



Charge Exchange Recombination Spectroscopy (CXRS) on the Neutral Beam Injection (NBI) (Ladungsaustauschspektroskopie am Neutralheizstrahl)

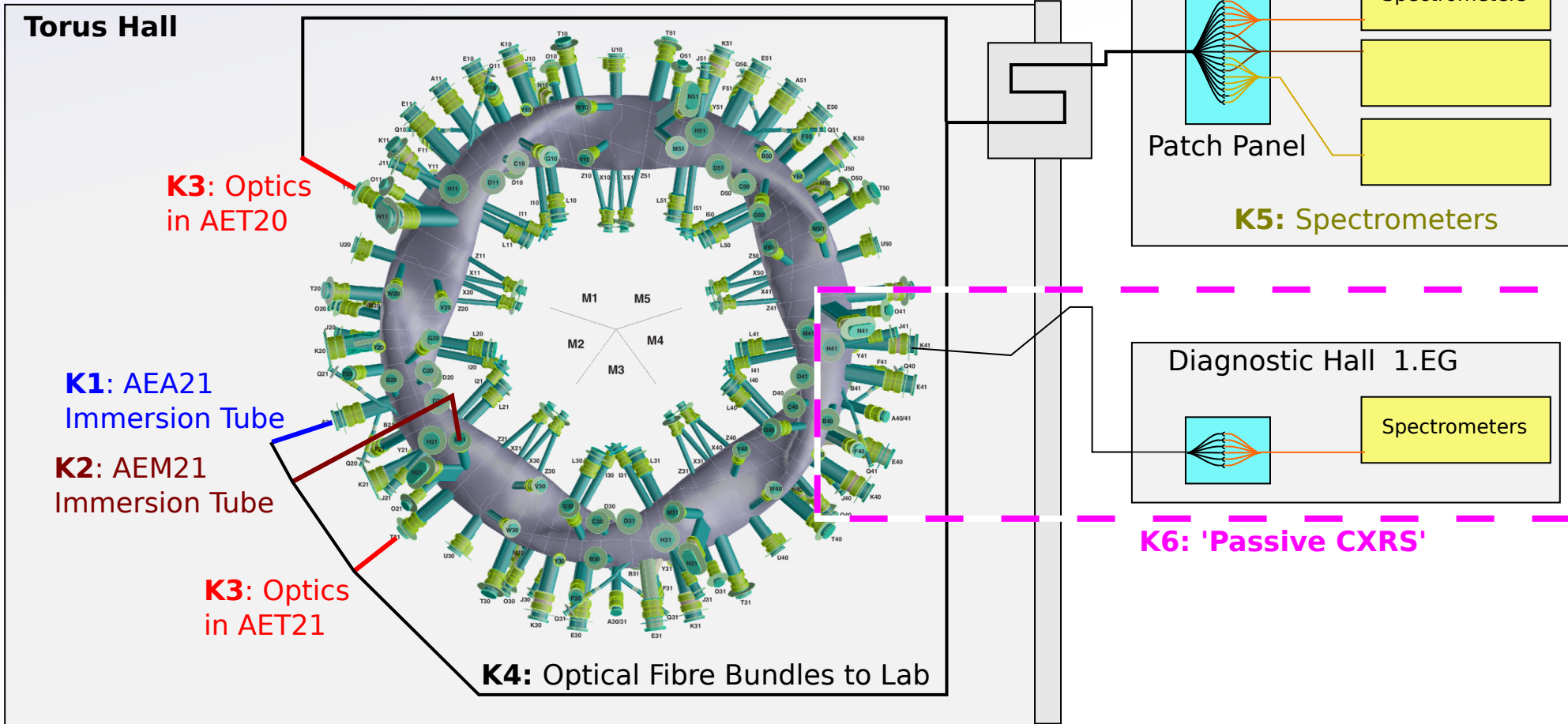
**Developed Design Review
31st Jan 2018**

O. P. Ford¹, M. Steffen¹, C. Biedermann¹

1: Max-Planck Institut für Plasmaphysik, Greifswald, Germany

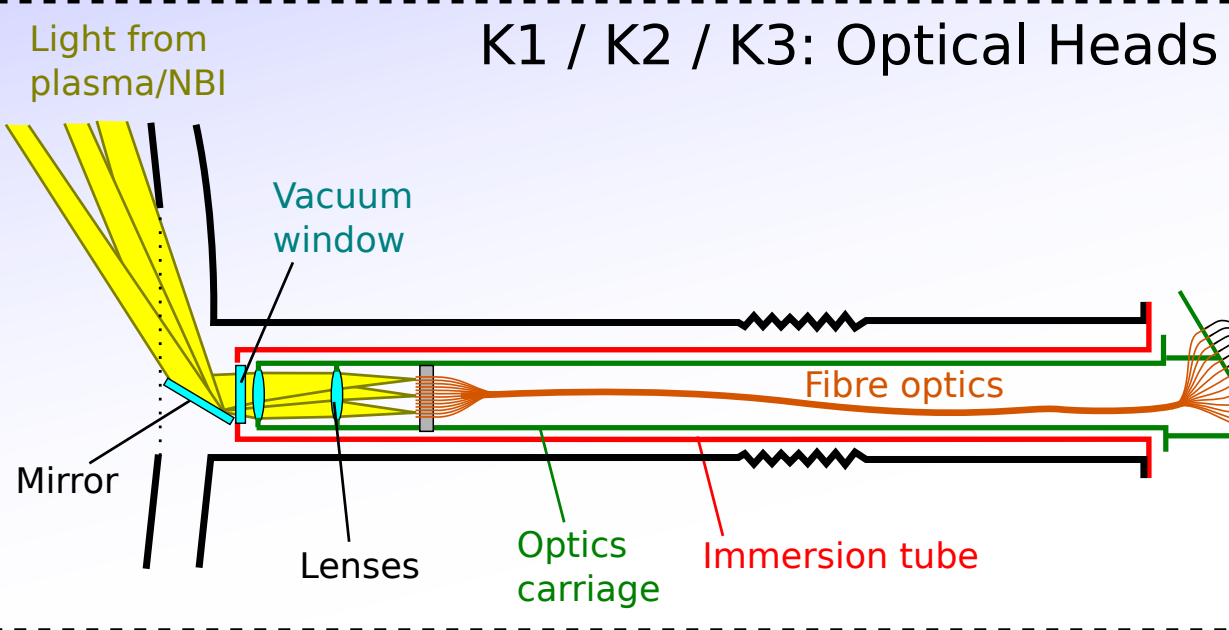


Components



Components

K1 / K2 / K3: Optical Heads

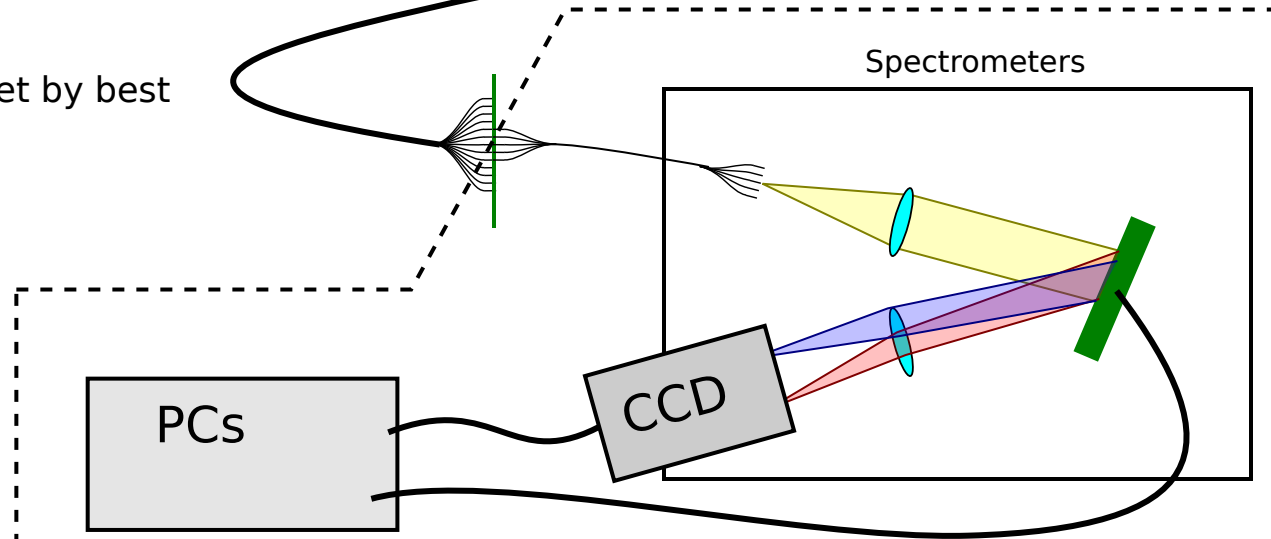


K4: Light Transfer

Specification of fibres and head optics set by best possible spectrometers.
 ASDEX Upgrade Spectrometer = F/2.8
 Requires fibres with NA > 0.18.

Same as AUG: d=400um, NA=0.22

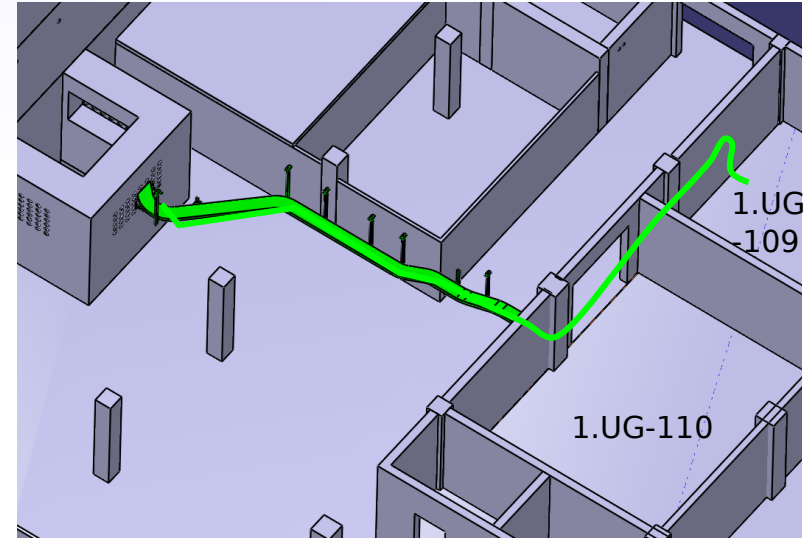
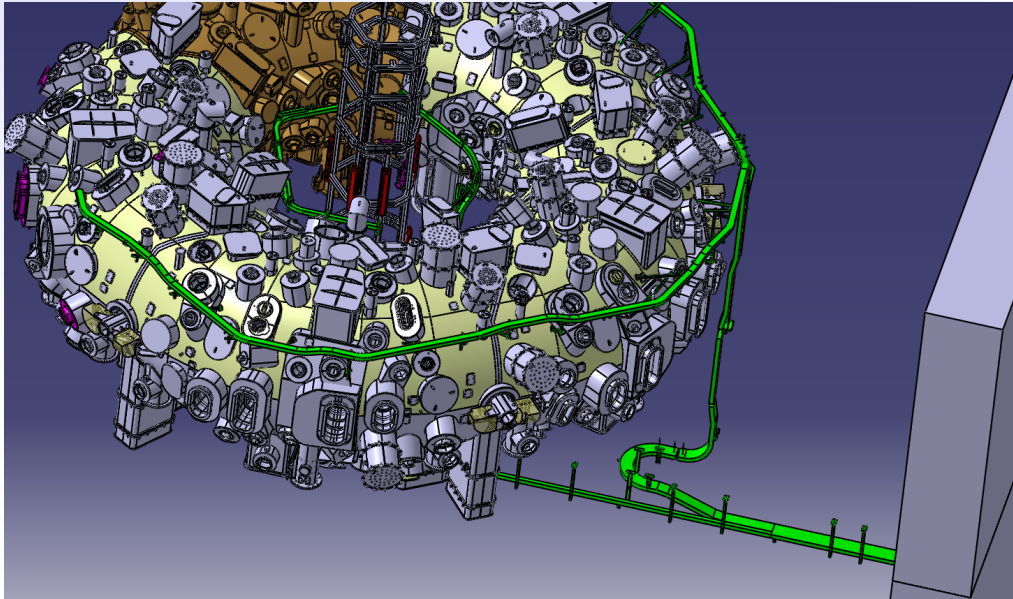
Spectrometers



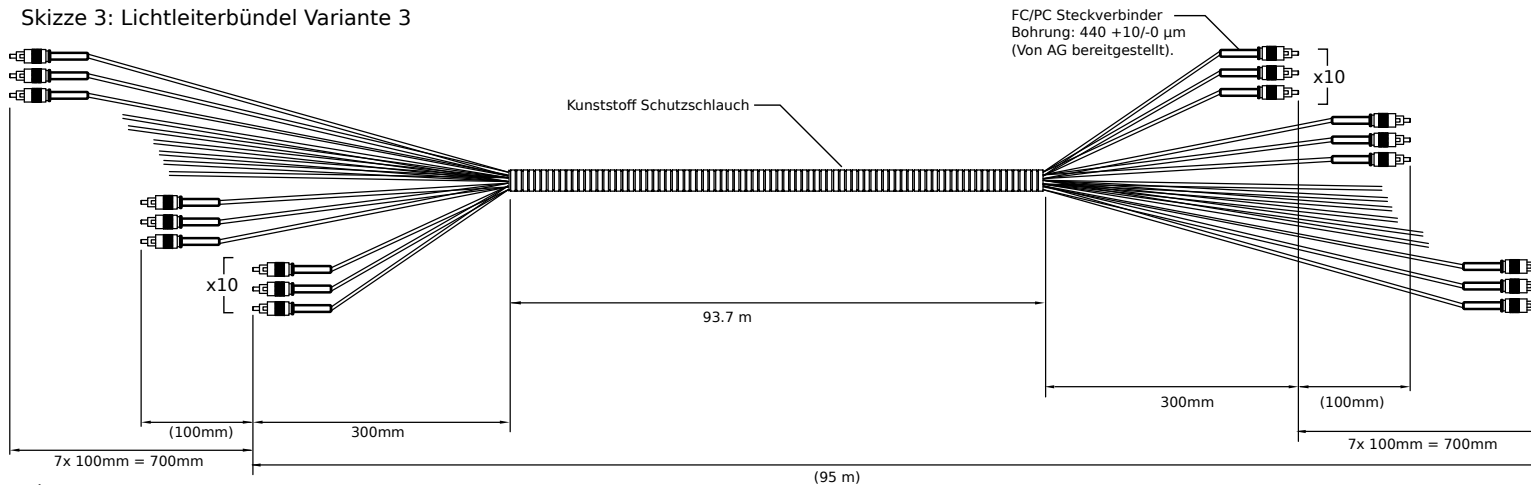
K5: (Spectroscopy Room)

K4: Transfer fibres

Transfer fibres purchased with call for tender in 2016.
Installed before OP1.2a and fully tested.

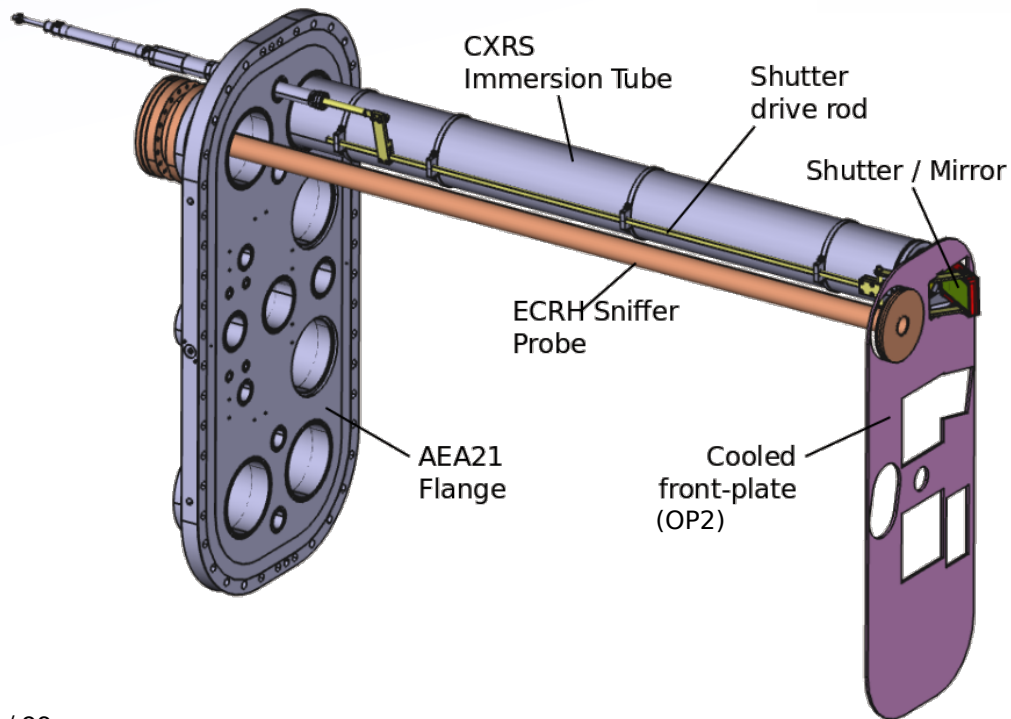
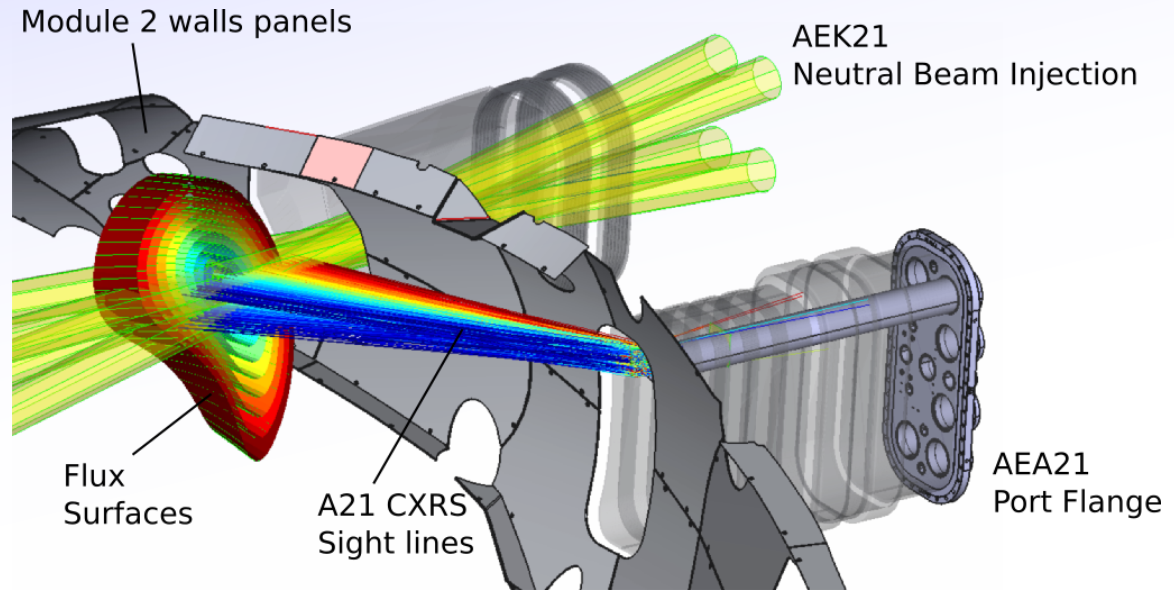


Skizze 3: Lichtleiterbündel Variante 3



AEA21 Concept

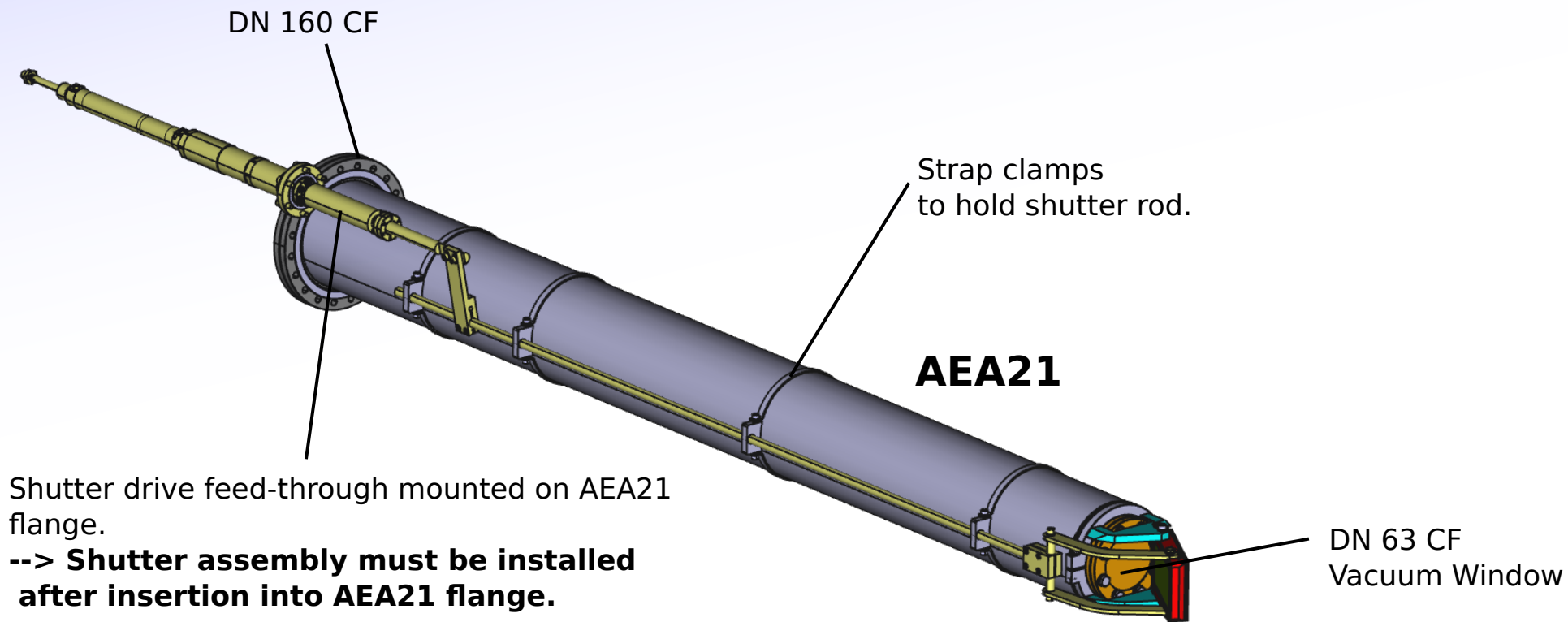
- Design complete for OP1.2b.
- Some consideration given to OP2. Initial calculations show the system should be applicable with minor modifications.



Immersion tube installed as plug-in to AEA21 flange.

OP2: AEA21 will have a cooled front plate instead of port liner. The CXRS plug-in is already integrated with the initial design.

AEA21 Immersion tube



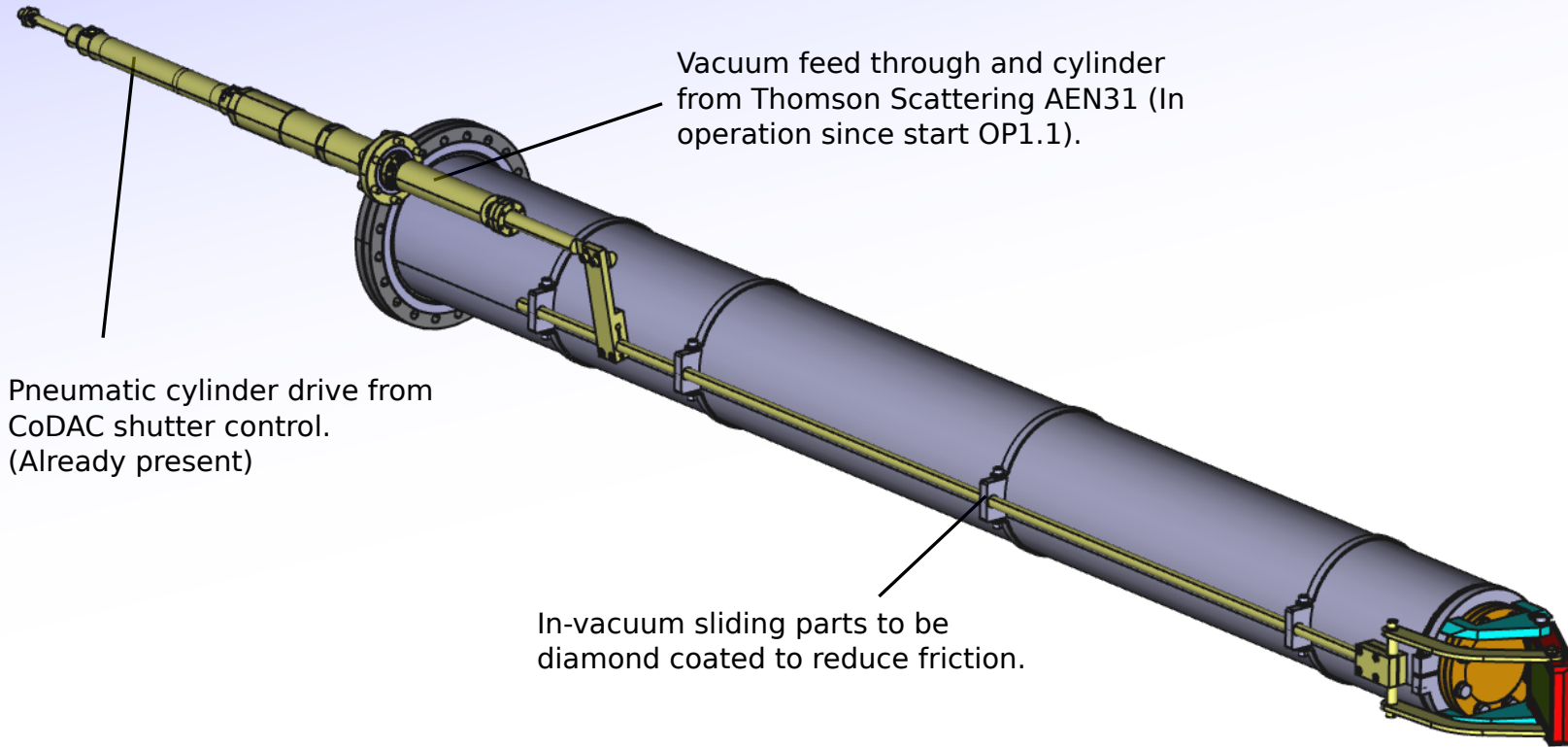
Shutter drive feed-through mounted on AEA21 flange.

--> Shutter assembly must be installed after insertion into AEA21 flange.

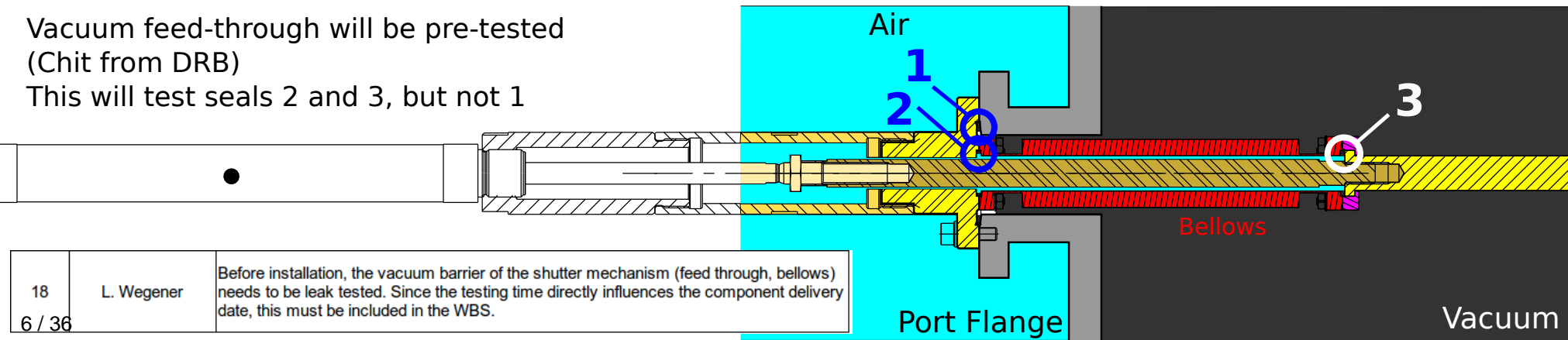
ø 140mm
25kg



Shutter Drive

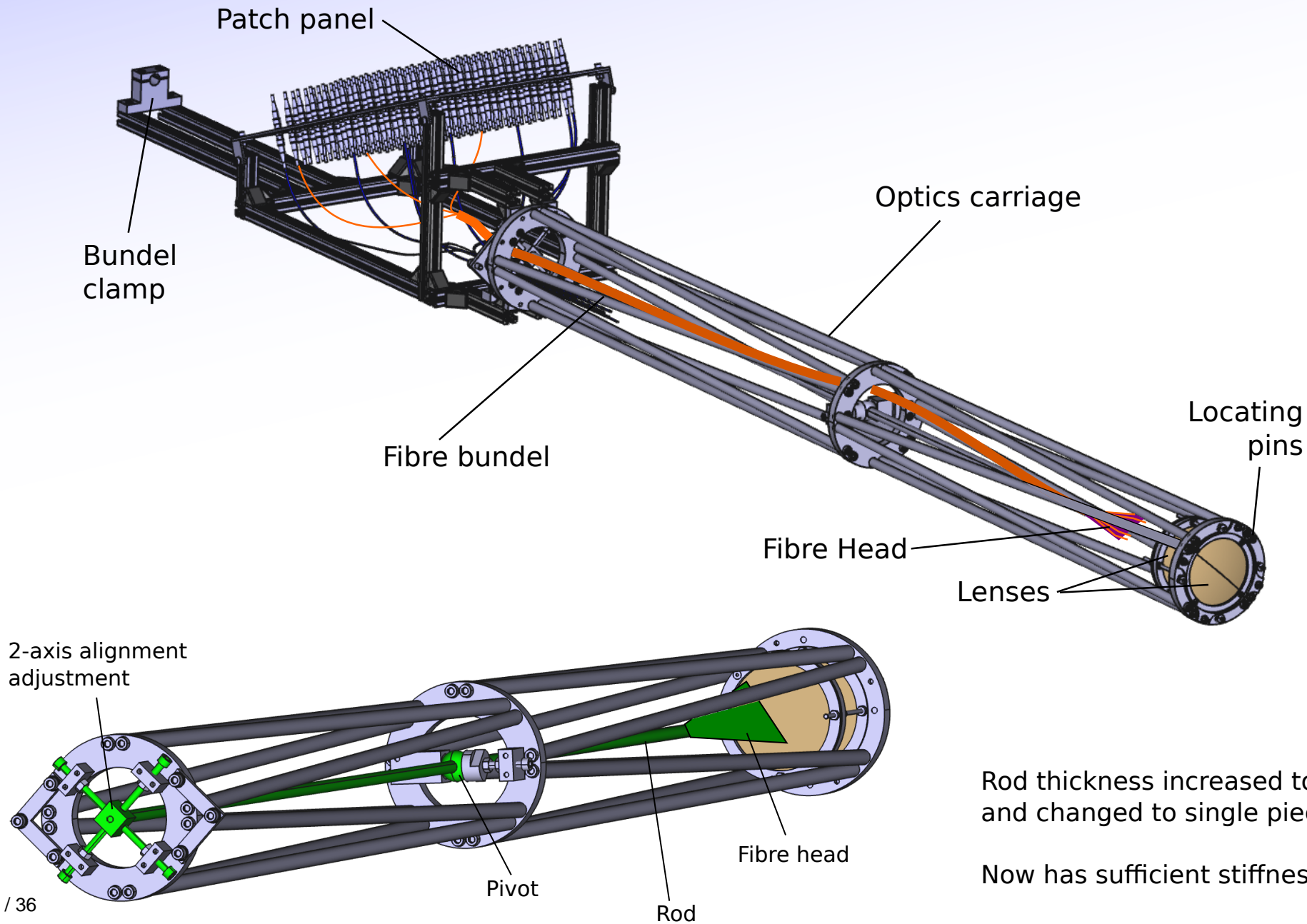


Vacuum feed-through will be pre-tested
(Chit from DRB)
This will test seals 2 and 3, but not 1



Optics carriage.

Optics



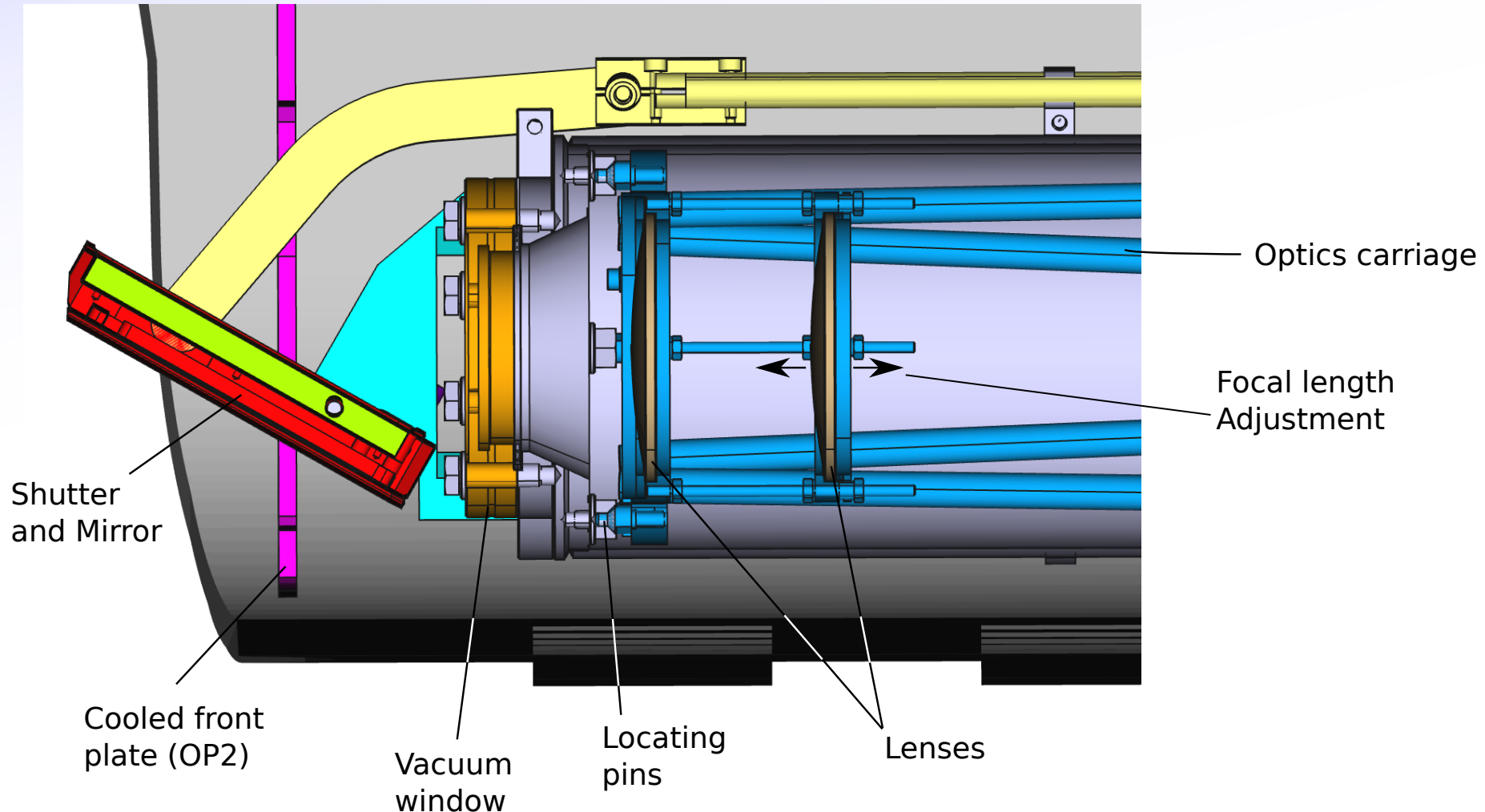
Rod thickness increased to 12mm and changed to single piece.

Now has sufficient stiffness.

Optics carriage.

Optics

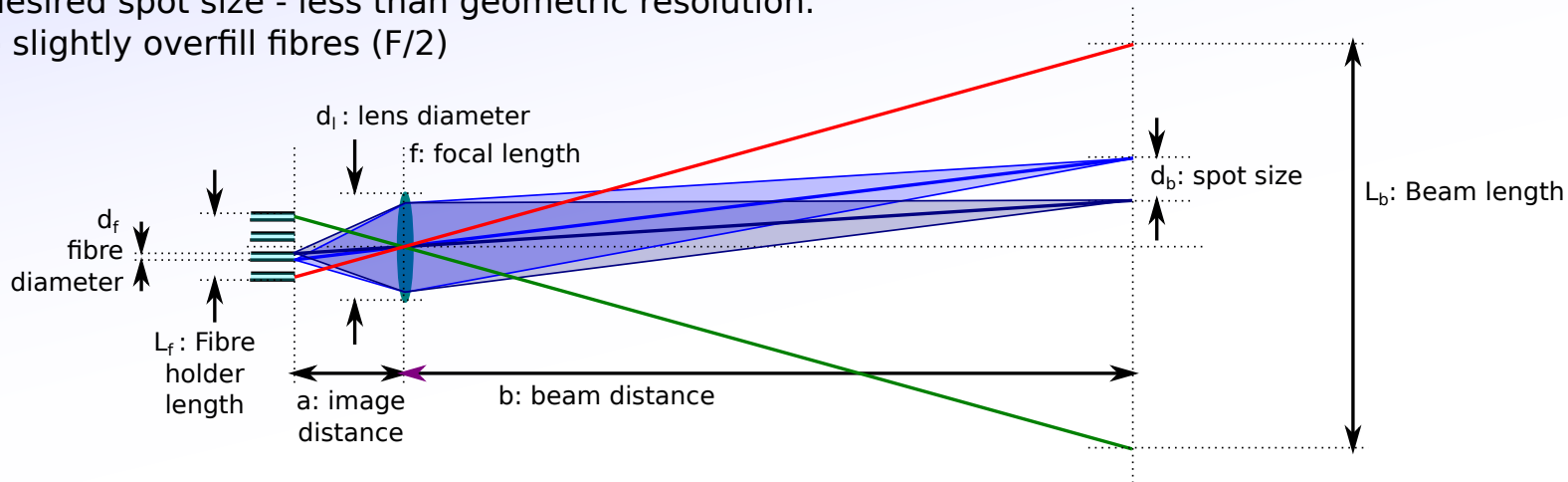
Adjustment of focal length by position of 2nd lens, if necessary.



K1: AEA21 Optical design (simplified)

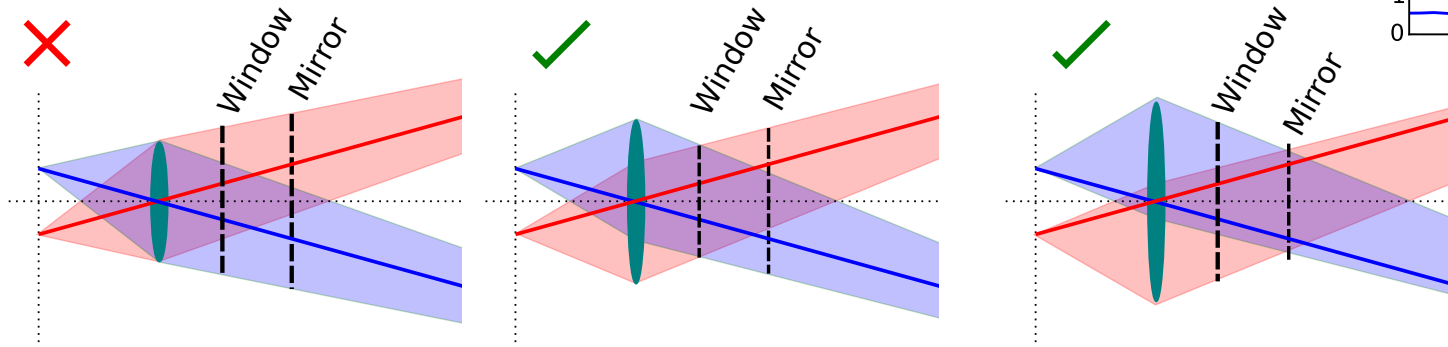
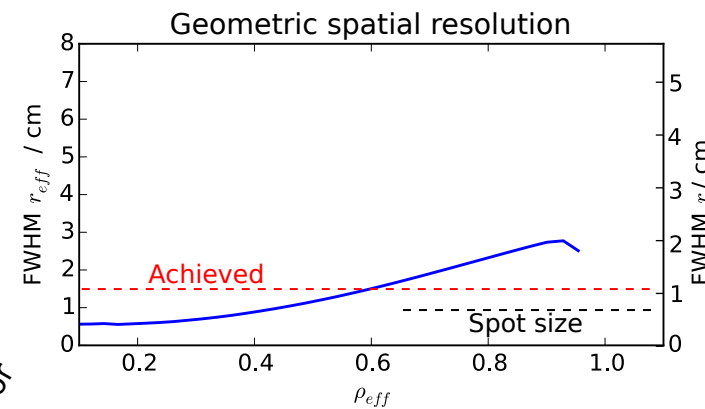
Basic optics design:

- 1) Fibres define etendu  required: 400 μ m, NA=0.22 (F/2.3)
- 2) Focal length set by desired spot size - less than geometric resolution.
- 3) Lens diameter set to slightly overfill fibres (F/2)



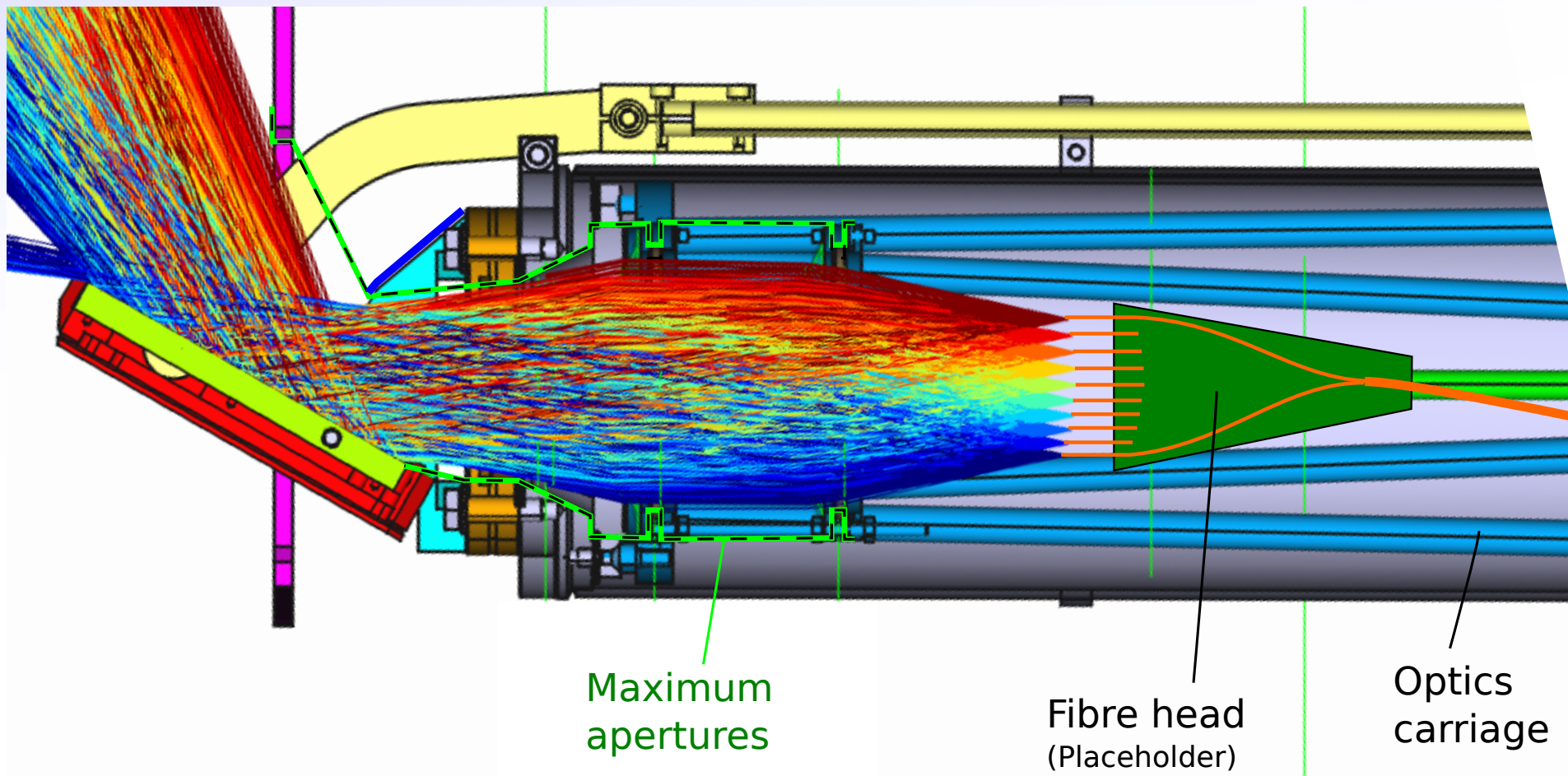
With geometric resolution of min 4mm, spot size of 2mm is desired.
This would require **150mm aperture** - **not mechanically realistic**.
Trade-off 80mm lens gives 5mm spot size --> 15mm resolution (reff).

Detailed design (with ray-tracer) optimises for minimum thermally critical window aperture and/or practical mirror size.



Optics carriage.

Optics



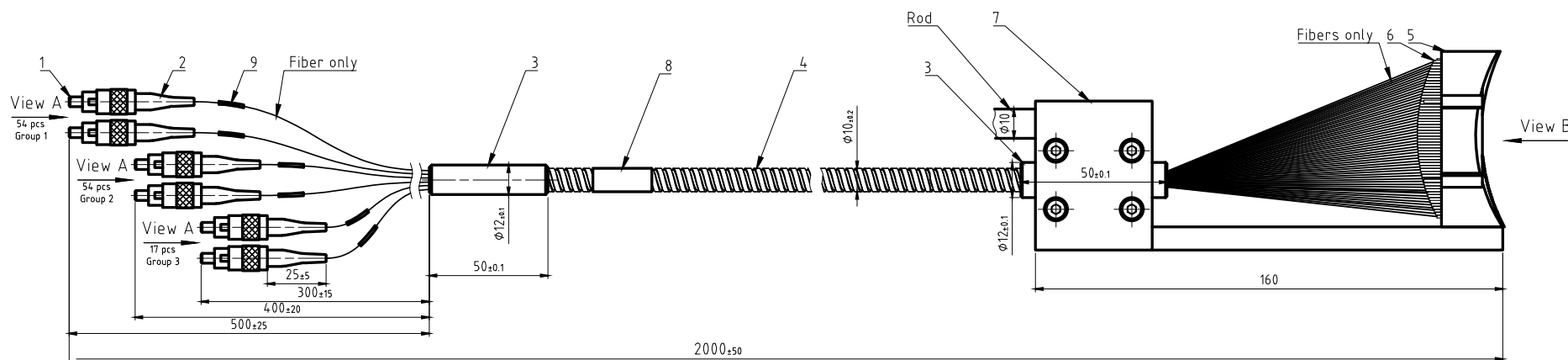
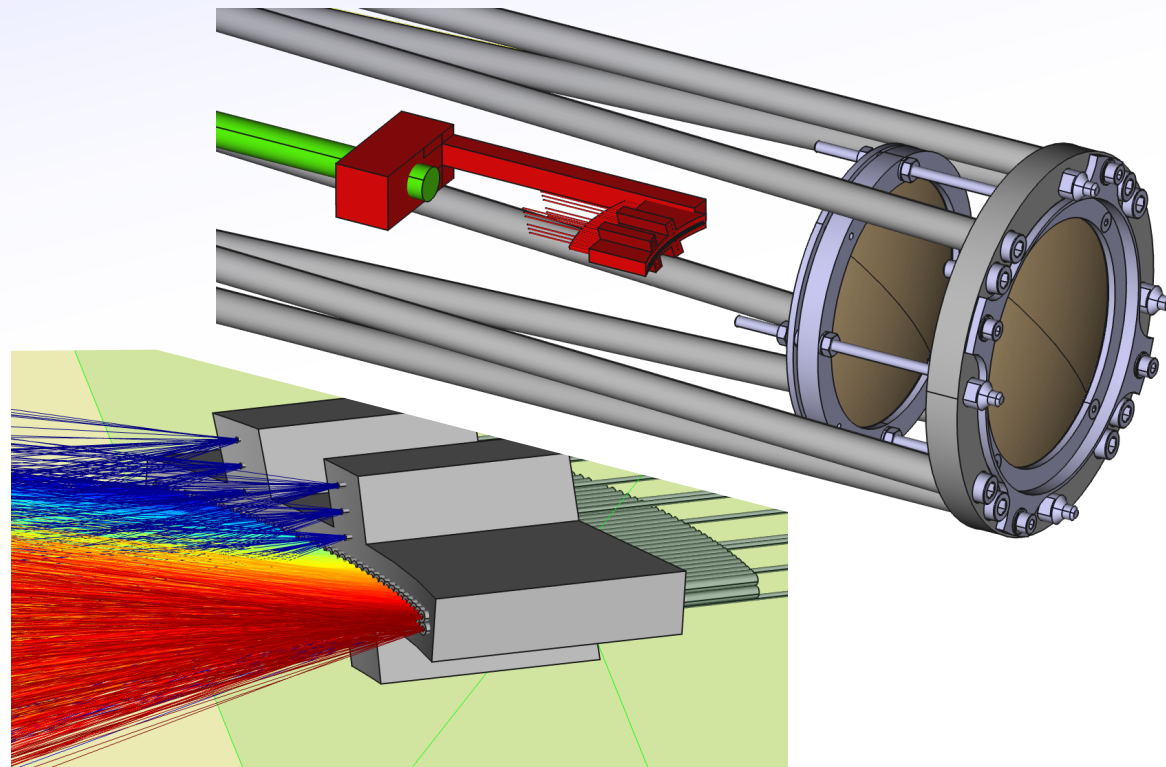
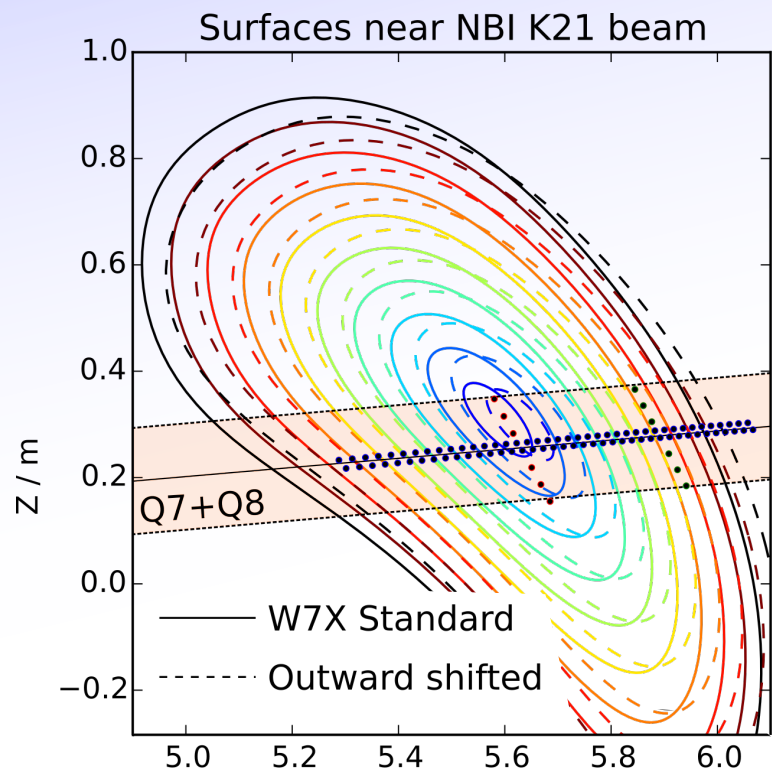
Maximum
apertures

Fibre head
(Placeholder)

Optics
carriage

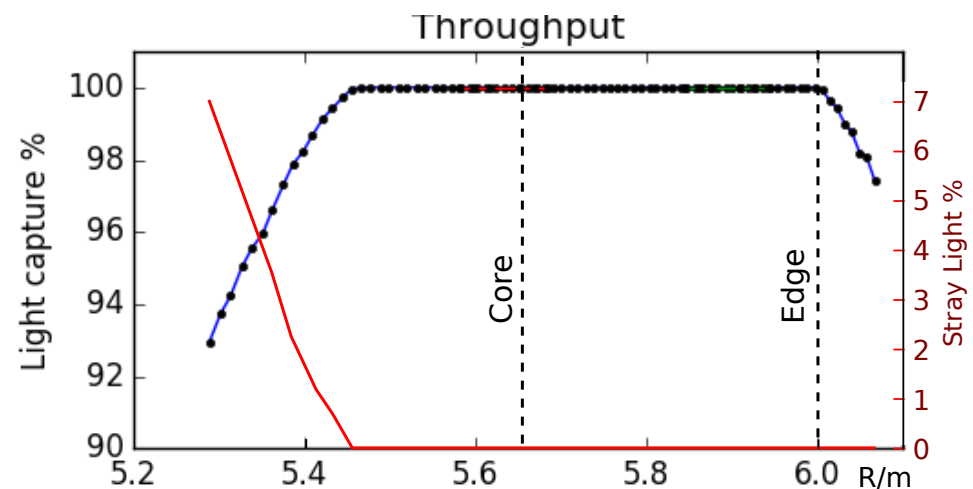
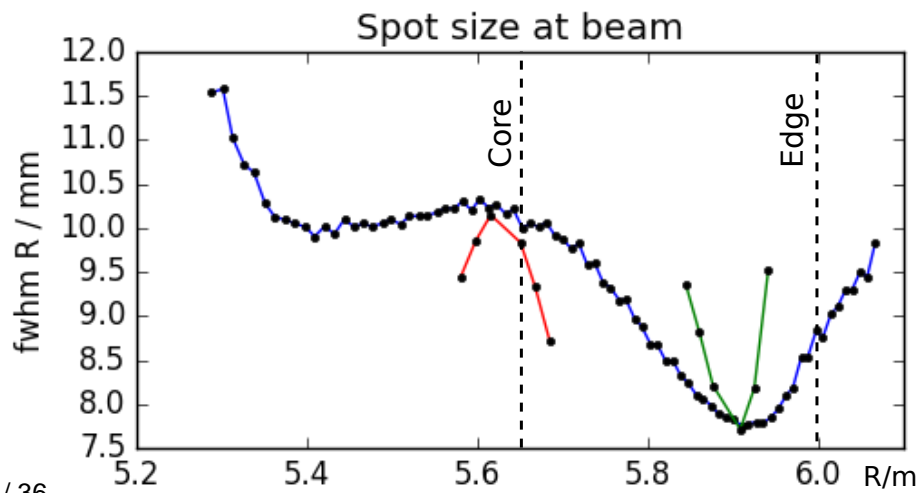
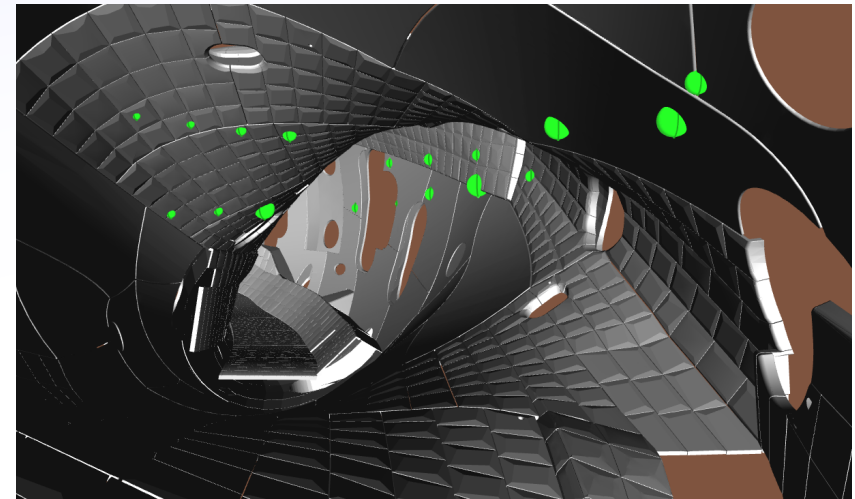
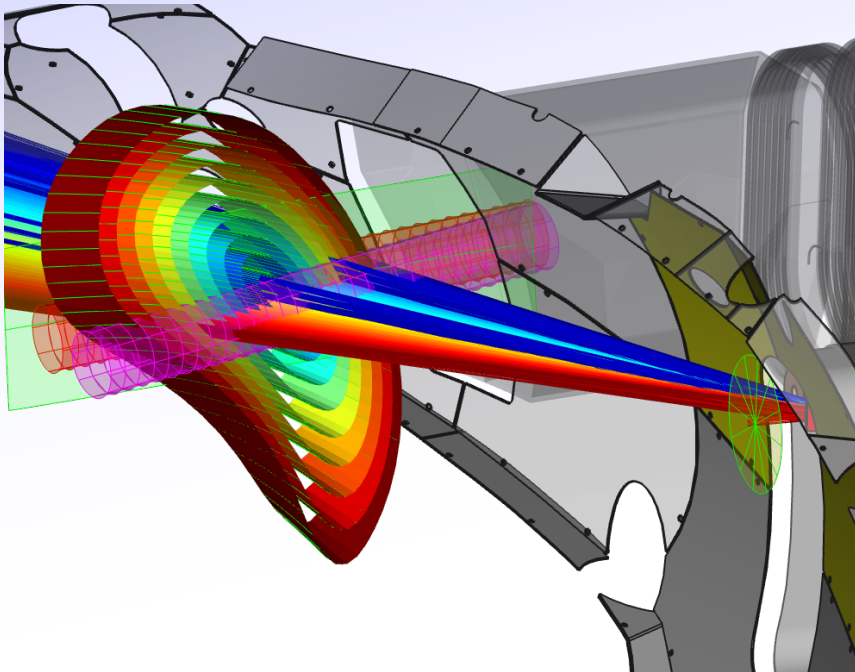
AEA21 Optical Head

Optimum fibre positions determined by ray tracer, iterated with CeramOptec to design fibre head:



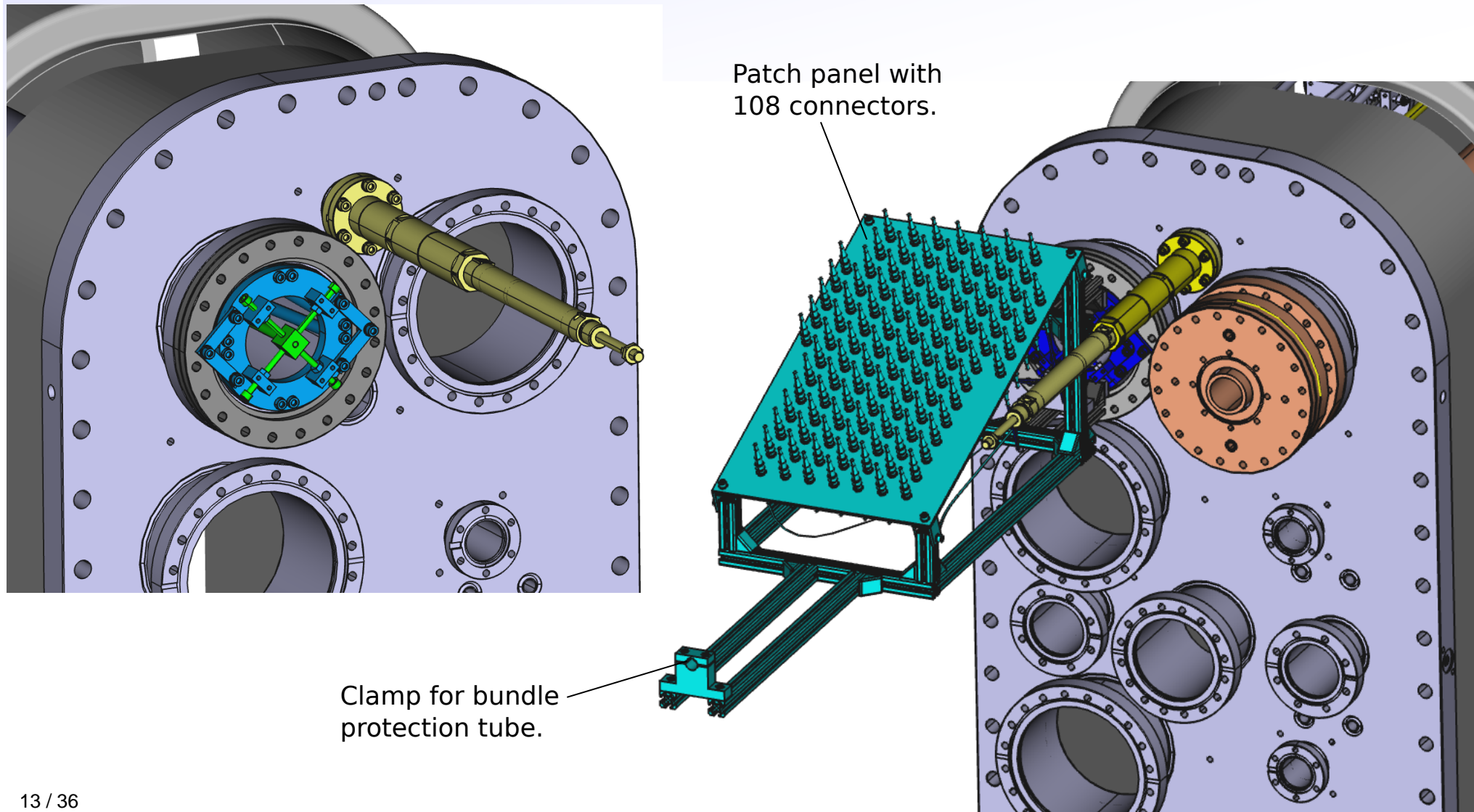
Optics

Ray tracing gives us the expected optical performance, spatial resolution, and targeting for spatial calibration:



K1-K4: Patch Panel

Patch panel provides interface to K4 (transfer fibres).



K1/K4: AEA21 Calibration

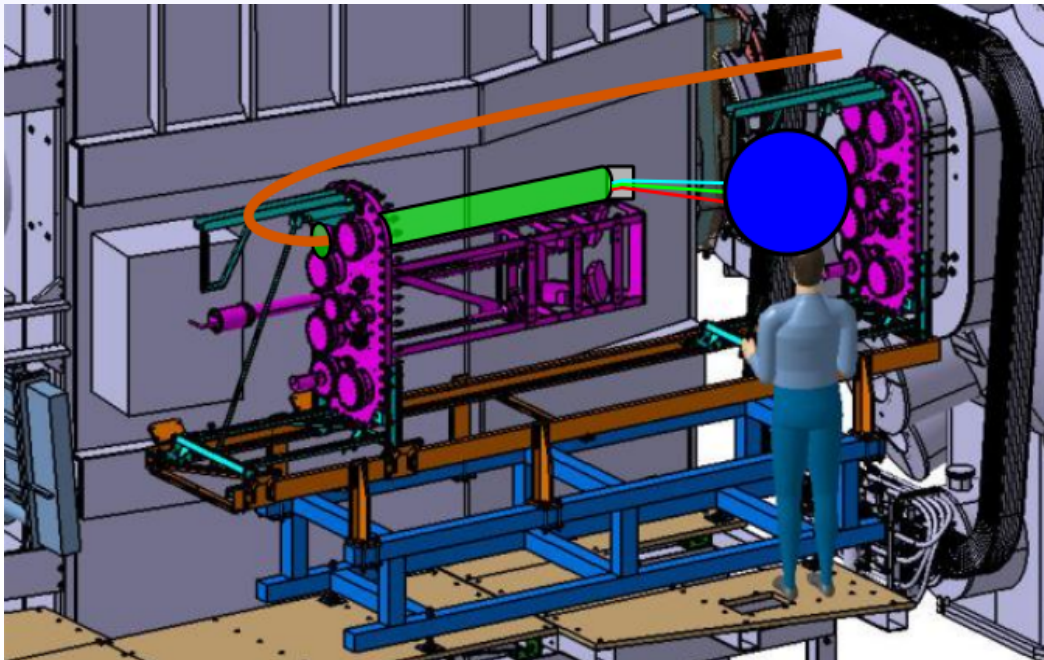
The system should be calibrated before operation.

- In vessel calibration not possible
- Fibres cannot be disconnected after calibration.

Calibration will be performed as part of AEA21 assembly (QAAP 2-EGG21-Q3400.0).

After flange is lowered onto insertion rails, but before insertion.

Allocated time: 4 hours (includes contingency)



- Install optics carriage in Lab during assembly of plug-in.

... Handover of A21 to Assembly ...

... Installation of A21 onto rails ...

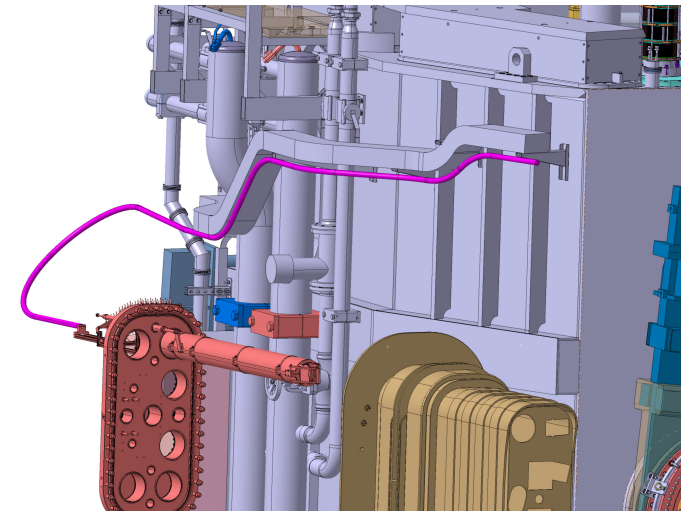
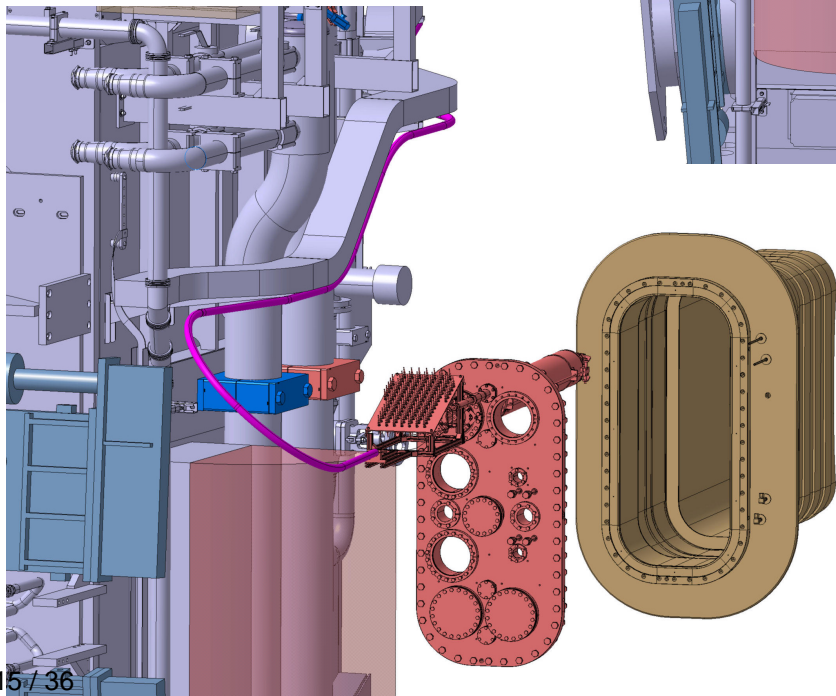
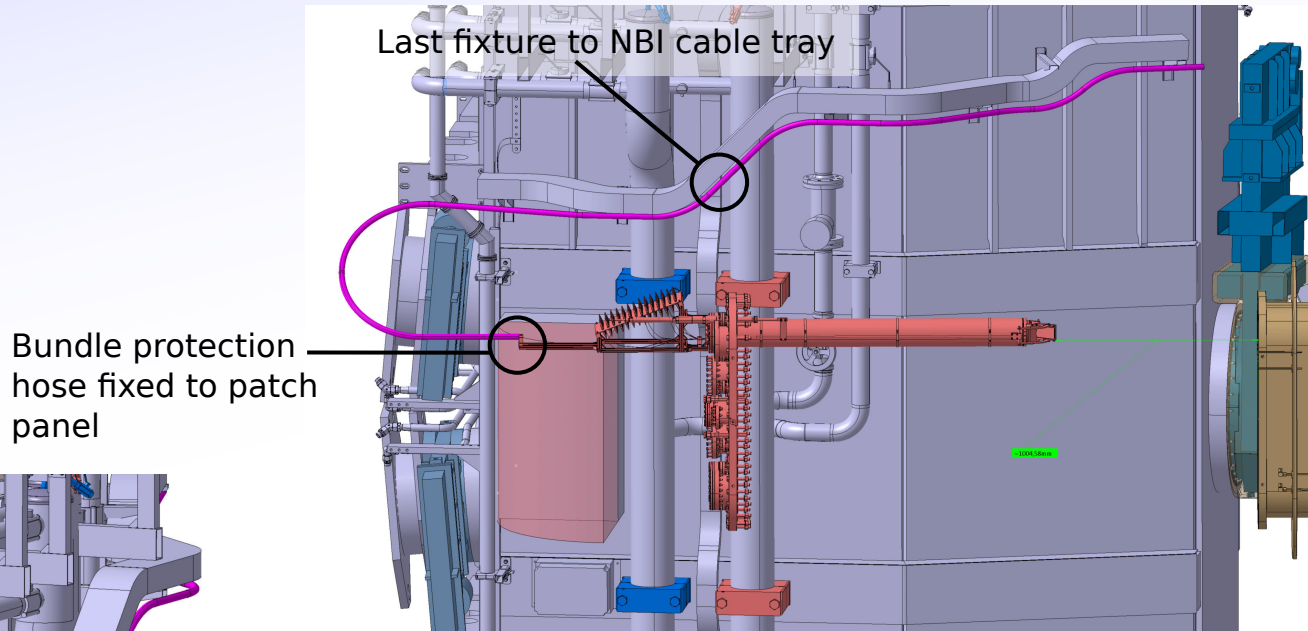
- Clamp fibre bundel hose to patch panel.
- Connect fibre optics.
- Install Ulbricht sphere + power supplies
- Hold sphere in front of mirror.
- Retract sphere while recording data.
- Repeat to cover all sight lines (~x8)
- Remove Ulbricht sphere.

Expected 1.5 hours. Allocated 4 hours.

8	L. Wegener	A concept for the cable handling for installation / calibration works in AEA21 and AEM21 has to be found and must be presented at the DDR.
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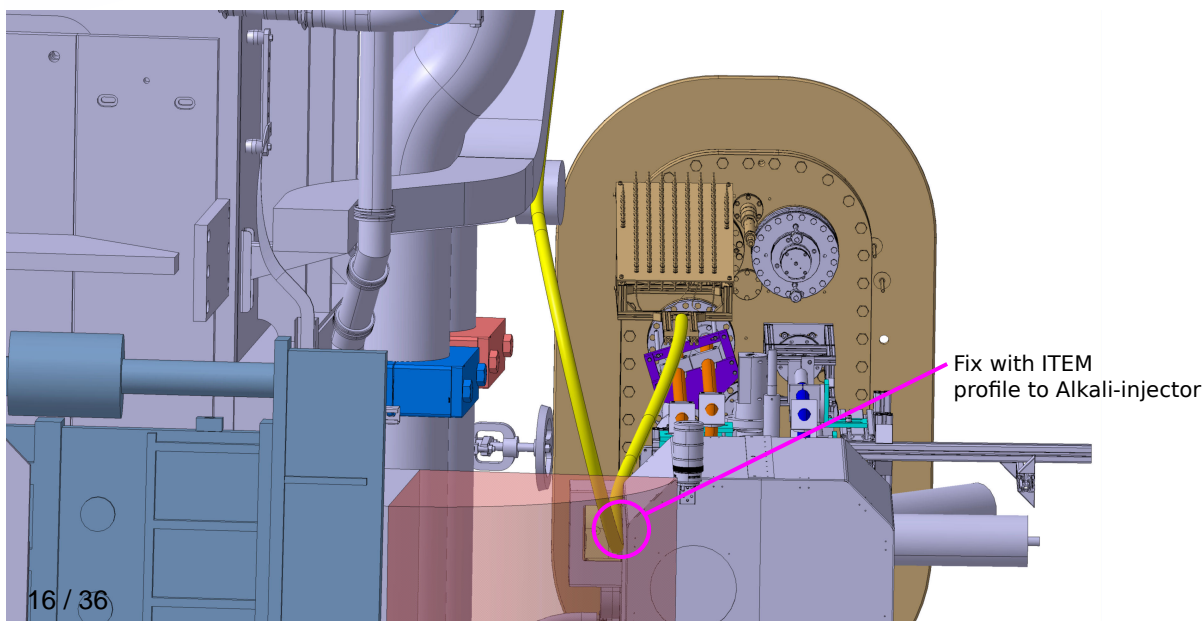
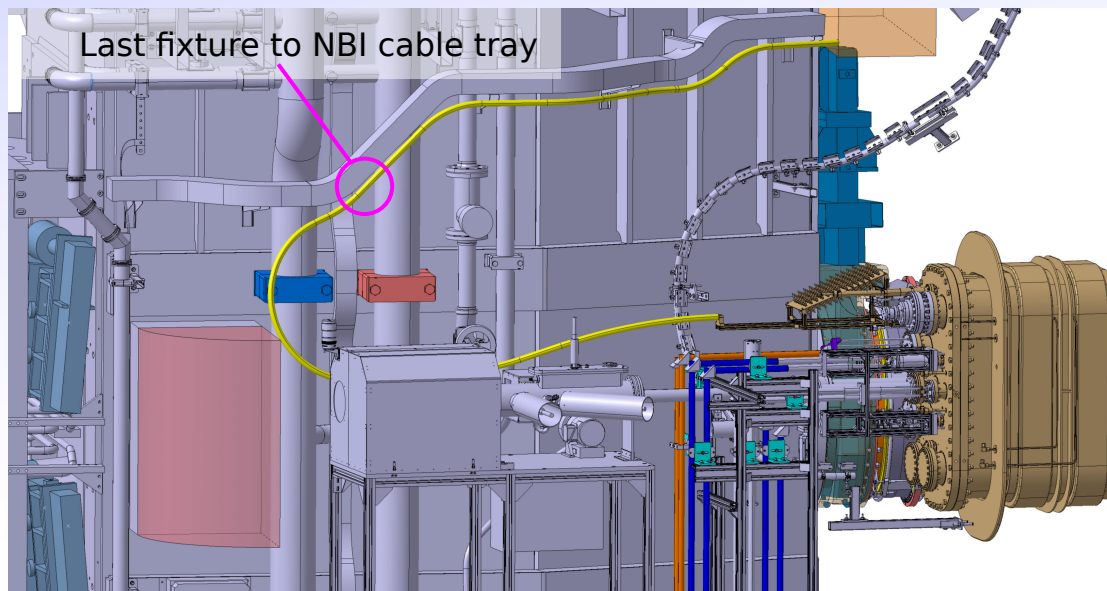
K1/K4: AEA21 LWLs (Calibration)

LWLs for AEA21 will be routed along underside of NBI cable tray with slack to allow insertion of AEA21.



K1/K4: AEA21 LWLs

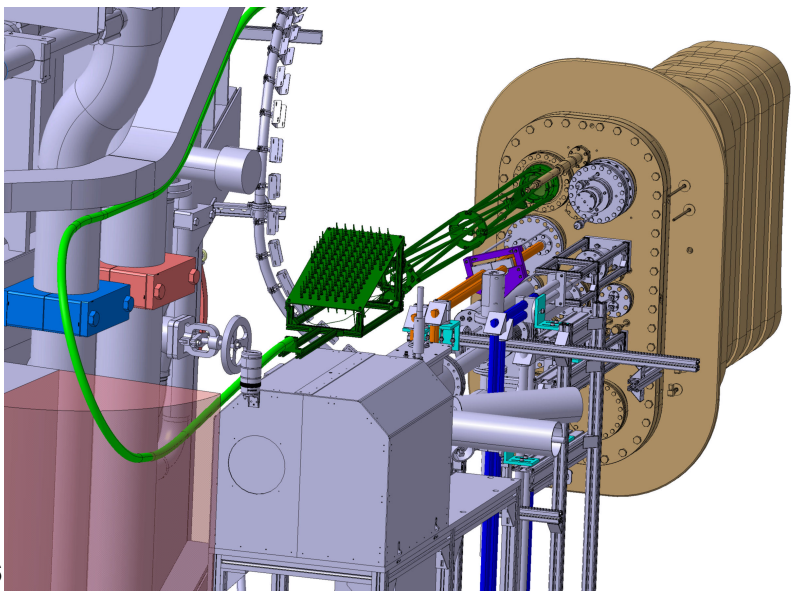
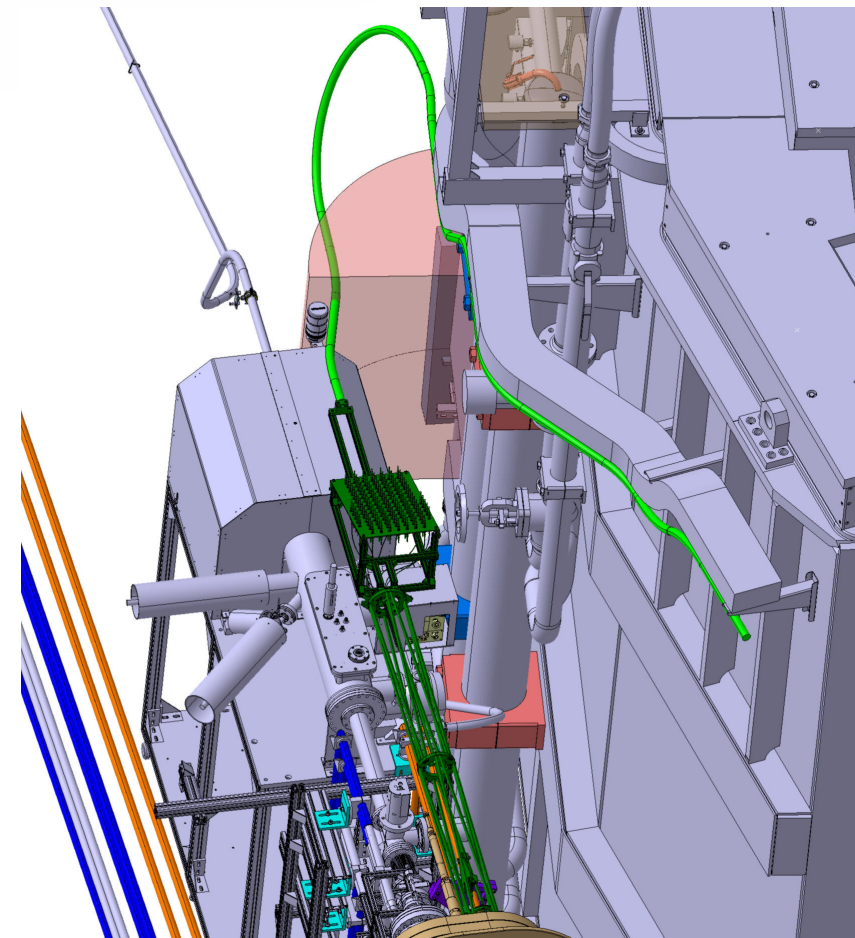
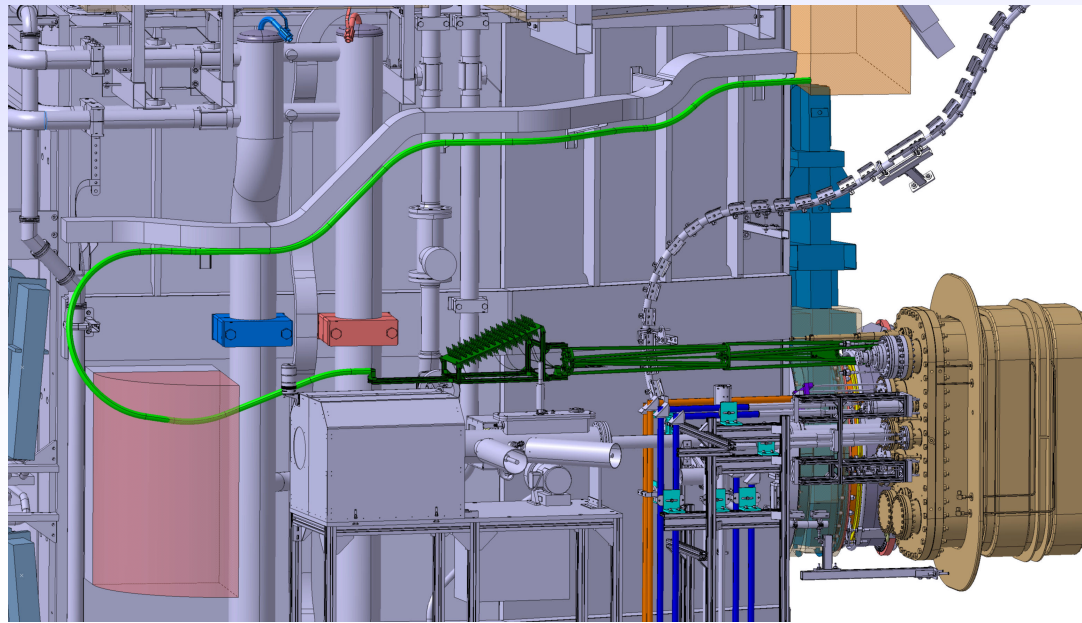
Fibre bundle is flexible but stiff and well protected enough to not risk damage to fibres while unsecured.



Bending radius:
Fibres: No less than 15cm.
Protection hose: Less than 30cm not possible.

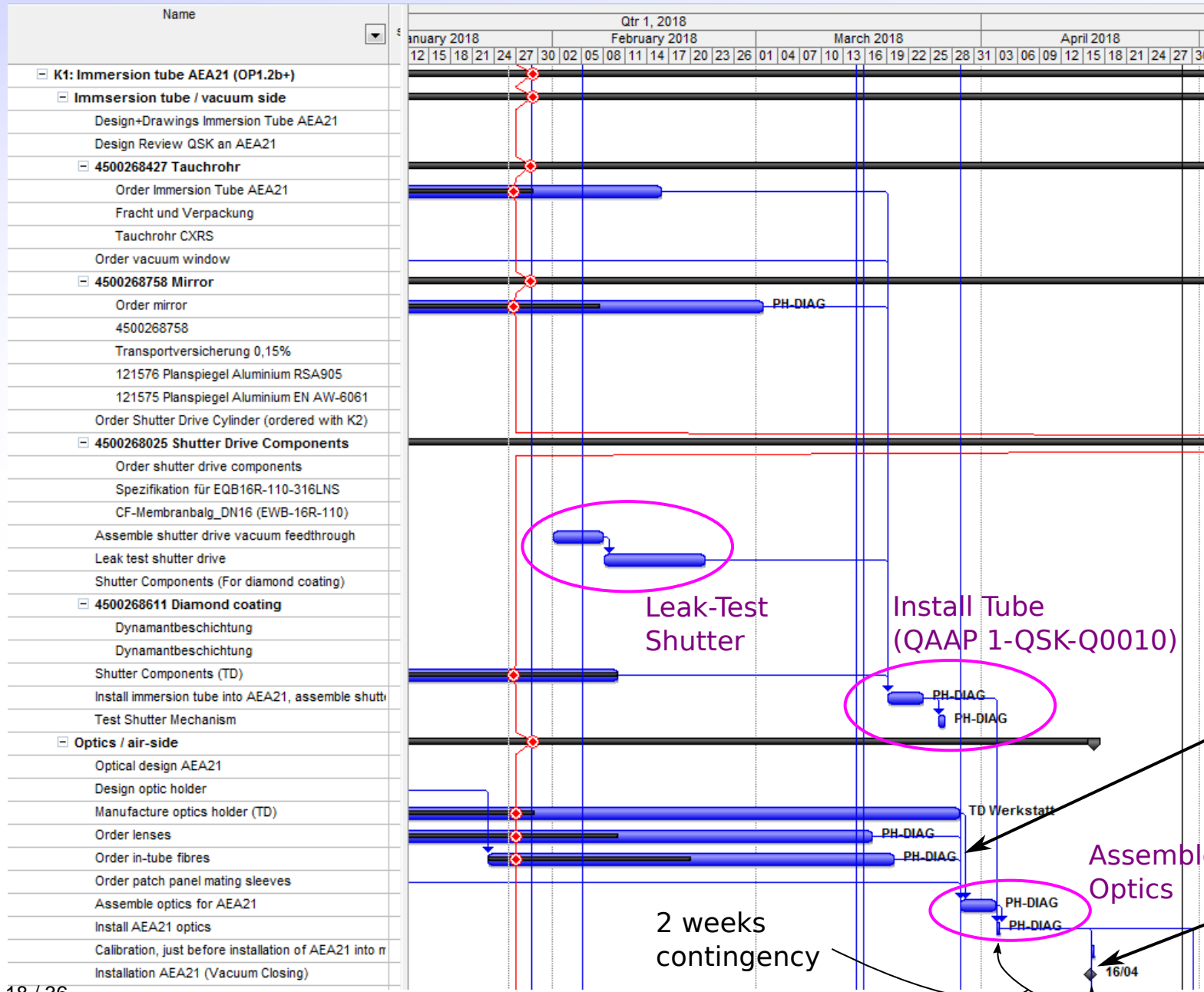
K1: AEA21 Optic Carriage Extraction

Optic carriage can be extracted if necessary for adjustments. Clear of conflicts with Alkali-beam injector.





K1/K4: AEA21 Schedule



Most critical is delivery of fibre head (Estimated). If later than 9.4.18, no calibration of A21.

Vacuum closing (fixed)

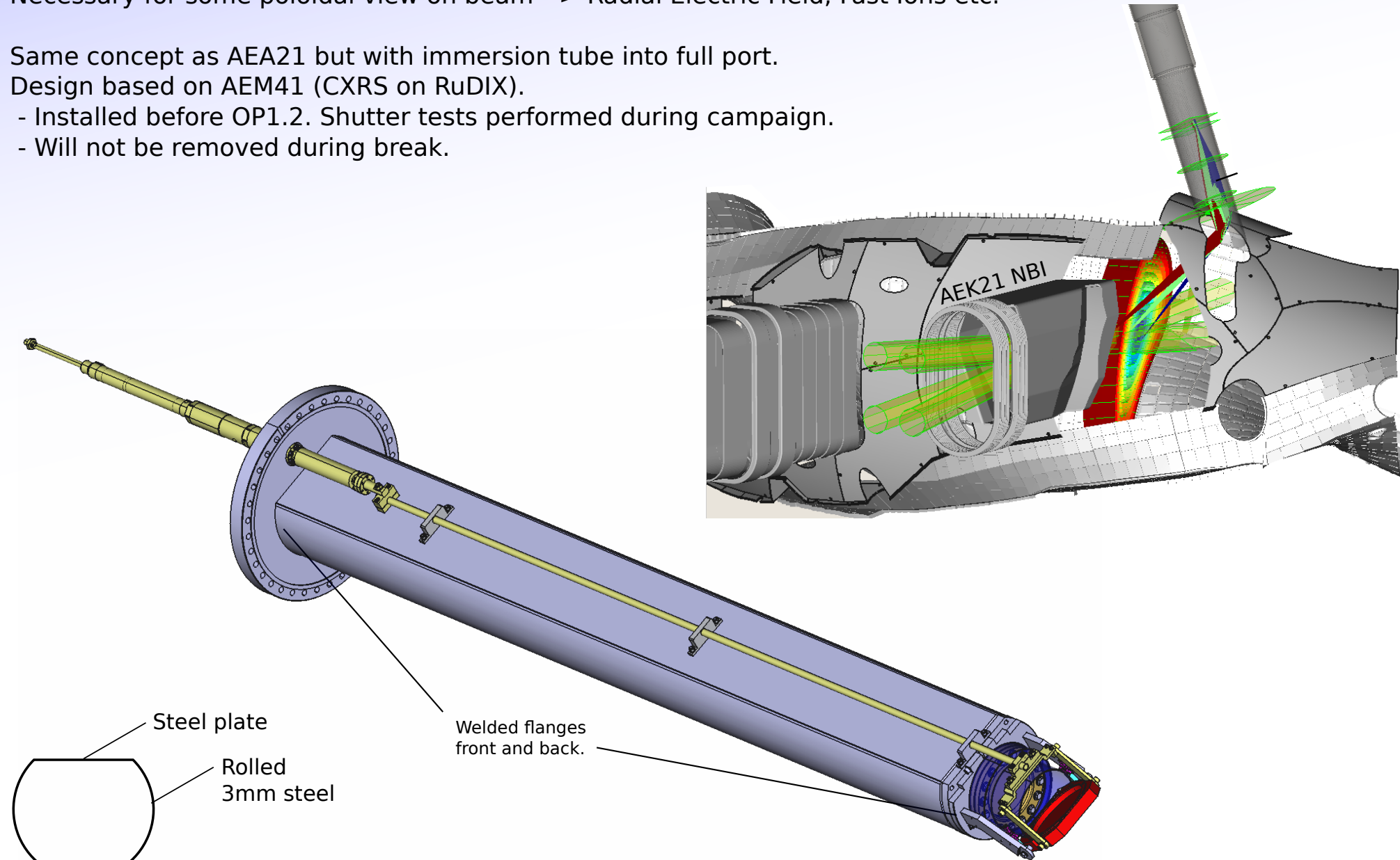
AEM21

Necessary for some poloidal view on beam --> Radial Electric Field, Fast Ions etc.

Same concept as AEA21 but with immersion tube into full port.

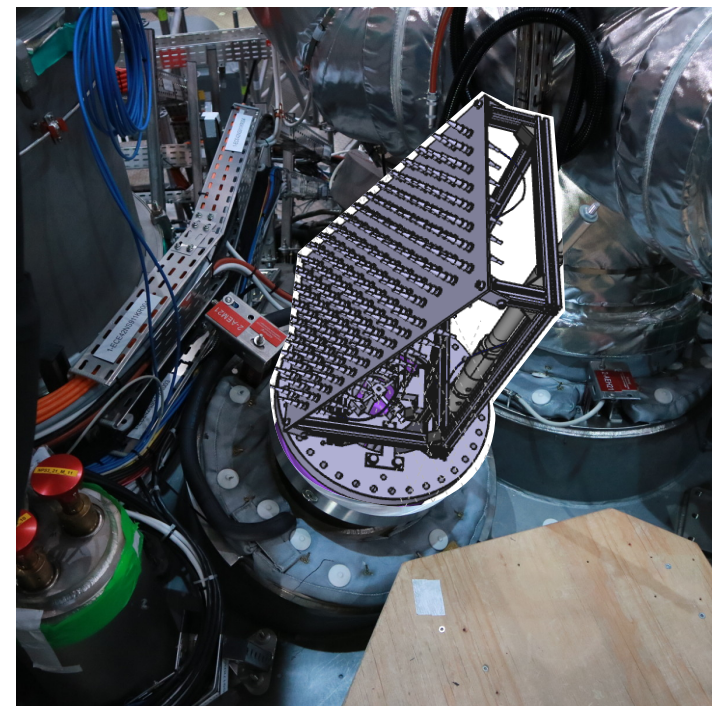
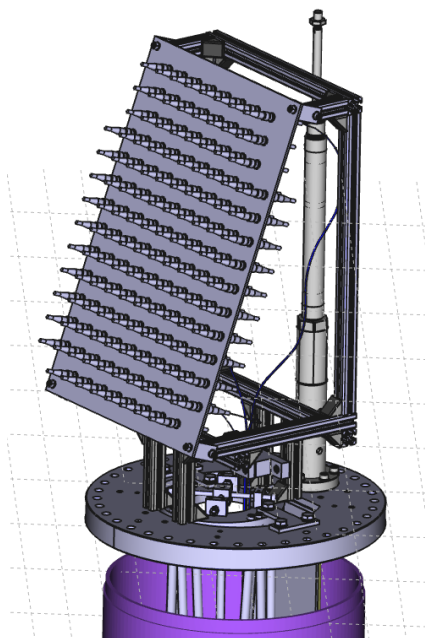
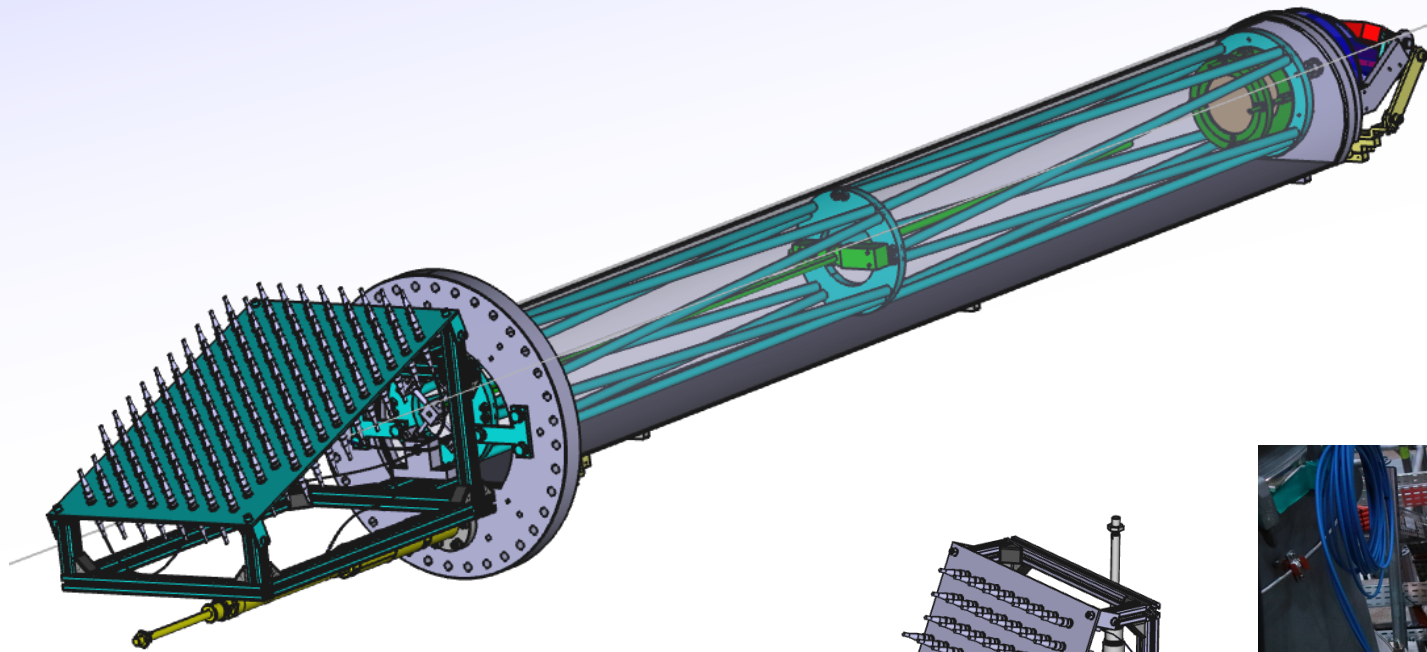
Design based on AEM41 (CXRS on RuDIX).

- Installed before OP1.2. Shutter tests performed during campaign.
- Will not be removed during break.



Optics

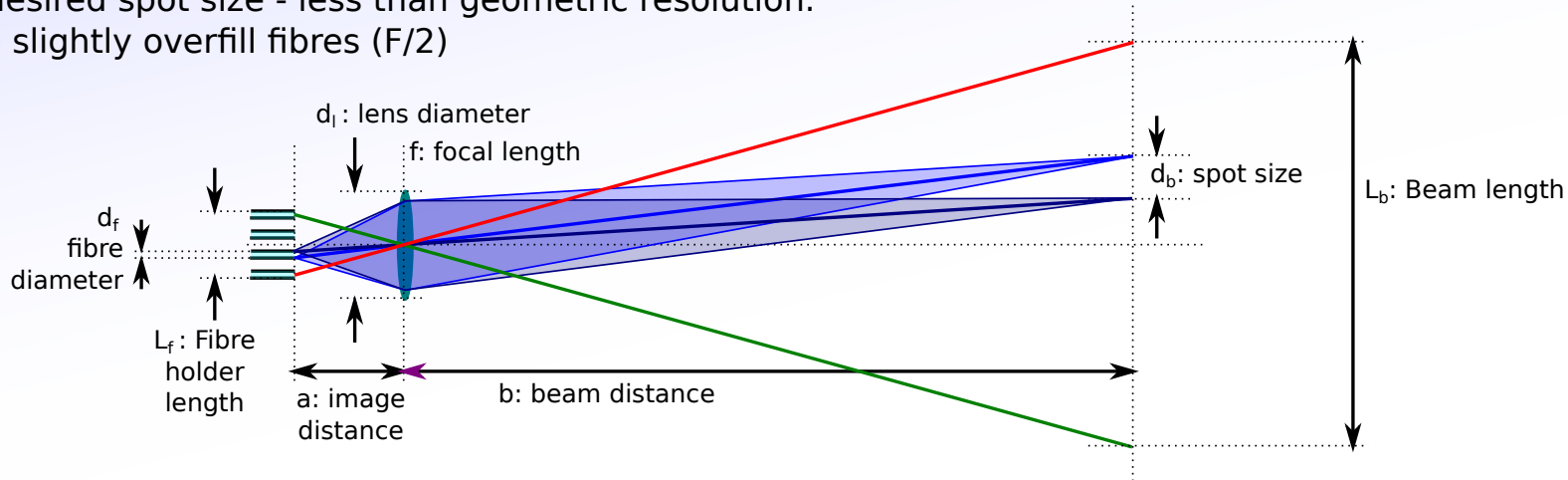
Optics carriage for AEM21 is almost identical design to AEA21.
Simpler patch panel as more space and easier access to port.
Carriage assembled Dec 2017 and rigidity tested - OK



K2: AEM21 Optical design (simplified)

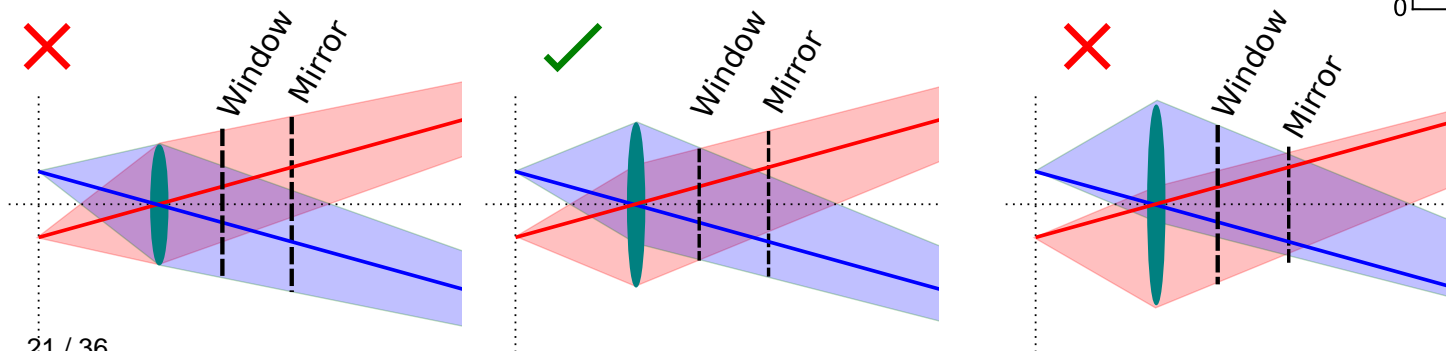
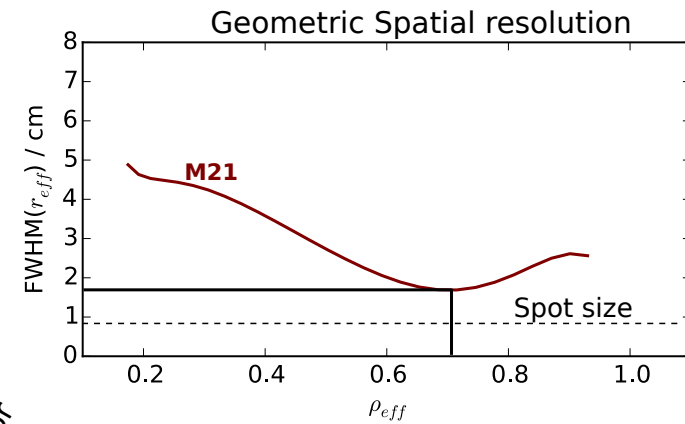
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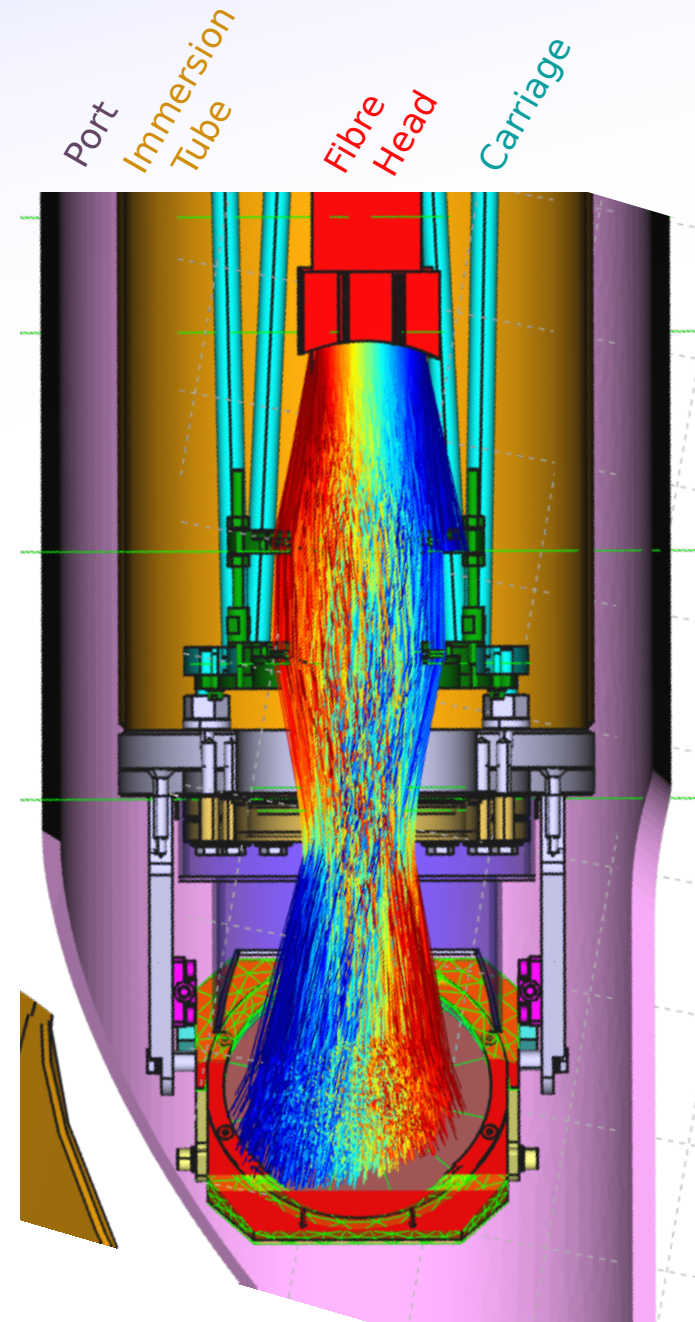
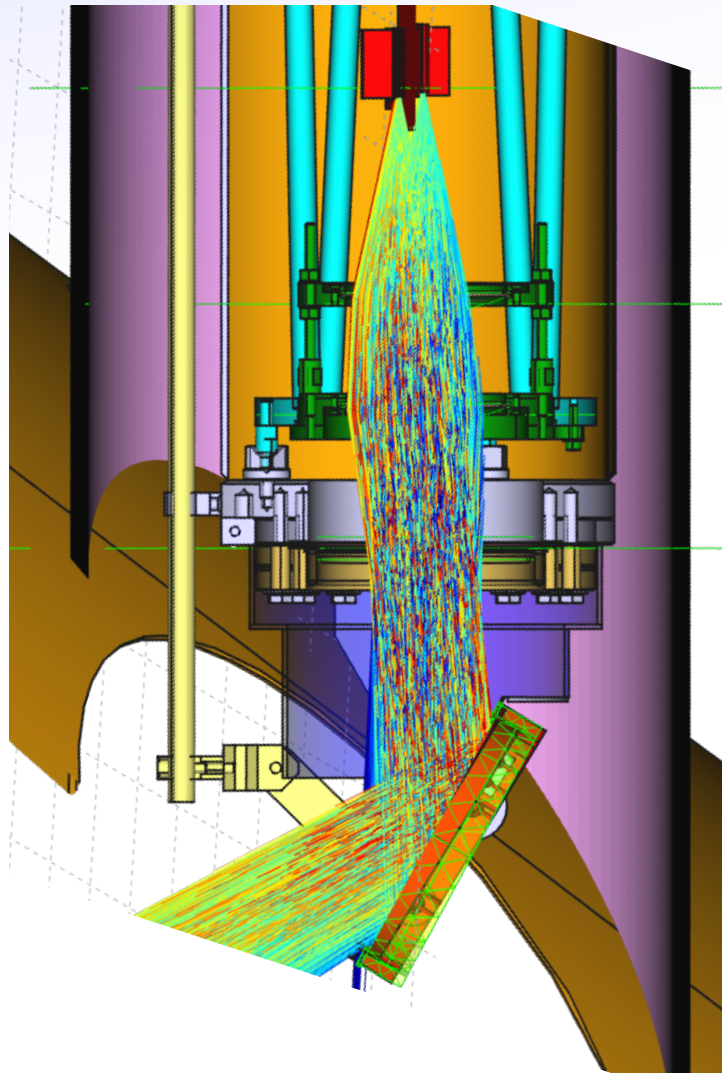
Geometric resolution: 12mm. Desired spot size of min 5mm.

Basic calculation requires only 50mm aperture, but in reality must be larger to enable a smaller mirror that does not project beyond panel level and feasibility optical head design (fibre spacing).



K2: AEM21 Ray-tracing

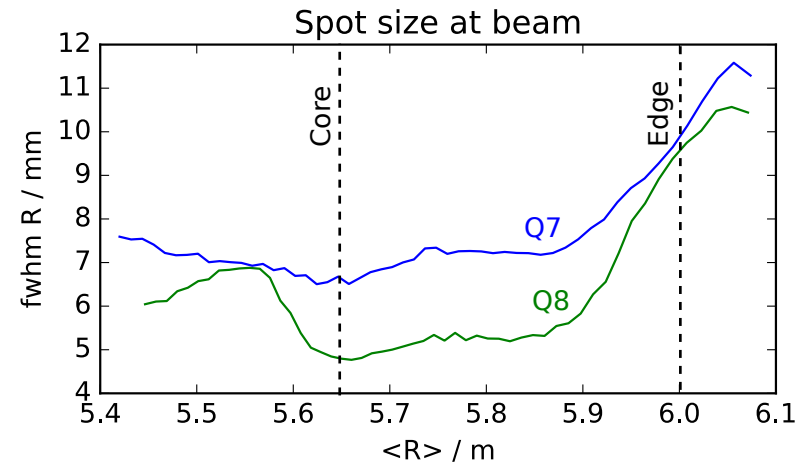
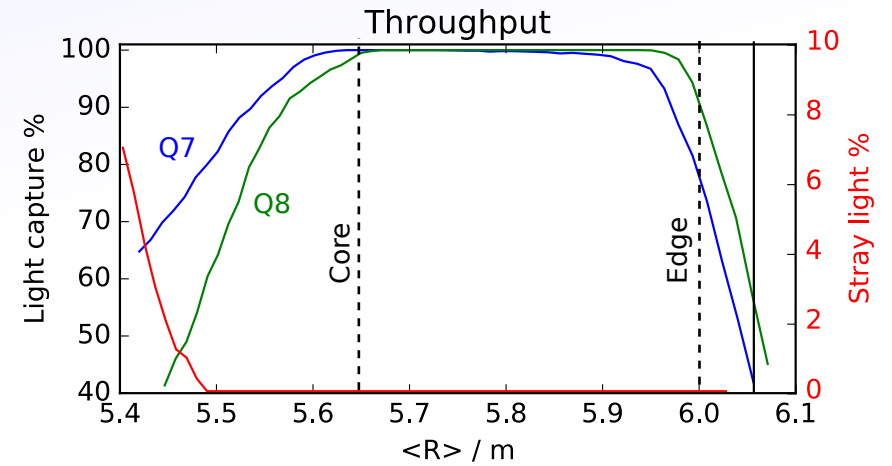
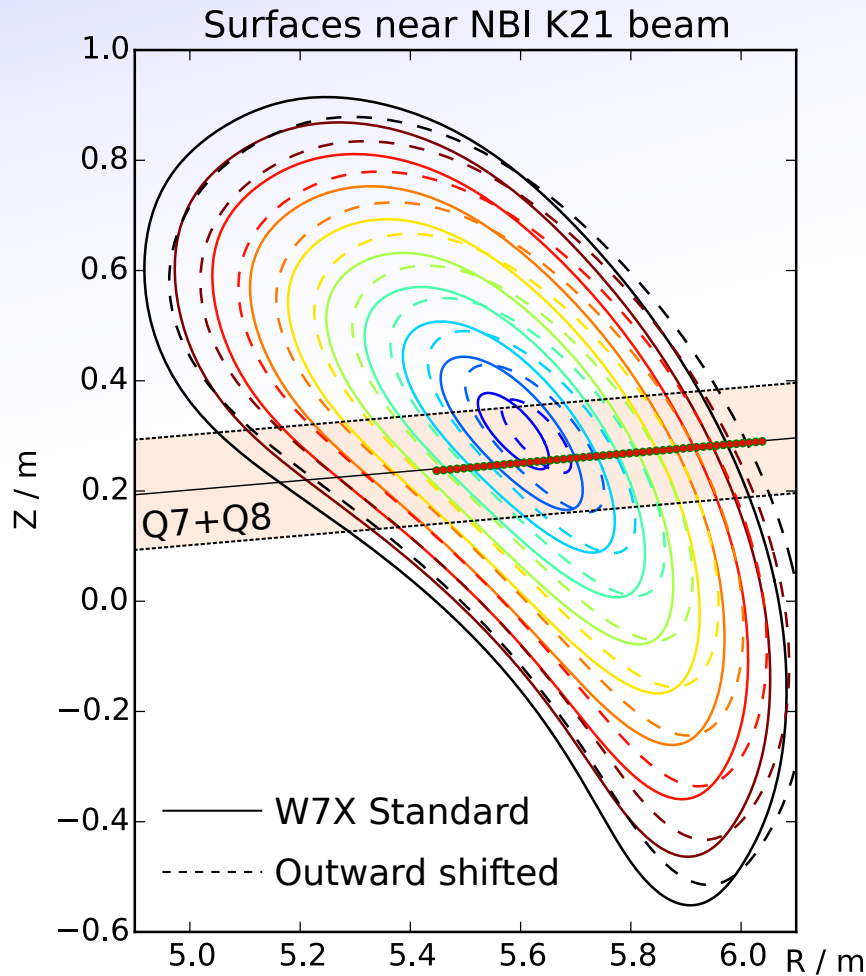
Optics carriage for AEM21 is almost identical design to AEA21.
Simpler patch panel as more space and easier access to port.
Carriage assembled Dec 2017 and rigidity tested - OK





K2: AEM21 Performance

Ray-traced performance of final AEM21 optical design:
Meets requirements.

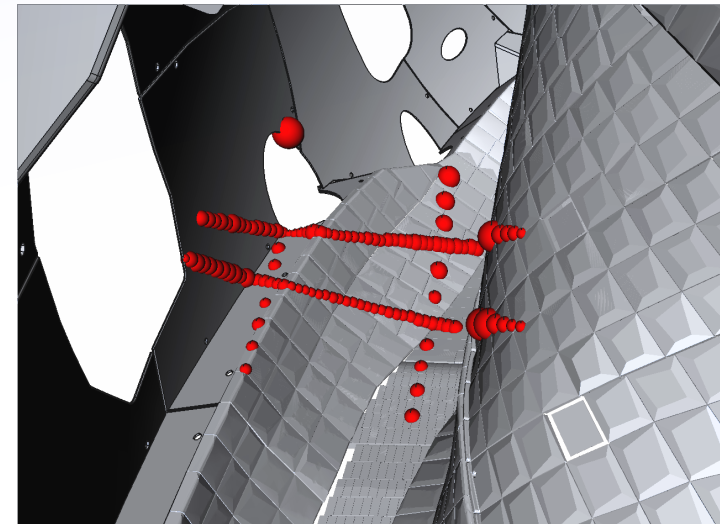
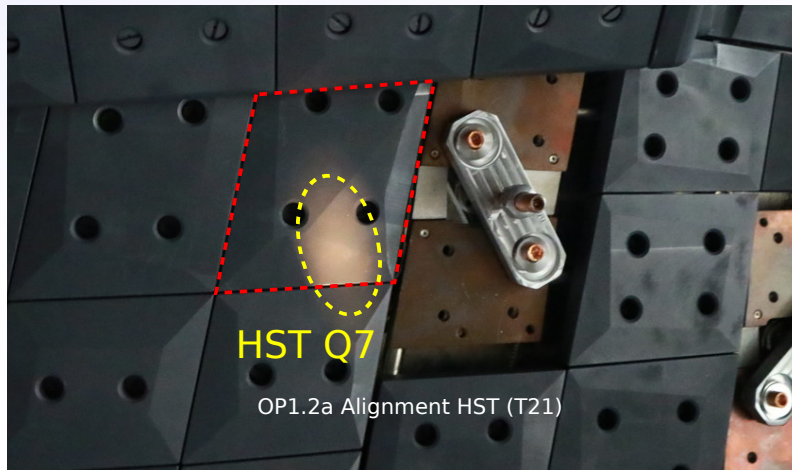


K2: AEM21 Calibration

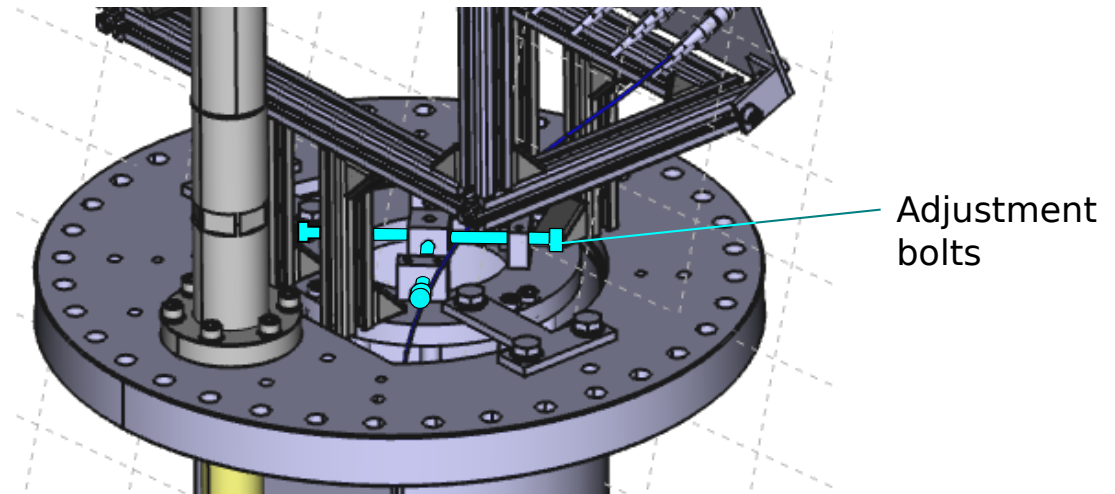
AEM21 must be calibrated from inside the vessel. (2-EGG21-Q2383.0)

1) Spatial Alignment

- 1.1) Backlight fibres and check light point on wall. As with T21 in OP1.2a. May be necessary to switch off vessel lighting briefly (~1min every 5mins for an hour)



- 1.2) If spots are more than 5cm from calculated positions, adjust alignment of optical head.
2nd person outside vessel at M21:



- 1.3) Photograph final alignment.

K2: AEM21 Calibration

AEM21 must be calibrated from inside the vessel. (2-EGG21-Q2383.0)

2) Intensity Calibration

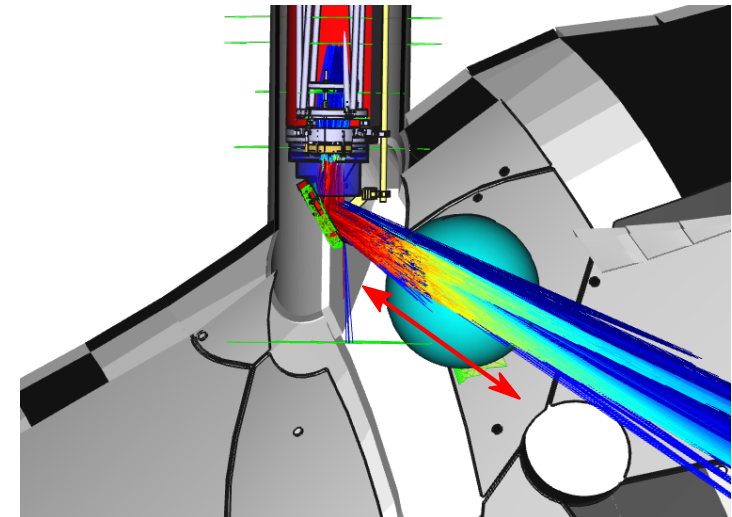
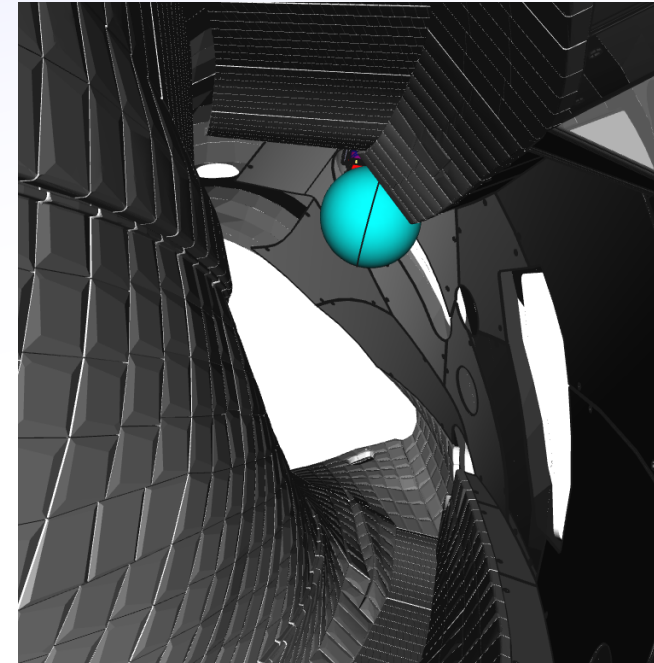
2.1) Set-up calibration sphere in-vessel.

Power supplies outside, 4x 12V cables through entry port.

2.2) Calibration sphere held in front of the optical head, approximately in line of sight (as seen from backlighting in part1)

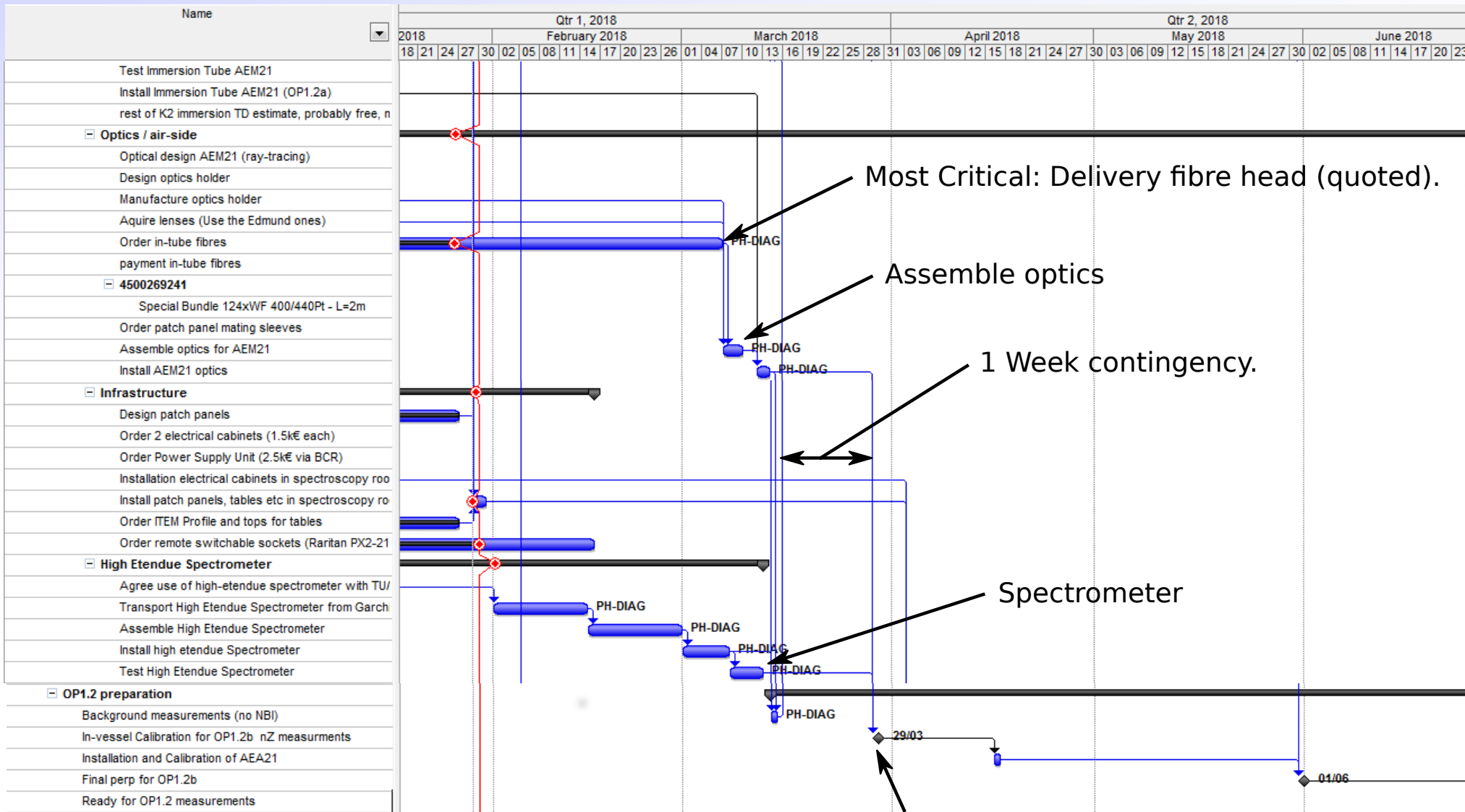
2.3) Gradually pull calibration sphere away from optical head to confirm non-changing intensity level.

2.4) Repeat as necessary to cover all lines of sight (~ x5)





K2: AEM21 Schedule



Expect calibration of AET21+AET20+AEM21.
Worst case: AET20+AET21 (already installed)

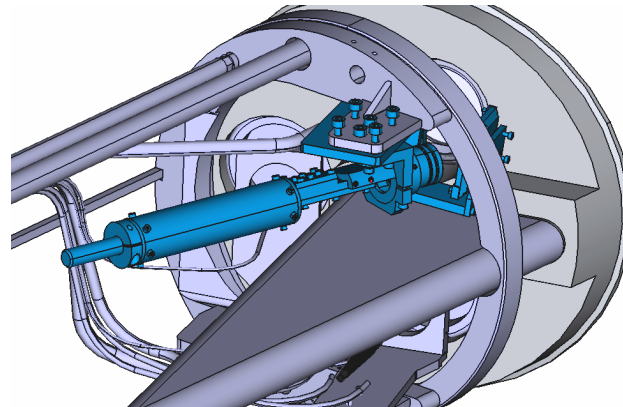
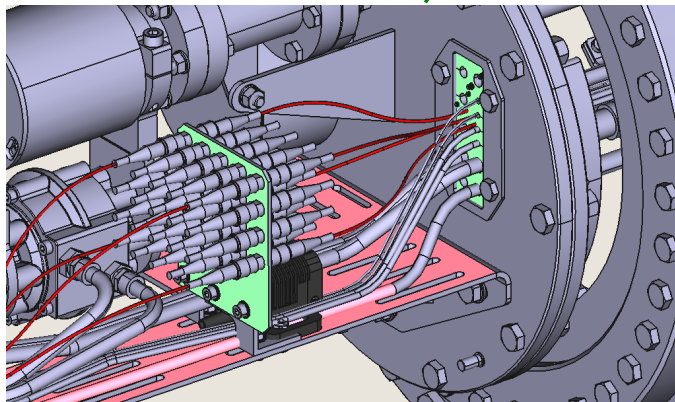
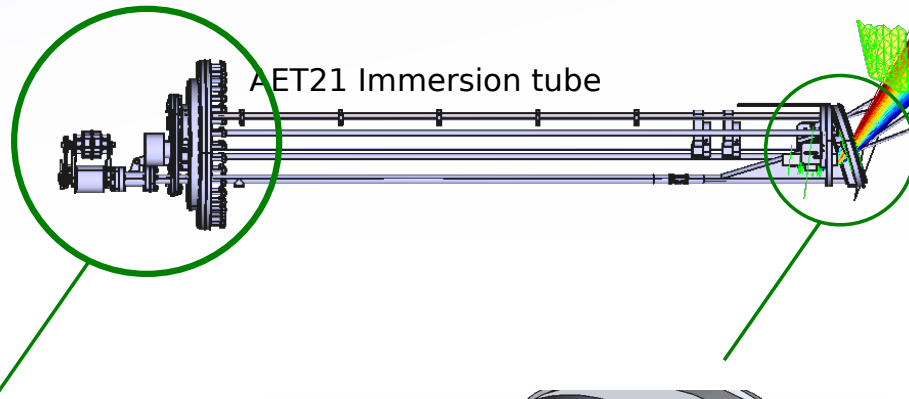
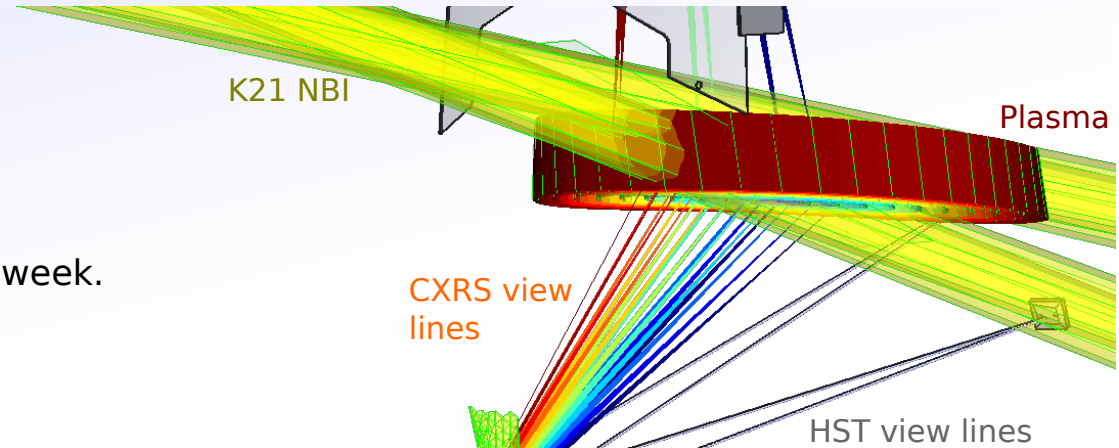
In-vessel calibration 29.03.18



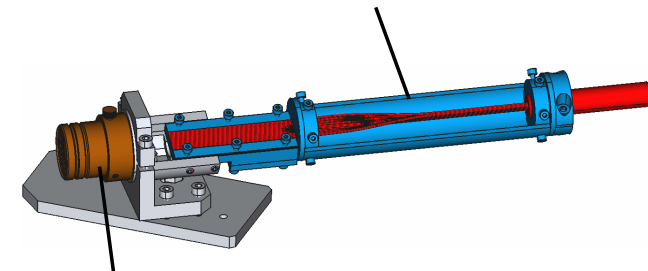
K3: AET20/21 Optics

In AET20/21 two simple optical heads installed in one window of each heat shield thermography (QYB) immersion tube. (like H-Alpha type 2 tubes).

AET21: Completed before OP1.2a. No issues.
AET20: To be installed in optics carriage next week.



All components fully enclosed to protect from ECRH stray radiation.

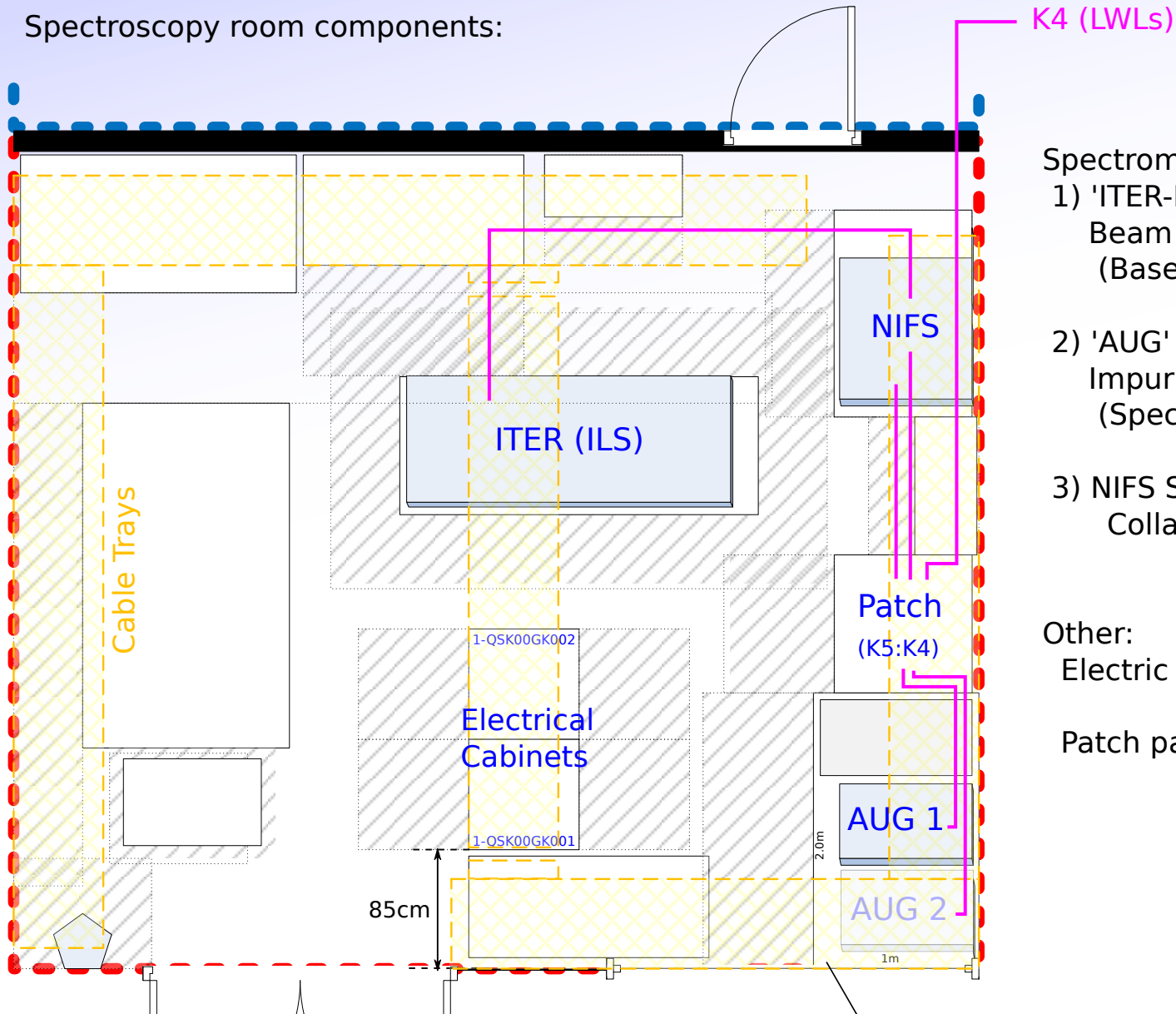


Aluminium commercial objective



K5: Spectroscopy

Spectroscopy room components:



Spectrometers:

- 1) 'ITER-Like Spectrometer' (ILS)
Beam density + Carbon
(Base system)
- 2) 'AUG' Spectrometer(s)
Impurities: B, O, N + FIDA (Fast ions)
(Specialilites)
- 3) NIFS Spectrometer
Collaboration: He/H

Other:

- Electric Cabinets with PCs.
- Patch panel

K5: Spectroscopy: ILS + NIF

ITER-like spectrometer:

- Collaboration of IPP with (FZJ, TNO, TU/E).
- Operated on ASDEX Upgrade for last several years.
- High performance, well understood.

KW8: Disassembly at AUG

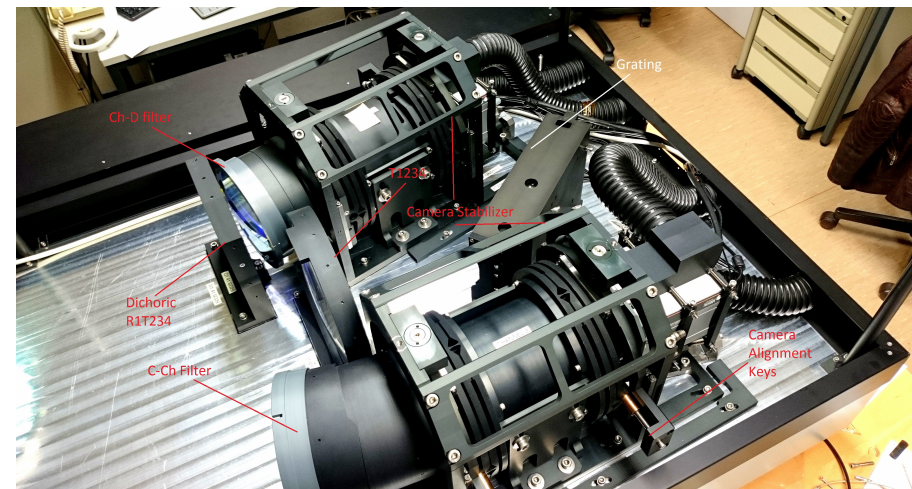
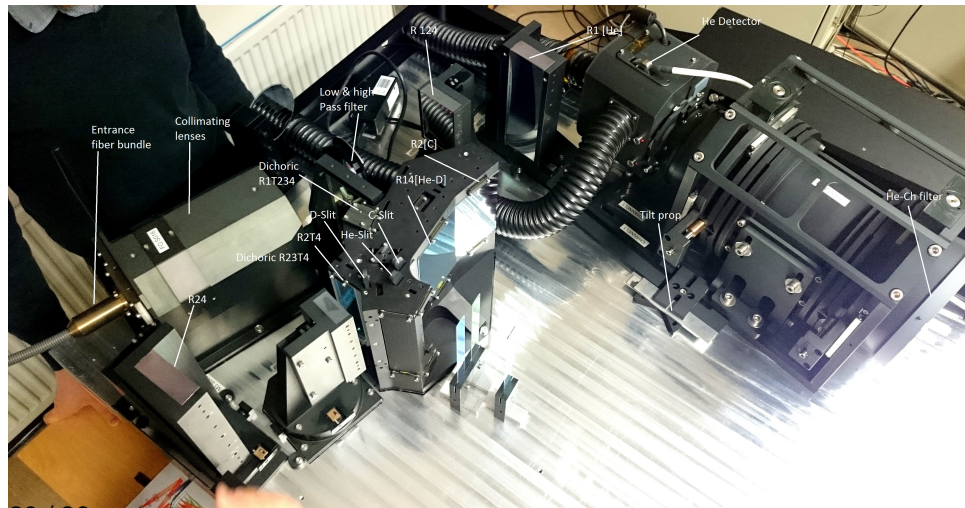
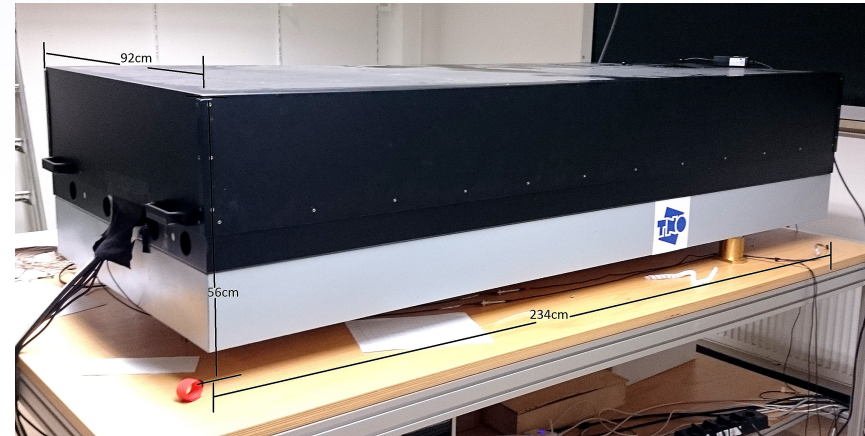
Documentation of light-paths and alignment.

KW10/11: Reassembly at W7-X.

All parts on localising pins, but may need to realign.
Assistance from TNO if required.

KW13: In-vessel calibration with AET20/21 + AEM21.

Base system for W7-X CXRS in OP1.2b



K5: Spectroscopy: AUG

'AUG' spectrometer:

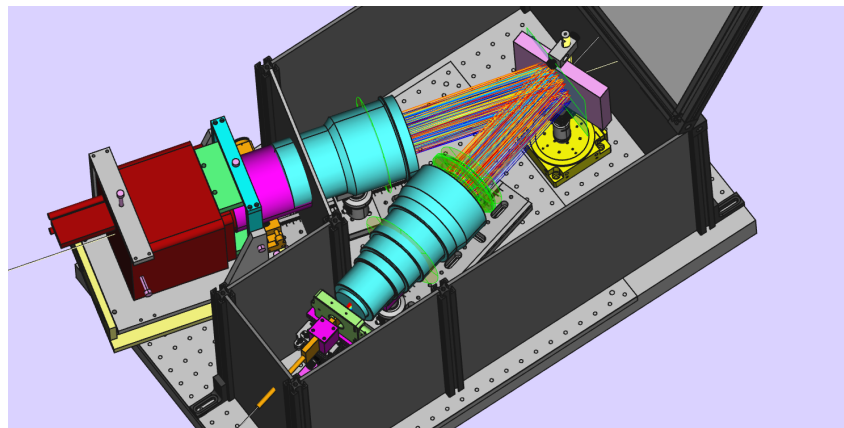
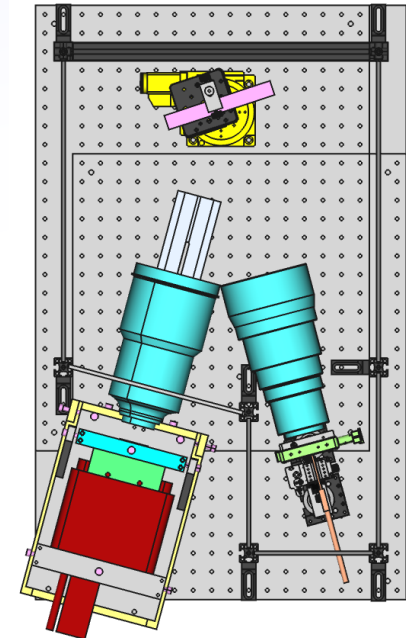
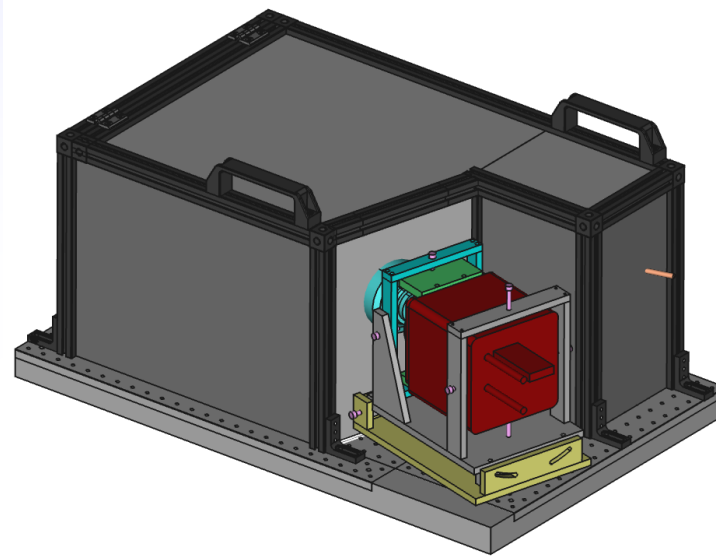
- Based on design of 'Dux' spectrometers from ASDEX Upgrade.
- Matches etendue of optical heads and fibres.
- Constructed using standard optical parts.
- Variable wavelength (He, B, C, N, O, FIDA)

KW2-5: Design

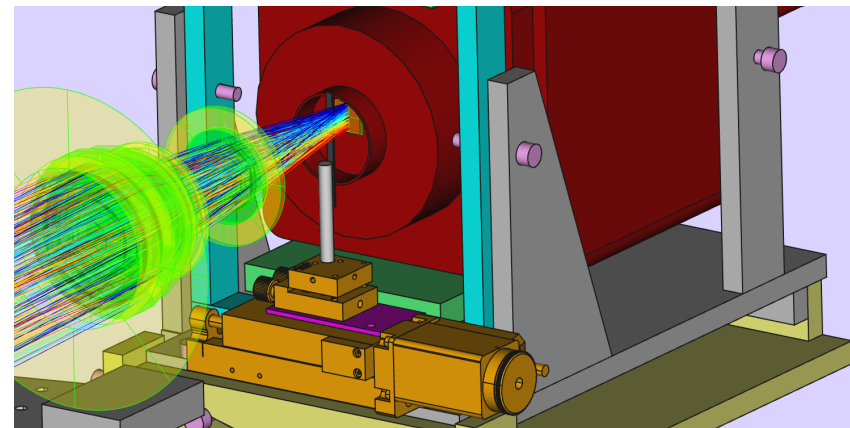
KW6: Order parts

KW22-...: Assemble, align, test.

- No pre-campaign intensity calibration.



Controlable blocking strip for Fast Ion D-Alpha measurements:

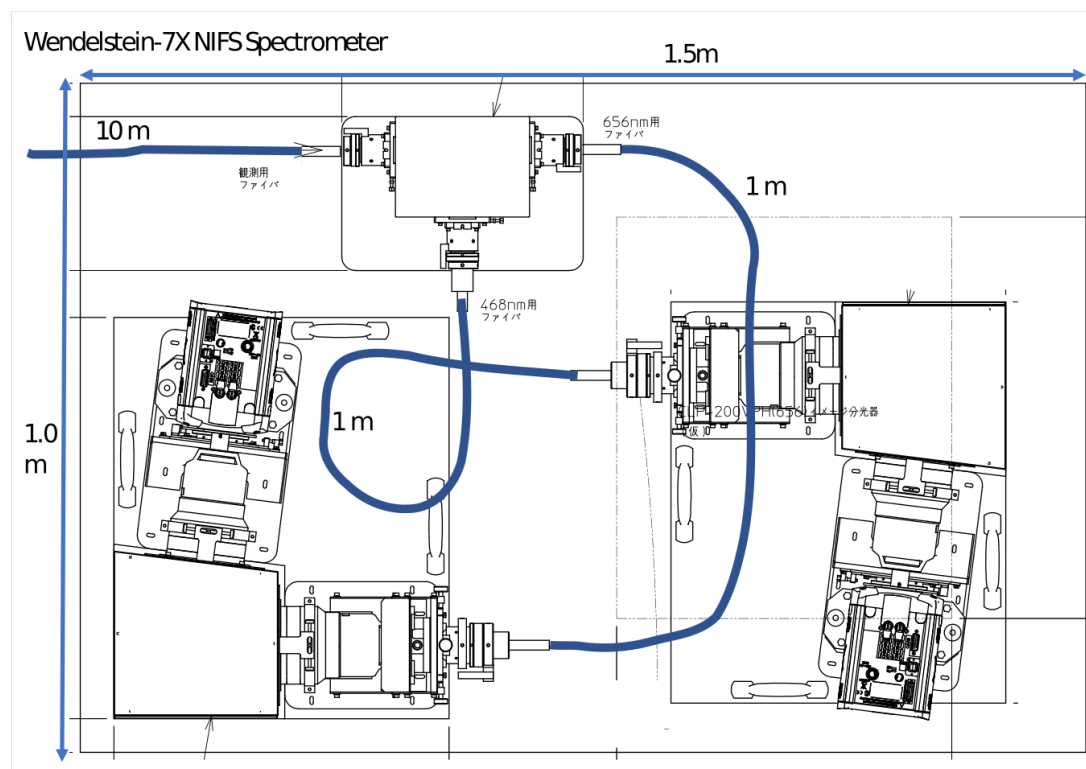


K5: Spectroscopy: NIFS

Collaboration with National Institute of Fusion Science, Japan (NIFS).
- Hydrogen / Helium density and ratio measurements.

KW11: Spectrometer delivery.
2 NIFS scientists
1 employee from manufacturer.
Installation.

KW13: Calibration with AEM21, AET20/21.



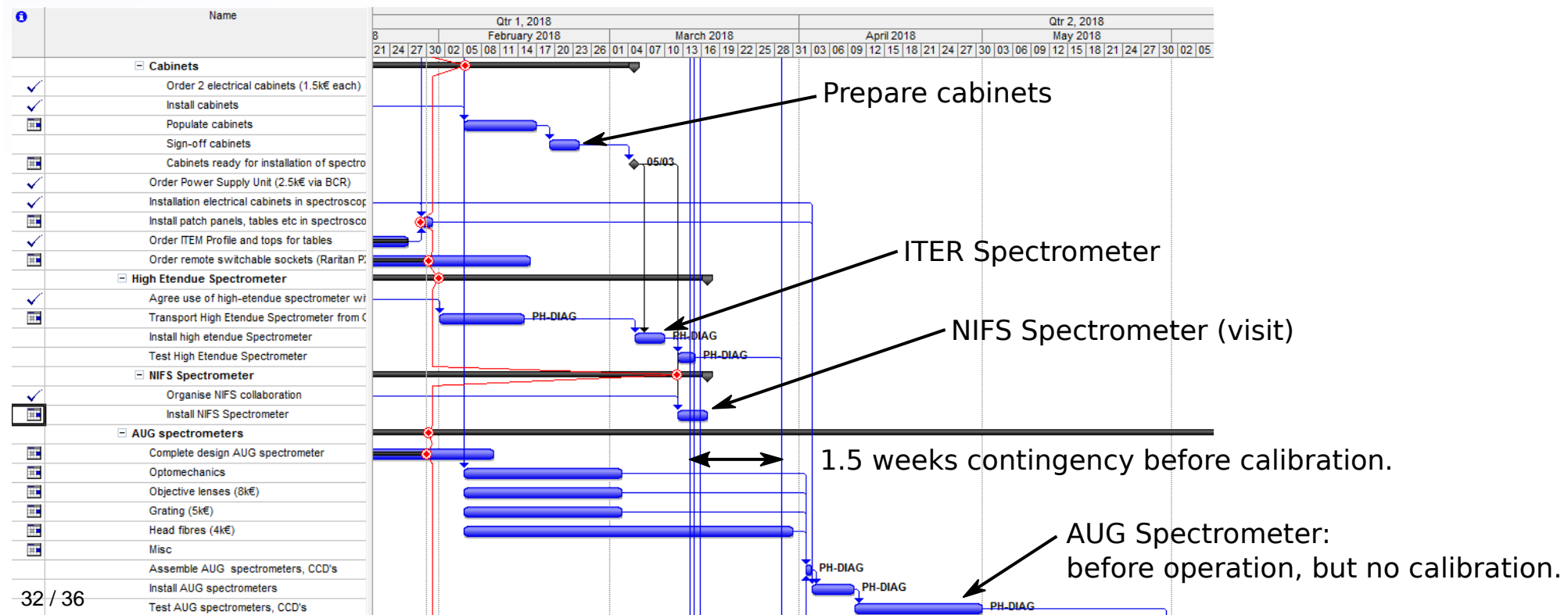
K5: Electronics and control.

Electrical cabinets:

- 2 Standard cabinets with water cooling (installed)
- 1 Power input from room distribution (ready)
- Electrical project created (copied from standard).
- EP to be updated after all devices installed (Rotschriftänderung): 3 PCs, Switch, TTE Module + IP power bar.
- All low-voltage/data connections to devices in same room only.

Software / CoDaC:

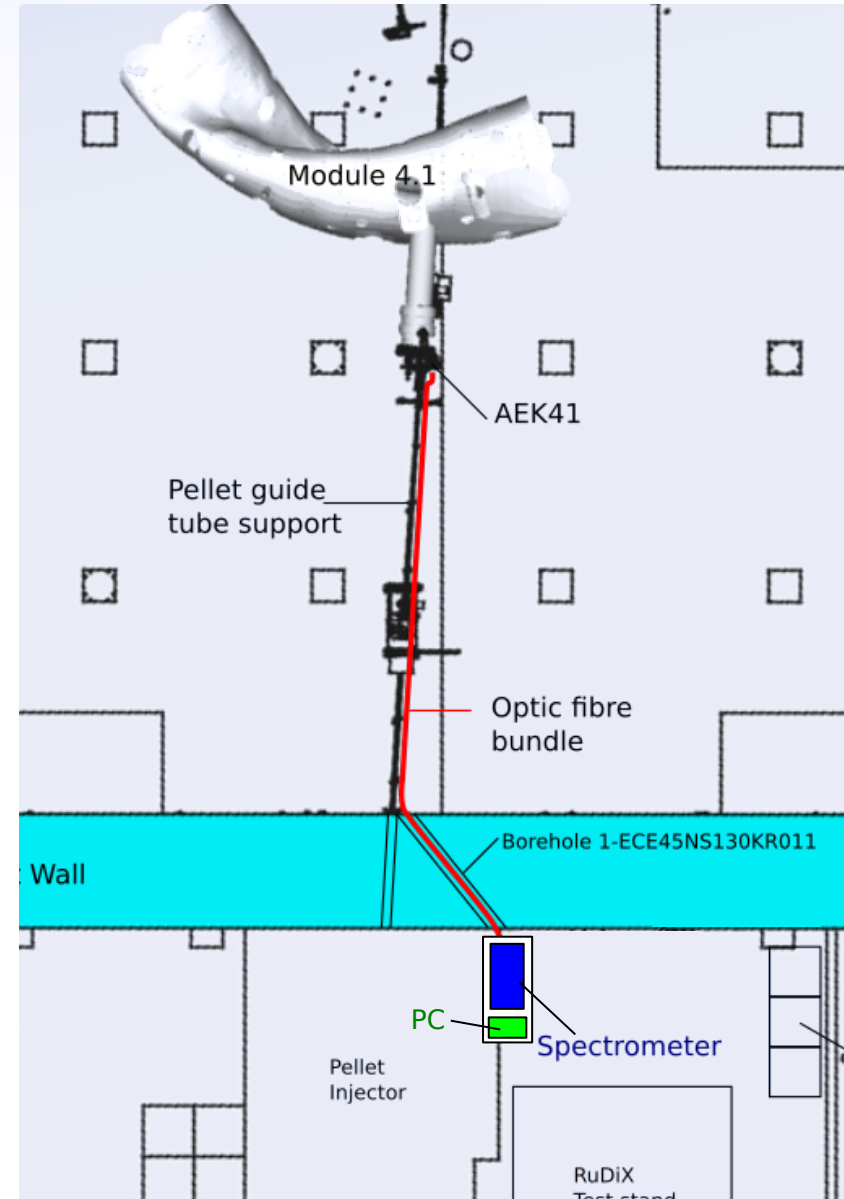
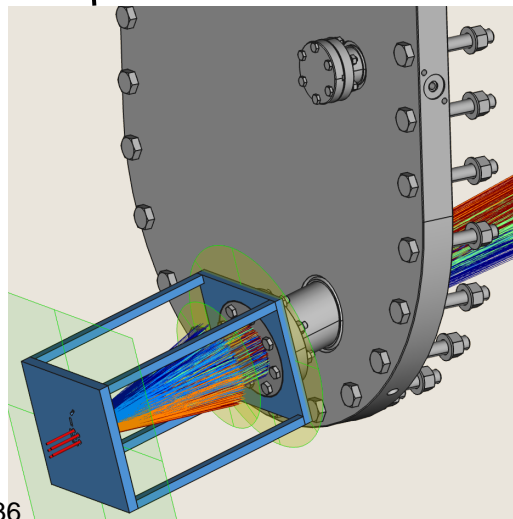
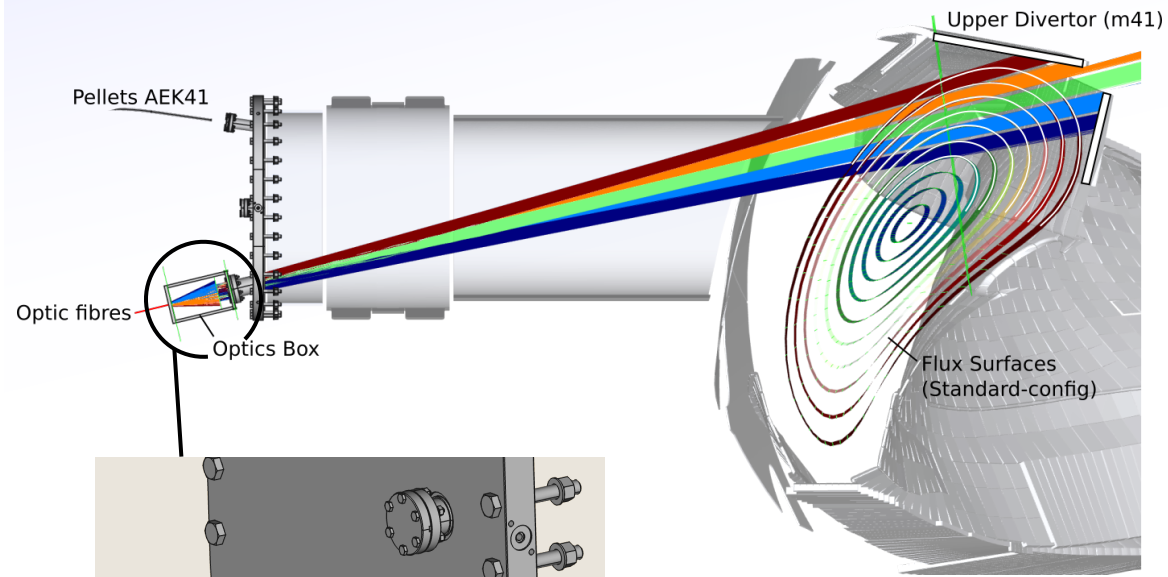
- Control software developed and tested during OP1.2a for passive CXRS + QSS, QRI.
- Fully automated and based on CoDaC webservice, writes directly to archive. (i.e. not MDS+).
- No further CoDaC support required beyond common services.



K6: Passive CXRS

Extension developed for OP1.2 to measure passive C, Ne, B at plasma edge.

- Optical head in box attached to vacuum window at AEK41.
- No shutter.
- Transfer fibres running to diagnostics hall.
- Tested and operational during OP1.2a.
- Also provides overview spectroscopy and H/He ratios.





Dokumentation

- 1-QSK-S0002 - Projektspezifikation - **Freigegeben**
- 1-QSK-T0003 - Sicherheitsanalyse - **Fertig**, bei OP-DO/DS für Prüfung.
- 1-QSK-S0000 - CoDAC Lastenheft - Fertig geschrieben (aber kein wesentlichen Inhalt)

Sonderfreigaben:

- 1-QSK-Q0000 - Stecker - **Freigegeben**,
- 1-QSK-Q0002 - Spiegel AEM21 - **Freigegeben**
- 1-QSK-Q0009 - Spiegel AEA21 - Wartet auf Permeabilitätsmessung

Montage:

- 1-QSK-Q0010 - Montage AEA21 Plug-in - **Fertig**
- 2-EGG21-Q2383.0 - Kalibrierung AEM21, AET20/21 - **In Arbeit** (AS)

Schaltschränke:

- 1-YEE-T0007 - Gefährdungsbeurteilung Elektrotechnik CXRS an NBI - **Fertig**
- 1-QSK-A0001 - Betriebsanweisung - **Fertig**
- 1-QSK-A0002 - Betriebsanleitung - **In Arbeit**
- Elektroprojekt - Standardschrank - Wird nach Aufbau aktuellisiert.

Backup - K1/K4: AEA21 LWLs (Insertion)

There was some conflict of QSK with the tools used to insert the AEA21 flange.
Solved with shift of patch panel and minor modification to tools (yellow):

