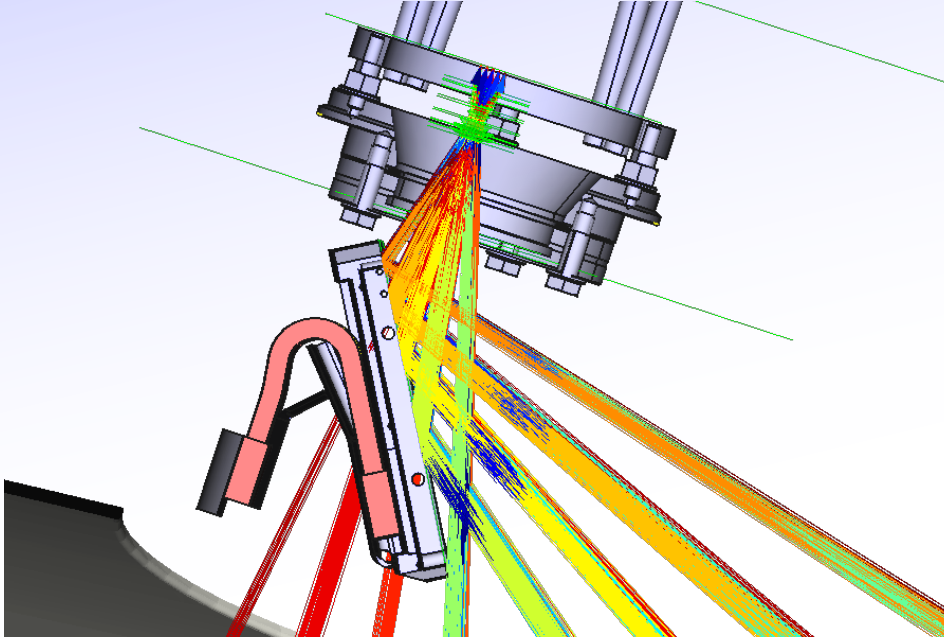


Mechanically, two could just fit
(difficult, but possible):



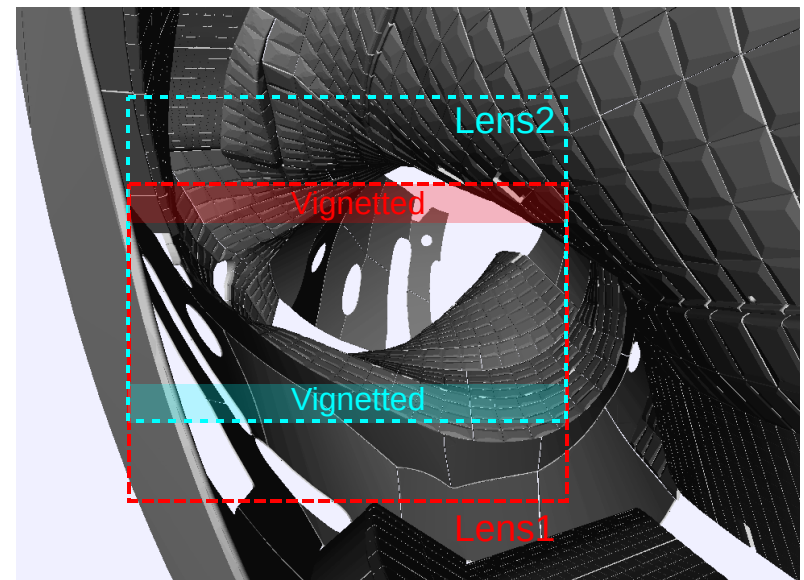
AEA21-U - Optics

Using scaled model of Nikon 50mm F/1.1 for ray tracer, fibre fill at F/0.95. 10 x 8mm fibre set (fibre bundle head)



Lots of up/down vignetting due to offset of lens and rays not hitting mirror.

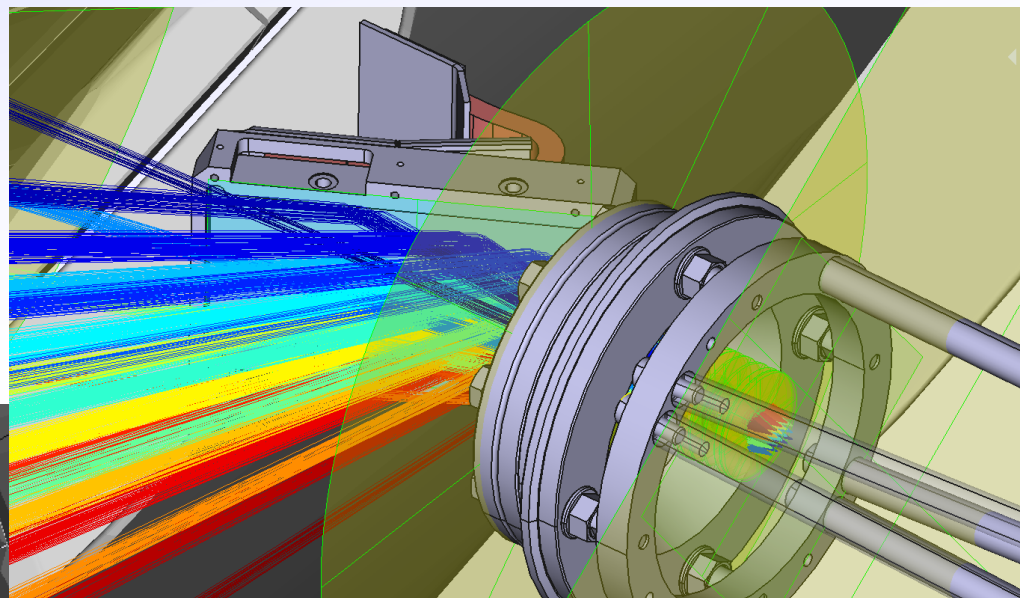
Focal length is very short - This wide angle won't be possible with two lenses!



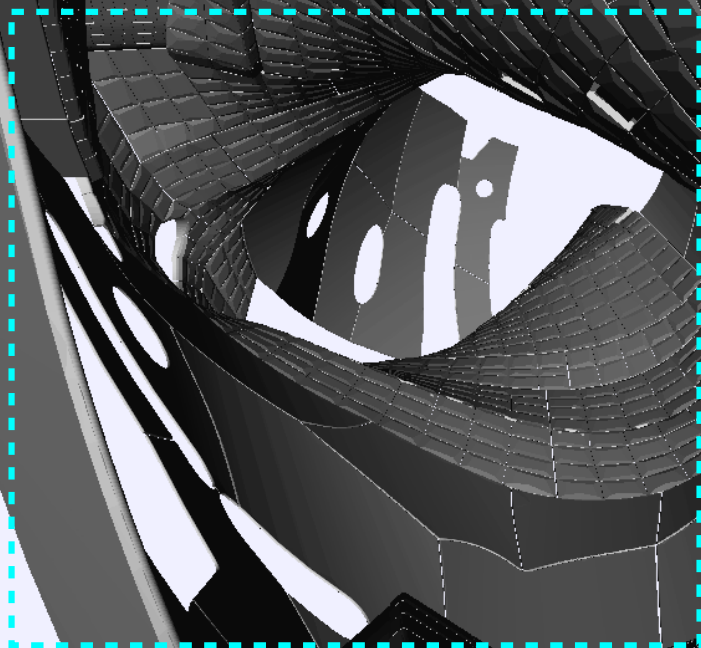
AEA21-U - Optics

A single 17mm F/1 lens works fine:
It's only slightly vignetted at top/bottom
but field of view is very large.

Do you need this much FOV??

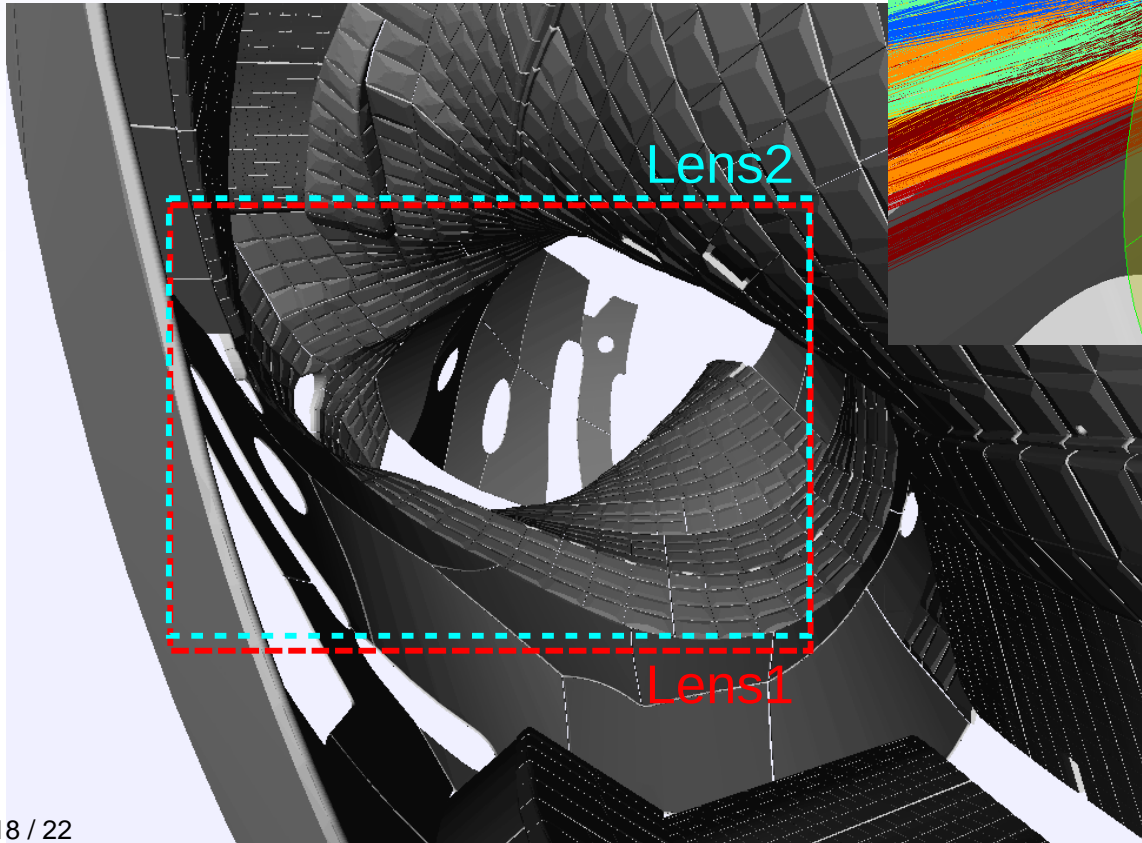
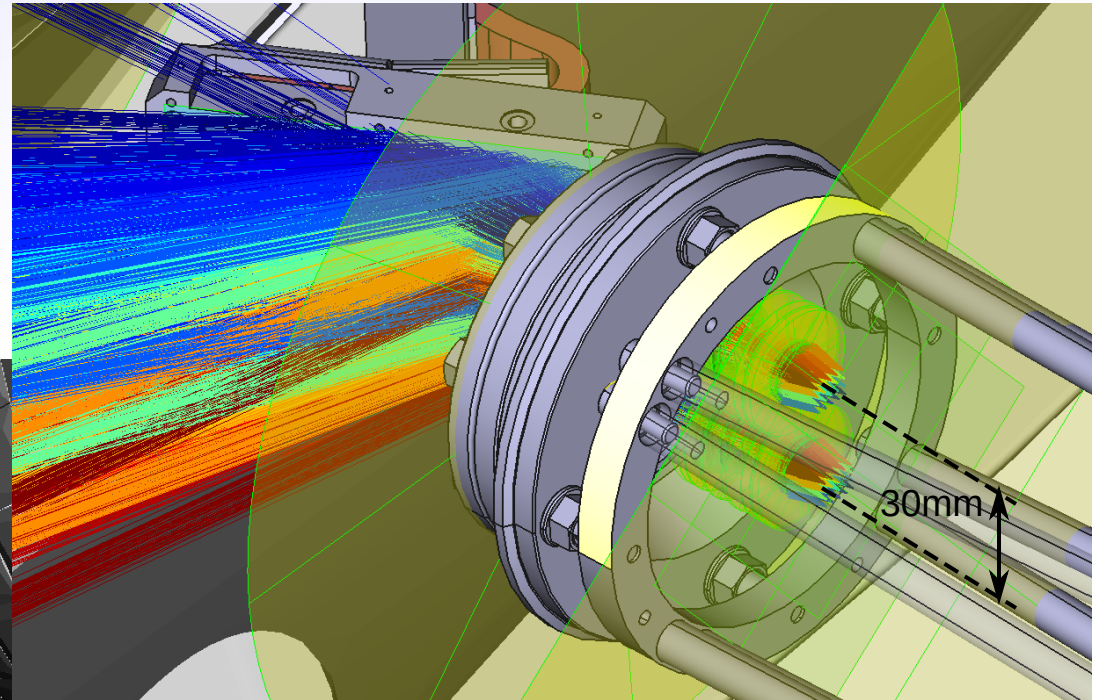


Single DO-1795



AEA21-U - Optics

Two 25mm F/1.4 lenses would probably work, with a slightly smaller FOV.
It would also be a lot easier to fit in mechanically
since you can find these lenses with $d < 30\text{mm}$,
so the spacing is less in the carriage.

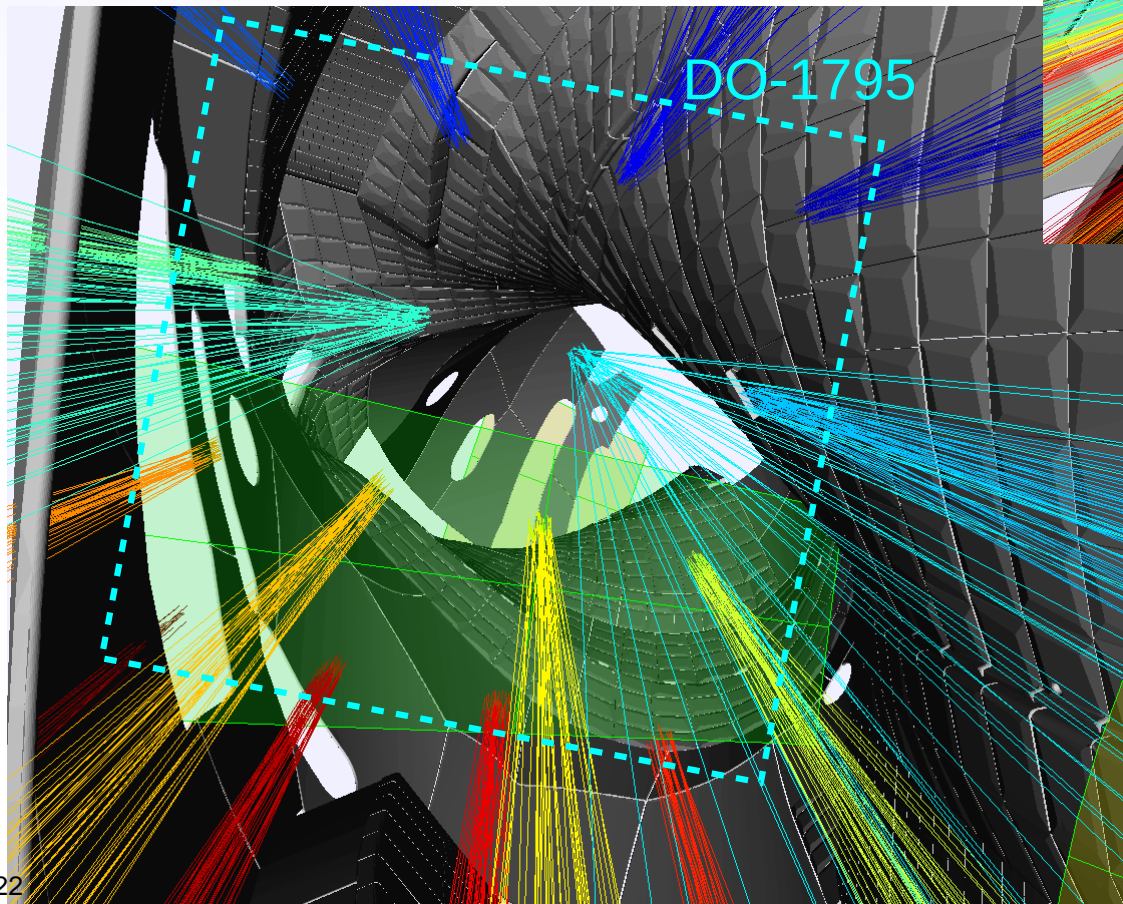
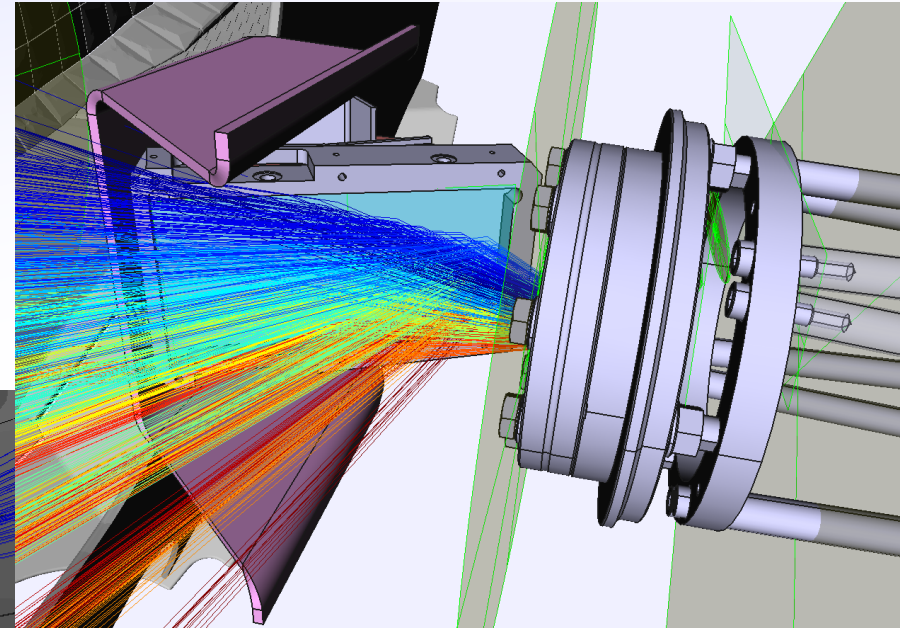


AEA21-U - Optics

One 17mm and one 35mm for divertor view
might be possible by tiling the mirror a bit downwards.

17mm F/1.1

It will be significantly vignetted at edges.

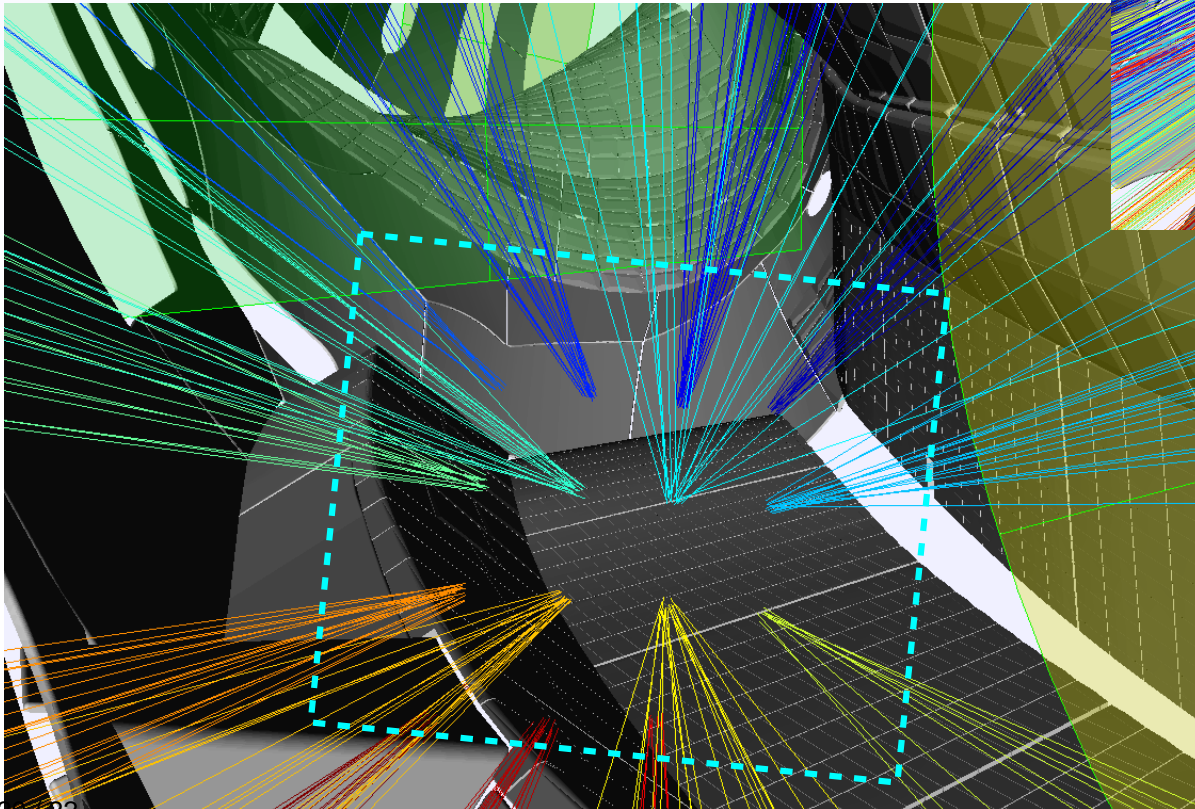
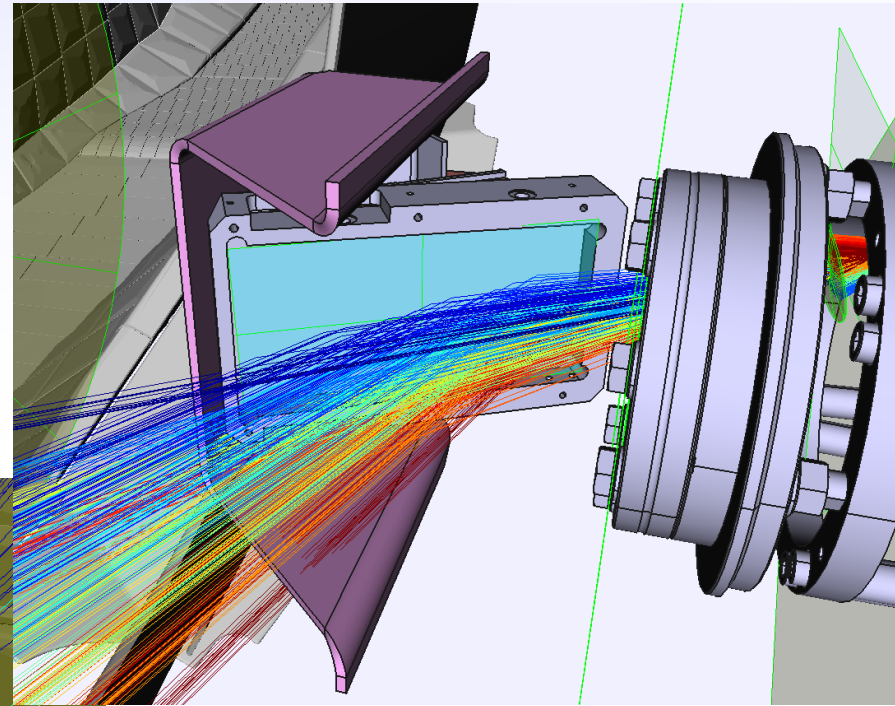


AEA21-U - Optics

One 17mm and one 35mm for divertor view
might be possible by tilting the mirror a bit downwards.

35mm F/2.8

At longer focal length and lower F/#, everything is easier.

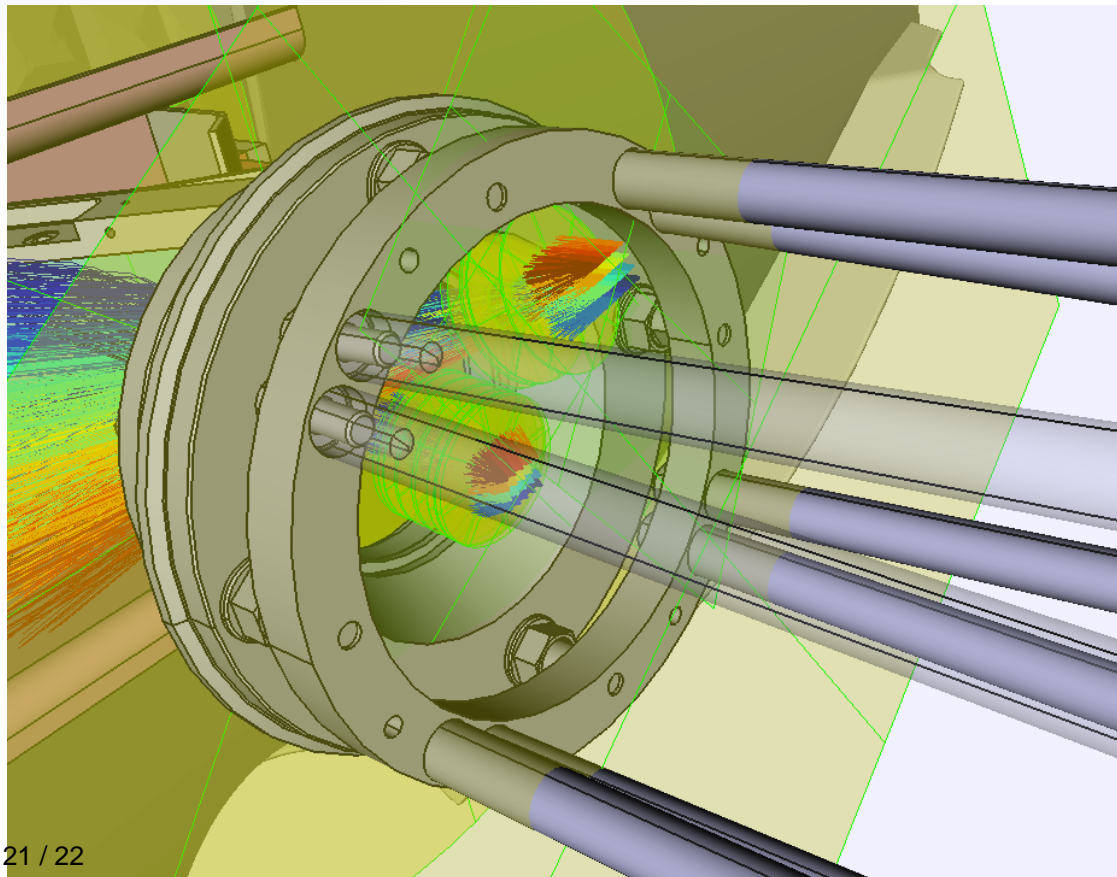


AEA21-U - Optics

One 17mm and one 35mm for divertor view
might be possible by tiling the mirror a bit downwards.

Mechanical design will be much more difficult:

- 17mm lens has to go very close to window to avoid vignetting.
- 35mm lens is very close to edge of optics cage - needs modifications.
- Bending radius of fibres?



- Fill of the F/0.95 lens model here is quite bad because of the parallel fibres.
--> Will likely not achieve F/1 for much of the image.
--> Strong vignetting.

