

Procedure to assemble the NAB

(Simon Zeidler)

General Notes

- Please read the section of this document you are going to work on today BEFORE you start the work and remember as much as possible as sometimes the work does not give you time to read this document.
- Clean the clean room everyday.
- Take the log. Leave them on k-log.
- Take many pictures. Leave them on k-log.
- Fix the suspension and cover it when you leave, and when you open the top window of the clean booth.
- When you moved tools, circuits, and so on, which belongs to the other subsystems, please make the log, and be sure to return it when finished. Especially, the information about where the circuits is necessary to be updated on the JGW doc DB.
- Take enough rest. If you feel tired, do not hesitate to go outside and take a rest.
- Wear proper items if necessary (safety gloves, helmets,,)
- You need two people who have crane licenses when you use the crane.
- If you got injured, please tell the responsibility person as soon as possible.
- When you work around/inside the vacuum chamber, wear clean inner wears and class-1 clean wear, which is the blue ones or ones with separated hood. And blow the air to remove your dust when you enter the clean room.
- Bring the clean suits outside for cleaning every Friday. After you brought them to the office, count the number of the suits w/ hood, suits w/o hood, hood, mask, gloves, and shoes.

*** Attention ***

In all steps of working, be advised to take special care of handling the (black-coated) baffle!

The special “solblack” coating is easily scratched or removed when touching it. Pay special attention to the most sensible parts of the baffle in terms of dumping scattered light:

- baffle edges of the inner hole
- The whole inner surface of the baffle-hole
- The surface (on both sides) closely around the inner hole

Drawings

Should be found in the JGW document server (Authors: Bungo Ikenoue and Sakae Saito).

List of Items

Detailed Description

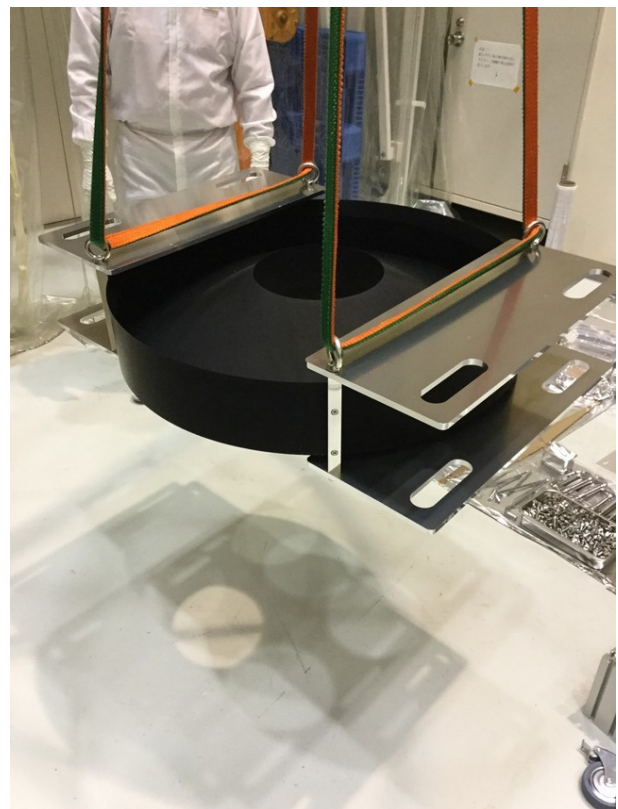
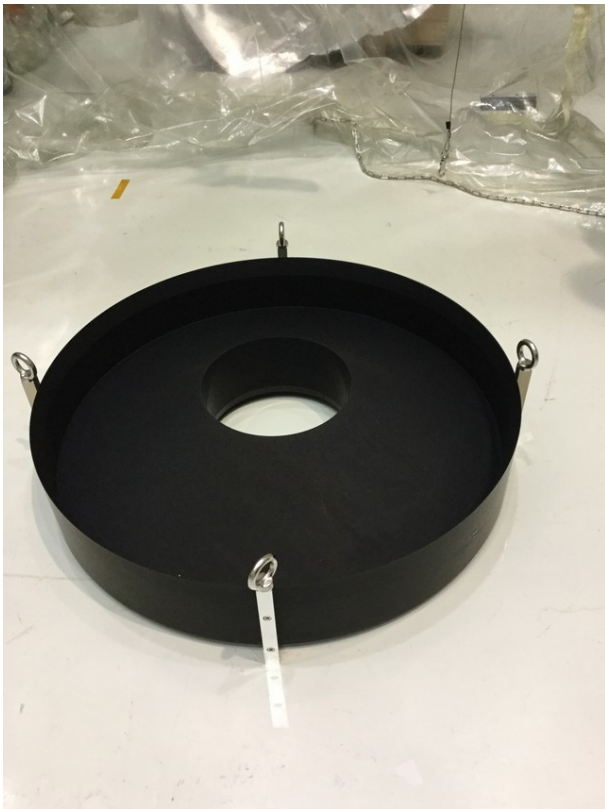
1. Preparation of Baffle

For an easier handling of the Narrow-Angle Baffle (NAB) itself, we have to exchange first the baffle feet on all four positions with a {stainless-steel feet having two M12 Screw-holes up and down}.

Procedure:

- As the baffle should not touch the ground, the feet has to be removed one by one
→ while two people take care that the baffle is in a good position for the replacement, one guy is replacing the feet
- Screw [M12 eyebolts] into the upper screw-holes and lift the baffle out of the wooden box with their aid (can be done by hand)
- Unscrew the eyebolts and set a {handle-plate} with its two screw-holes on top of two feet and screw it again with the eyebolts. Do the same on the other side
- Lift the baffle up again, now with a crane (and the 4 eyebolts), and mount the {handle-plates} on their respective positions at the bottom side (screw them with common [M12 screws])

After this preparation, set the baffle aside.

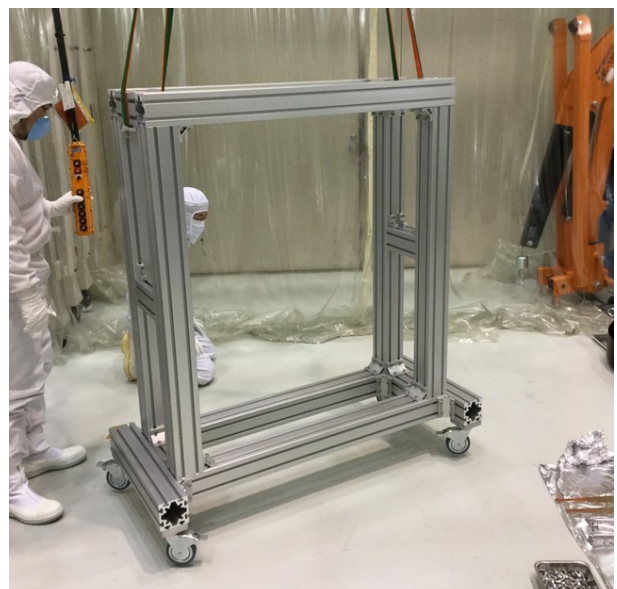


2. Set up the Assembly-Jig

(Because we already assembled the jig, this point can be skipped)

- Construct the lower-half of the Jig by forming a rectangle with 2 *{long}* and 2 *{medium-long*}* frame bars and fix them together with brackets on the inner part
 - **Important:** it is necessary for the next steps to insert *{Screw-holder-nuts}* into the rails of the bars before actually mounting the bars together! – in each rail put 2 in the upper and 2 in the lower bar, and each 3 in both side bars
- Set 4 *{short}* bars vertically on the corners of the frame and 2 in the center of each side-bar. Also fix them with big brackets (for the corners) onto the frame and small brackets for the side-bars
 - Also here, insert some *{Screw-holder-nuts}* now inside the rails of the *{short}* bars in order to fix them accordingly
 - Insert the same amount of *{Screw-holders-nuts}* again into the small bars in order to fix brackets for the upper half of the frame
- Set up the upper-half of the frame, which is the same as the lower-half
 - Insert the respective amount of *{Screw-holder-nuts}*
- Put both halves together and fix them with the brackets on the *{short}* bars
- Lift the main-body on the top side to place the whole jig upright; thereafter, lift up the whole body with a crane by at least a half a meter
- Mount 2 *{wheel-holder}* on the *{medium-short}* bars
- Mount the 2 *{medium-short}* bars on the bottom side of the lifted frame (parallel to the *{short}* bars)
- Mount the wheels on the *{wheel-holder}* on the bottom side of the mounted *{medium-short}* bars

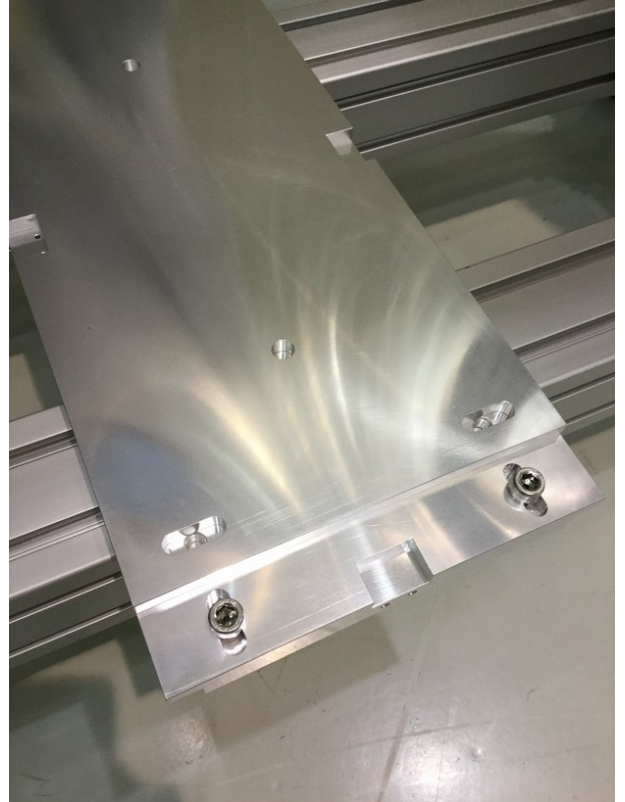
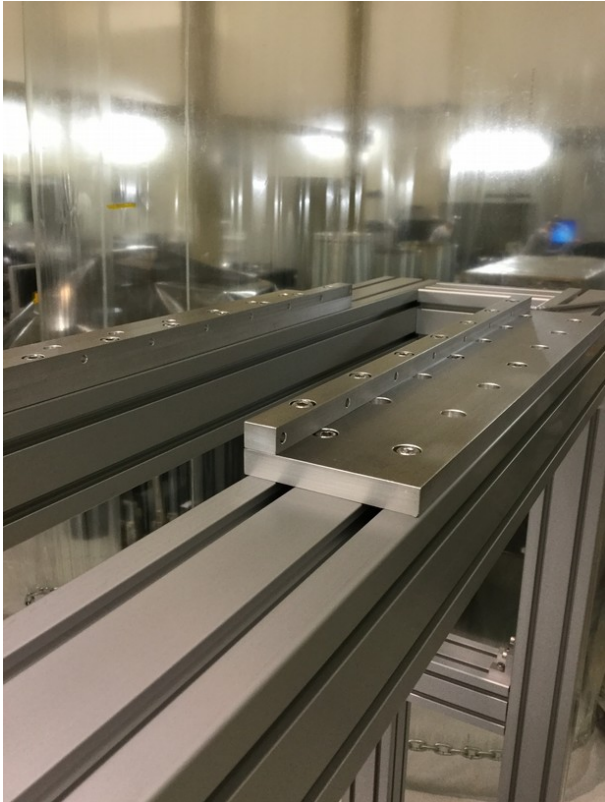
Note: The (Aluminum) bars for the jig usually have an error in their aspect length! Due to this, it is somehow natural that the jig will not be 100%ly straight or plane-parallel. It may be thus necessary to insert shims under the *{jig-NAB-connector plates}* in order to make the NAB-suspension plane-parallel.



3. Setting-up Top-Stage

The top-stage needs to be assembled first as it will hold everything related to the NAB on the Jig. Furthermore, the top-stage is also hosting the horizontal translator, the yaw-adjuster, and the vertical adjustment stage.

- As a very first step, one should attach the 2 *{jig-NAB-connector plates}* on top of the jig. They are to be placed on each side (front and back) of the frame
 - Make sure that they are placed centered on the respective bar/frame-side
 - Insert *{rail-nuts}* in each rail of each bar (3 per rail should be enough) and use *[M8x20 screws]*
 - Assure they are plane-parallel with each other
- Mount the *{IF M5 holes}* bar on it (with *[M8x20 screws]*)
Take the *{base-plate}* and mount the *{horizontal side-adjustment plate}* on top of it
- Mount the *{horizontal front/back-adjustment plate}* on top of them; do all this with *[M10x20 screws]*
- Mount the *{base-plate yaw-adjuster}* (the plate with the big hole) on top! Use again *[M10x20 screws]*
 - There are also *[M10x25 jack-screws]* to be inserted from top of this plate which are an additional possibility for a +Z vertical and tilt/roll adjustment

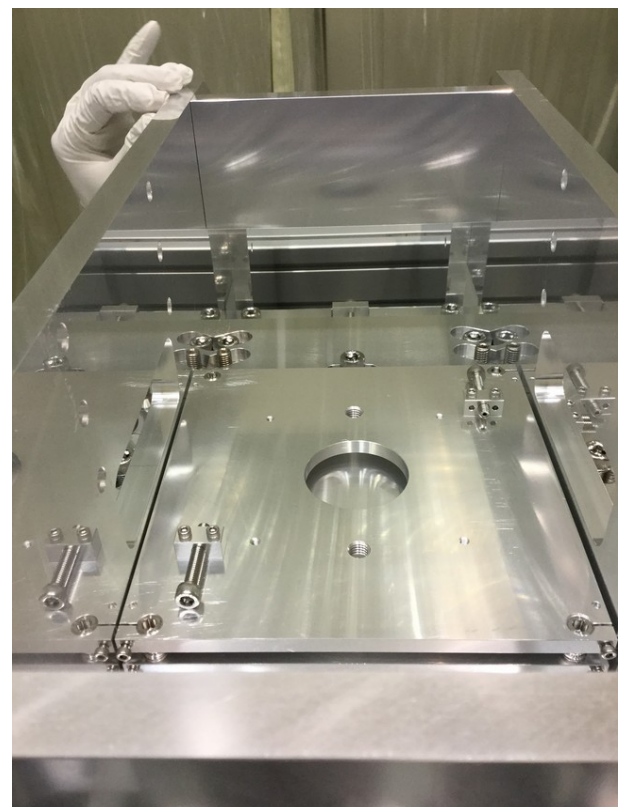
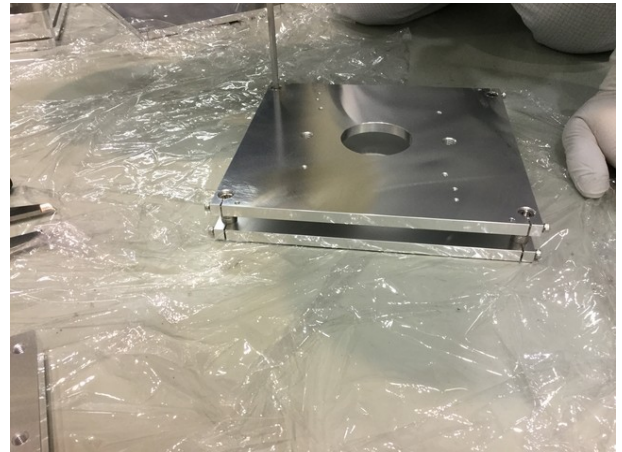
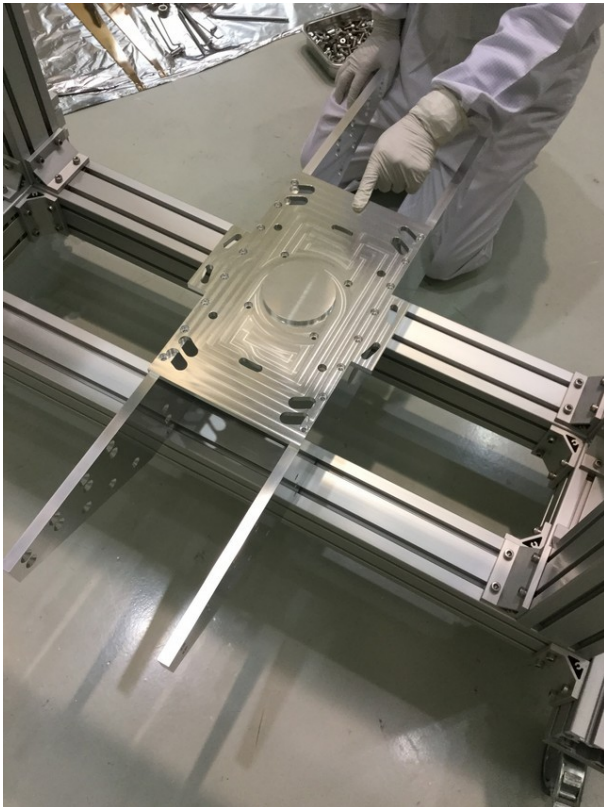


- Apart from that, connect the *{base-plate yaw-adjuster counterpart}* to both *{front/back shields}* separately

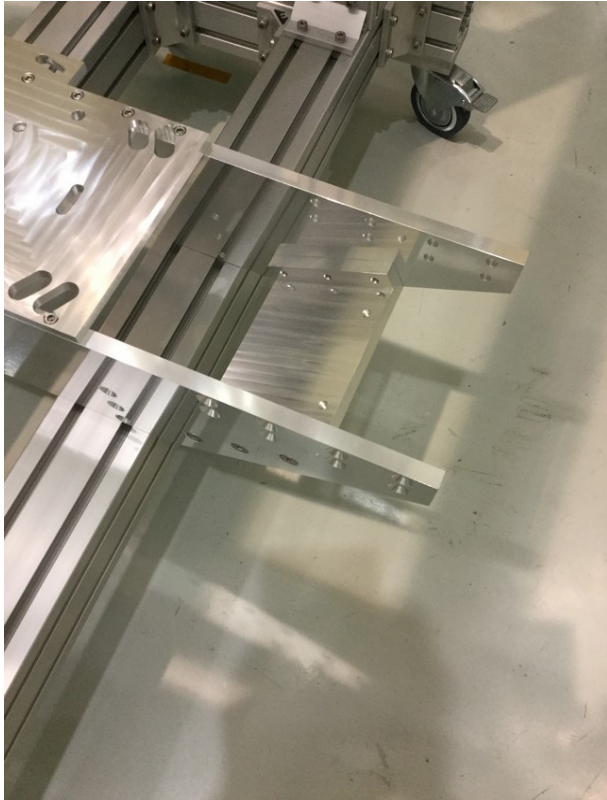
→ The shields are to be mounted on top of the *{base-plate yaw-adjuster counterpart}* and the screws (*[M6x20 screws]*) are inserted from the bottom

Note: do not tighten the screws yet!

- Assemble the *{vertical-adjustment stage}* and set it on top the *{base-plate yaw-adjuster counterpart}*
 - The *{vertical adjustment stage}* consists of 2 square plates with counter-threaded screw-holes at the corners
 - 4 *[M6 jack-screws]* should be put in between the two plates to be inserted in between the respecting screw-holes at the same time
 - mount the *{yaw trigger screw holder}* on the *{vertical-adjustment stage}* and insert the *[M6x50 screws]*
 - Fix the *{vertical adjustment stage}* with screws from underneath the *{base-plate yaw-adjuster counterpart}* ; use *[M?x? screws]*



- Take the *{second yaw adjuster and blade-spring base}* and mount the two *{XY translators}* on it with *[M6x12 screws]*
→ the horizontal adjuster screws for the translators would be need to be assembled too
- Set the *{second yaw adjuster and blade-spring base}* with the translators inside the hole on top of the *{vertical-adjustment stage}* and fix both by two *[M8x20 screws]*; take care that the orientation of the base is the same as in the picture below!

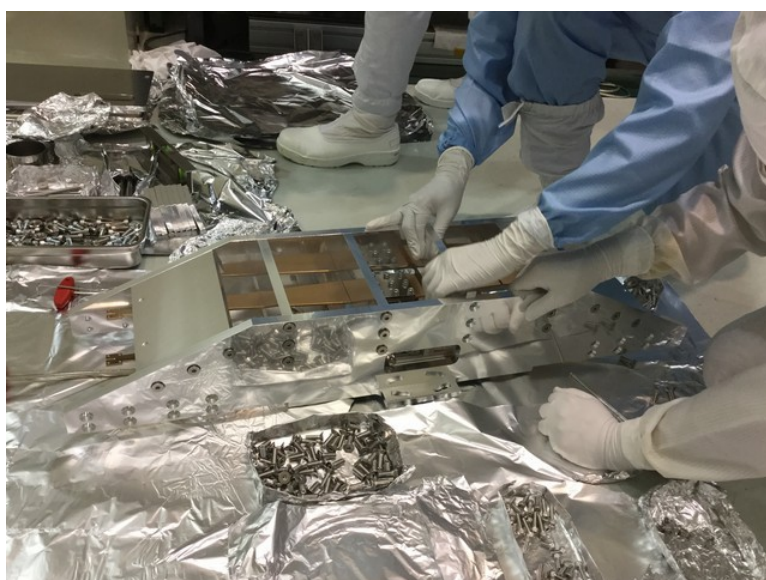
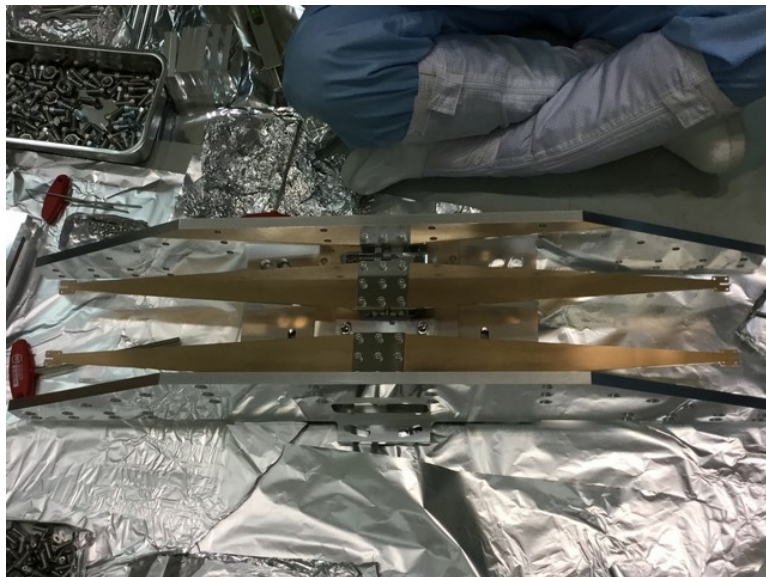


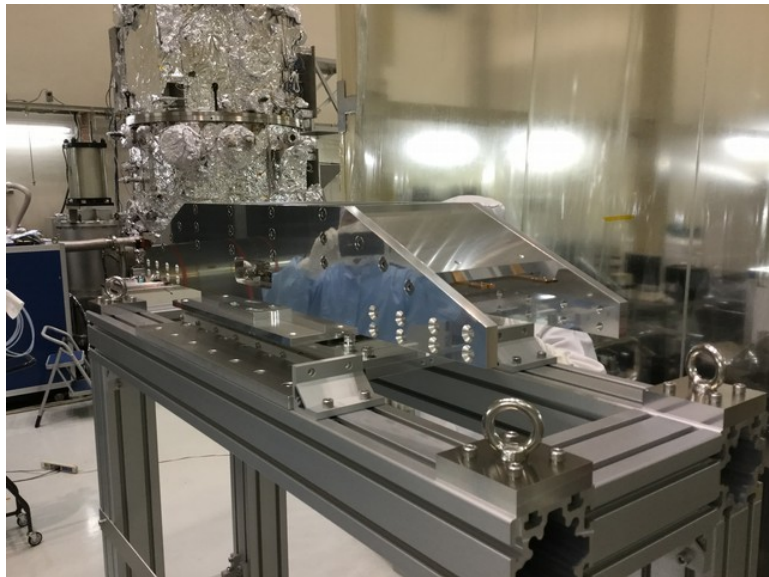
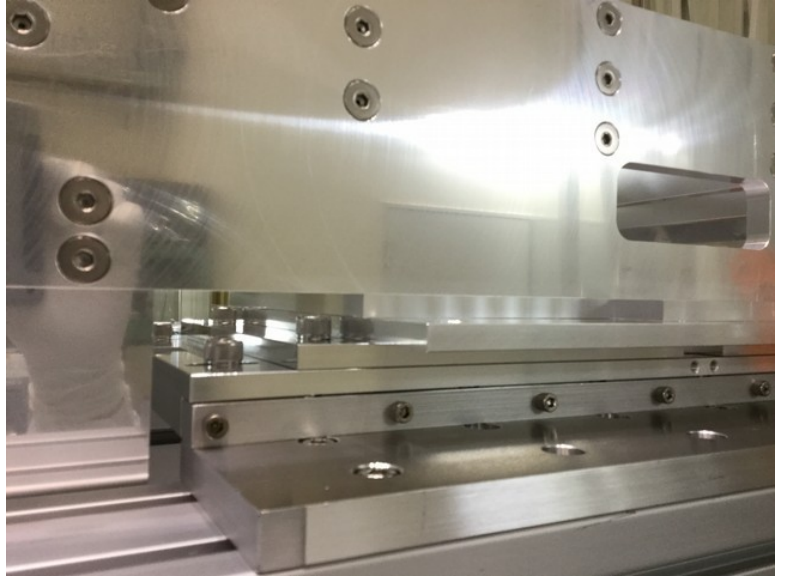
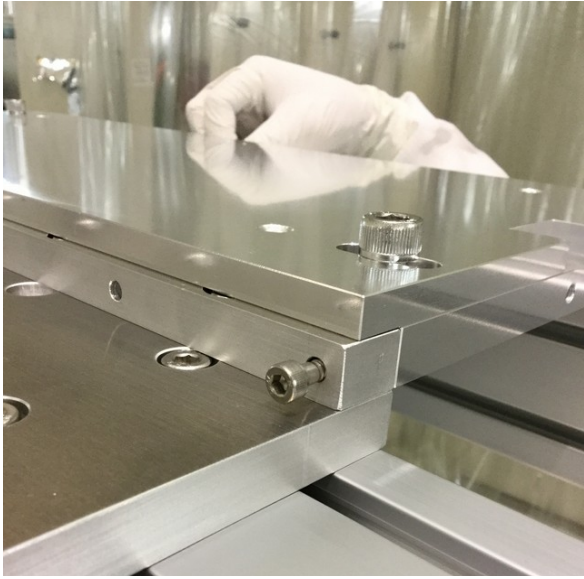
- Set the *{blade springs}* on the translators, set a

{spring fixing plate} on each spring and fix both with [M6x20 screws] (9 for each blade-spring)

→ basically, this can be done also after the whole top-assembly has been set on the jig, but then you have to insert the blade-springs from the side as the {reinforcement frame} parts will have to be fixed at that time

- Place both {reinforcement frame 1} in between the {front/back shields} and fix them with [SVFCS M8x25 screws], but do not tighten the screws yet
- Fix the {reinforcement frame 2} between the {front/back shields} with [SVFCS M8x25 screws]; start tighten all the screws!
 - take care that the two M8 screw-holes on top of them are oriented downwards
 - we will refer to this whole structure now as top-assembly!
- Put the {base plate} with the horizontal adjusters on top of the {jig-NAB-connector plates} and screw them together with [M5x25 screws] from the side
- Put the top-assembly on top of it. Screw them together from upside with [M10x20 screws]
 - be aware that you have to do some adjustments to the actual position of the baffle.Therefore, it is not necessary to tighten the screws in those parts you will need to access later





4. EQ-Stopper Wings

The EQ-Stopper wings are assembled from the top-stage sitting now on the jig.

Attention: Do the installation only on one side first (front or back*)! Do consider that the baffle has to be inserted yet!

- Screw the *{upper wing part}* (each wing consists of an upper and a lower part) at the side of the top-stage with *[SVFCS M8x25 screws]*
→ screws are inserted from outside, the wings are placed from inside against the *{front/back shields}*
- Screw the *{lower wing part*}* to each upper part



* Please take in mind that there are two lower parts with a small separation for the photodiodes and two without! The parts with the separation are the front of the assembly and will face the 3km arm cavities in the final installation!

5. EQ-Stopper

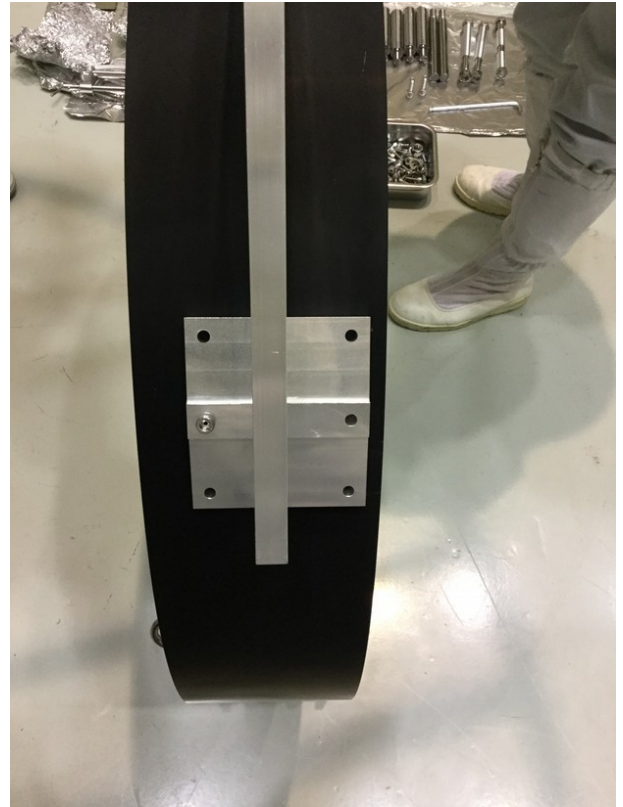
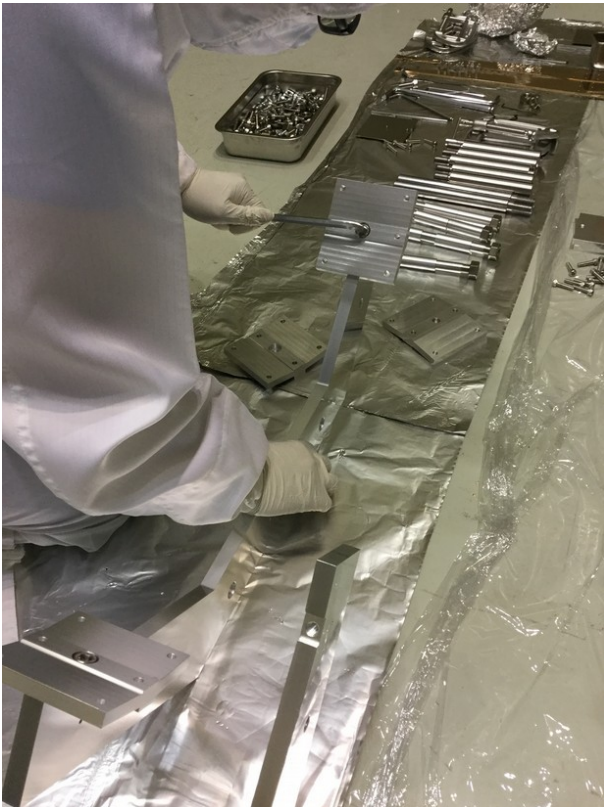
The actual EQ-stopper are to be mounted directly on the *{EQ Stopper Wings}* at four places symmetrically aligned along the baffle. They are designed to hold the “ears” of the baffle within a certain margin defined by the tips of screws (the actual “EQ-Stopper”).

- At first, assemble the *{EQ-Stopper plates}* separately by mounting the *{EQ-Stopper Screw-holders}* on a *{Mounting plate}* with *[M6x25 screws]*. There are two different kinds of screw-holders, a bigger one and a smaller one. The bigger ones are always facing the *{EQ Stopper Wings}* while the small ones are to be set lateral to them. Also set the EQ-stopper screws already inside the *{EQ-Stopper Screw-holders}*: *[M10x35]* for the bigger ones and *[M10x45]* for the smaller ones
 - **Note:** let one side of the plate without a screw-holder (mount only 2 out of 3 holders) and set a *[M10x35 screw]* , as pictured in the photograph below!
Remember that the side to be left open is defined whether the *{EQ-Stopper}* is to be placed on top or bottom of the *{EQ Stopper Wings}*!
This is important for inserting the baffle! So, please consider beforehand!!
- Mount the plates on the *{EQ-Stopper Wings}* at each of the four designated places with *[SVFCS M8x25 screws]*



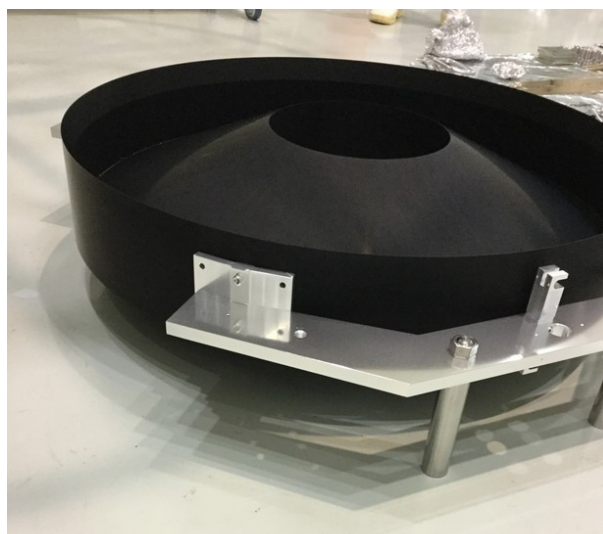
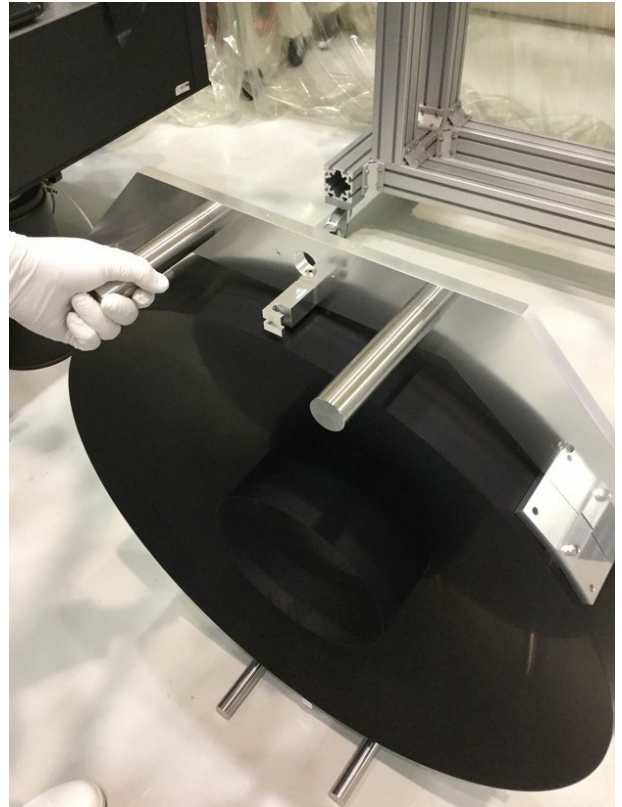
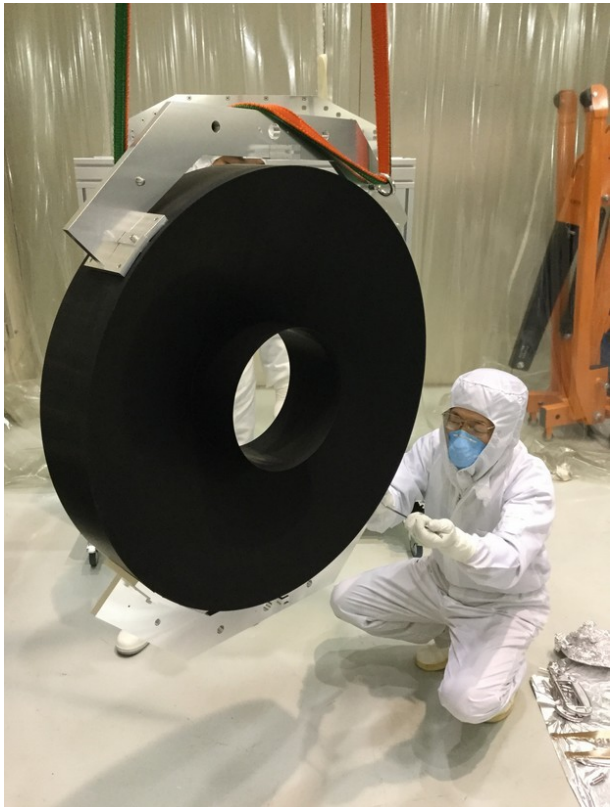
6. Inserting and Fixing the Baffle

- Mount an *{ear fixing plate}* to each end of the *{baffle ear}* (there are two “ears”) with a *[M10x20 screw]*
 - take care that each *{ear fixing plate}* has the same orientation on one ear as their fixing screw-hole is not in the plate’s center position
- Mount a *{wire catch}* inside the central opening of each ear with a *[M10x20 screw]*
 - Be careful! For one pair of ears, the *{wire catch}* should have the same orientation!
 - Don’t forget to insert *[M2x10 screws]* sideways into the wire-catch! This will hold the wire-clamp in position
- Put the baffle in an upright position by using the *{handle plates}* on one side as feed, and detach the *{handle plates}* on the upper side
- Mount the *{baffle ears}* on the baffle with the aid of the *{ear fixing plates}* and their two central M6 screw-holes on the upper side of the baffle; use *[M6x20 screws]* and take care that these screws have a vent-hole!
 - Place the ear in a way as shown in the picture below, so that it is positioned along the center-of-gravity-plane of the baffle itself



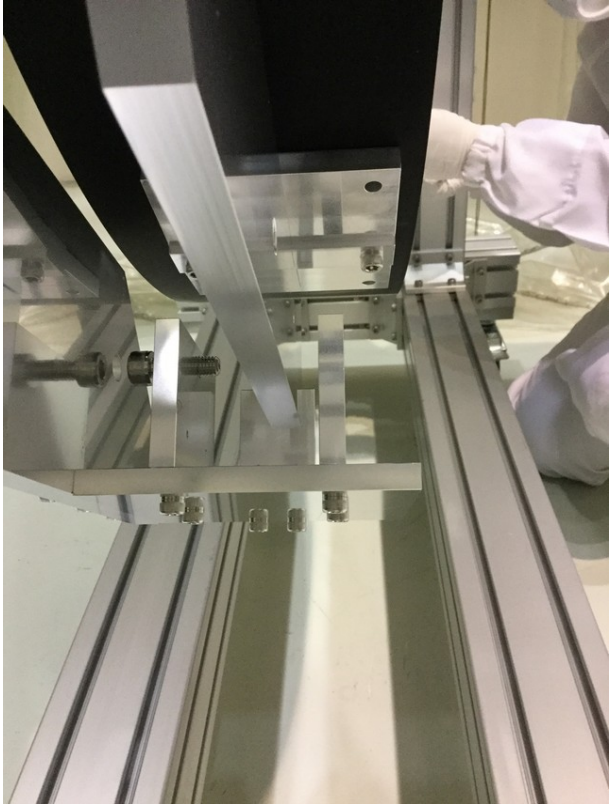
- Screw eyebolts (counter-oriented) into each of the two M8 screw-holes on the ear’s side and lift-up the whole baffle structure with the aid of a crane
- Replace the bottom *{handle plate}* with the other prepared ear in the same manner as the first one

- Now, on the bottom ear, mount *{baffle foot pedestals}* by putting their threaded part inside the M16 through-holes and fix them by nuts; put the baffle back to the ground
→ although the *{baffle foot pedestals}* should give stability enough in this position, an additional support by human hand is necessary
- Remove the eyebolts and mount another pair of *{baffle foot pedestals}* on the upper ear in the same orientation as the bottom ones
- Lay the baffle down so that it rests on these pedestals

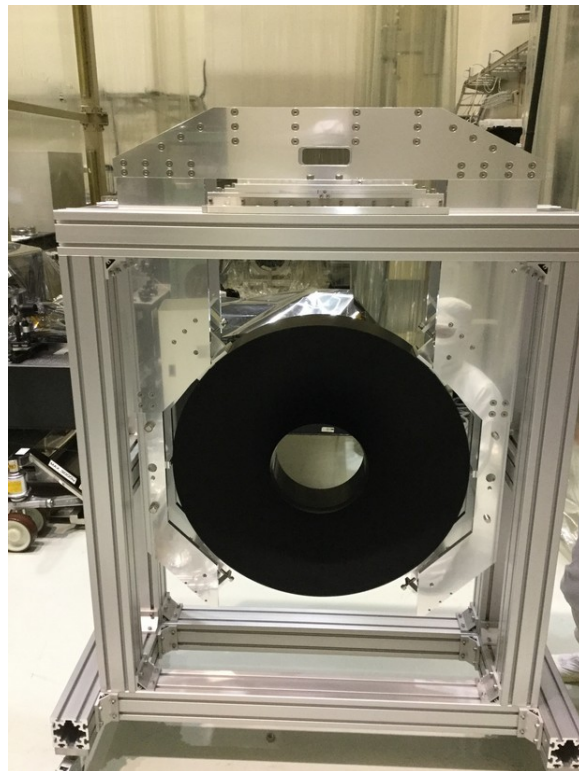


- In each bottom part of the mounted *{EQ-stopper wing}* there is a 25mm through-hole. In each of it set a *{baffle guiding pedestal}* by using washers and nuts, oriented inwards
- Take the baffle structure by the *{baffle foot pedestals}* (one person on each ear) and hook the big central opening on each ear onto the *{baffle guiding pedestal}* of each wing's bottom part
 - Take care that the openings of both *{wire catch}* show to the ground!
- Remove the *{baffle foot pedestals}* and insert 4 *{baffle fixing pedestals}* in the now disposed openings so that they also pass through the opposite openings on the wings; fix them by using nuts
 - Don't forget to slip a *{baffle distance holder}* over the *{baffle fixing pedestals}* before inserting it into the wing's opening
- Slide the baffle structure along the pedestals to its destined position (defined by the distance holders)
- Complete the *{EQ-stopper}* assembly by mounting the last *{EQ-Stopper Screw-holder}* onto it (the ears should be covered by the *{EQ-stopper}*) and set a *[M10x35 screw]* in each of them
- Assemble the wings on the other side (back or front, depending on which side the first wing assembly started)
 - Don't forget to insert a *{baffle distance holder}* before the bottom wing parts are striped over the *{baffle fixing pedestals}*!





- Insert all remaining screws for the wings and the respective nuts for the *{baffle fixing pedestals}* and tighten them!
- Remove the two *{baffle guiding pedestals}*



7. Wiring and suspending the baffle (2 persons)

Before setting-up the dampers, the baffle needs to be attached to the Tungsten-wires and actually being suspended. Setting-up the wires is an essential step in the whole assembly procedure and even a small mistake here can lead to severe consequences later on during the adjustment.

Therefore, take the following points into account seriously:

- Setup a working area for the wire-preparation. You will need a ruler that is straight and at least 1m long
- Take a roll of cleaned Tungsten-wire and screw a *{wire-clamp}* (consisting of a threaded and a non-threaded part, held together by two *[M4x5 screw]*) on one end; let 1~2cm of the wire sticking-out
→ for a sophisticated tightening, hold the clamp with an adjustable wrench and fix the screws
- Then, unroll the wire and set another clamp so that the overall length of the wire in between both clamps is 749mm!
Set the second clamp so that its orientation is 90° shifted to the first one! That is important as the wire-catch on the baffle and wire-holder the spring-blades are shifted in that way and doing otherwise would cause a drill of the wire. Cut the wire 1~2cm after the second clamp and bend the sticking-out tips of the wire a little bit on the edge of the clamps (see picture below)
- Do this 4 times and check the length again after you finished

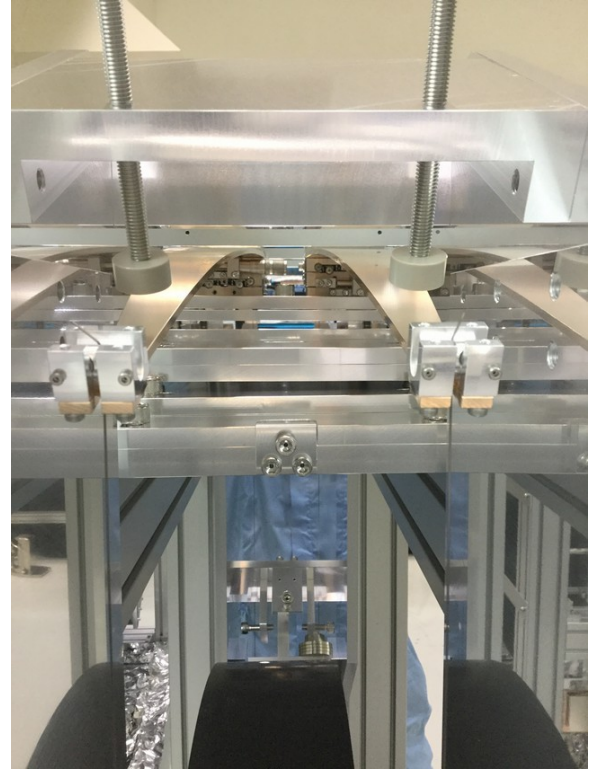
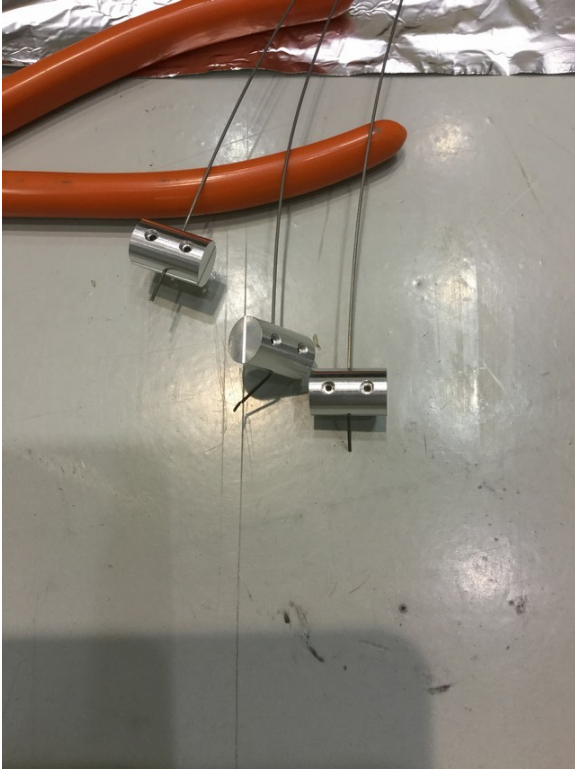
If you haven't done this yet, mount the *{wire-holder}* on every tip of the blade-springs! Use 4 *[M3x10 screws]* for each holder

Before actually hooking-up the baffle, you have to make sure that the baffle is fixed. Do the hooking on one blade-spring after another.

- Start inserting one end of a wire from the top opening close to the end of a blade-spring and down to the wire-catch. One person should hold the upper end and another one has to insert the clamp into the wire-catch
- Once this is done, one person has to bend those end of the blade-spring which is right above the used wire-catch strong enough that the upper clamp can be inserted into the wire-holder
→ You will need some strength to do this!
→ Use also here *[M2x10 screws]* to be inserted from the sideways into the wire-holder ensure that the upper clamp is in position
Note: it is sometimes possible that the clamp is not correctly fastened around the wire. In these cases, the clamp cannot be inserted into the wire-holder completely and you will have to repeat the tightening process
- Repeat this procedure for the other three wiring points
- Assemble the *{M8 spring push assembly}* by inserting the *{M8 spring push}* screw into the screw-hole from top of the *{reinforcement frame 2}* and fixing the *{M8 spring push peek}* from bottom onto it with the aid of a *[M2x10 screw]*
→ This assembly is an additional security in case the wire is breaking so that the blade-spring will not be shattered on the reinforcement-frames

The very last step in suspending the baffle is now to release the baffle by removing the fixing rods. Depending on the actual alignment of the baffle structure, removing those rods can become difficult when the baffle has too deep or high its balance-point or when the baffle is obliqued.

In these cases, it can be useful to lift the baffle by hand on one or both sides by taking the ear, or to move it into a more non-obliqued state.



8. Alignment Setup

For doing the alignment at least one laser-level, a bubble level, and two rulers with more than 1m length are necessary!

Please follow the following procedure for doing the alignment on the NAB:

- Place the jig with the NAB on a stable ground and adjust the balance of the NAB until the jig and the suspension frame have become maximally even
 - use the adjustable feet of the jig and the bubble-level
 - be aware that the frame of the jig can be slightly misshaped or misplaced so that measuring the balance on it can be tricky. It is therefore better to concentrate those initial balance measurements on the suspension frame itself!
 - if the difference between jig and suspension frame becomes too large, use the bottom Z-stage for finding the even point
- Release the baffle and check its balance

Pitch:

- This is the first degree of freedom that should be aligned!
- Use the balance-masses for doing this:
 - place them by using a [*M6x30 screw*] on the unused M6 (threaded) screw-holes on the *{side flanges}*. Choose those holes that are on the side which needs to be balanced
 - Try to place the masses equally distributed around the center of the baffle! Since there are 4 side-flanges, the same mass should be attached at each of them
- Check the pitching by putting a small bubble-level on top of the baffle-ear
- If it is not enough to use balance masses, use also the upper Z-stage for putting a counter-pitch to the baffle

Height:

- Place the laser-level in front/back of the NAB and measure the height of the center-line on the suspension wings from the upper edge of the bottom jig bars (nominal height is 620mm)
 - this is, at the same time, also a measure for the even state of the suspension itself; adjust if necessary
 - fix a ruler on one of the vertical bars of the jig. At this state, they should be even enough for an accurate reading
- Do the same for the distance of the bottom wire-clamps to the bottom edge of the suspension-frame wings! The wire-clamps also have an indication line that should be adjusted to the same height as the line on the suspension-frame wings (nominal distance 435.2mm)
 - Also here, this is a good timing for adjust any misplacement of the baffle in roll (use the upper Z-stage for adjusting)
 - depending on the alignment of the suspension-wings during assembly (small misplacement can always happen - please check!)

- Measure the distance between the indication line of the wire-clamps and the upper edge of the IF-plate (nominal distance 710mm)
→ since the IF-plate cannot be adjusted, it will have the same balance as the jig's upper bars
- Measure also the distance between upper edge of the baffle and the center-line (it should be 400mm) in order to make sure that the center-line actually marks the center of the baffle

Roll:

- A misalignment in roll of the baffle will alter the suspension properties of the whole structure and is therefore to avoid!
Since the roll-measurement and the height measurements are strongly related to each other, both should be done in parallel!
- Use the horizontal center-line measurements for checking a misalignment in roll
→ compare the center-line indications on the bottom wire-clamps with the center-line indication on the suspension wings
- If you find a difference in the position of the left and right wire-clamp indications to each other, adjust the upper Z-stage accordingly
→ be aware that also a misalignment of the whole suspension structure in roll can cause such effects on the baffle. Double-check the balance of the suspension structure before taking any actions!

Transversal:

- In its current position, you can also check the transversal alignment of the NAB with the laser-level. For that, fix a ruler on one of the horizontal bars (preferably the upper one) facing the laser-level and start taking the relative distances between prominent structures on the baffle (like edges of the ear) and the fixed structures of the suspension (the suspension-wings would be a nice target as checking their straightness can be done at the same time)

Yaw:

- Measuring the yaw of the NAB is actually quite tricky as the baffle itself is relatively small and a possible yaw of it will not lead to much (measurable) consequences. Also, due to a missing indicator along the baffle's vertical center-line, you have to take the edge(s) of the baffle-ear and take relative distances to the suspension-structure (like the wings). However, this is probably decreasing the overall precision...

Longitudinal:

- A mm-precise longitudinal alignment-setting is probably not so important as due to the installation procedure, the setting of the baffle has an error margin of $\sim 1 - 5$ mm

9. Eigenmodes and Q-factors for KAGRA-NABs

	NAB 1		NAB 2		NAB 3		NAB 4	
	f	Q	f	Q	f	Q	f	Q
longitudinal	0.59	7.2	0.58	5.2~6.1				
transversal	0.65	3.2	0.6	2.8				
vertical	2.02	20	2	18				
yaw	0.98	1.6(?)	0.88	2.7				
pitch	0.56	4.76	-	-				
roll	-	-	2.3	7.8				

Eigenmodes after design:

(Simulation done on SUMCON, without any dampers or balance masses)

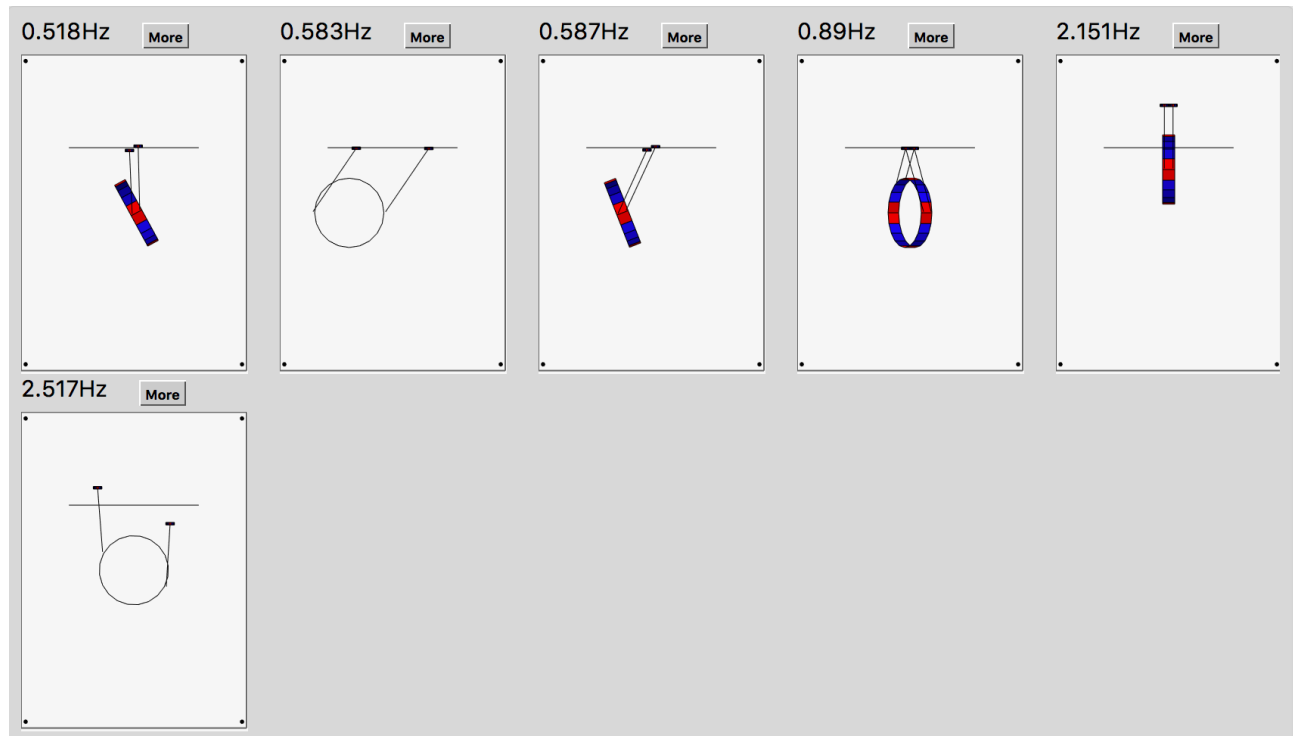


Figure 1: Eigenmode denomination from top-left to the right: pitch, transversal, longitudinal, yaw, vertical, and roll.