TAMA/SAS Installation report

LIGO-G010180-00-D

Riccardo DeSalvo

LSC Meeting

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Presentation

- What SAS tower was designed for TAMA

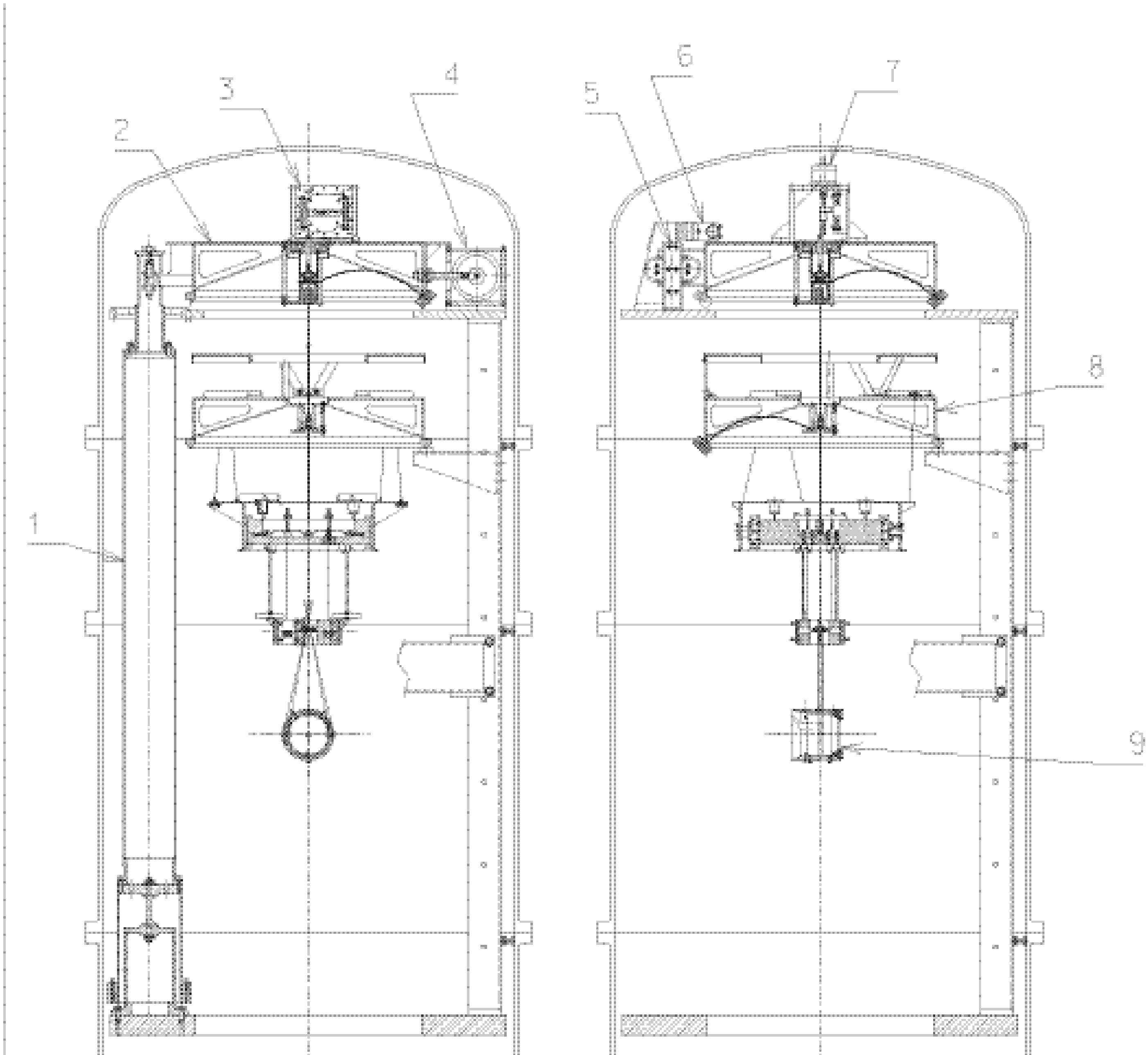
- What was delivered to Hongo Campus (photos, please see
- http://www.ligo.caltech.edu/~takamori/images/tamasas/)

- What performance TAMA/SAS will deliver

  (please also see: "Report to NSF on the TAMA-SAS Passive Seismic Attenuation Chain Test for the Tokyo University 3 meter Interferometer" DCC # LIGO-T010006-00-R)

TAMA SAS
side and front view

- The top filter is mounted on a low frequency (<30 mHz) Inverted Pendulum
- The filters are all equipped with Monolitic Geometric Anti Springs (MGAS) for low frequency vertical resonance operation.
- The top filter is equipped with accelerometers, position sensors and contact free actuators for rigid mode resonance damping
- The next (completely passive) filter suspend the double pendulum payload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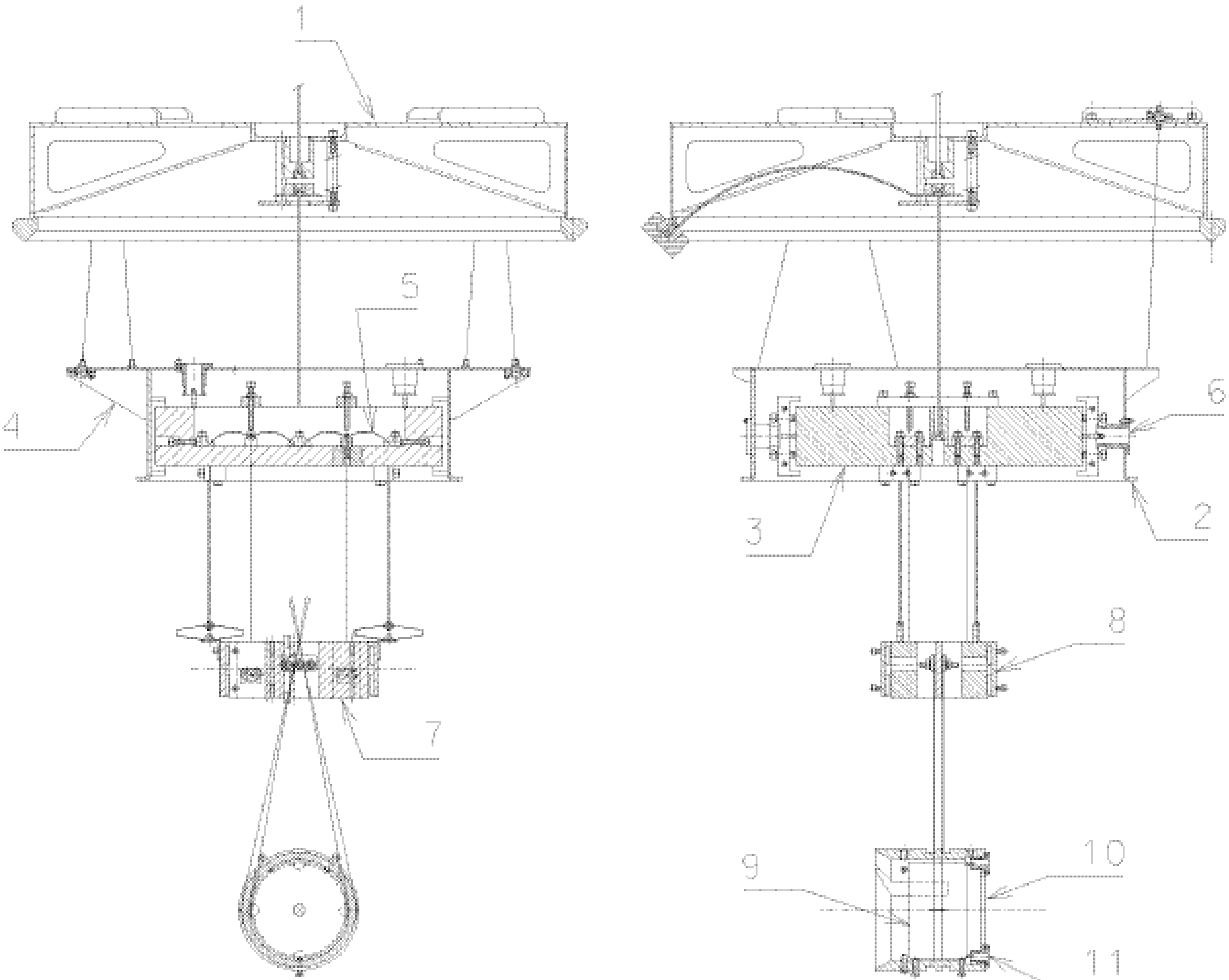
Double pendulum payload

- The Filter supports a payload that takes advantage of several effective techniques
- The top mass of the double pendulum is provided with MGAS springs to lower the vertical resonant frequency of LIGO design.
- The top mass is actuated from a coil box rigidly attached to the last filter.
- The intermediate mass is surrounded by a magnet box, also suspended from the top mass, that provide passive Eddy current damping of all double pendulum modes. This technique has been thoroughly tested by the TAMA interferometer.
- The test mass is surrounded by a recoil mass for protection and quieter mirror actuation. The recoil mass is equally suspended from the intermediate mass.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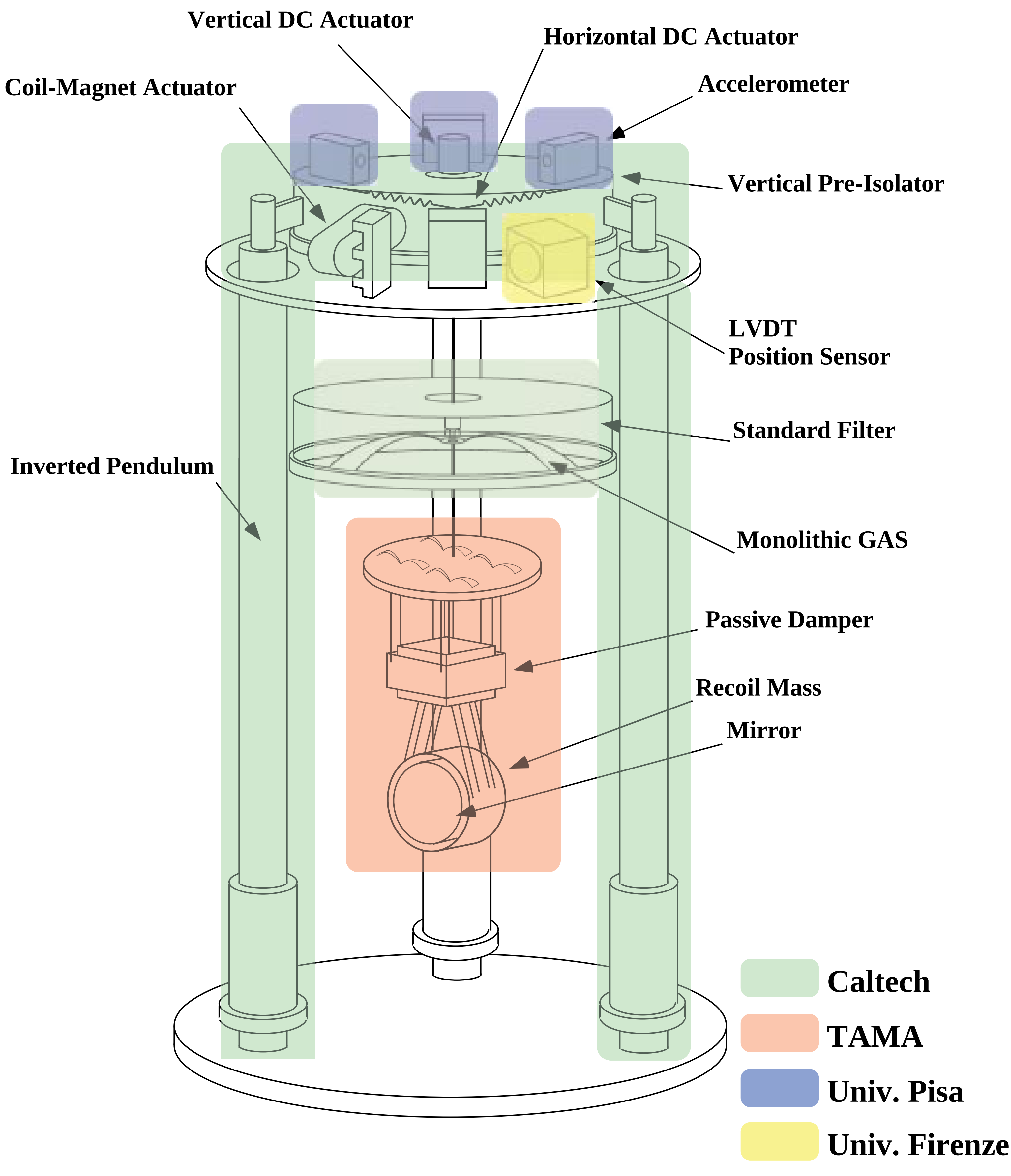
Schematic view of a TAMA SAS seismic attenuationtower

TAMA SAS Overview

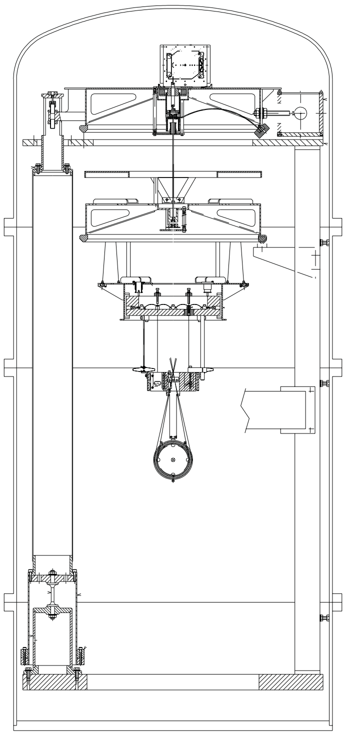


TAMA SAS catalog

- Due to Japanese regulations we had to “sell” the TAMA SAS towers to NAO.
- This is the catalog from which you can buy one,
- If your credit card has a 120K$ credit limit !!!

MIRROR ISOLATION SYSTEM

MODEL: SAS10



Vibration Isolation for Sensitive Optics

Highly Accurate Control

Features

- **Geometric Anti-Spring (GAS) Technology**
- **Ultra Low Frequency[*1] Pre-Isolators**
- **Low Frequency[*2] Passive Filters**
- **Inertial Damping**
  with Advanced Position/ Acceleration Sensors,
  High Precision Digital Control System
- **Advanced Mirror Suspension**

Specifications

- Horizontal Isolation

-60 dB at 1Hz by Pre-Isolation Inverted Pendulum
tuned at 30 mHz
Additional Isolation from Passive Filter Chain
and Suspension

- Vertical Isolation

- 55 dB at 1Hz by Double Cascaded GAS Filters
tuned at 200 mHz with 100 / 20 kg Payload

- Mirror RMS Displacement

~ 10 nm[*3] with Typical Seismic Disturbance[*4]
achieved by Inertial Damping

1 Order of 10 mHz
2 Order of 100 mHz
3 integrated from 100 mHz to 1 kHz
4 10e-7/v^2 m/ sqrt(Hz)
Specification of this product may change without notifying.
Part of specification is derived by simulation.
Design of this product may change to meet clients' requirements.
All the pictures in this catalog are based on engineering prototypes.

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LIGO

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TAMA SAS assembly procedure

- Tama SAS assembly lab
- Two towers visible
- Behing he far tower the “betoniera”filter assembly machine can be seen
- On the left a filter is being tuned on its stand

CLEAN BOOTY LINE

Inverted Pendulum counter-weight tuning setup (2 figures)

- The black structure at the bottom suspends the IP bottom disk.
- The bar bolted to ground constrains the system to linear motion
- The black block (back on first figure, front on second is an electromagnetic piston moving up to +/-1 cm
- The black blocks at the top provide a dead weight equivalent to the filter and payload
- The counterweights are tuned to get up to 80 dB attenuation (60 dB specs)
- The tuning is made at high frequency tune (0.2 Hz), then the load is increased to obtain a 10-30 mHz IP tune

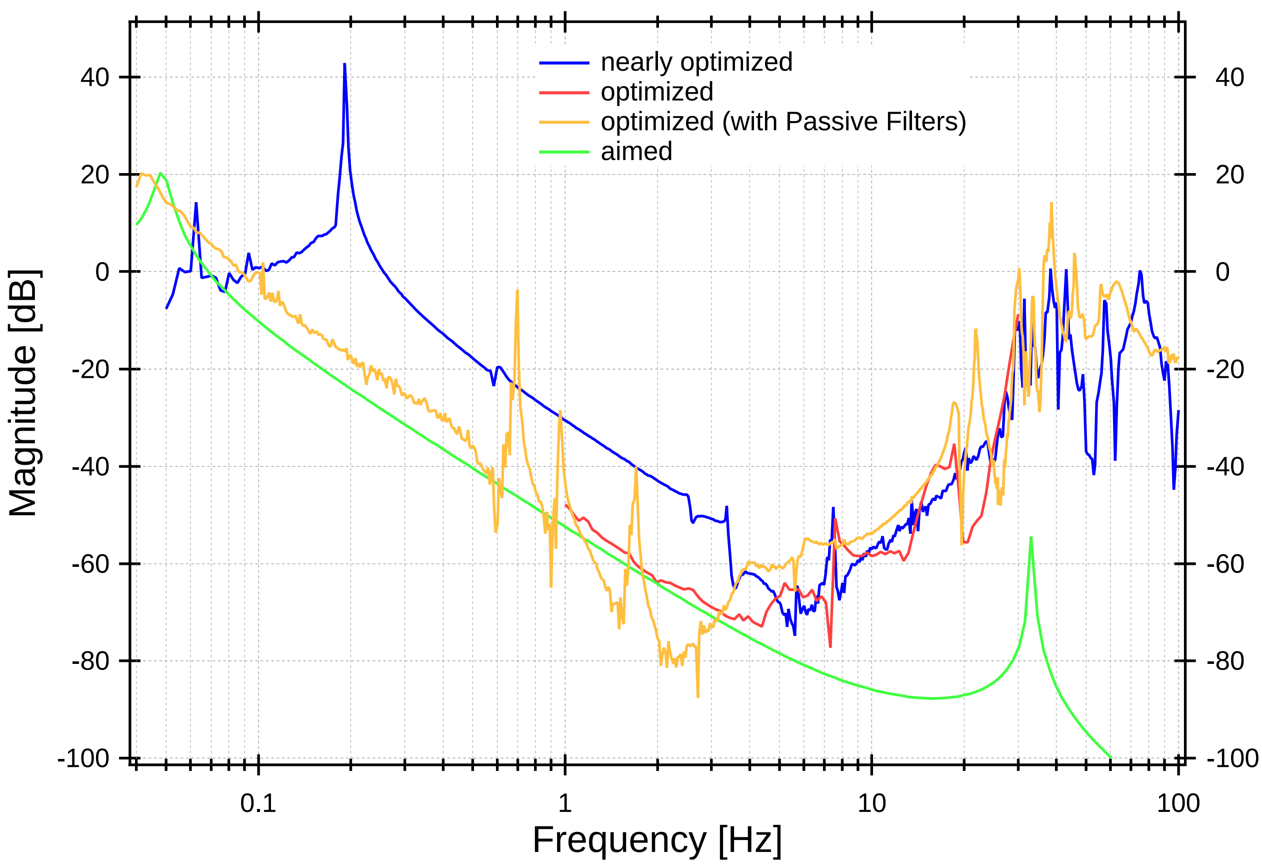
Inverted Pendulum Counter-weight tuning results

- The tuning is made at 0.2 KHz (blue line) The structure above 10 Hz is due to the ballast weight and other resonances.
- The bottom disk is shaken Accelerometers are mounted on the bottom disk and on the top filter to measure the transfer function
- The attenuation performance with a suspended chain is described in yellow.
- The three peaks at 0.7, 1 and 1.8 Hz are the chain's rigid body modes and will be damped by the active inertial damping loop
- At low frequency the curve is pushed up by 10-20dB by the presence of parasitic springs in the tuning setup. The corresponding simulated curve is shown in green

IP Characterization

Optimization

- Counter Weight Tuning



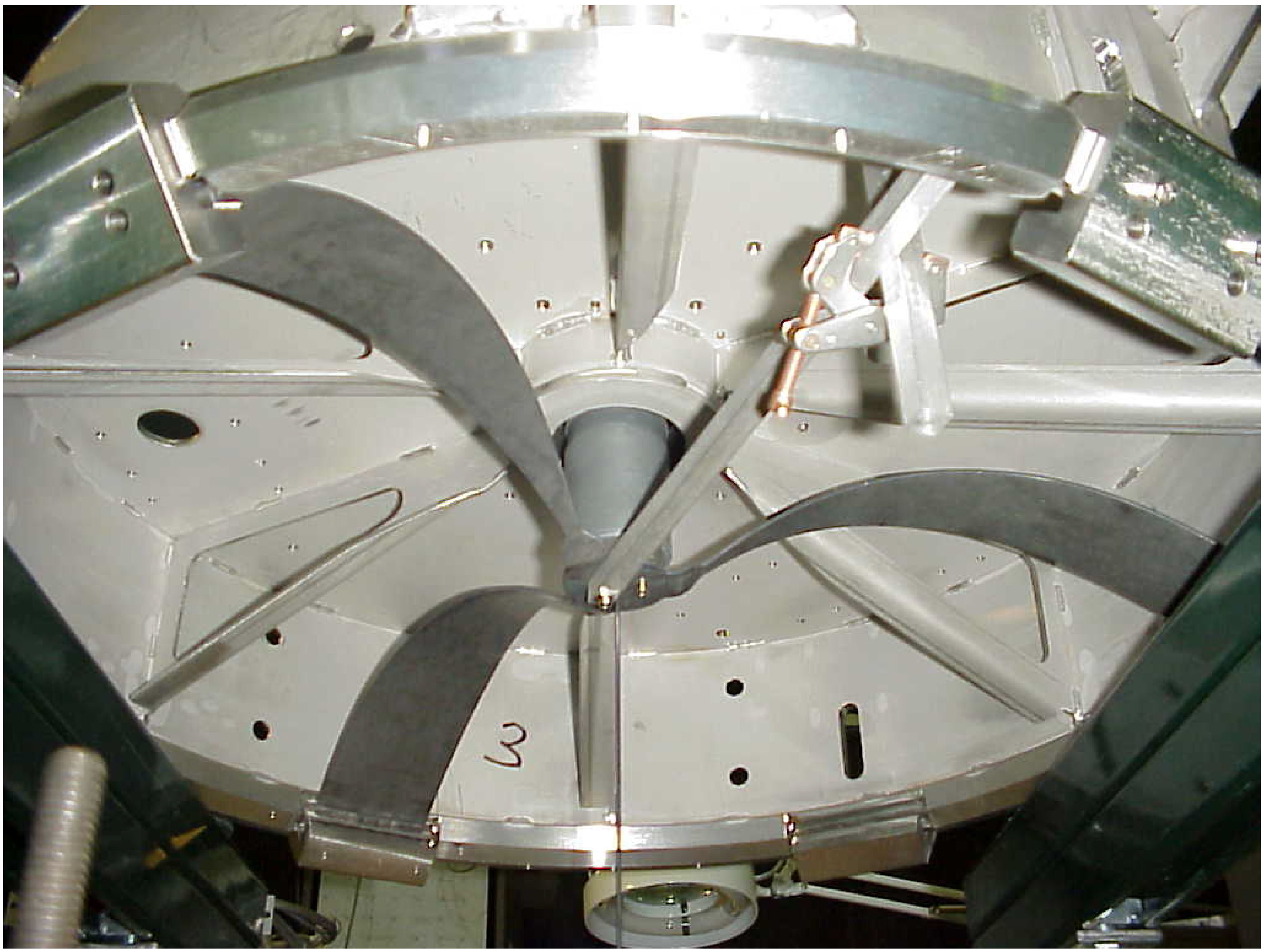
Longitudinal Transfer Function of IP

Top filter tuning

- The radial compression of the blades is increased or decrease until the desired vertical resonant frequency is achieved (200-300 mHz for the top filter, 300-400 for the other one)

Bottom view of top filter

- The filter simplicity is evident, the three blades are held by 3 C-shaped clamps and 3 wedges.
- In the center is visible the coil holder of the vertical actuation coil holder, It’s magnet id hidden in the cylindrical part above.

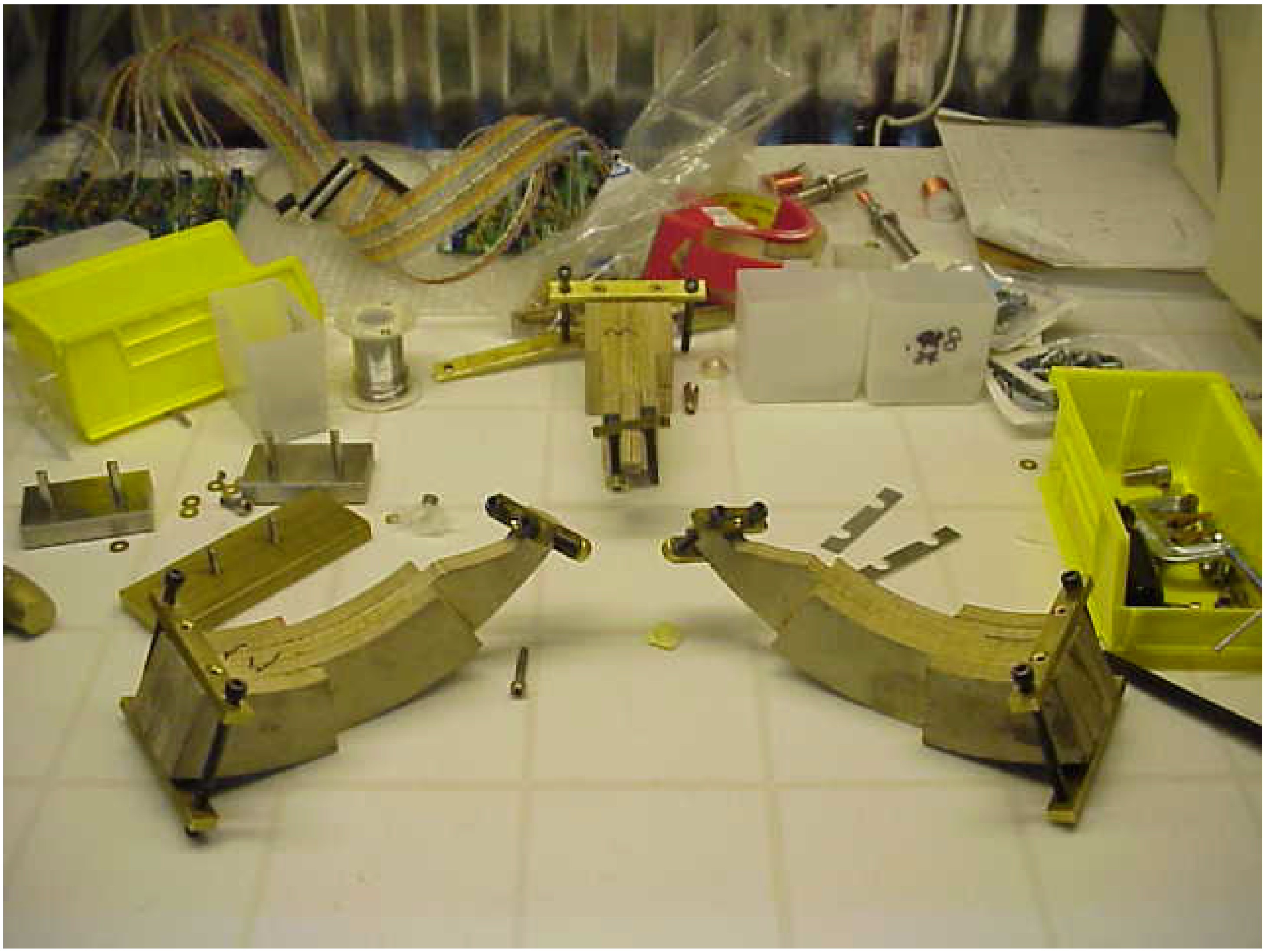


Bottom view of filter one

- This filter is even simpler, it is completely passive.
- In the photo it is shown in its travel configuration, bolted to three shelves (one visible on the bottom left of the photo)

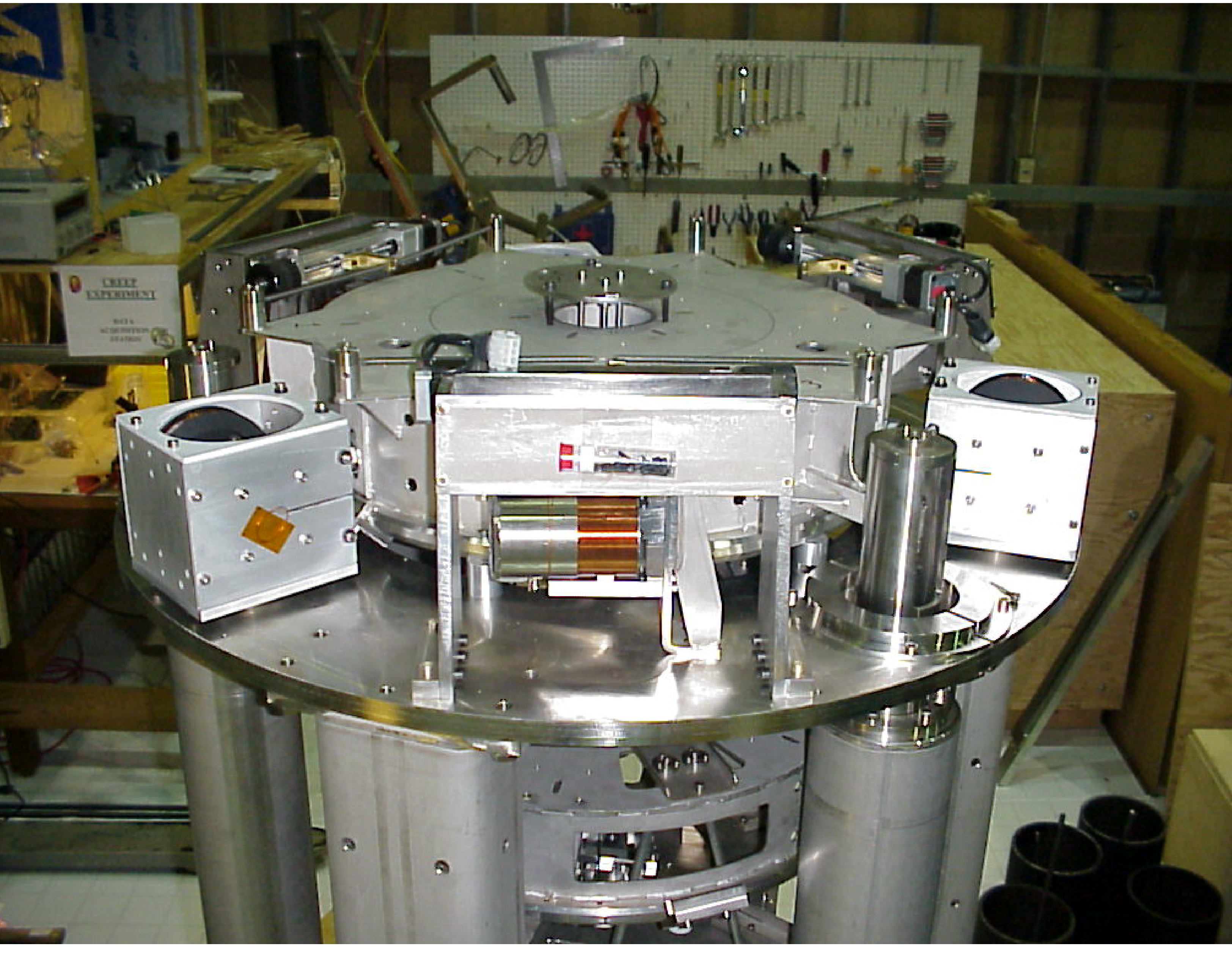
Filter assembly tooling

- The unbent blades (second next figure) are prestressed to their working shape by means of wooden bending tools (next figure)
- Then the blades are clamped in place, the stress transferred to a support tool and the bending tool are extracted



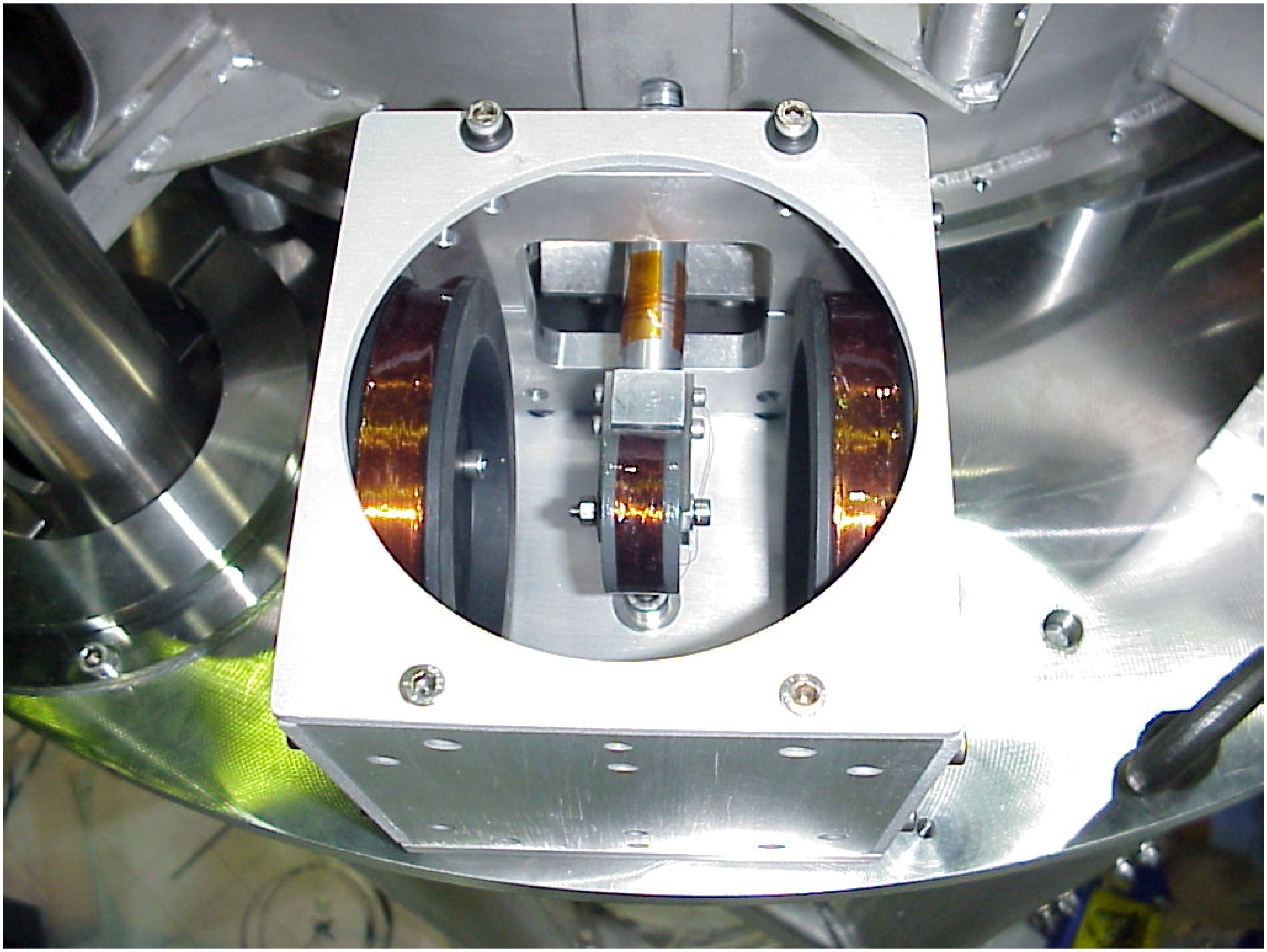
Top view of a SAS tower

- The instruments have 120o symmetry
- Visible are
- One linear voice coils, in the center front (linear to 0.1% over 12 mm
- Two LVDT position sensors, the two cubic boxes linear to 1% over 25 mm, insensitive to 1% to the transverse direction and 10 nm resolution
- The three motorized sprigs used to tune the IP transversal working point
- Still missing are
- 3 accelerometer, that will be mounted on the top surface of the top filter
- The op filter vertical LVDT and motorized spring


CREEP
EXPERIMENT

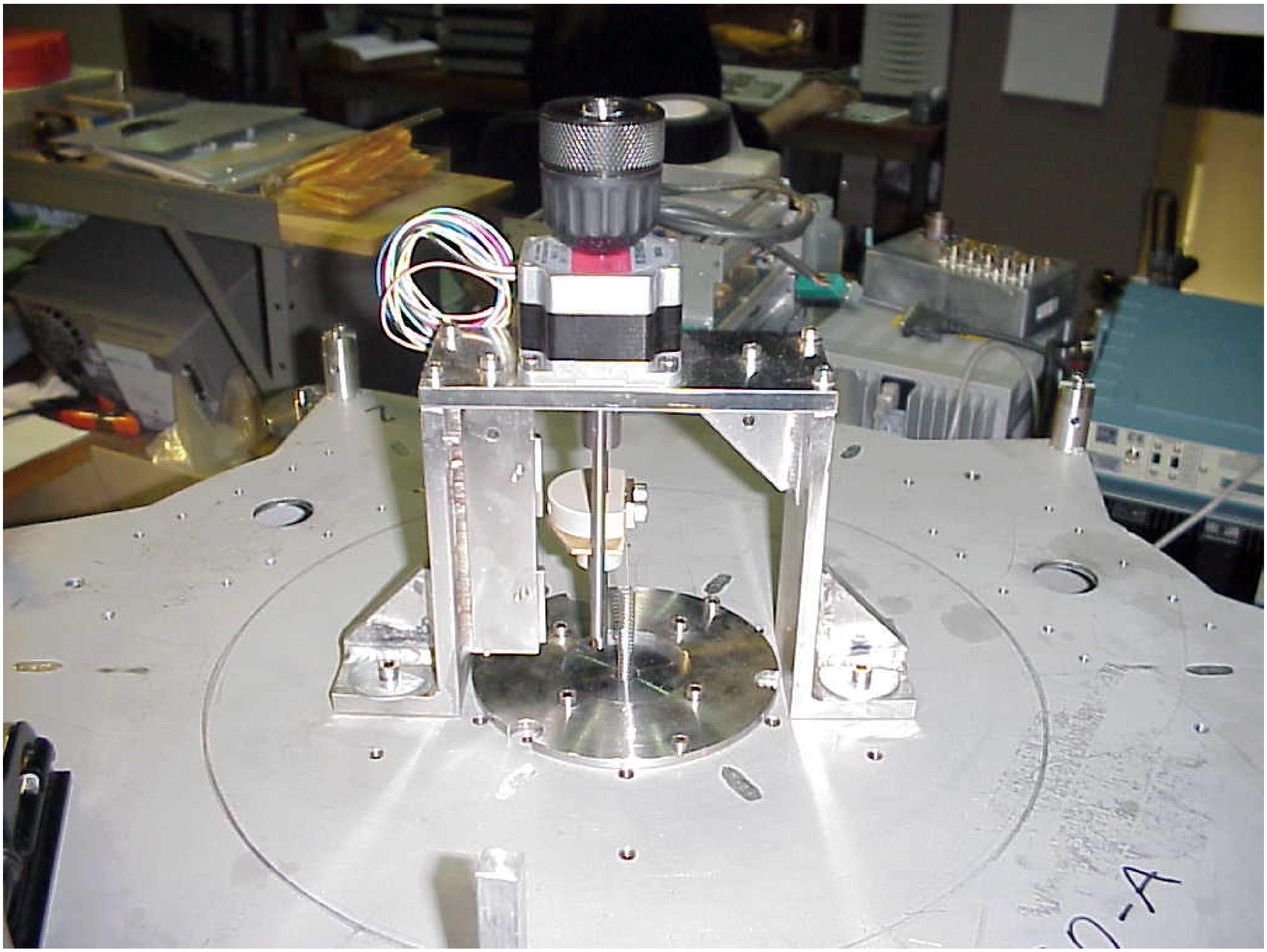
LVDT position sensor

- The center coil is excited at 10-20 kHz
- The twin coils are counter-wound and pick-up a signal proportional to the position along the main axis of the device
- On the left side of the LVDT the IP range limiter disk is visible, more than 12 mm movement range is allowed to absorb earthquakes and other large performances without disturbing the mirror



Top filter motorized spring

- The three accelerometers fit in the position marked by the three 20 mm holes (two visible)



Inner view of the TAMA SAS tower

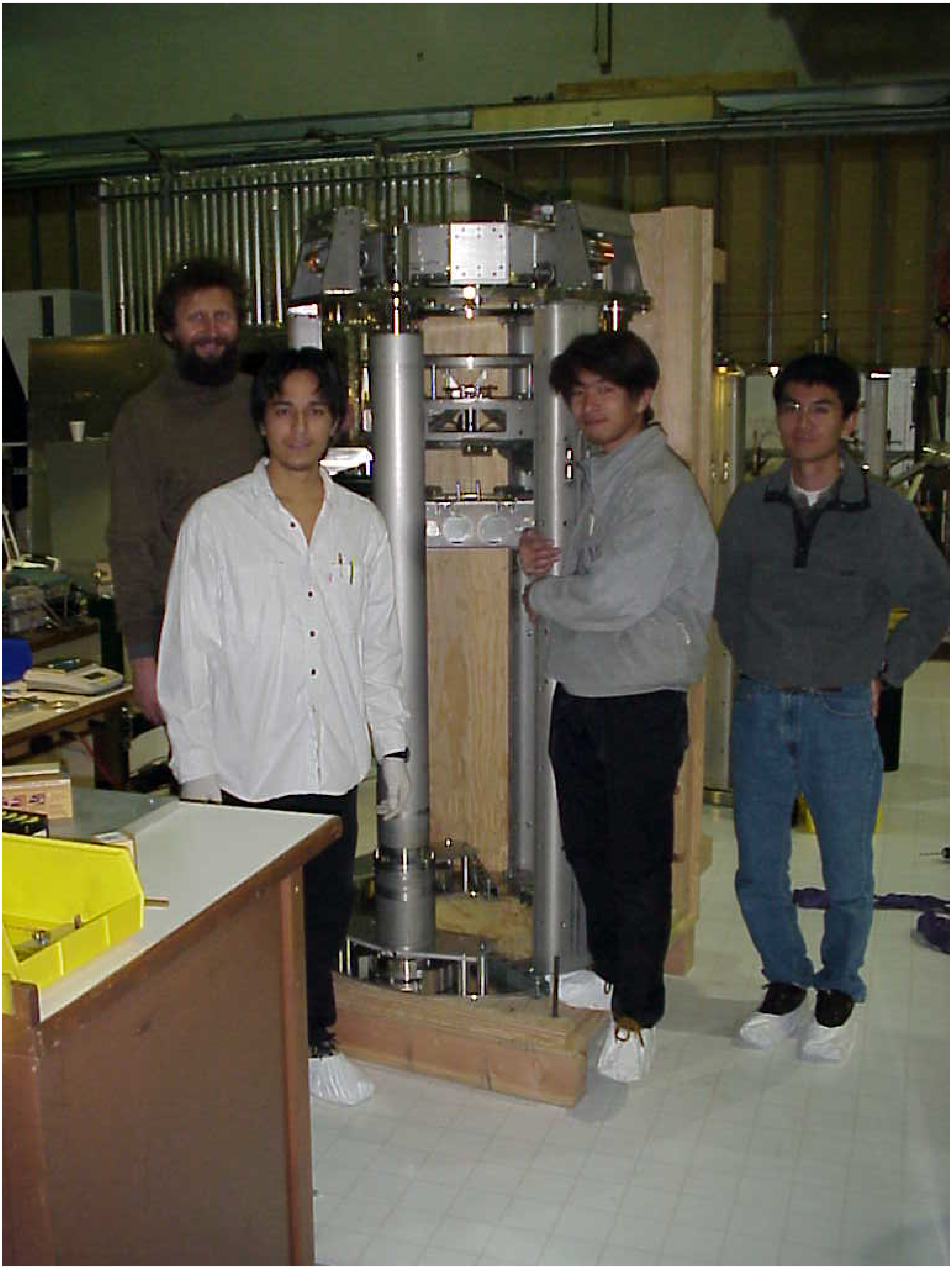
- Visible from the top are the top filter, the first filter and the coil box actuating the double pendulum top mass (no double pendulum present yet
- The IP leg visible at the left is immobilized at the top by its transport clamp

TAMA SAS ready for shipment

- Please Note the transport clamp immobilizing the bottom of the IP legs

TAMA SAS tower being bolted to the crate's bottom plate

- Shown is a tower already bolted down
- The second photo shows Szabi and Akiteru lowering the second tower in position
- Left to right Riccardo, Edwin, Tatsuo, Akiteru

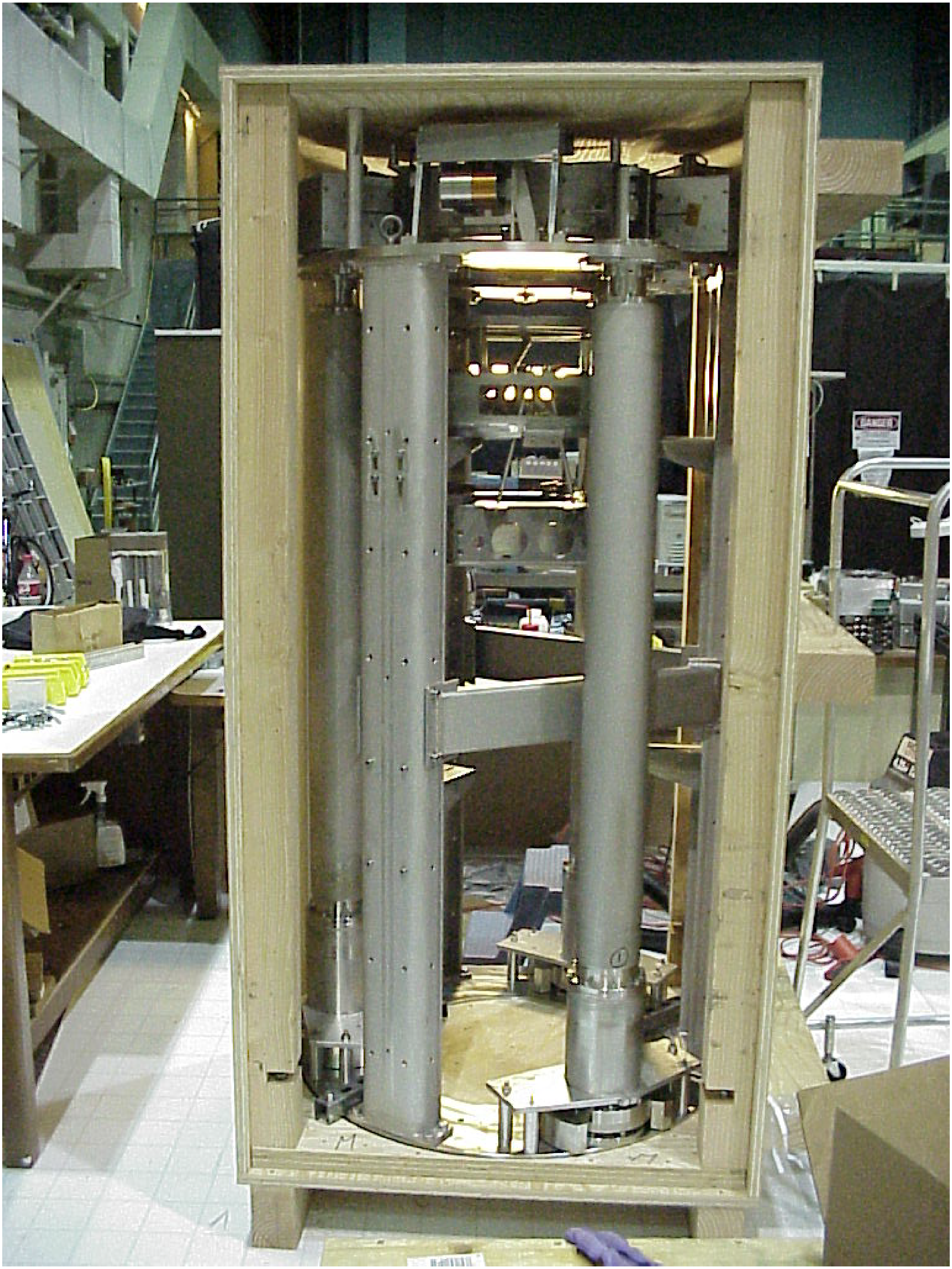


Crate buildup

- The back panel of the crate is bolted to the bottom one and to the TAMA SAS safety structure
- Happy Edwin

Crate buildup

- Top and front panel assembled



Crate buildup

- One crate side panel have been mounted, the crate has already being turned 90o for shipping

Crate buildup

- Comfortably ready to fly to Japan

Crate buildup

- Last box closed up
- Left to Right Szabi, Virginio and Akiteru

Arrival in Hongo campus

- Professor Tsubono supervising the unloading of the crates in Hongo campus

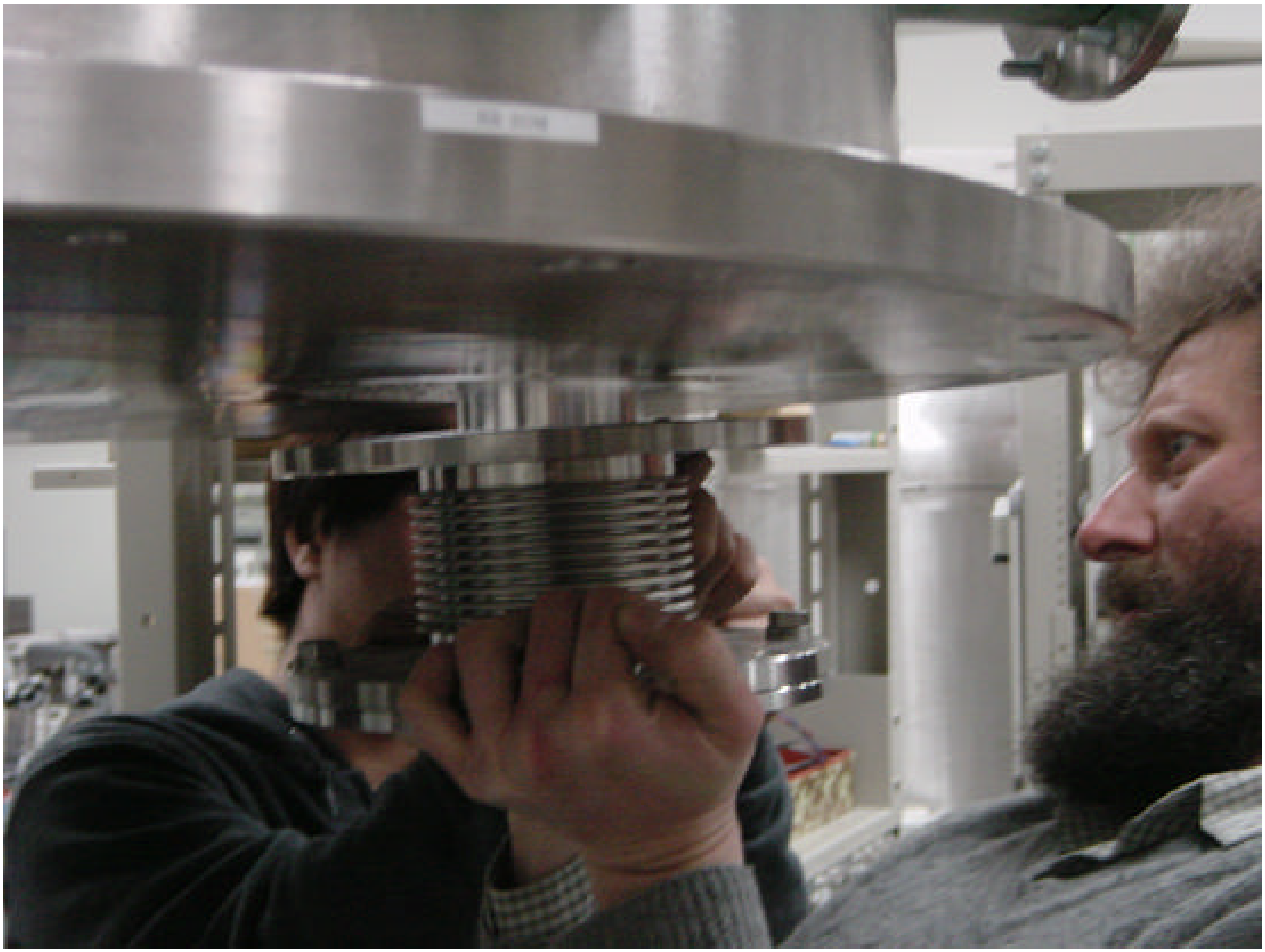

UNIC

Arrival in Hongo campus

- Entering the elevator
- Yamamoto, Tsubono and Ando watching

Assembly of the vacuum vessels

- Monday morning, arrival of the vacuum tanks
- Monday afternoon
- Mounting the Tower feet below the vacuum tank bottom
- Heavy !!



Assembly of the vacuum vessels

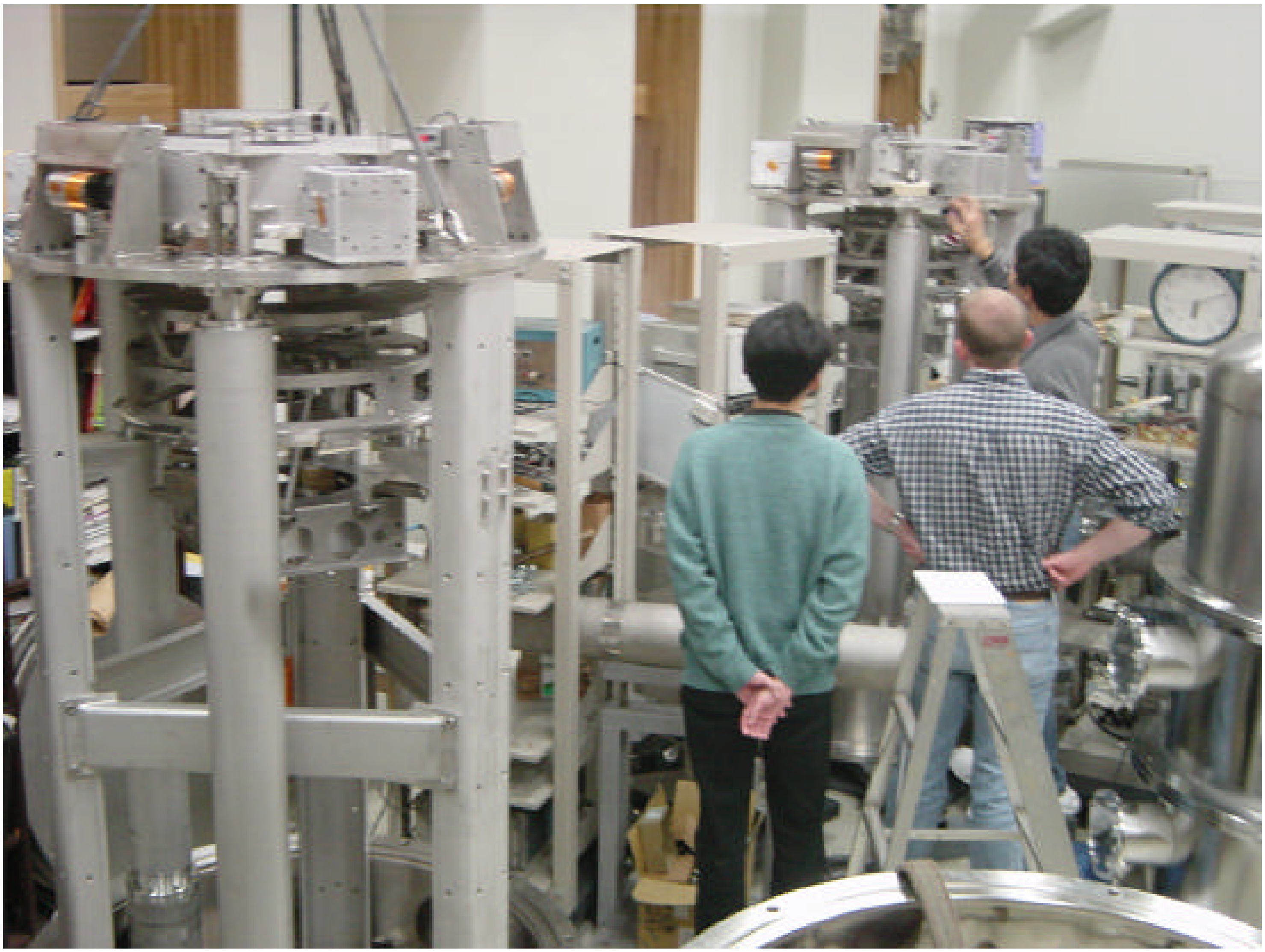
- Tuesday
- The Tower feet are assembled
- Bringing the vacuum tank in its location and later bolting it down

Assembly of SAS towers

- Wendnesday
- Lowering the first TAMA SAS tower in its vacuum tank

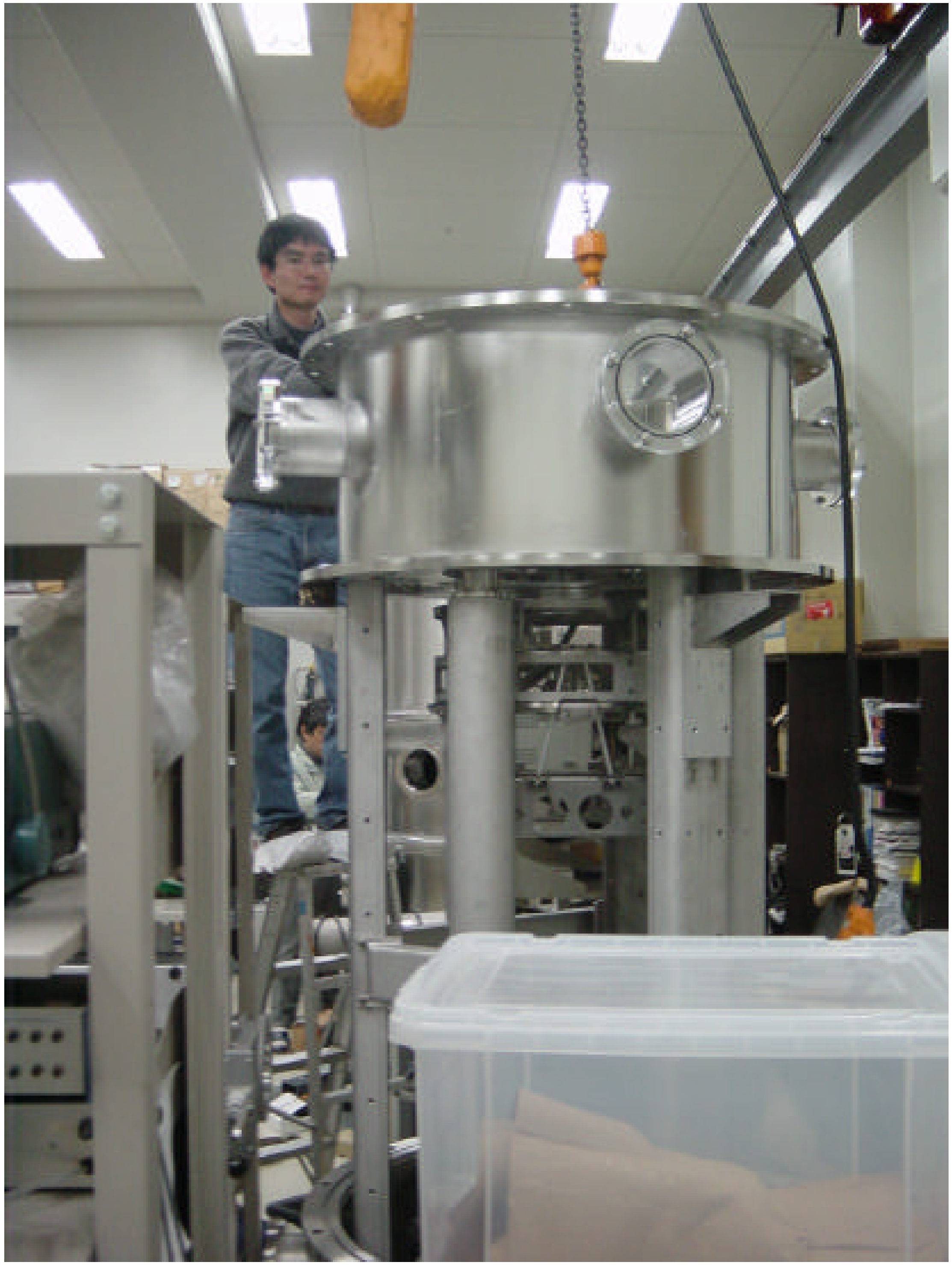
Assembly of SAS towers

- thursday
- Second TAMA SAS tower in place in the 3 meter test F.P. interferometer
- Akiteru illustrating it to Colin Taylor



Closing down the vacuum

- Thursday afternoon/Friday
- The first section is lowered on temporary shelves in the first photo
- The tank is lowered in sections using the upper section to extend the lower one in the second photo
- Note that the crane hook is only 10-20 cm above the top section

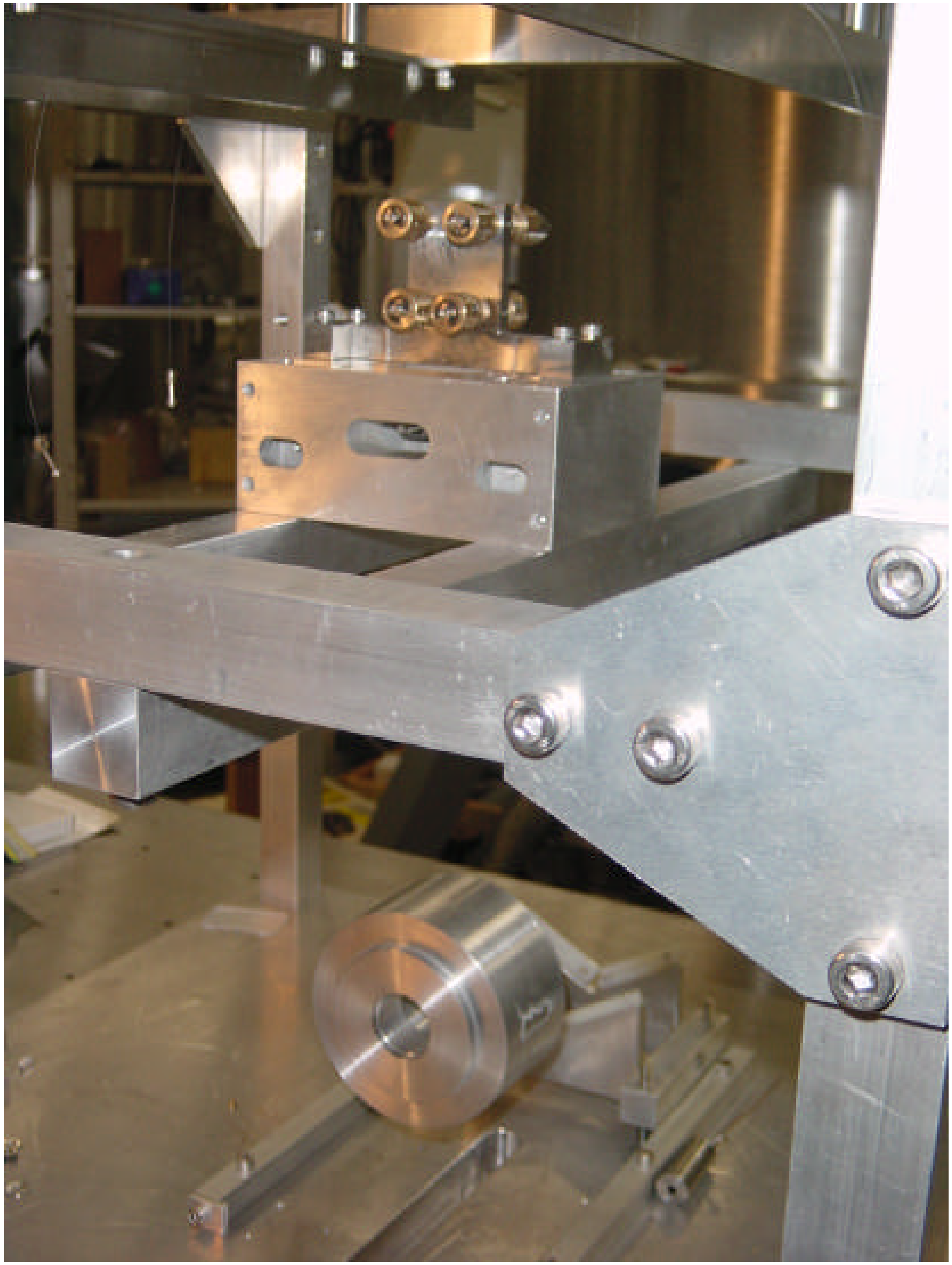


Closing down the vacuum

- Friday afternoon
- Tired, pumping it down

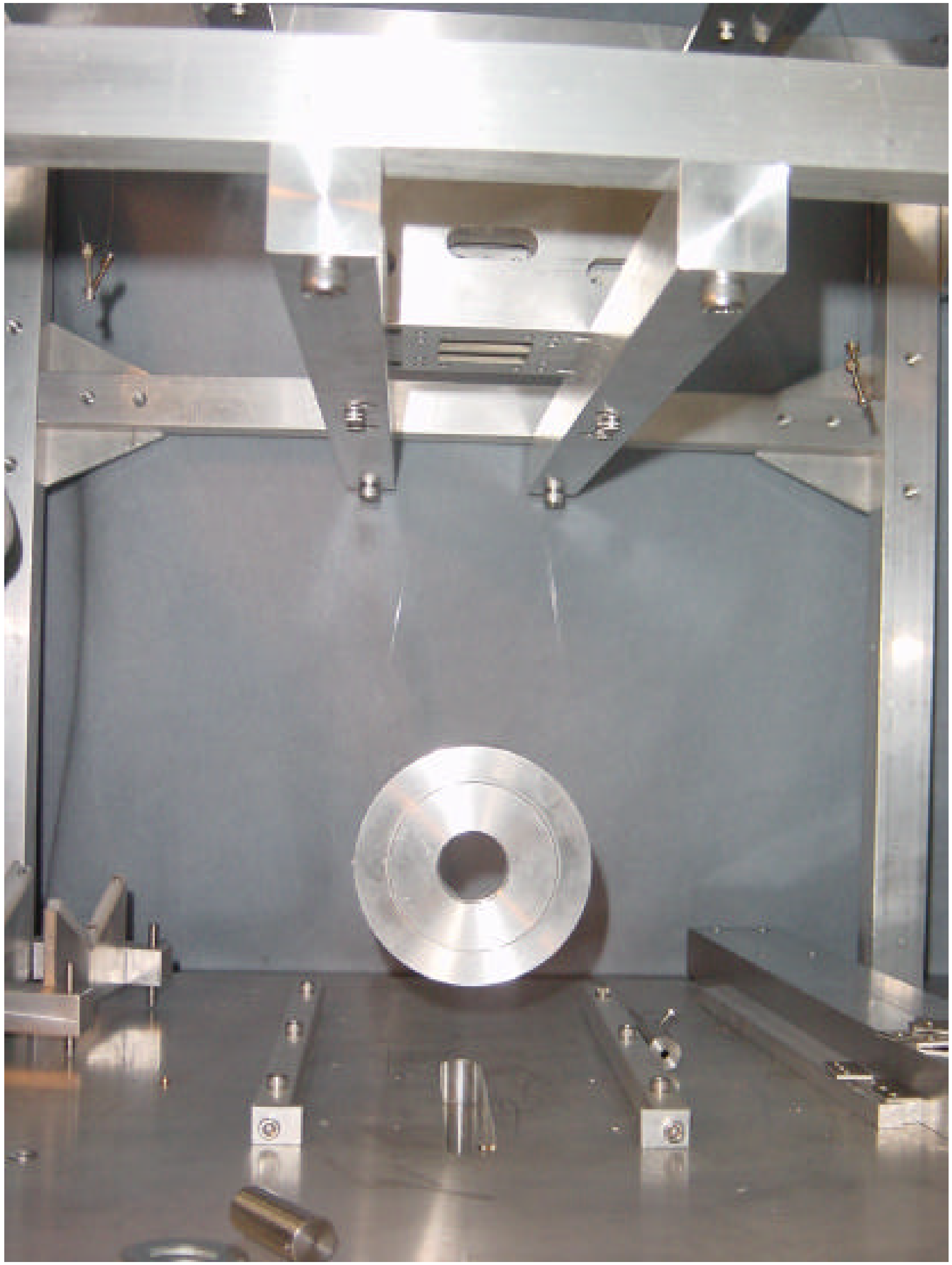
Second week: Assemblying the double pendulum

- The mirror (an aluminum mass of the same shape of the real TAMA mirror) is suspended.
- The positioning tool used for the sospension procedure has been retracted behind the “mirror”
- The top four guitar knobs above the intermediate mass are used to pull the individual wires and position the mirror in 3 D



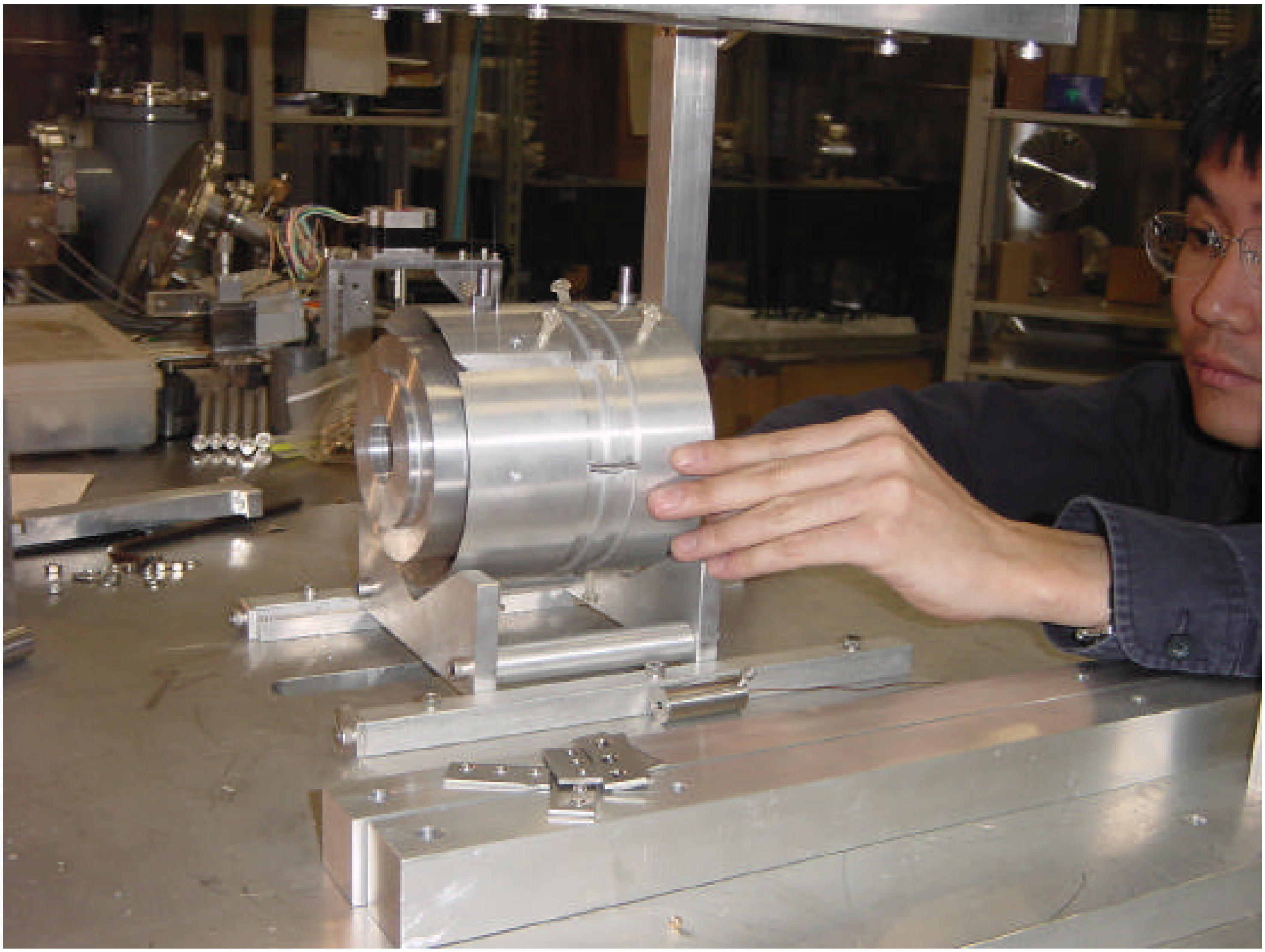
Second week: Assemblying the double pendulum

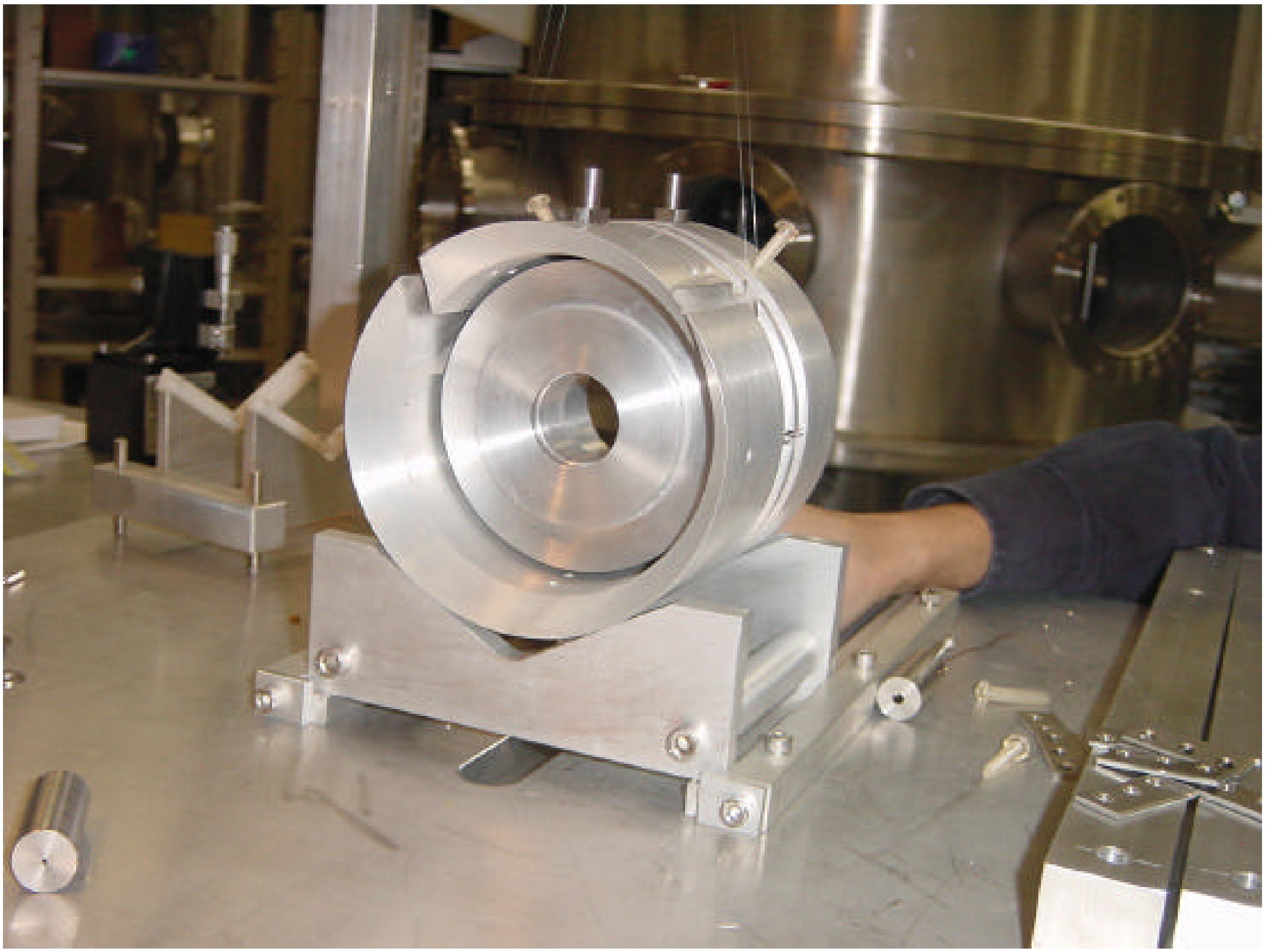
- Mirror suspended from the intermediate mass, supported by the assembly jig.



Second week: Assemblying the double pendulum

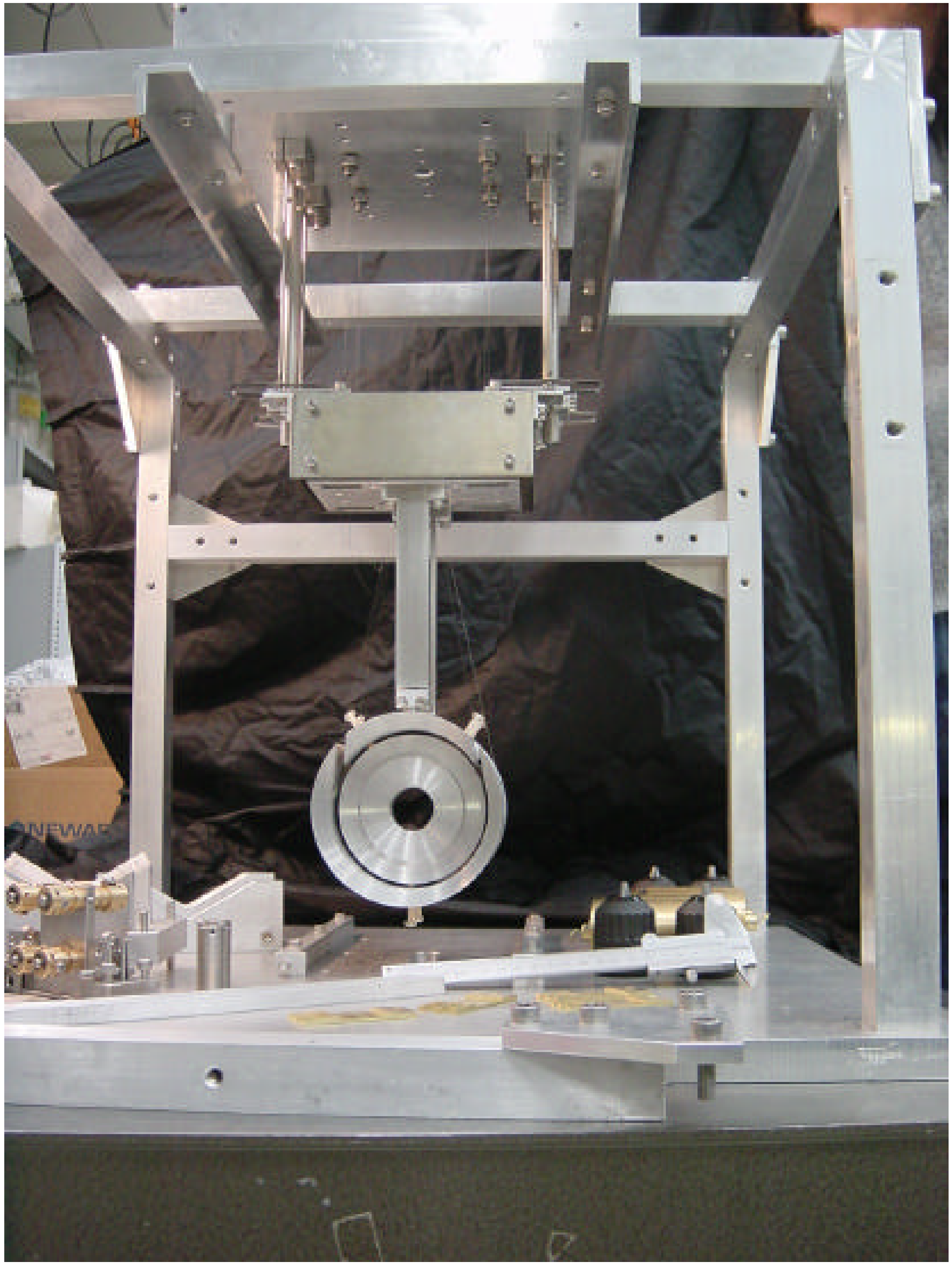
- Akiteru sliding the recoil mass into position
- Next photo, recoil mass positioned
- Wiring the recoil mass





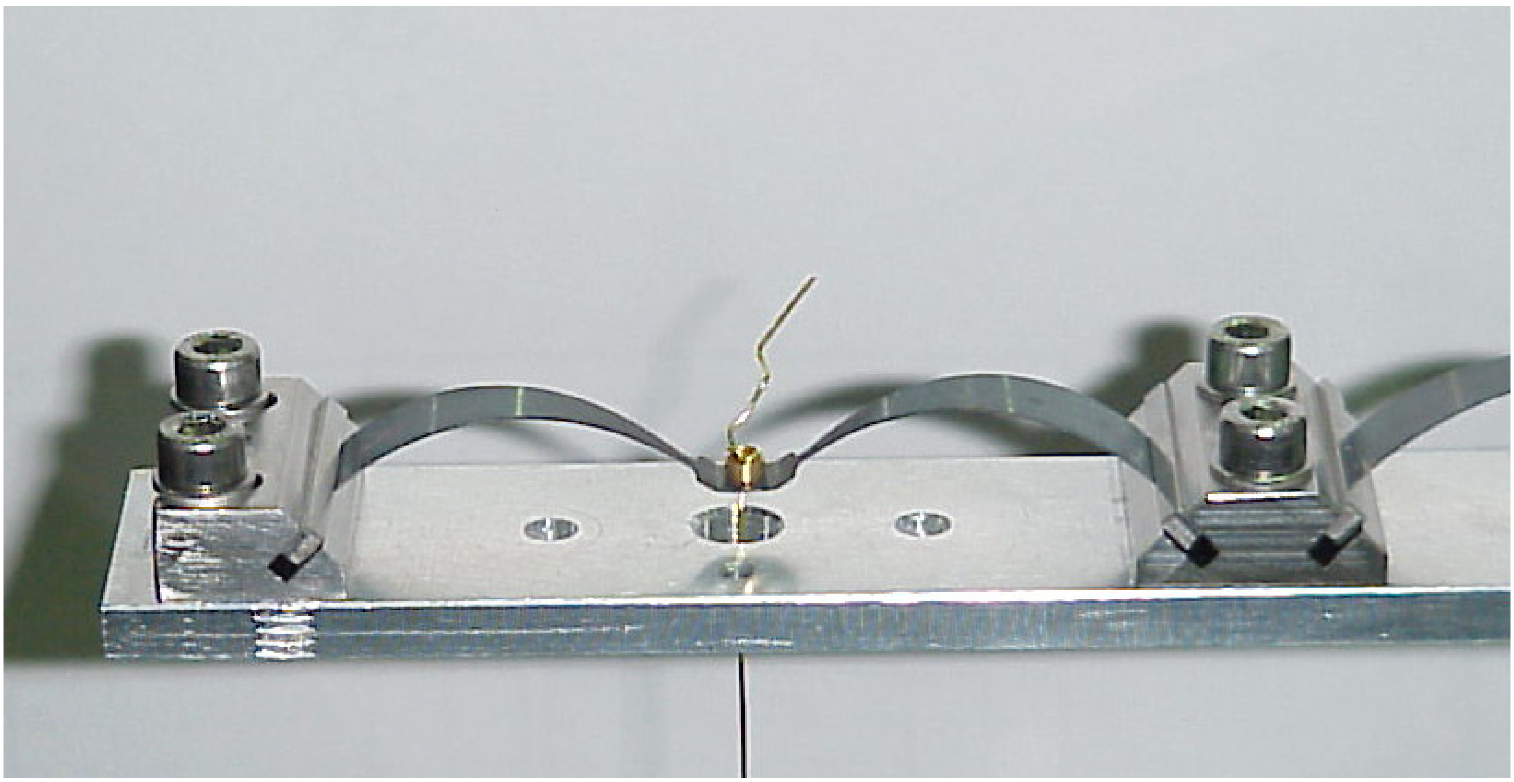
Second week: Assemblying the double pendulum

- Complete double pendulum in its assembly structure, complete with its transport struts
- The mirror is locked inside the recoil mass by the 6 nylon screws
- The recoil mass is secured to the intermediate mass with two aluminum struts
- The intermediate mass is secured to its magnetic damping box using 6 pointed screws (4 visible)
- The magnetic damping box is secured to the top mass by means of 4 rods
- Barely visible in front and behind the transport rods are the magnetic box suspension (thin rods and butterfly springs)



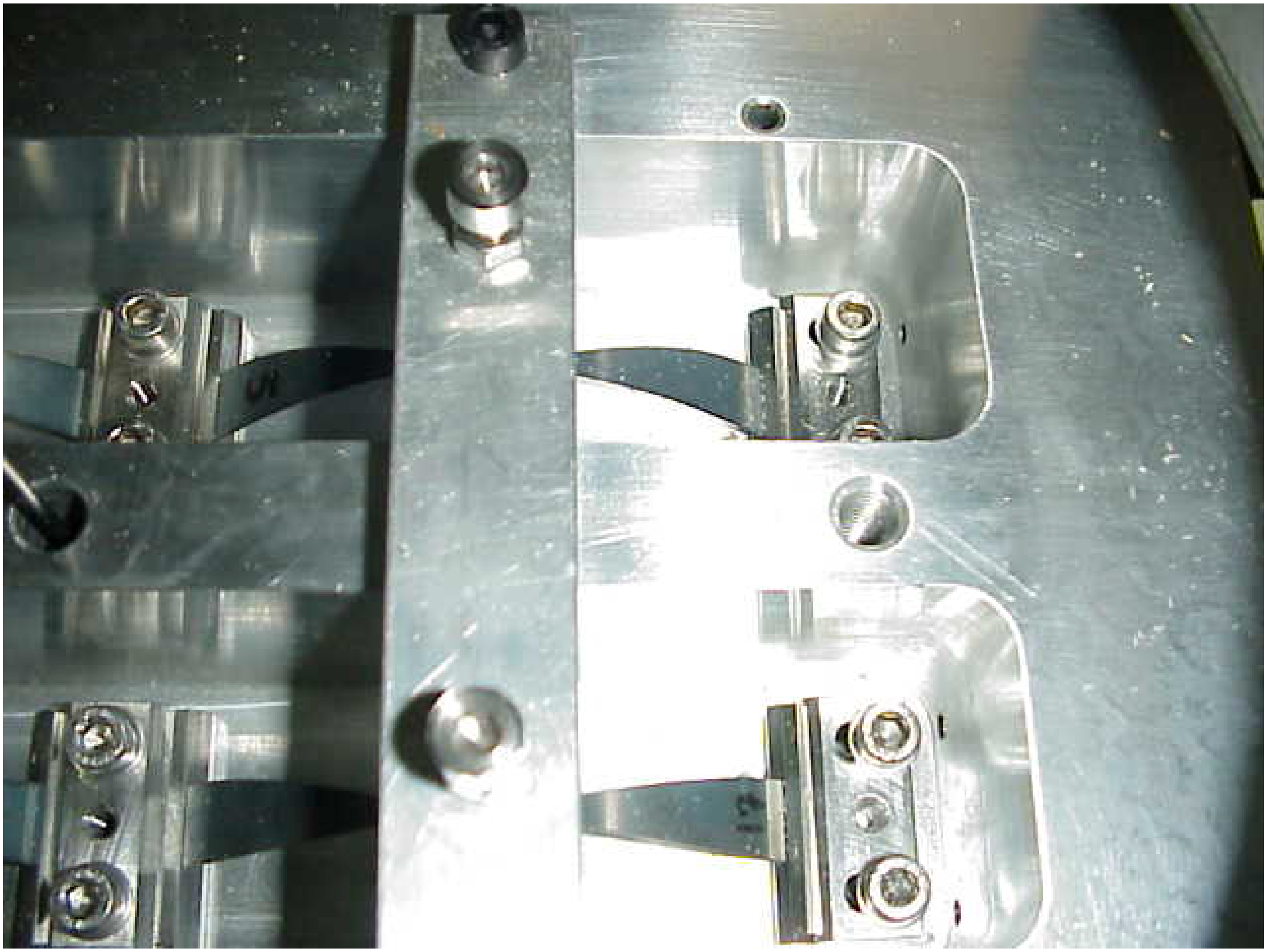
Second week: Assemblying the double pendulum

- Two of the four mini-MGAS springs ready for installation in the top mass.
- They support the intermediate mass with 1.5 Hz vertical resonant frequency



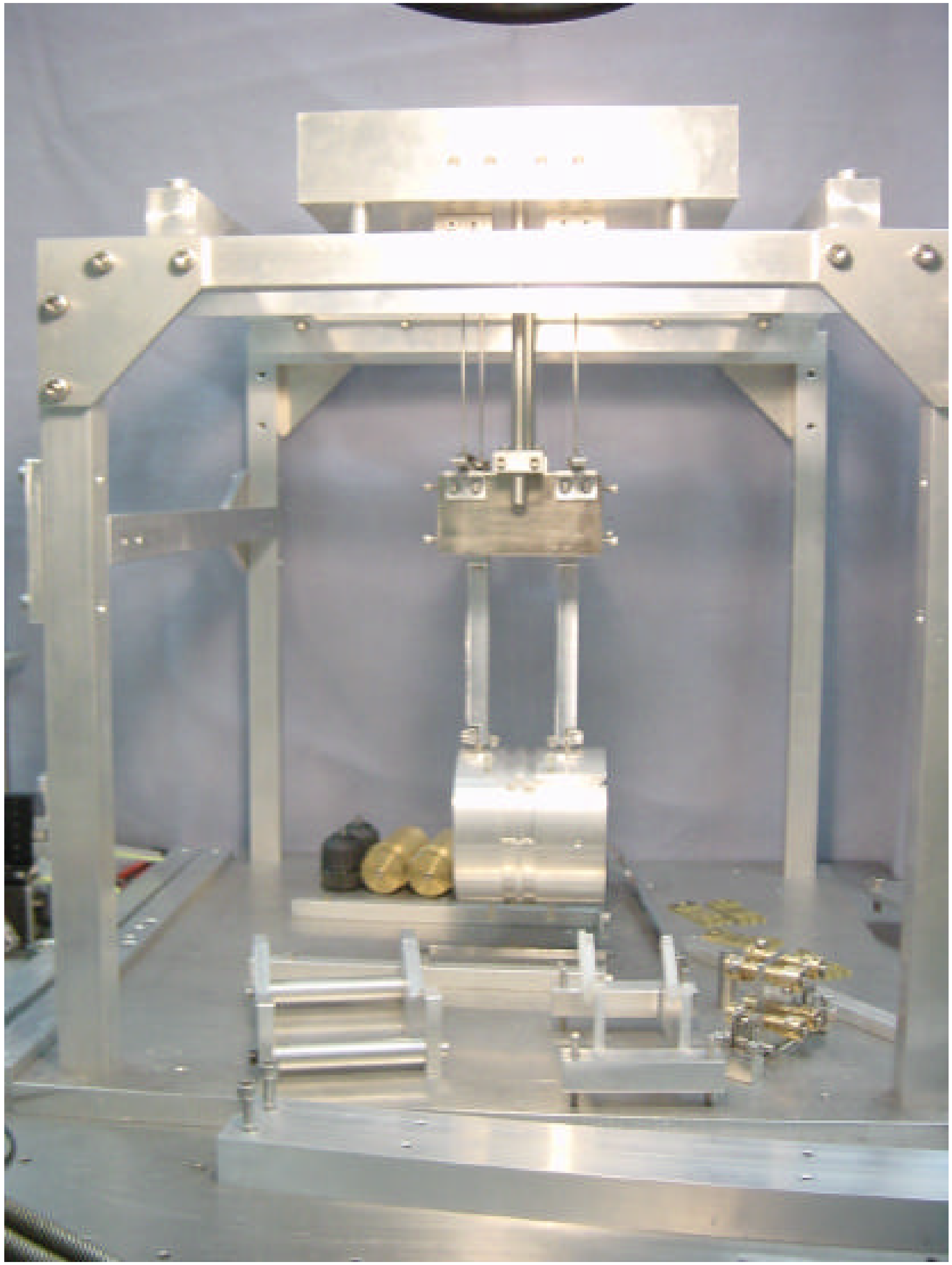
Second week: Assemblying the double pendulum

- Mini-MGAS springs installed into the top double pendulum mass.



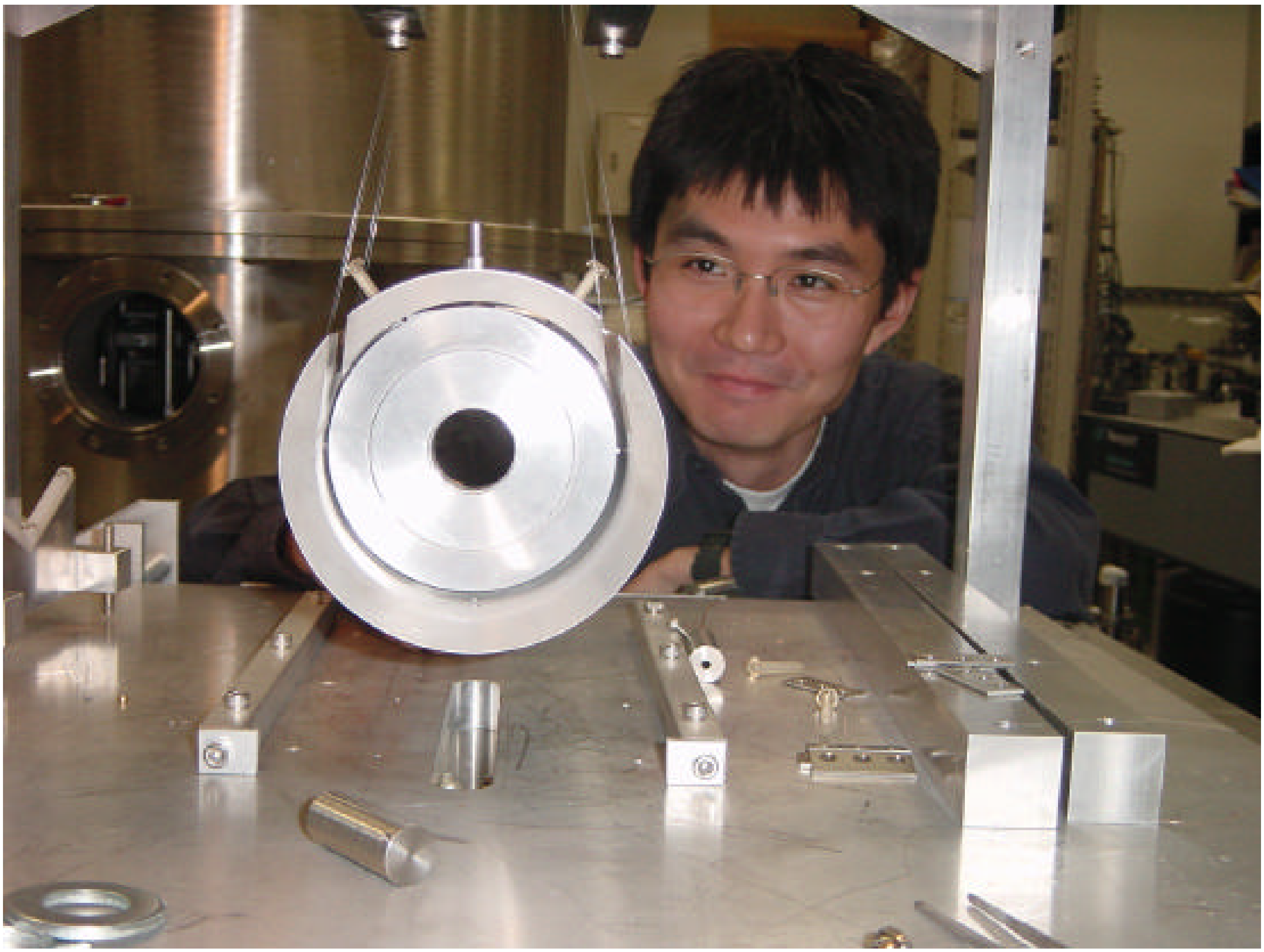
Second week: Assemblying the double pendulum

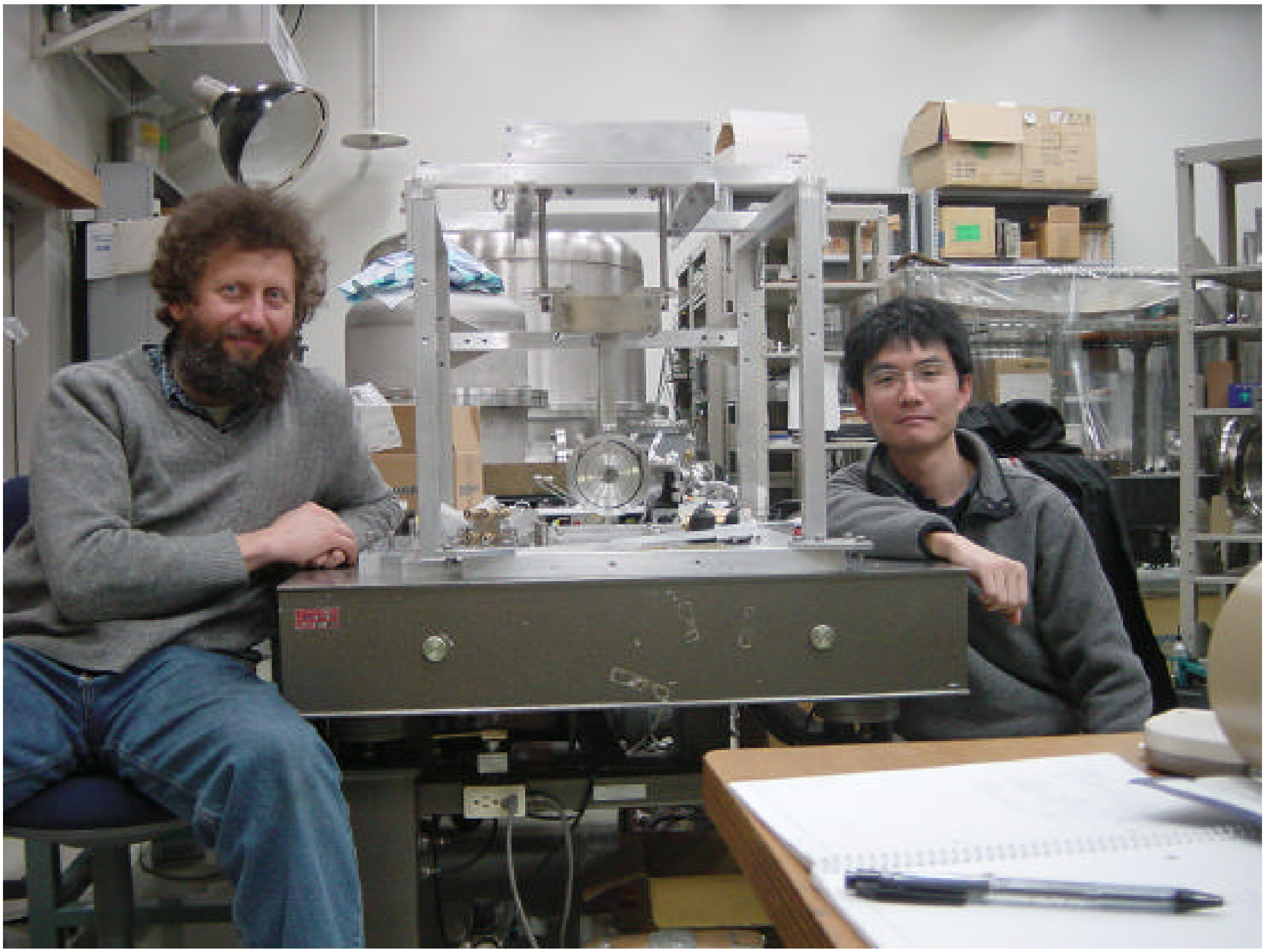
- Side view of the double pendulum ready to be suspended from the middle filter
- Note between the top and the intermediate masses, the thin rods constituting the magnet box suspension system
  Inside the rods are visible the wires suspending the intermediate wire from the MGAS springs. At the center the transport rods
- Between the intermediate mass and the recoil mass are visible the two transport struts
- Assembly tooling is acattered around



Second week: Assemblying the double pendulum

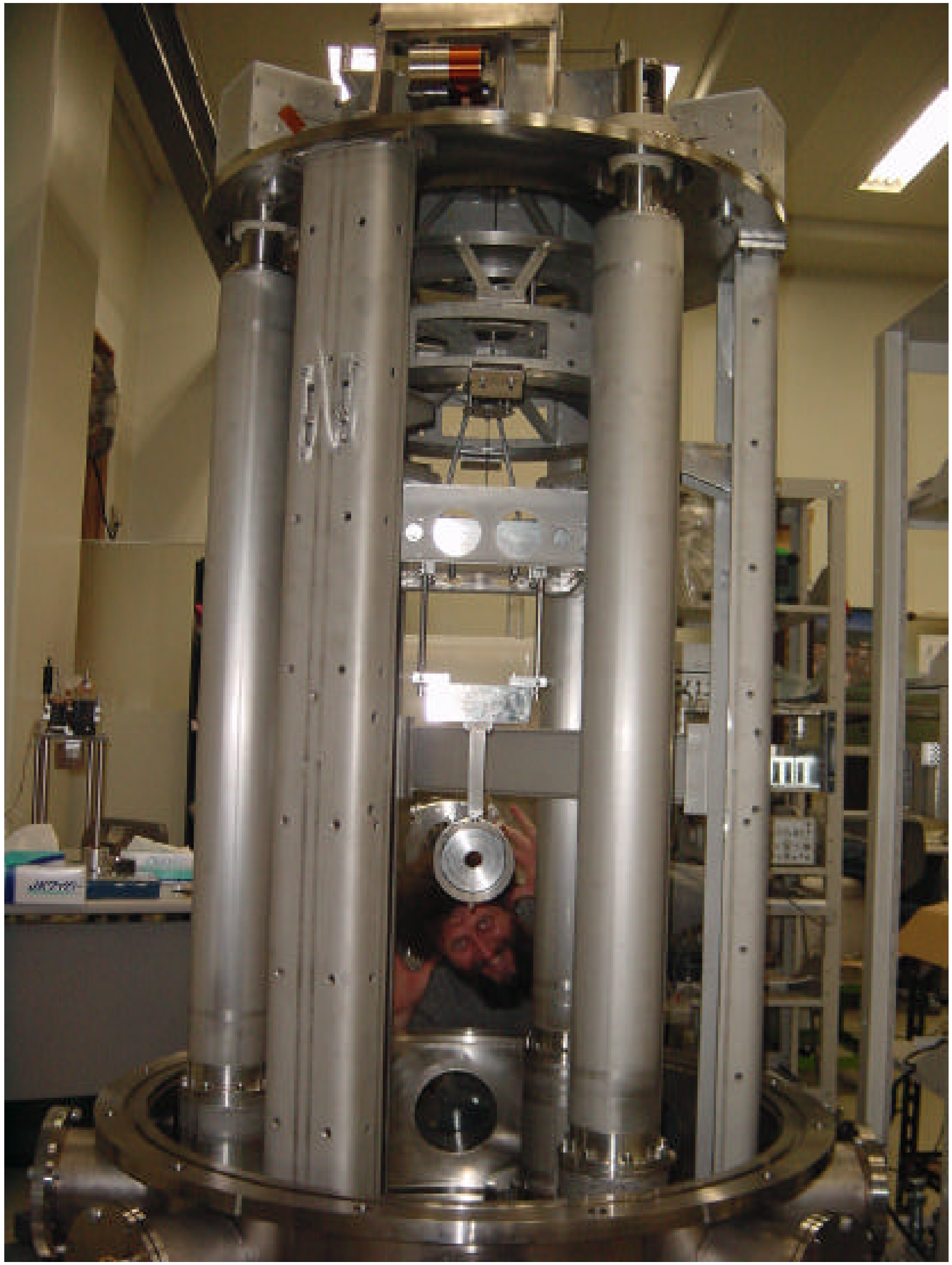
- Akiteru, satisfied, admires his the concentric recoil mass and the mirror
- The drive coils to actuate the mirror are mounted in a square on the back of the recoil mass
- Next photo,   a deserved pause before installing the double pendulum





Second week: Assemblying the double pendulum

- Two side views and a front view of a complete TAMA SAS/SUS

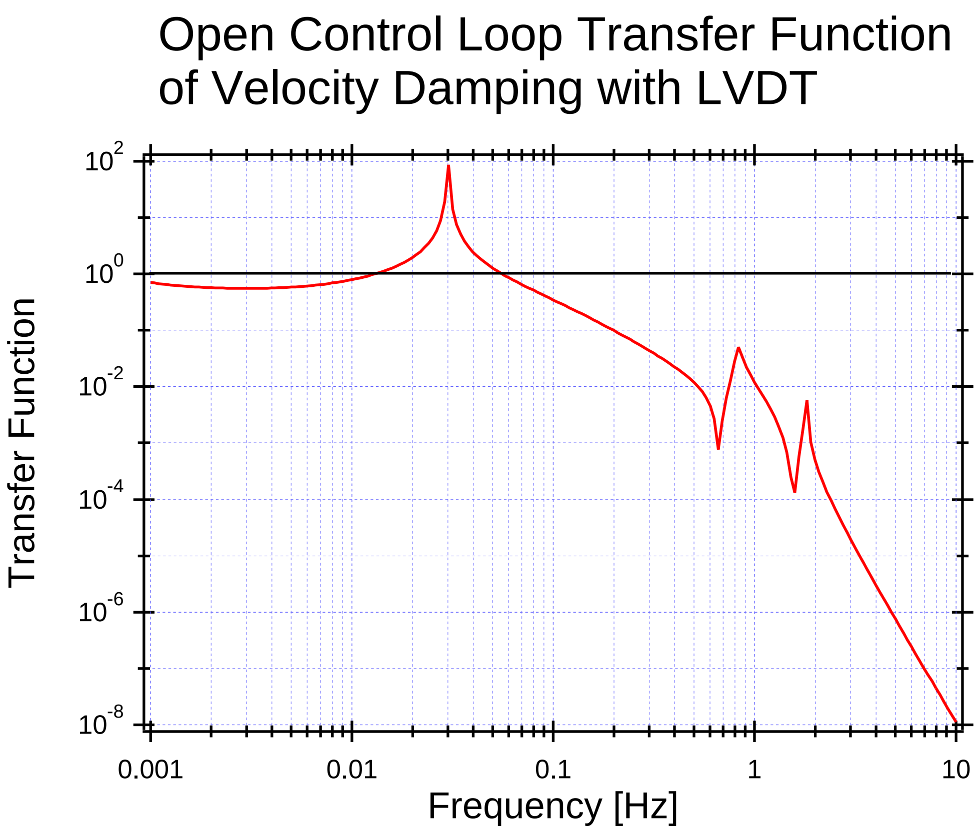


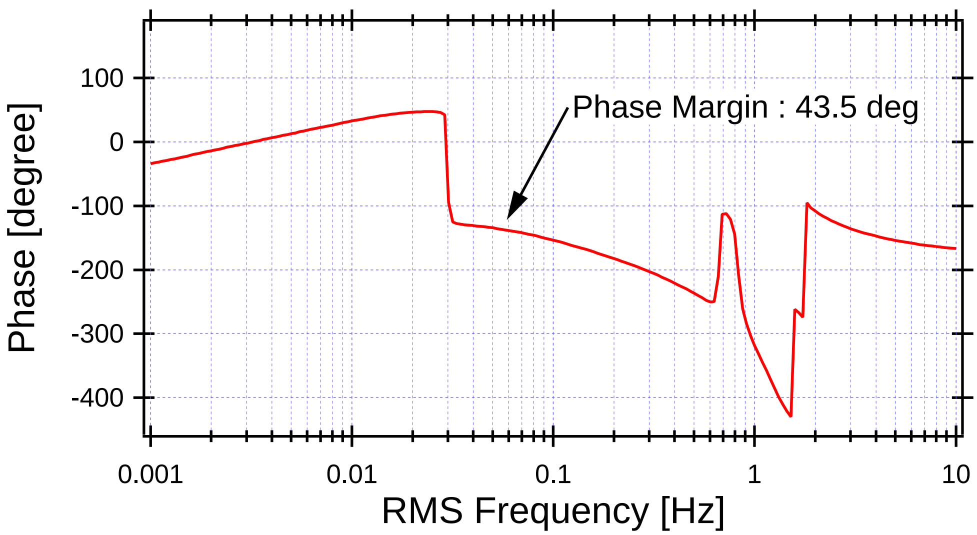
Expected (simulated) TAMA SAS/SUS performances

2. IP Local Control

2. 3. Simulation

Control with LVDTs

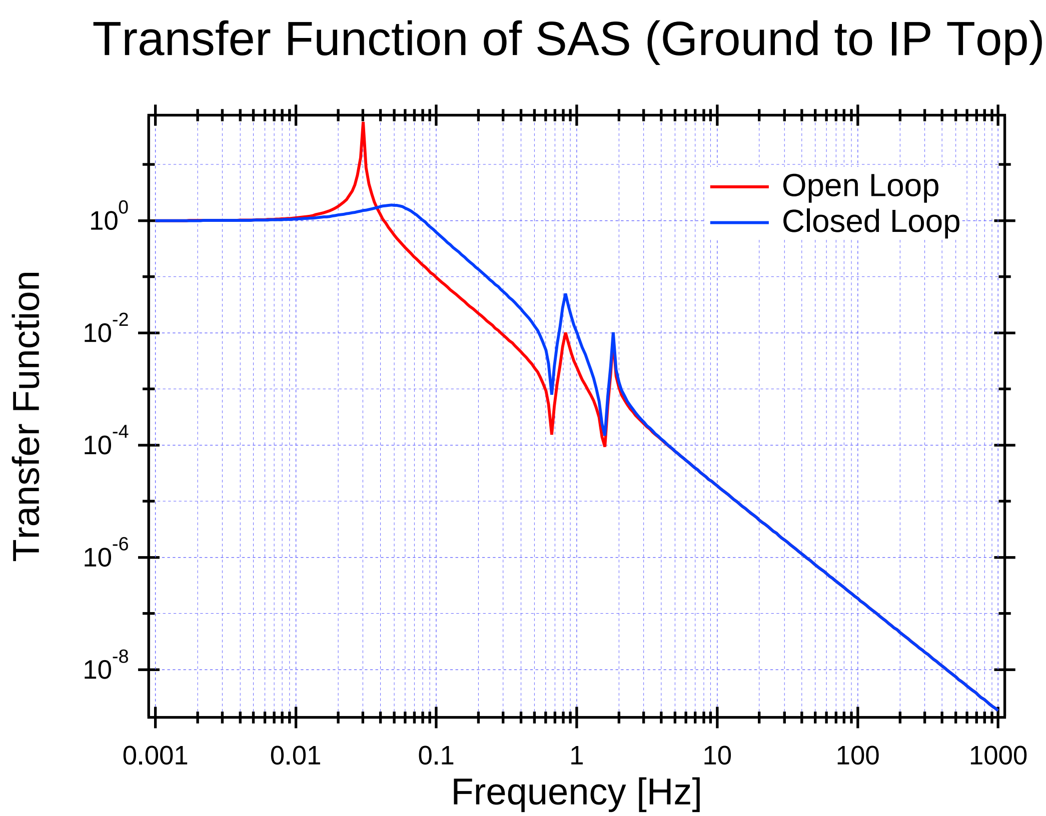




2. IP Local Control

2. 3. Simulation

Control with LVDTs

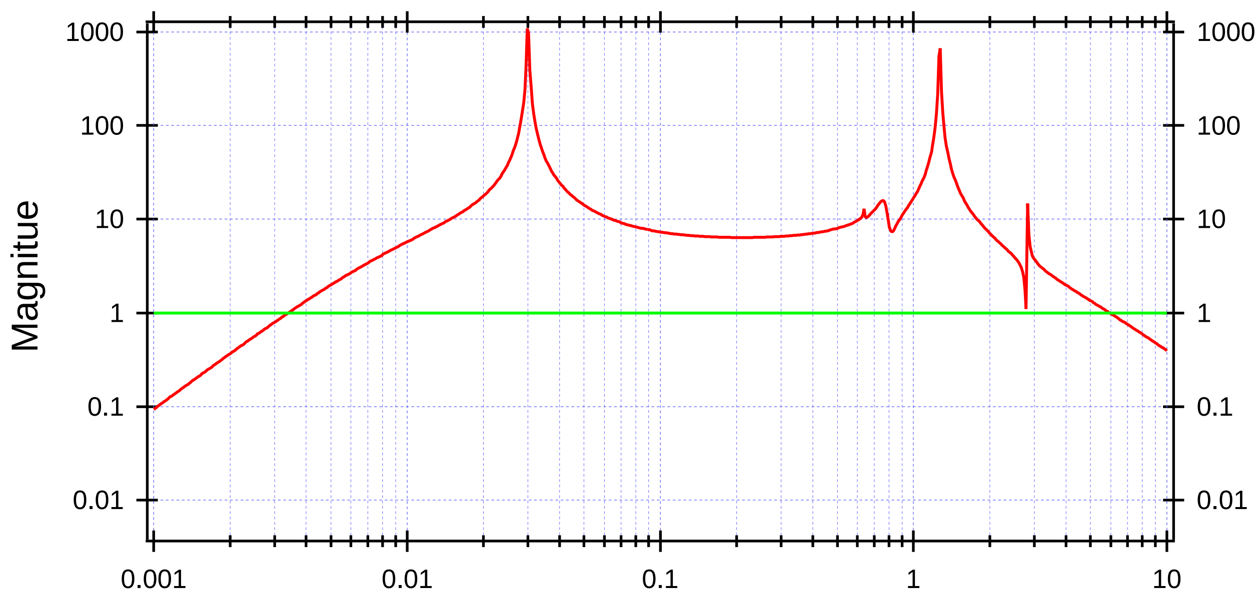


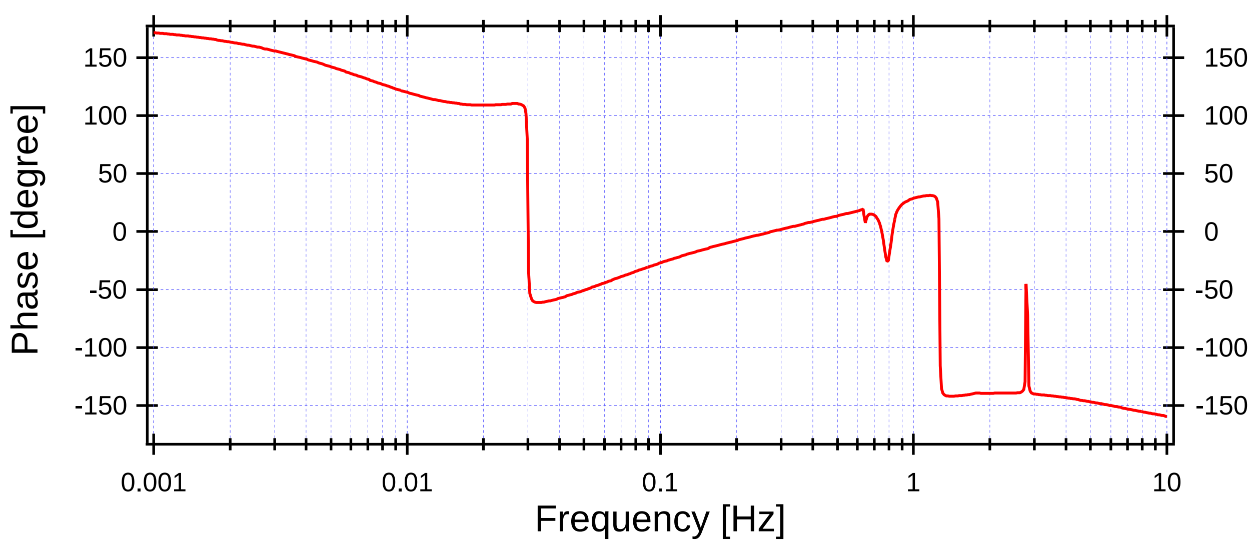
2. IP Local Control

TAMA SAS

2. 3. Simulation

Inertial Damping



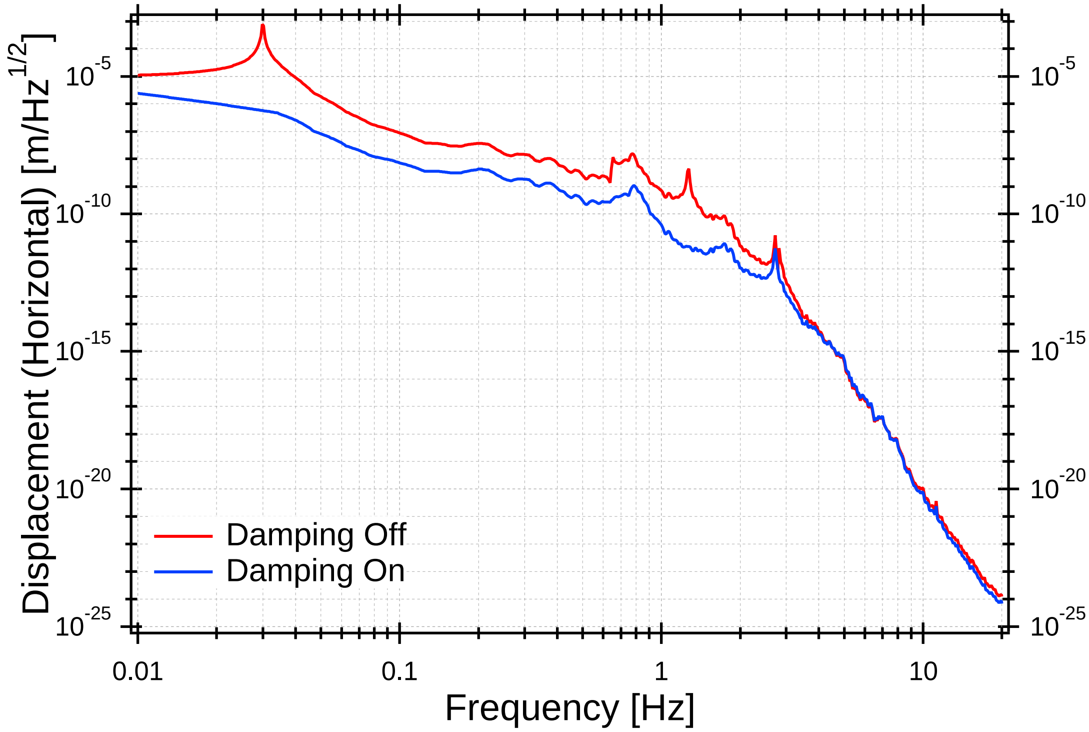


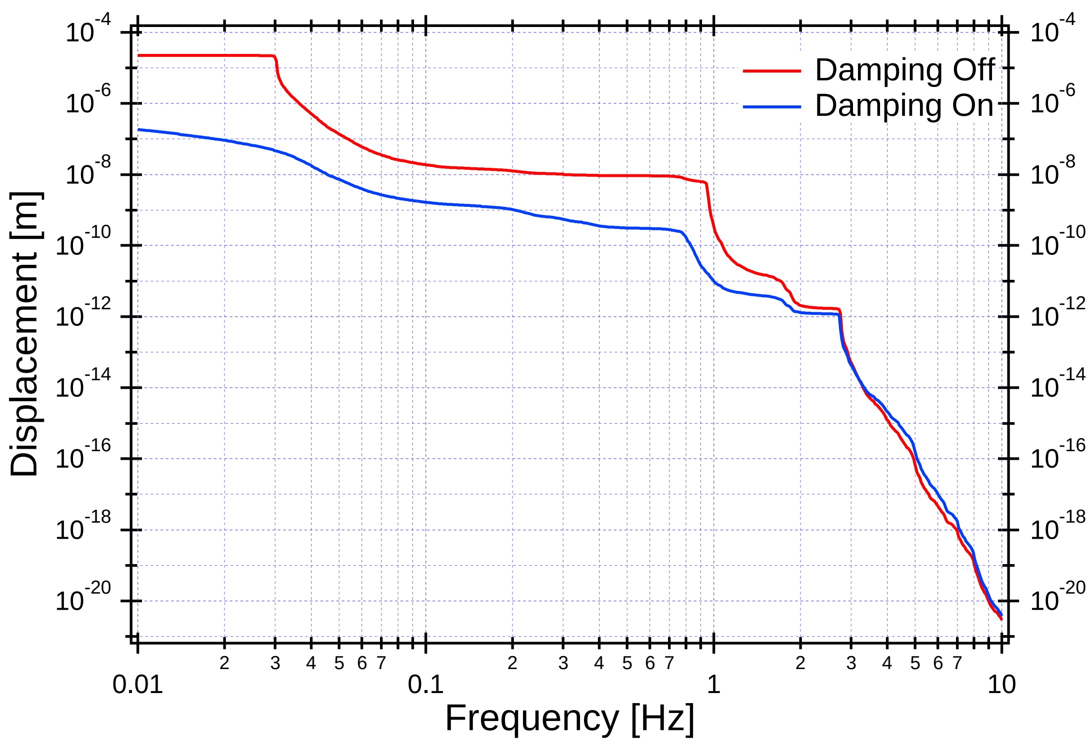
2. IP Local Control

SAS

2. 3. Simulation

Inertial Damping





Conclusions

- Simulations show that TAMA SAS/SUS should deliver 10-20 m/Hz-1/2
- Above 10 Hz with a comfortable few tens of nanometers of mirror residual motion between 0.1 and 10 Hz