The COMET Straw Tracker System

by Hajime NISHIGUCHI, *KEK*

On behalf of the COMET Straw-Tracker Group

TIPP2014, 02-06.June.2014, Amsterdam

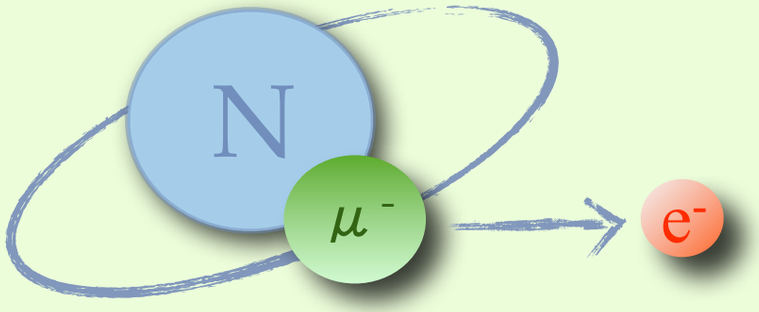
Contents

Motivation

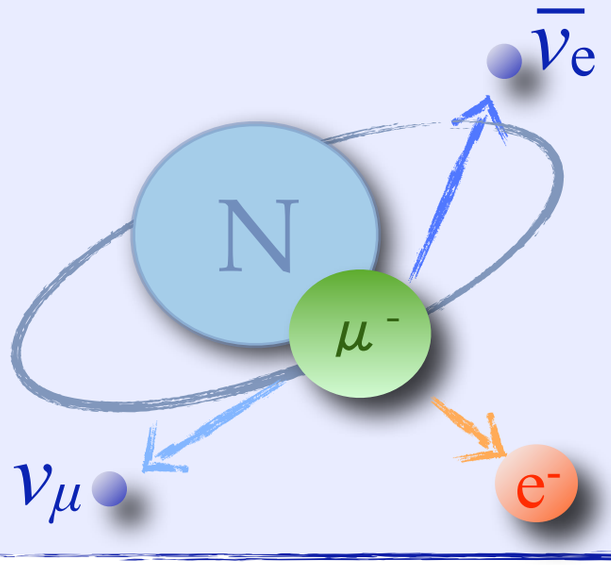
The COMET Experiment

- **An Experiment to Search for "$\mu^- N \rightarrow e^- N$" at J-PARC**
  - Muon-to-Electron Conversion = Lepton Flavour Violation
  - Very sensitive to the TeV-scale new physics, BSM

    → **Complementary** and **Competitive** to the **LHC**



- **Signal**
  - $E_e = m_\mu - B_\mu \sim 105\text{MeV}$
  - Coherent Process ($Z_{ini}=Z_{end}$)



- **BGs**
  - **Prompt (Beam-related)**
  - **Decay in Orbit (DIO)**
  - Radiative π/μ-capture
  - Decay in Flight (DIF)
  - Cosmic-rays

The COMET Experiment

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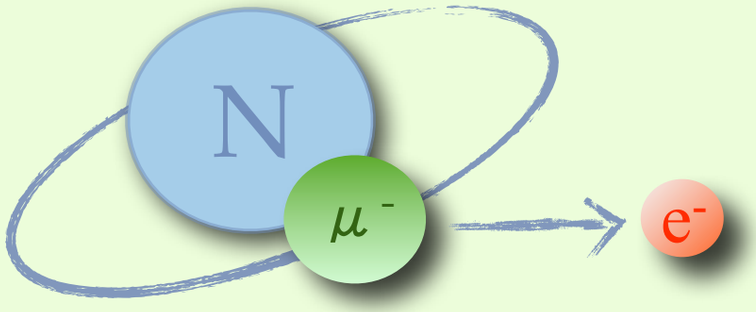

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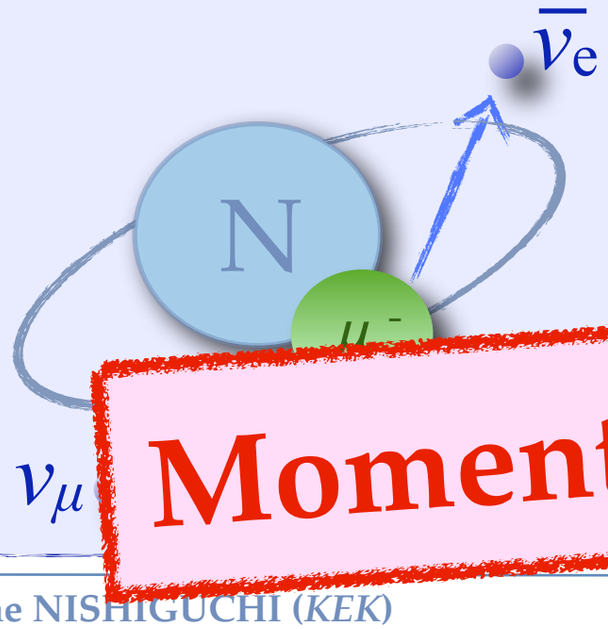

- **BGs**
  - **Prompt (Beam-related)**
  - **Decay in Orbit (DIO)**
  - **Radiative Muon Capture (RMC)**

Momentum Resolution is Essential !!!

The COMET Experiment

- **An Experiment to Search for "$\mu^- N \rightarrow e^- N$" at J-PARC**
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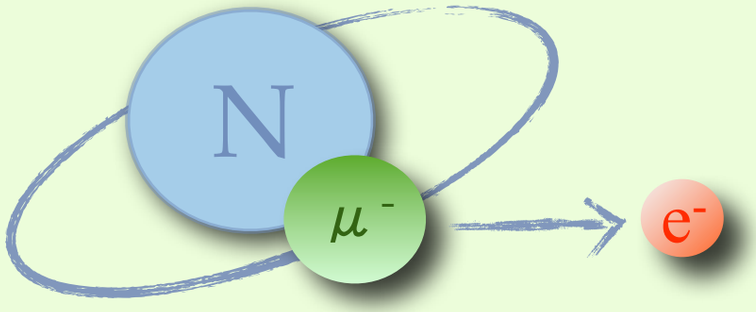


- **Signal**
  - $E_e = m_\mu - B_\mu \sim 105$MeV
  - Coherent Process ($Z_{ini}=Z_{end}$)

(Beam-related)

Need to achieve, at least, < 200 keV/c for 100MeV/c e^-

Momentum

…l !!!

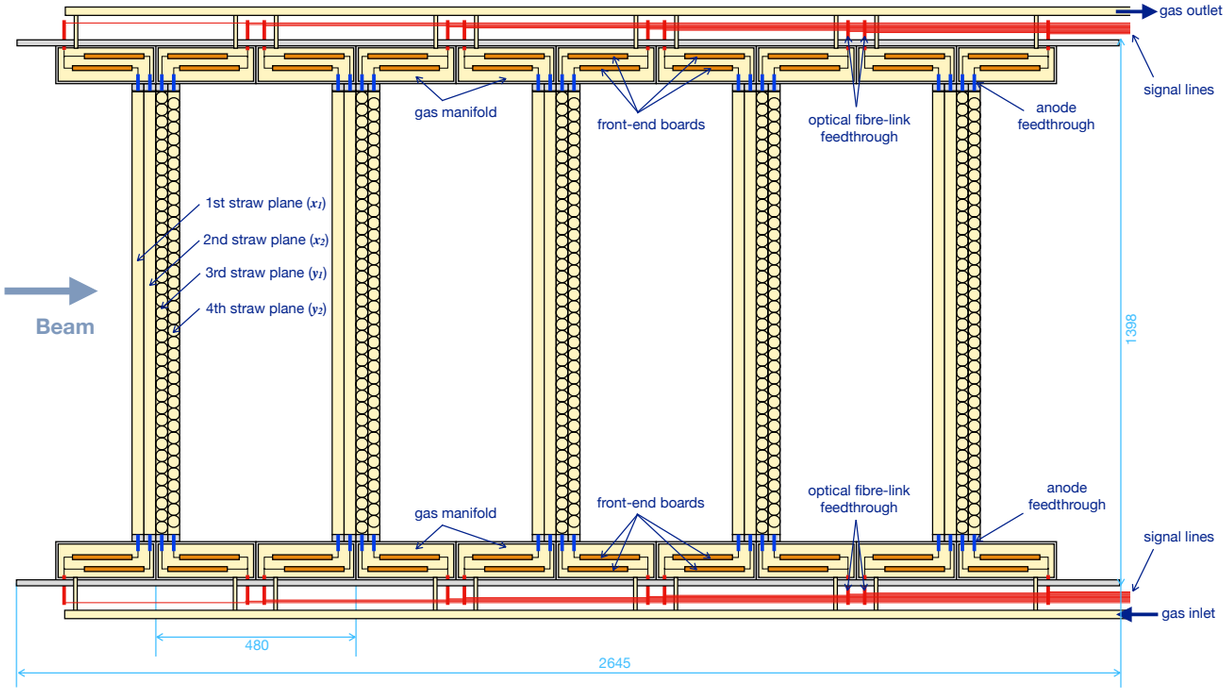
Tracking detector in Vacuum

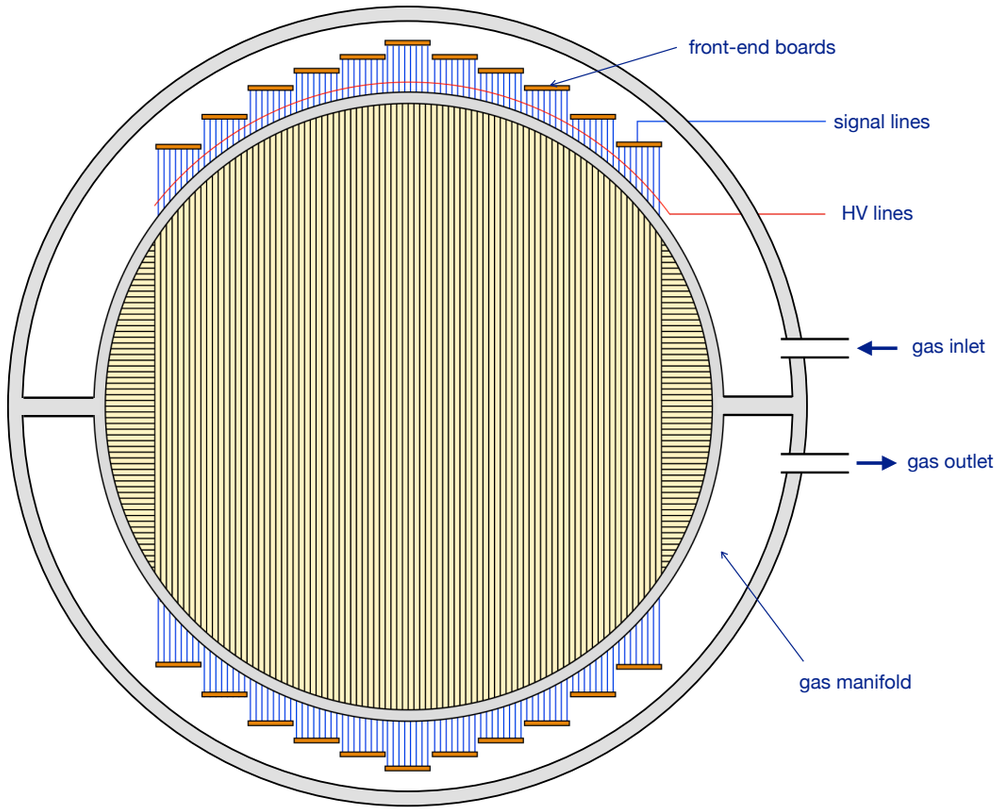
- **Old**
  - **GM tube, bubble chamber, cloud chamber, etc.**
- **Modern**
  - **Single volume gaseous detector**
    - **MWPC → Drift Chamber / TPC**
- **New**
  - **Gaseous detector is modularized in the fiducial tracking volume** like MEG, *etc.*
    - **Rest space is filled with light gas (He)**
- **Challenge**
  - **Modularized gaseous detector**
    - **But rest space is evacuated !!!** like NA62, *etc.*
    - **Ultimate stye of Light Gaseous Tracker**

Straw Tracker in Vacuum

The COMET Straw Tracker

- **Planner** wire-chamber-base tracker in **Vacuum** → **Straw Tracker**

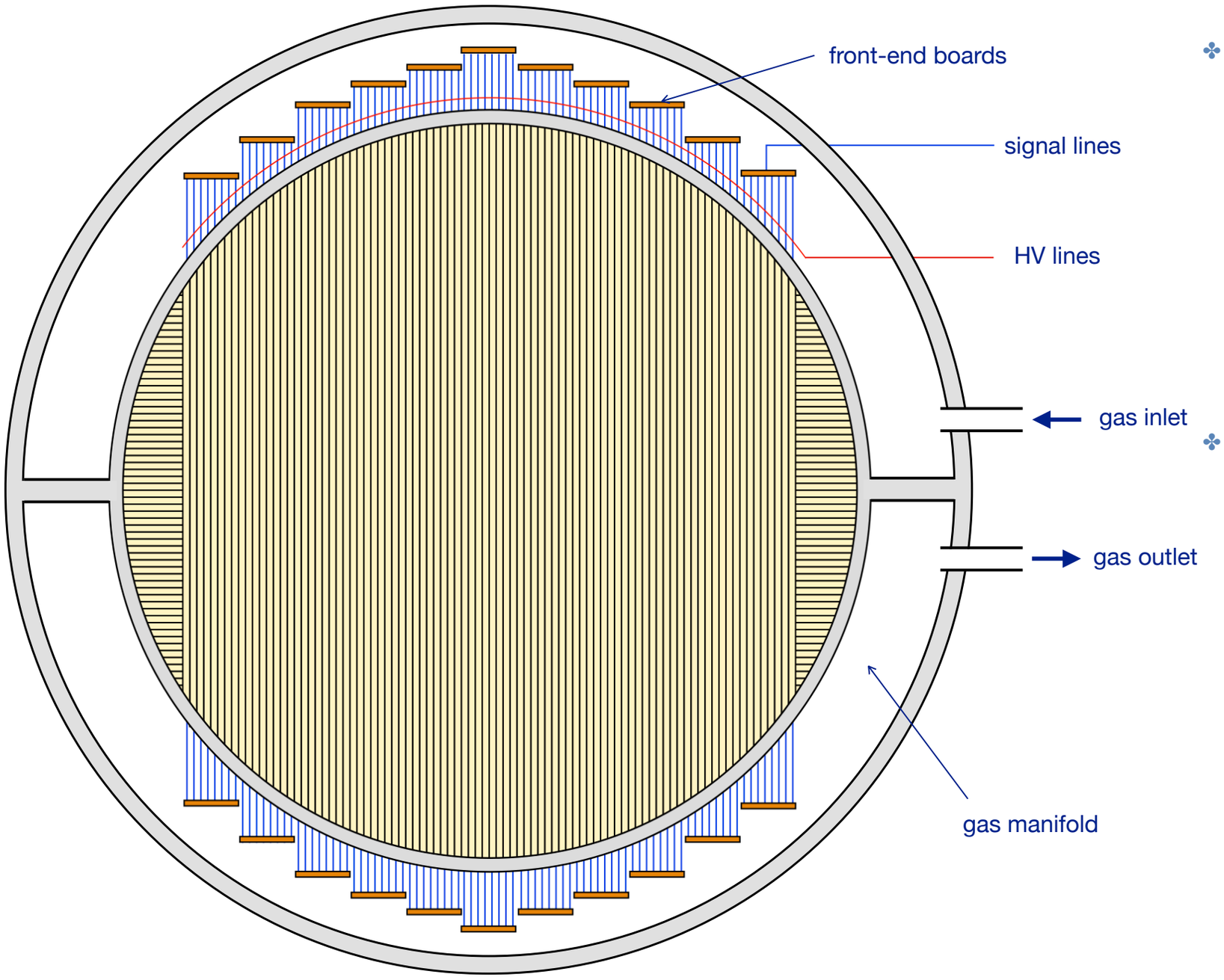




- Five super-layers (module) consist of 4 planes of straw tubes
  - 2 planes for x-coordinate and 2 planes for y-coordinate, each layers are staggered by half a cell to solve the left-right ambiguity.
- All tracker modules are installed in **vacuum**.
- Timing(Trigger) is provided by the electromagnetic calorimeter.

The COMET Straw Tracker

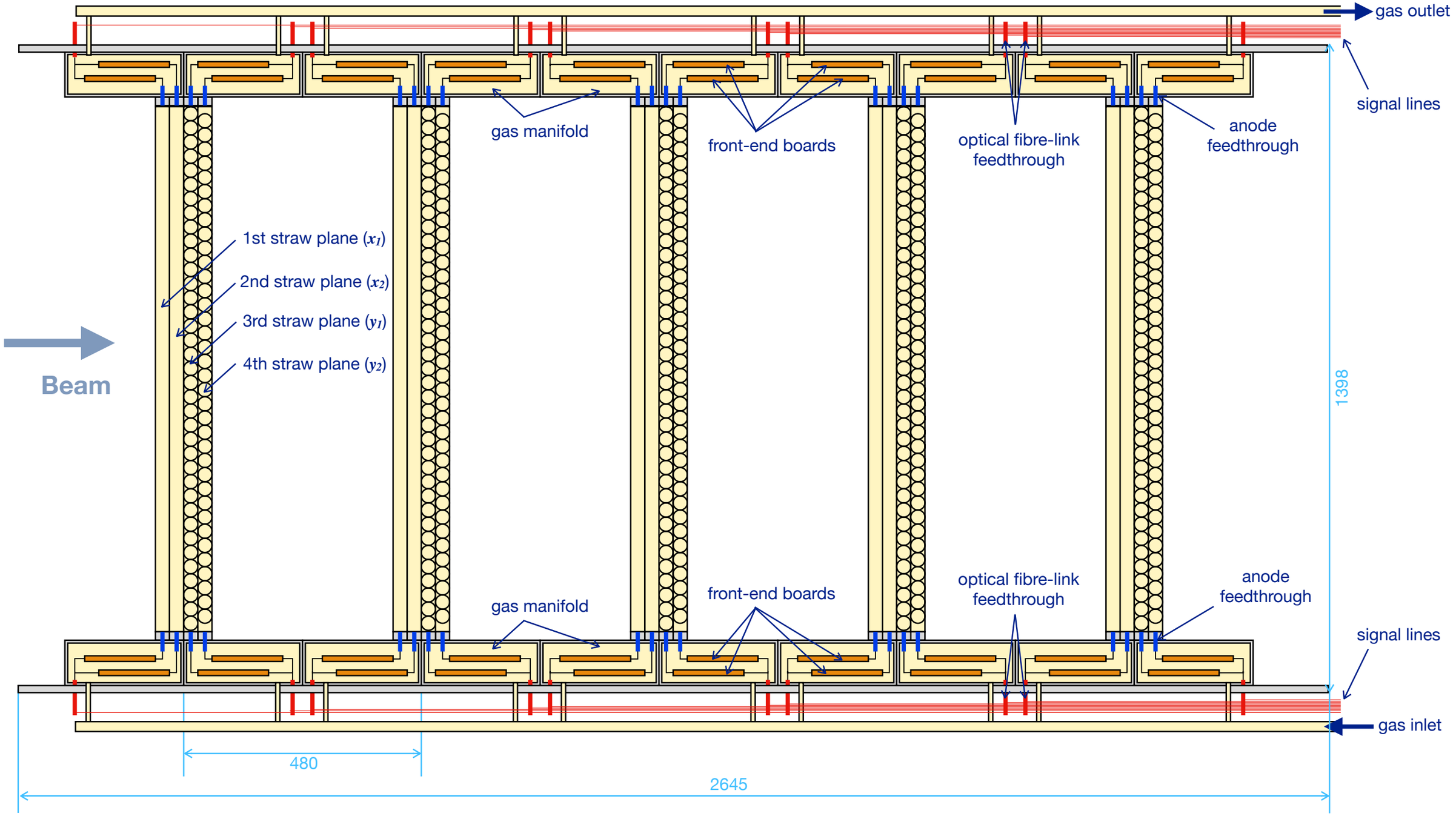
- **Cross-section view**



- Dimension
  - 1.4m diam.
  - outer region : gas manifold, FE boards are installed.
- Straw specification
  - 9.75mm diam.
  - 0.6～1.2m length
  - **material :**
    - **mylar 20 or 12 μm**
    - **Al-cathode**

The COMET Straw Tracker

- **Lateral view**



Straw Development Strategy

- Three-staged strategy to develop the thinner straw tube

NA62 straw
36μm-thick+
70nm Cu+Au deposition

→

1st trial
20μm-thick+
70nm Al deposition

- Recently done -

→

2nd trial
12μm-thick+
70nm Al deposition

- ongoing -

- Tracker development is ongoing in parallel to the straw development

- Assembly prototype -

- Using NA62 straws
- Installation/Assembly studies
- Vacuum-handling studies
- Gas-manifold optimization

1st trial
20μm-thick+
70nm Al deposition

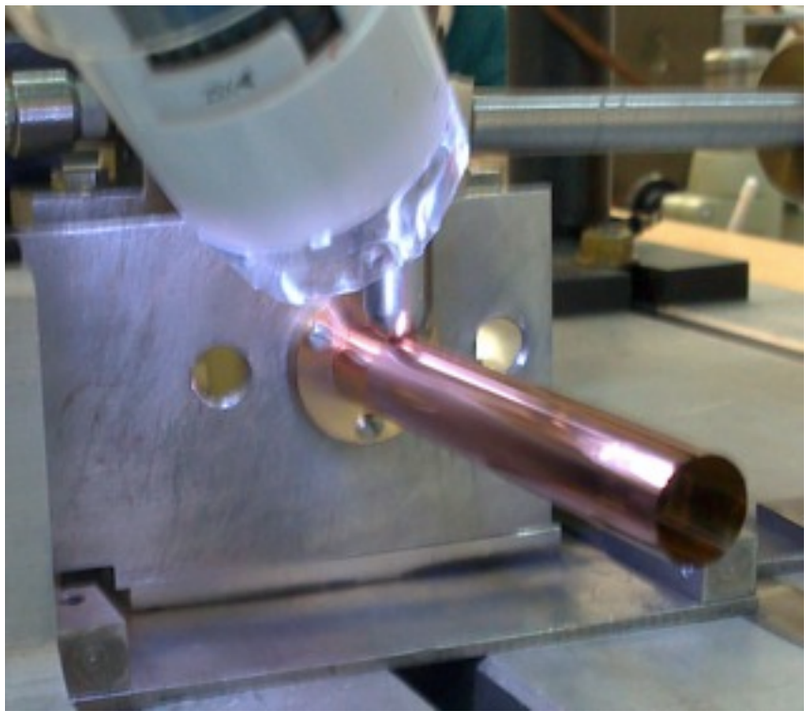
2nd trial
12μm-thick+
70nm Al deposition

⇒

- Assembly technique, gas-manifold optimization, are done by using NA62 straws.
- NA62 straws will be replaced by COMET straw (1st) & (2nd).
- Have a look at straw properties in vacuum and compare.
- Final decision will be made.

Status of straw development

- **1st trial** (20μm-thickness + 70nm Al deposition) was successfully done.

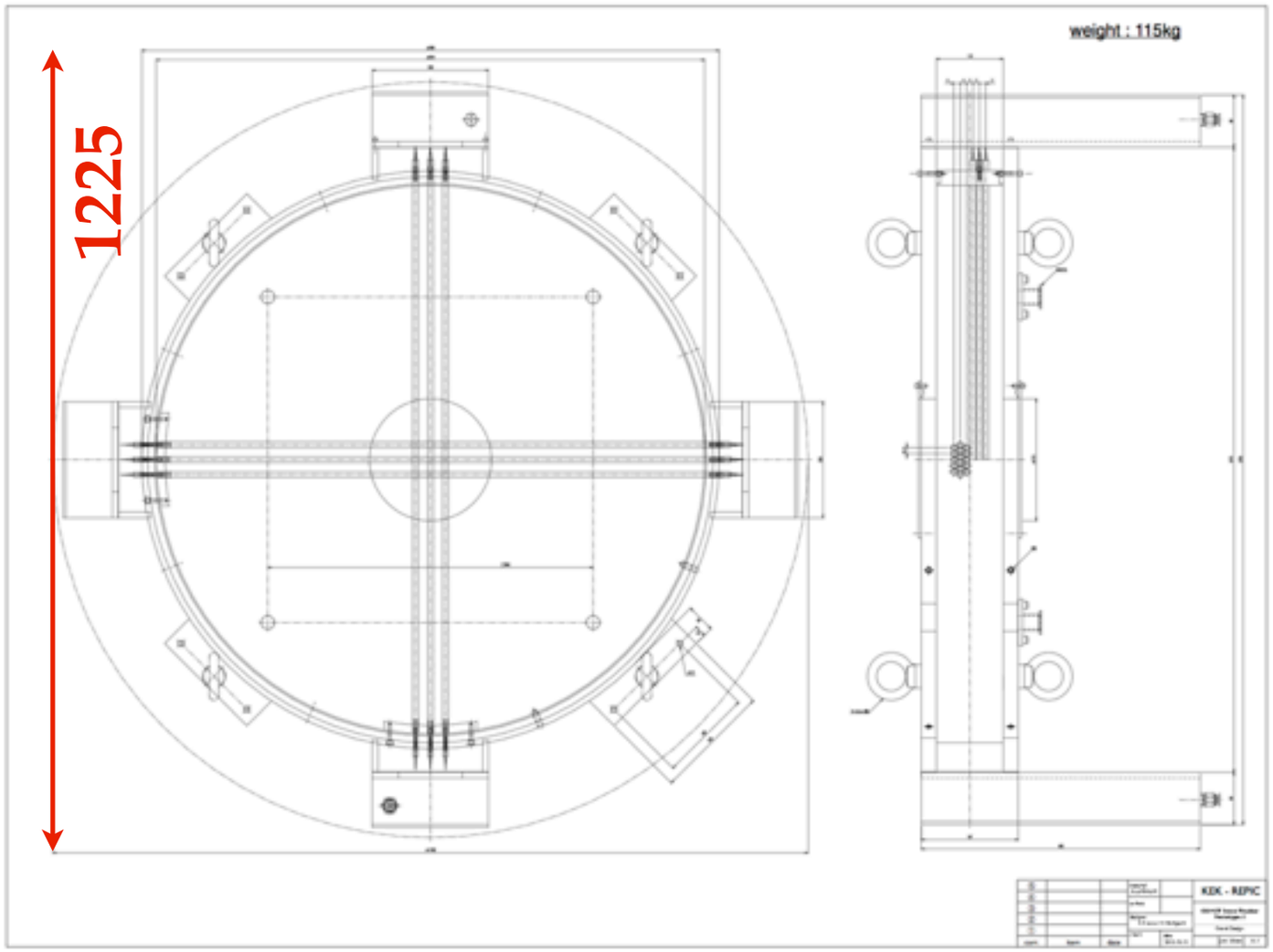


- Pressure test was performed, deformation starts around 6 bar and breaks out over 7 bar → enough tough for our usage.
- as soon as it will arrive at KEK, NA62 straws in the assembly prototype will be replaced by this COMET straw "1st trial version"
  - **then straw mechanical properties in vacuum will be studied.**
- **2nd trial** (12μm-thickness + 70nm Al deposition) is ongoing.

Assembly Prototype

- "**1-*to*-1 Prototype**" using NA62 straw is constructed.

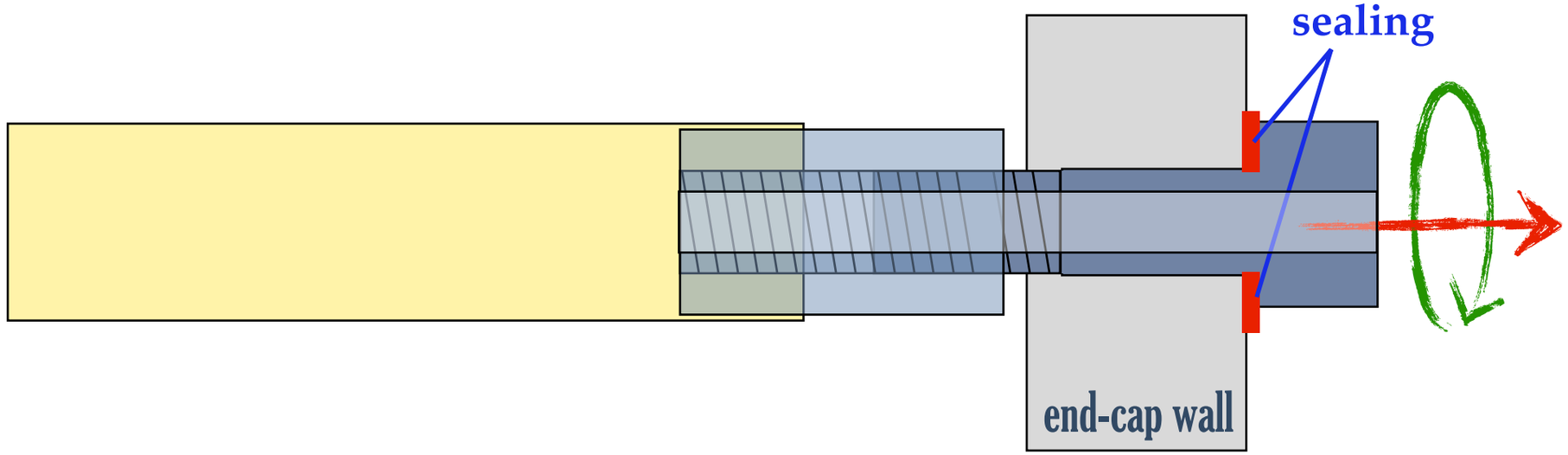
- Completely same as the actual detector other than the straw tube.
- **Al support, Vacuum operation, assembly R&D.**
- Performance study will be done by RI, CR, and test-beam.
- Assembly studies by this prototype will give important feedbacks to the final tracker

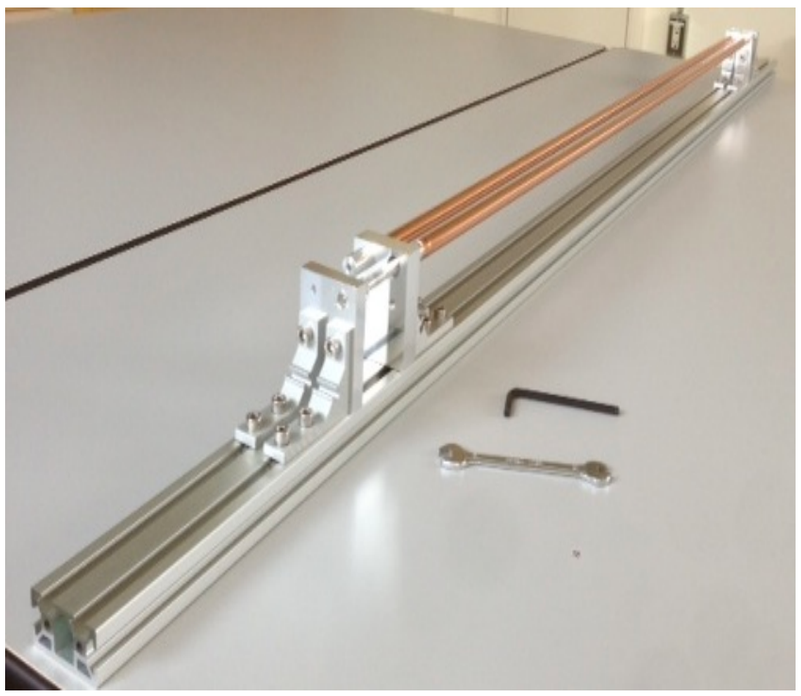


- In particular, special feedthrough for straw has to be developed to apply tension as well as provide gas flow and signal feedthrough.

Feedthrough/Tensioning system

- *eg*. Pretensioning on straw by Newly developed feedthrough system





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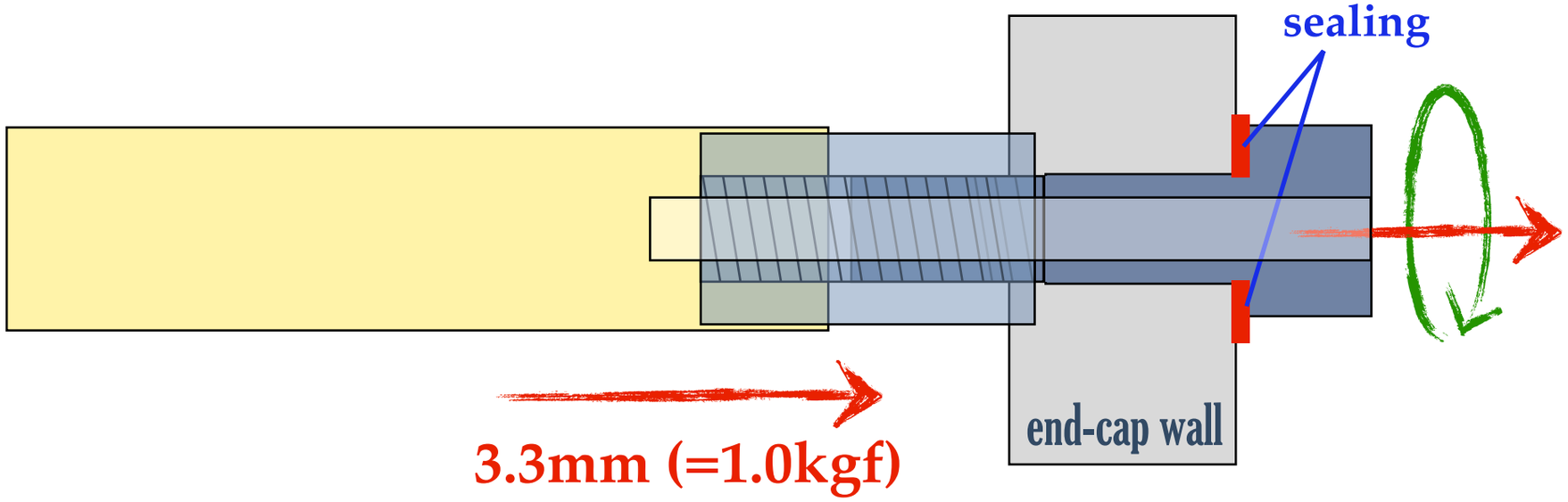

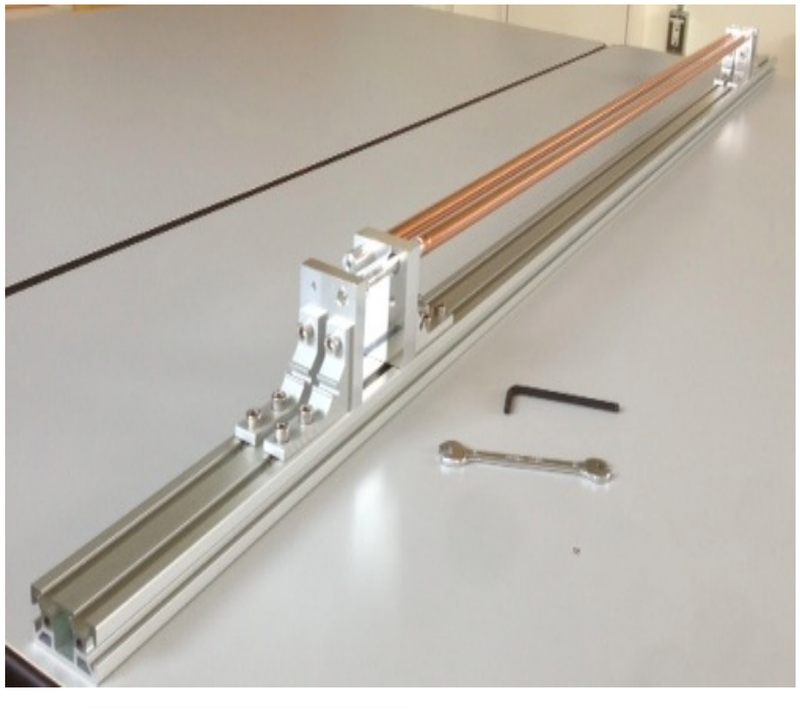

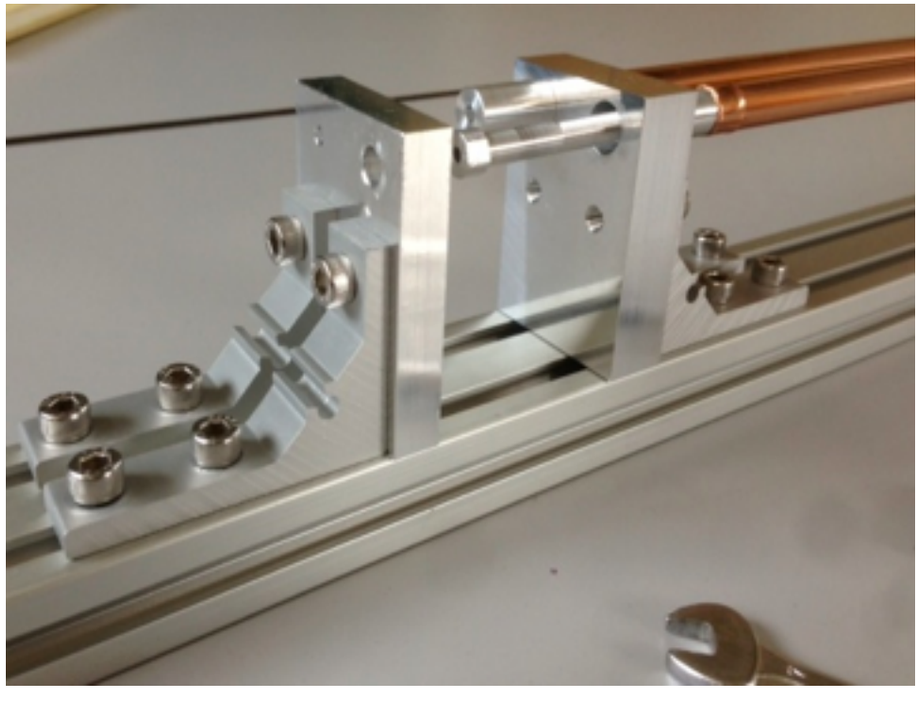

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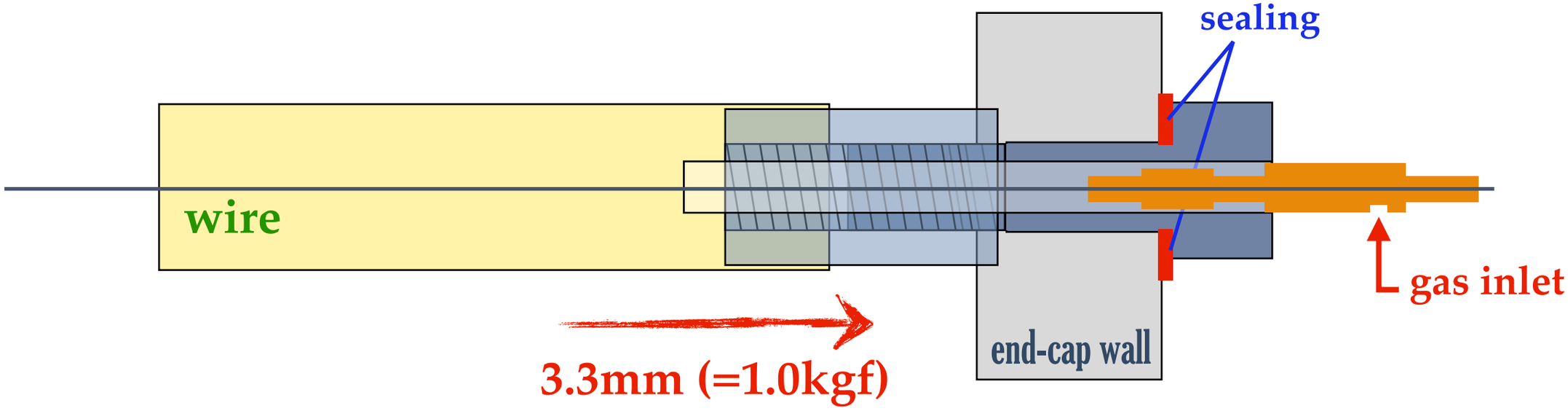
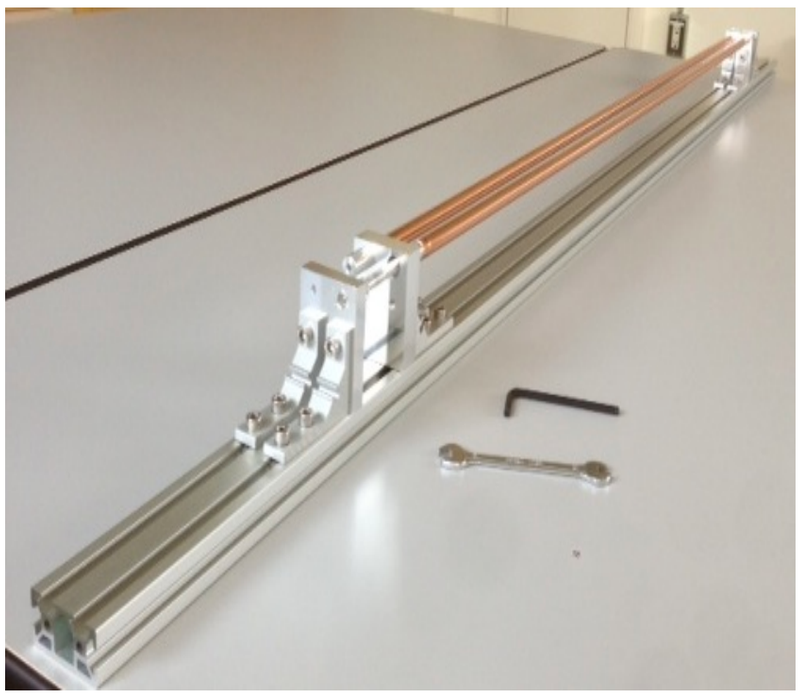
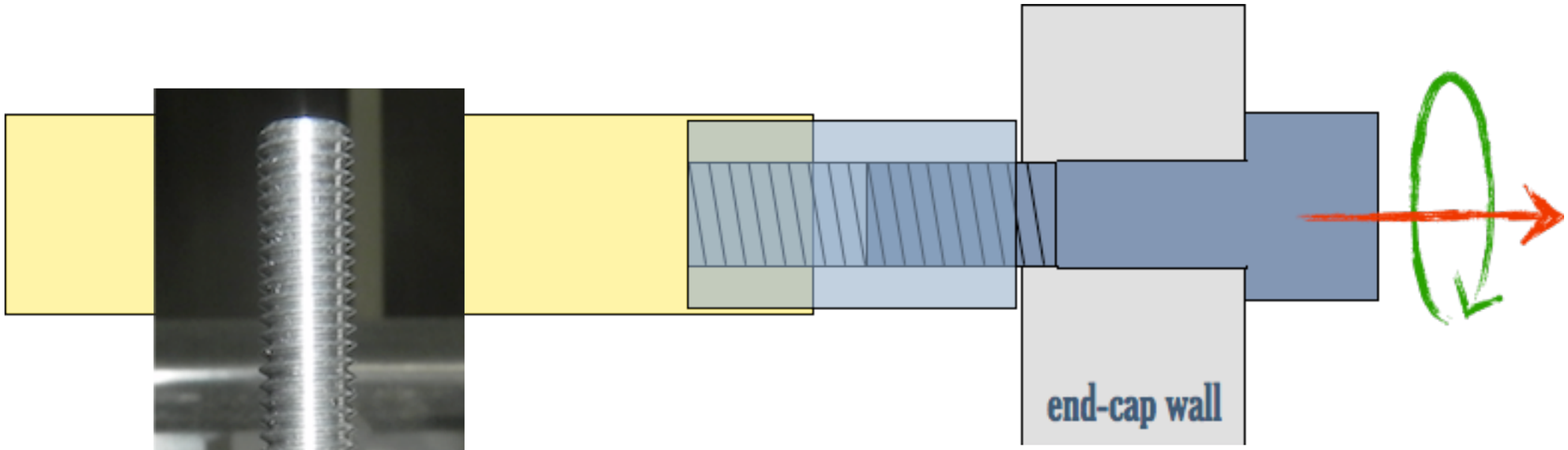
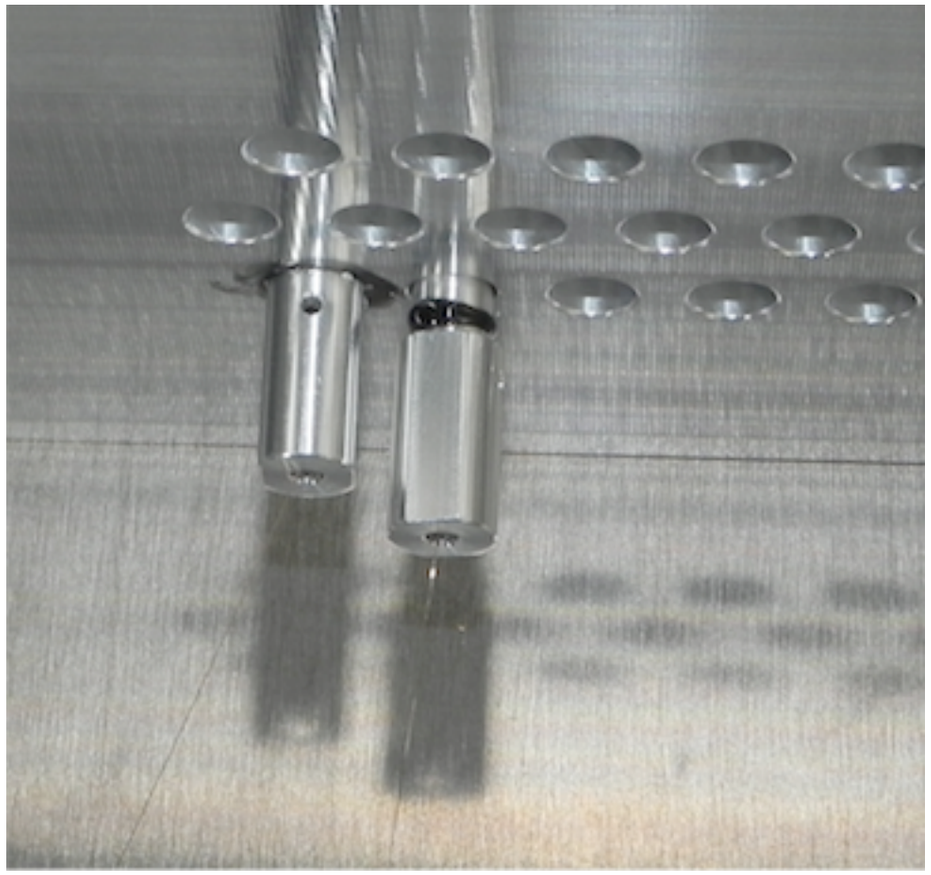




Prototype Assembly





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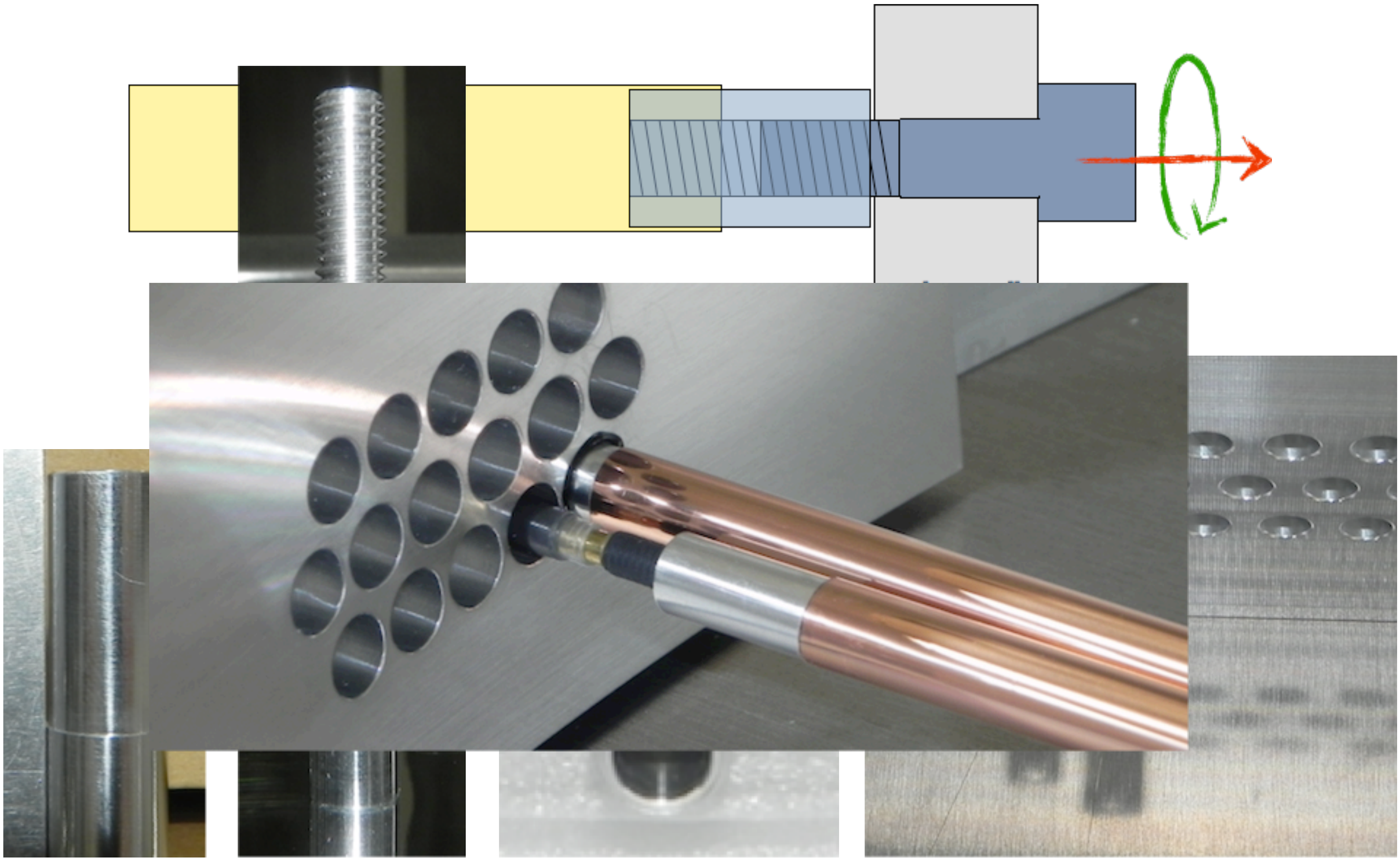

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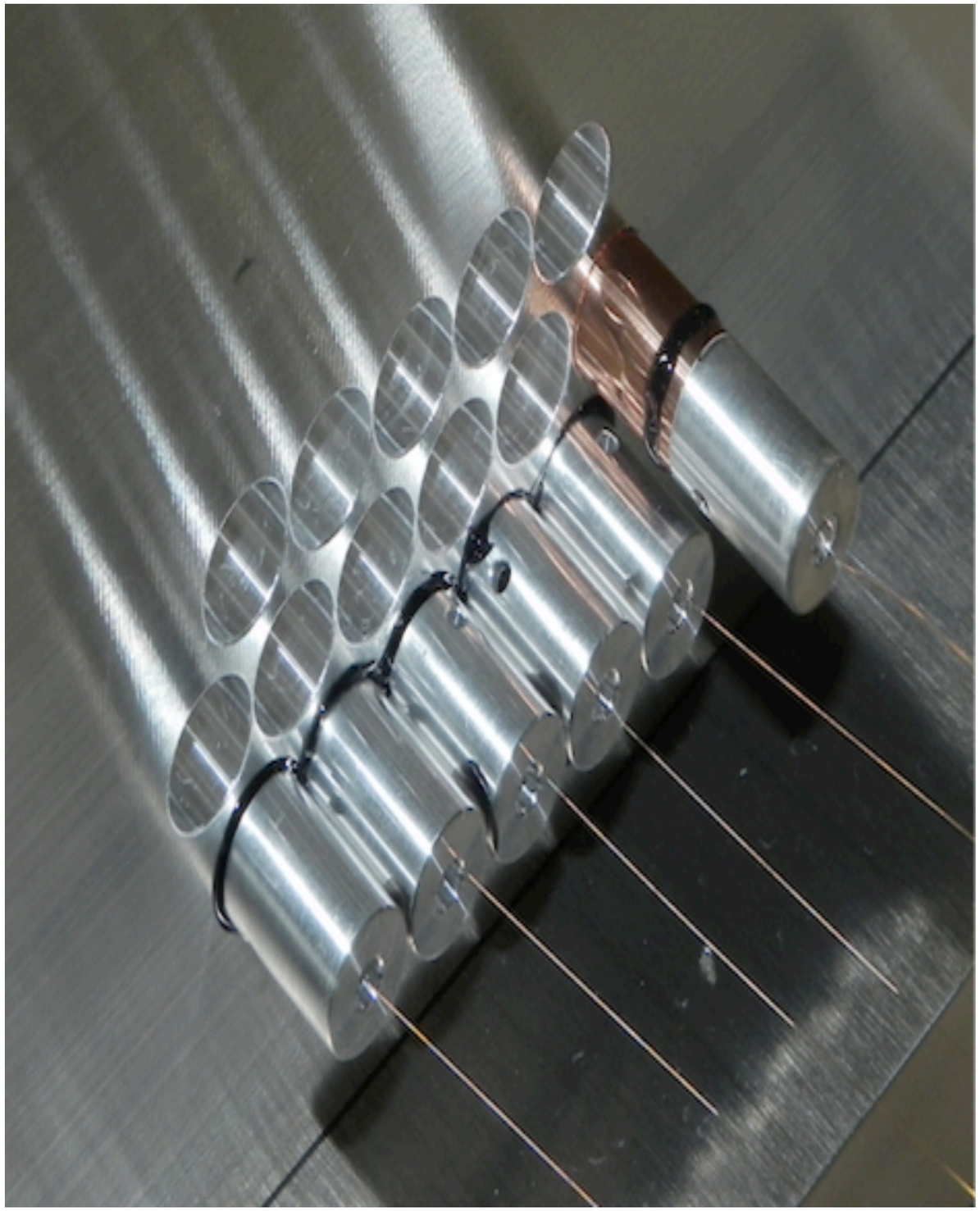

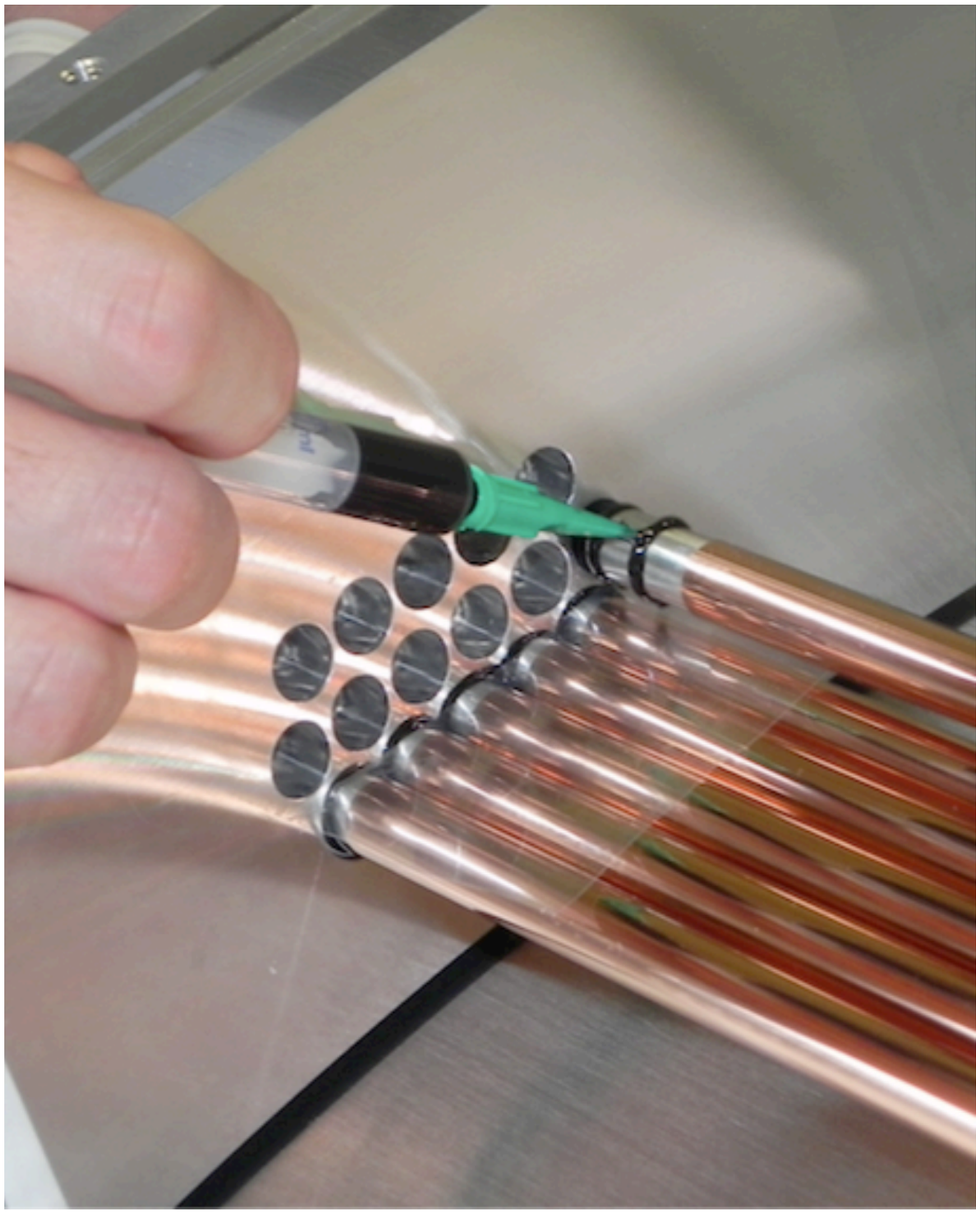

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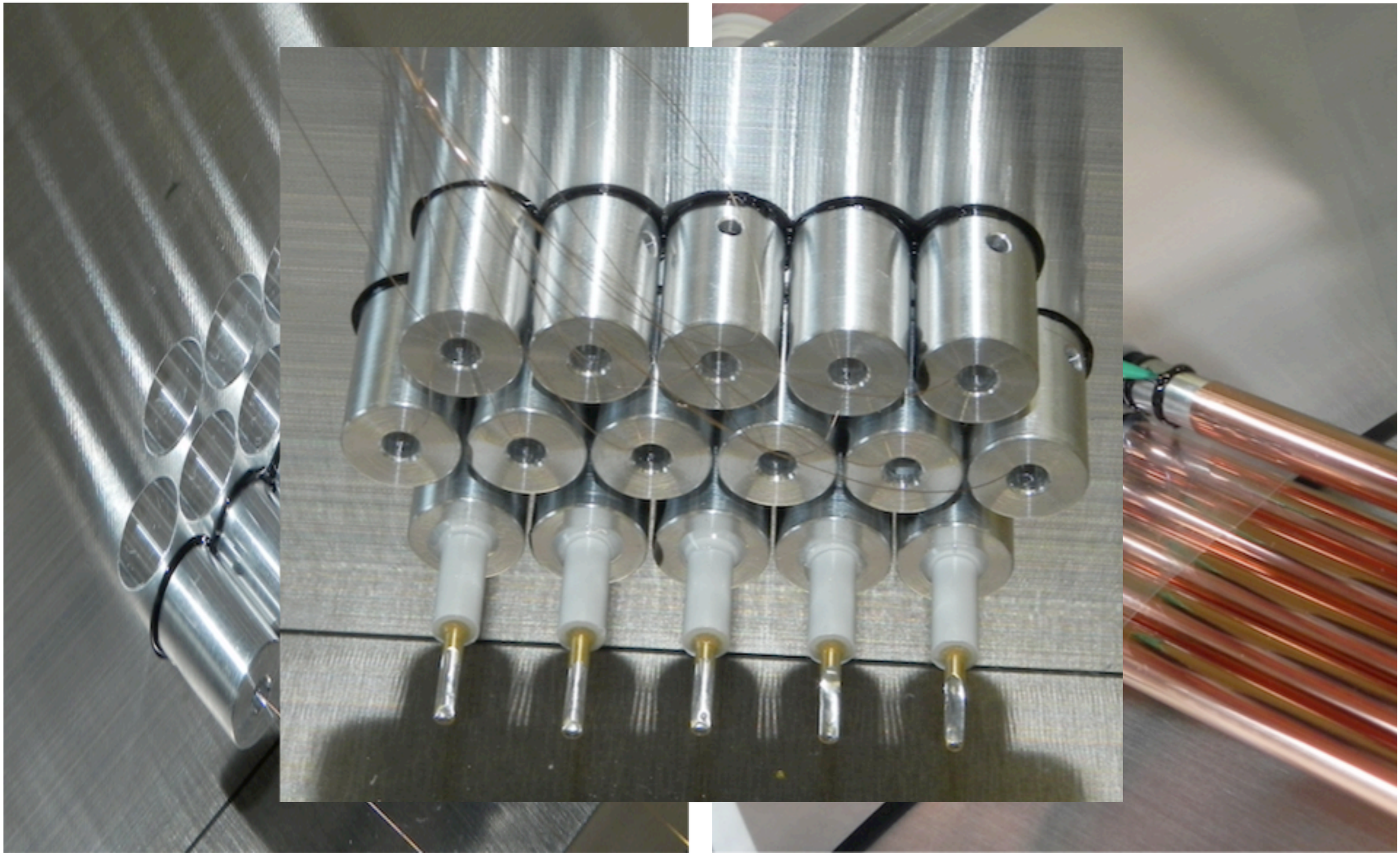

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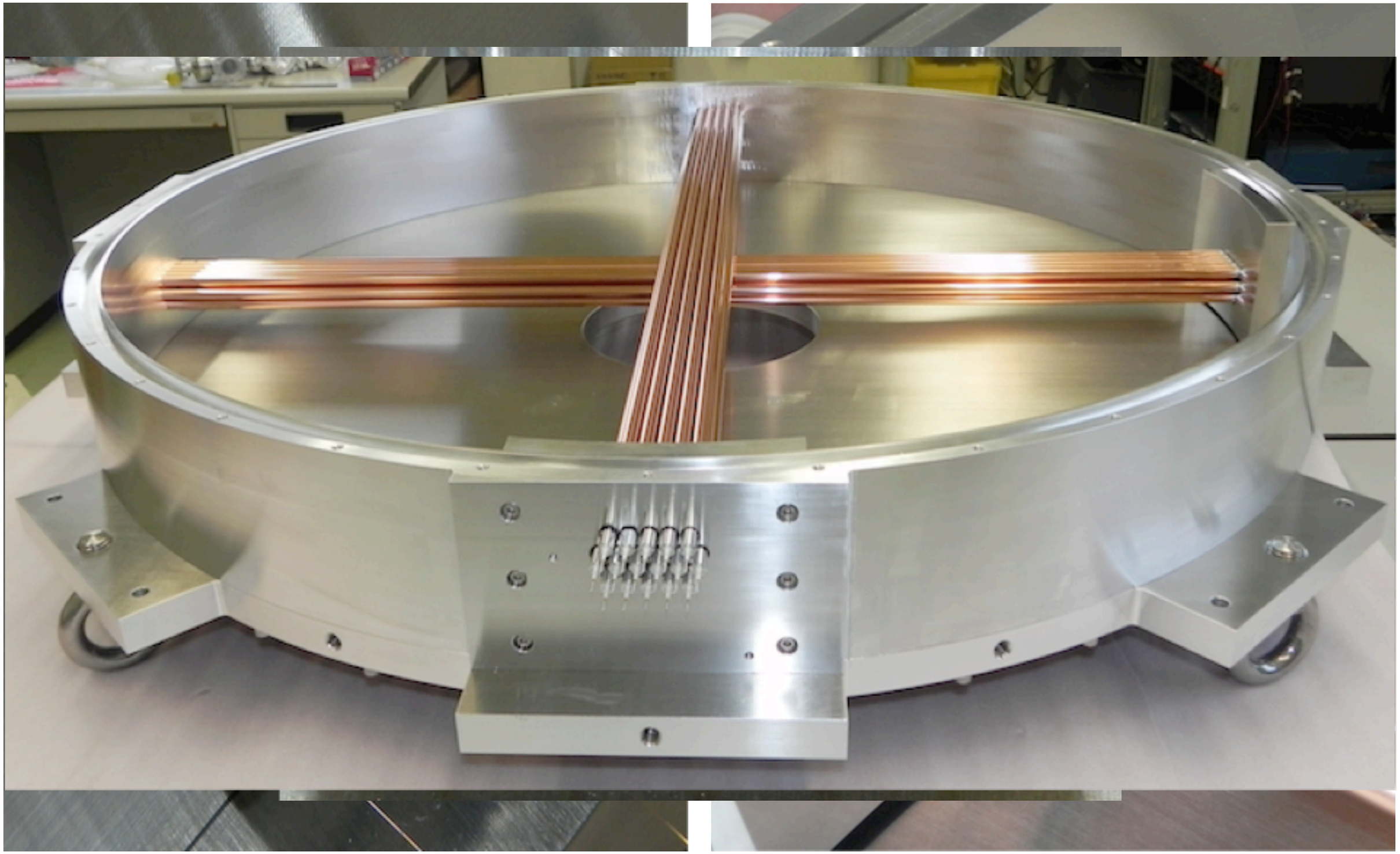

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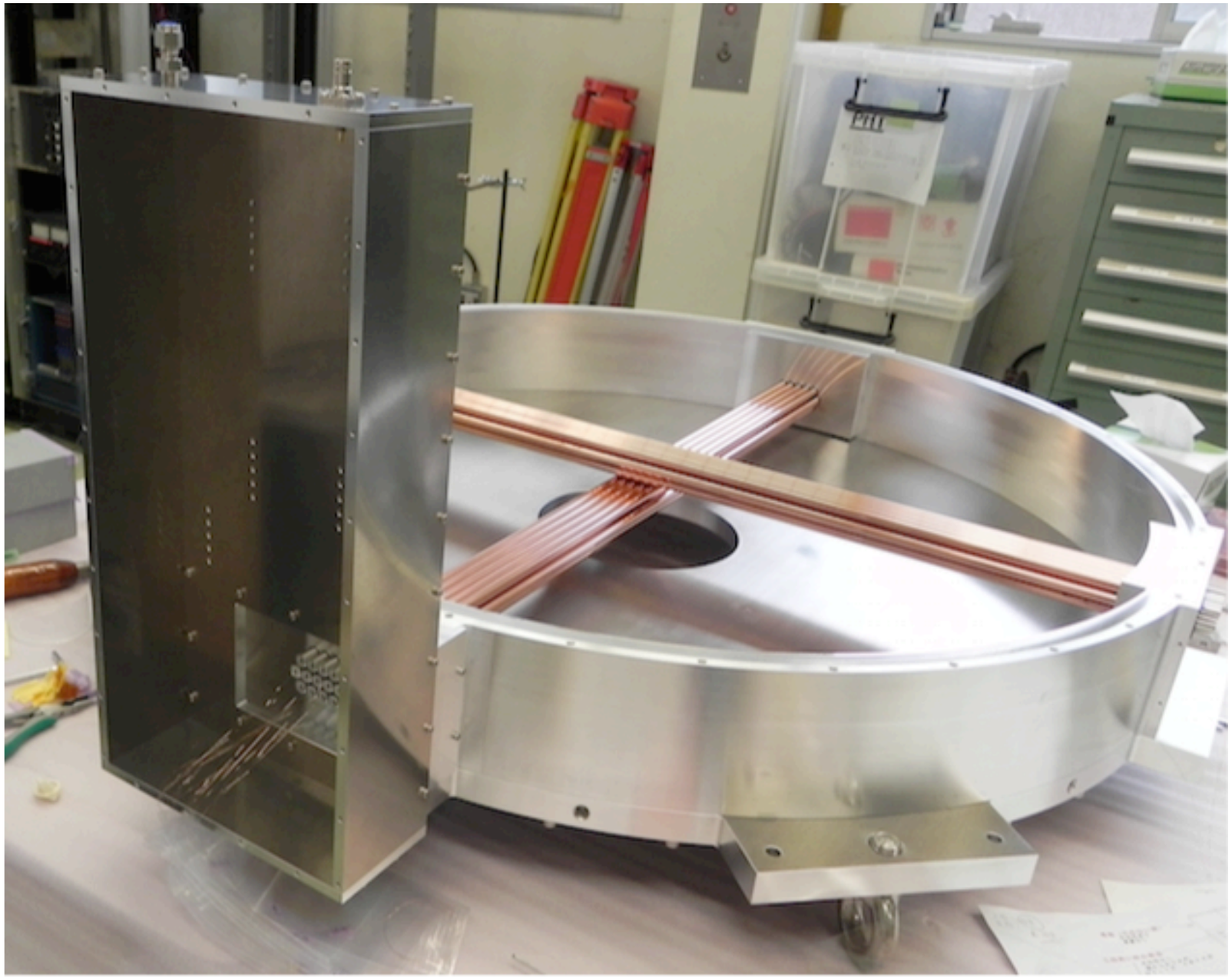

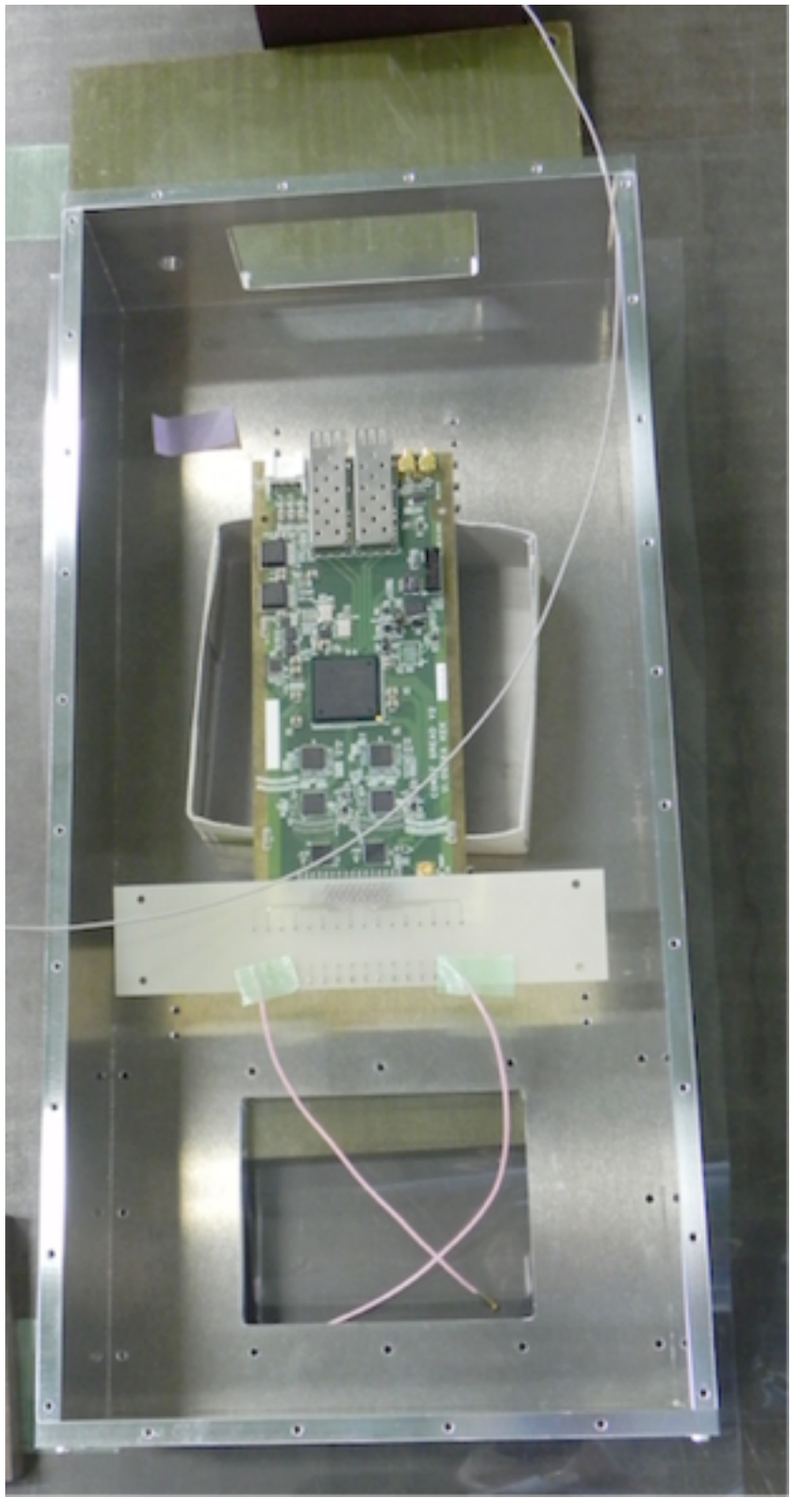

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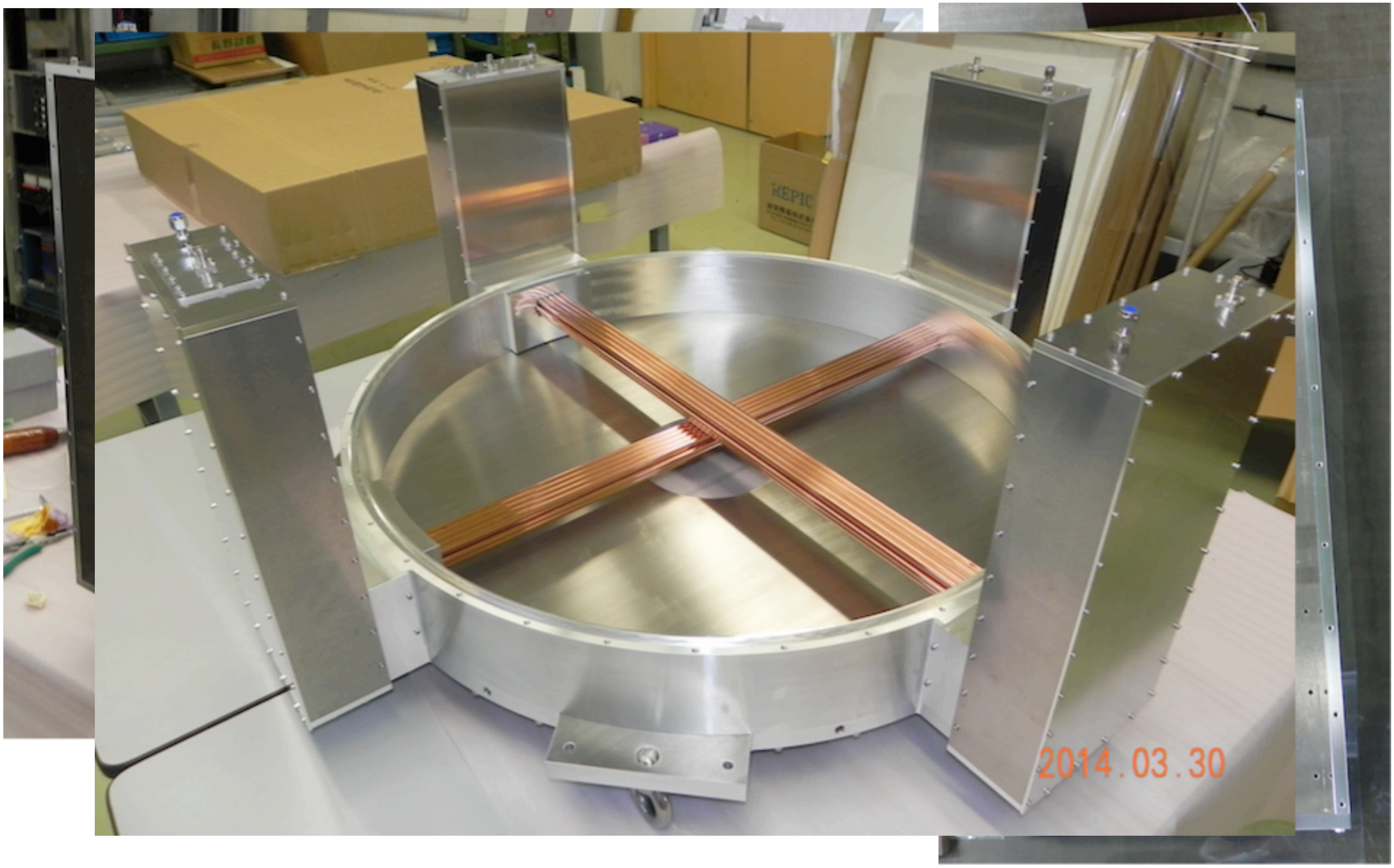
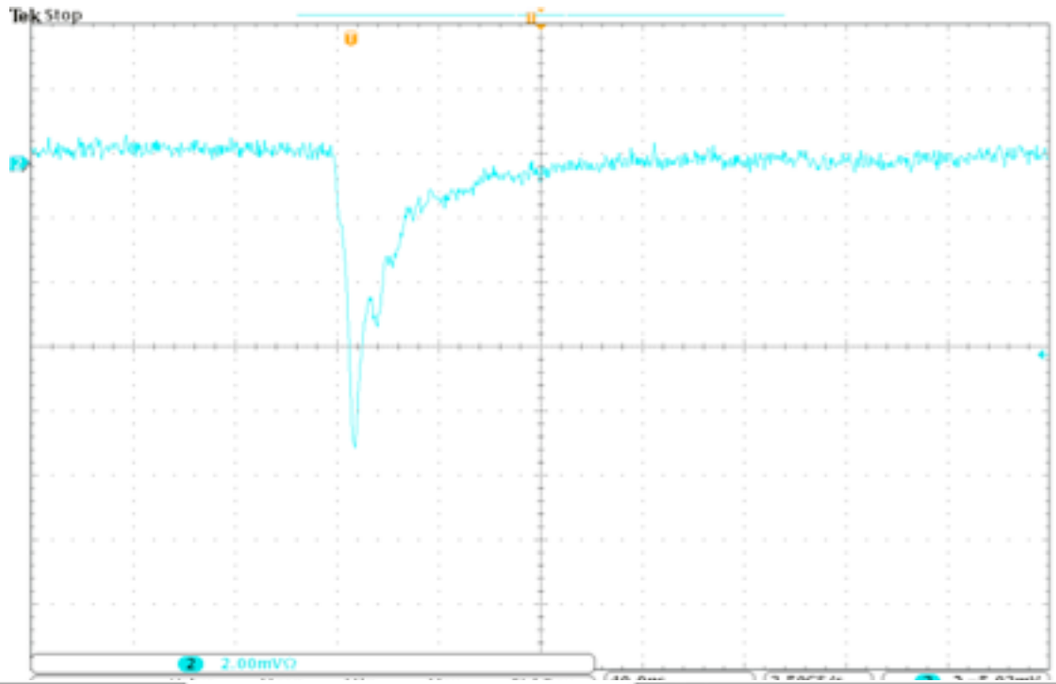
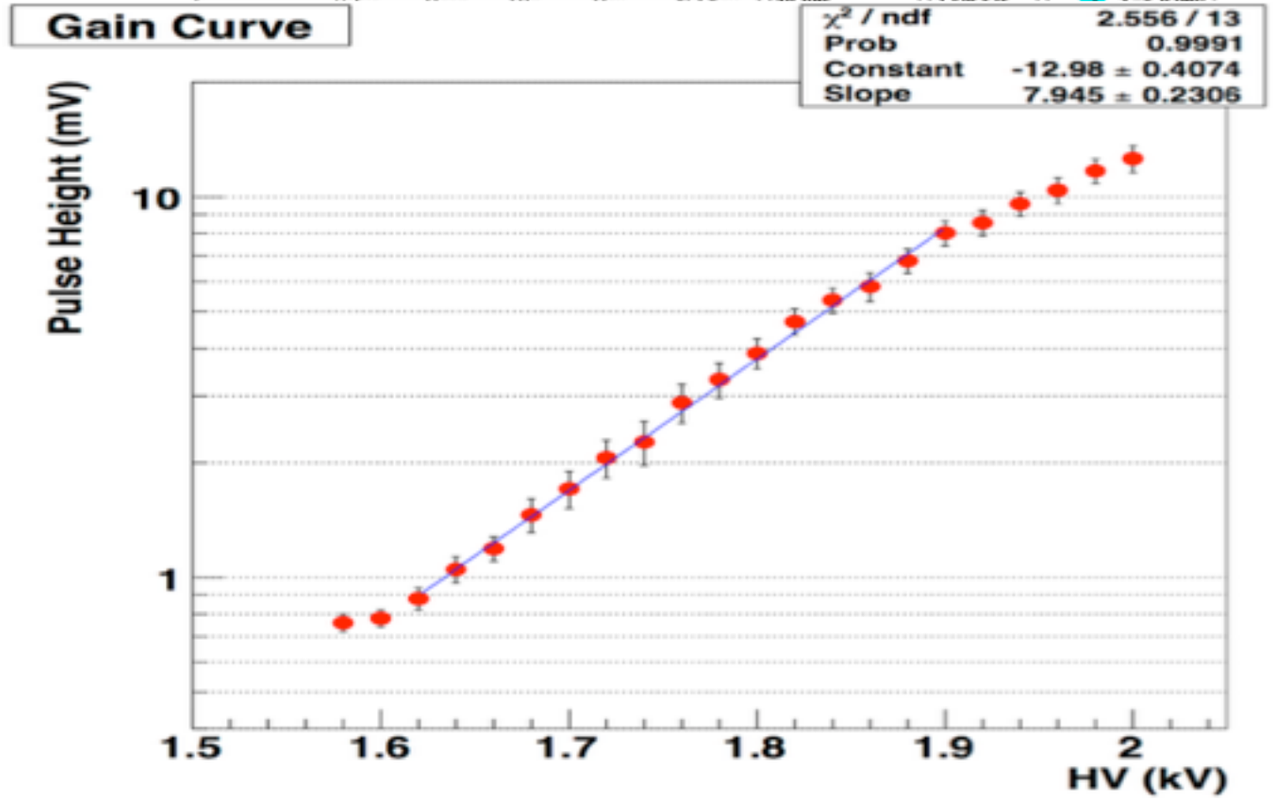


Current status of assembly prototype

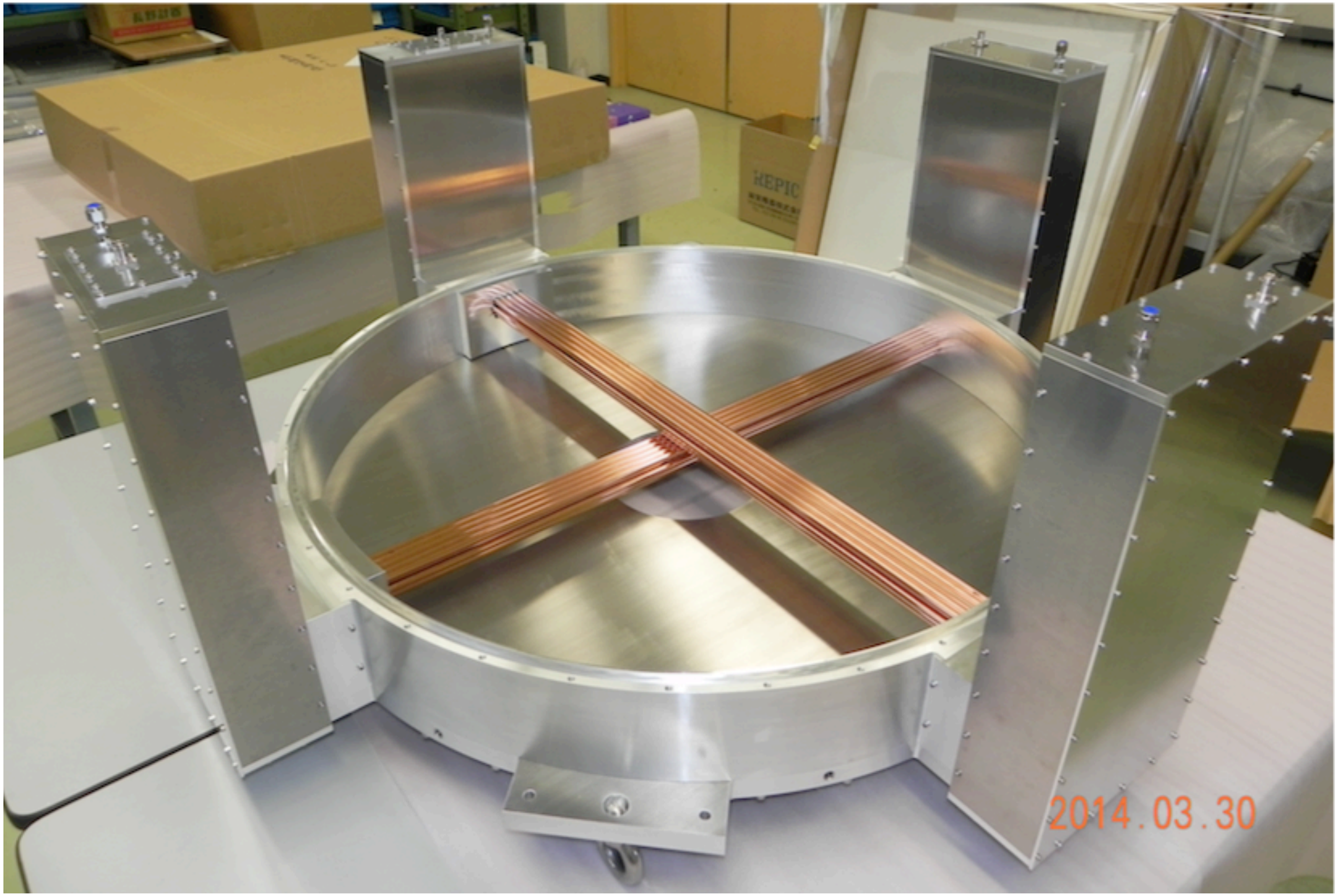
- Prototype was completed just last month, then now HV conditioning and some fundamental studies are ongoing; gain, efficiency, resolution, *etc*.



- In parallel to the fundamental studies, preparation for the vacuum test is also ongoing;
  - straw mechanical properties in vacuum is important study item for this prototype.



Vacuum Test



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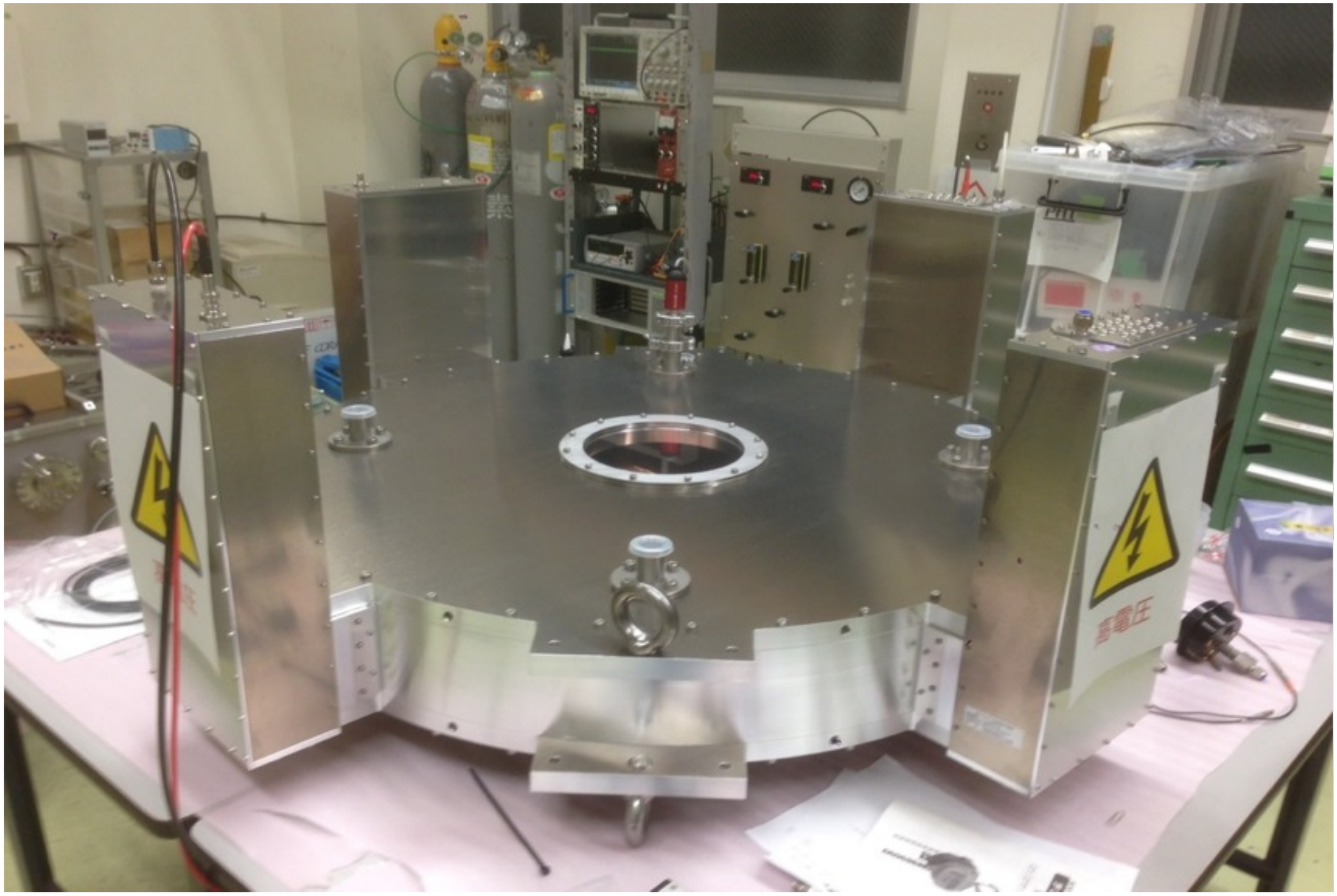

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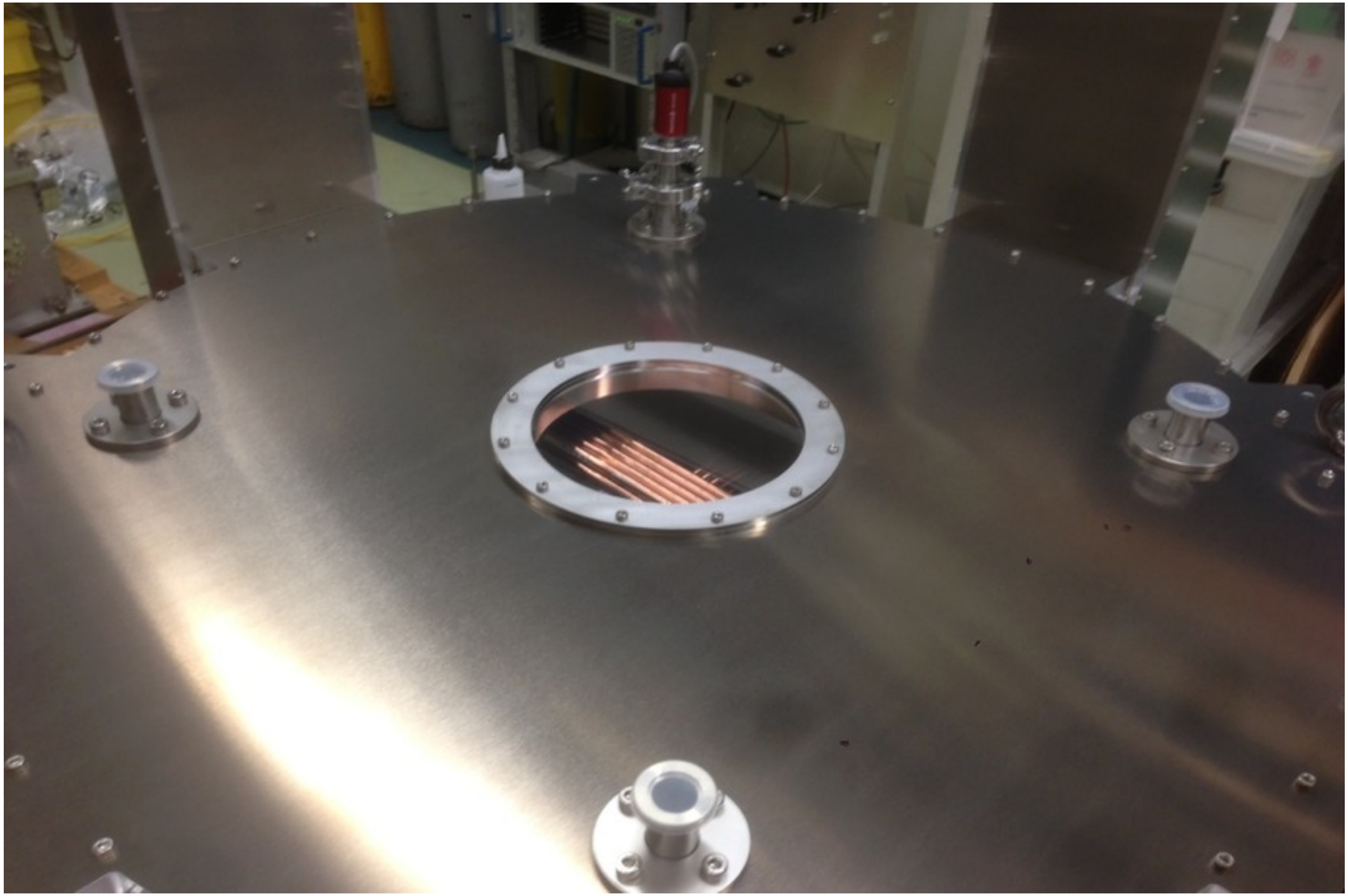

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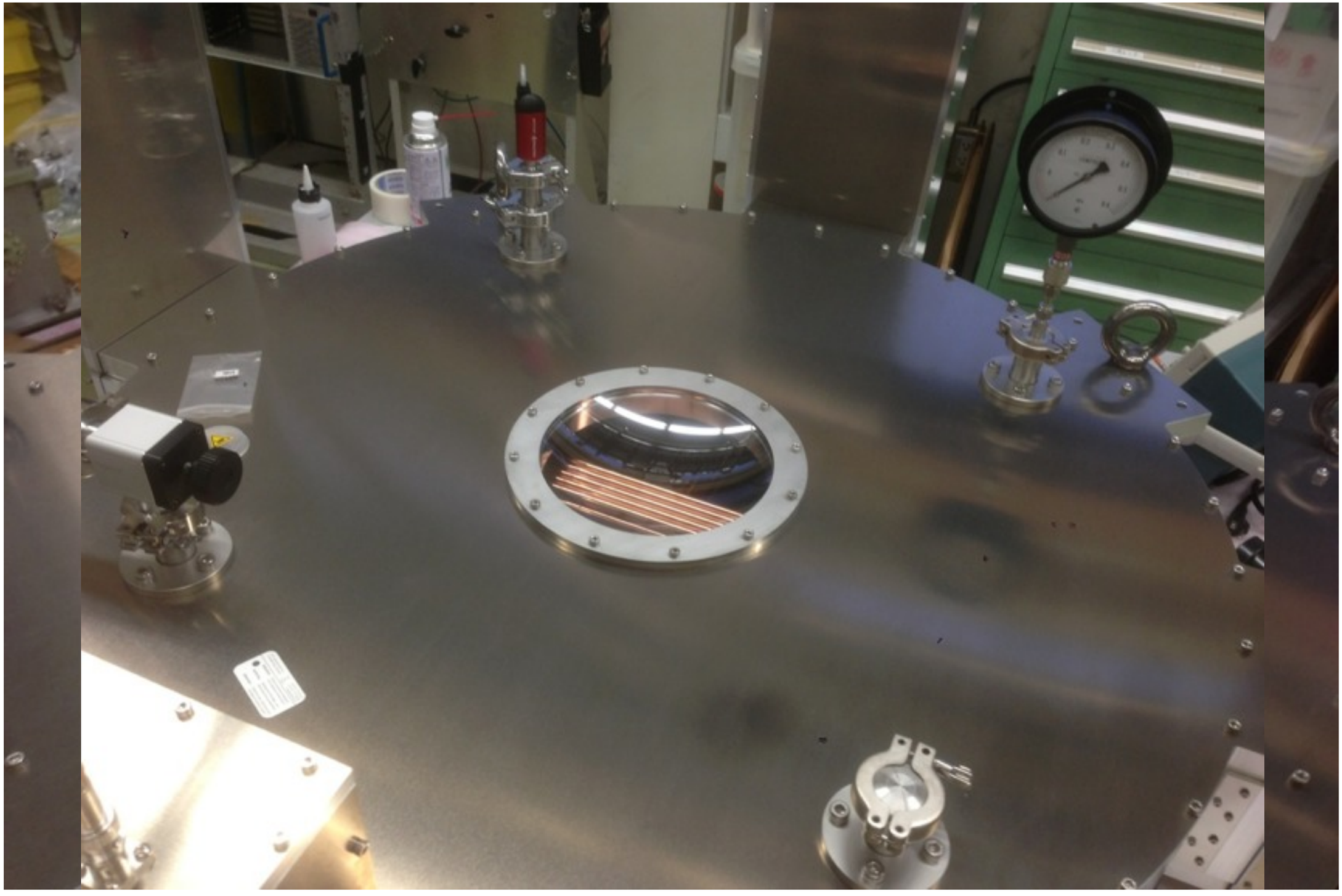

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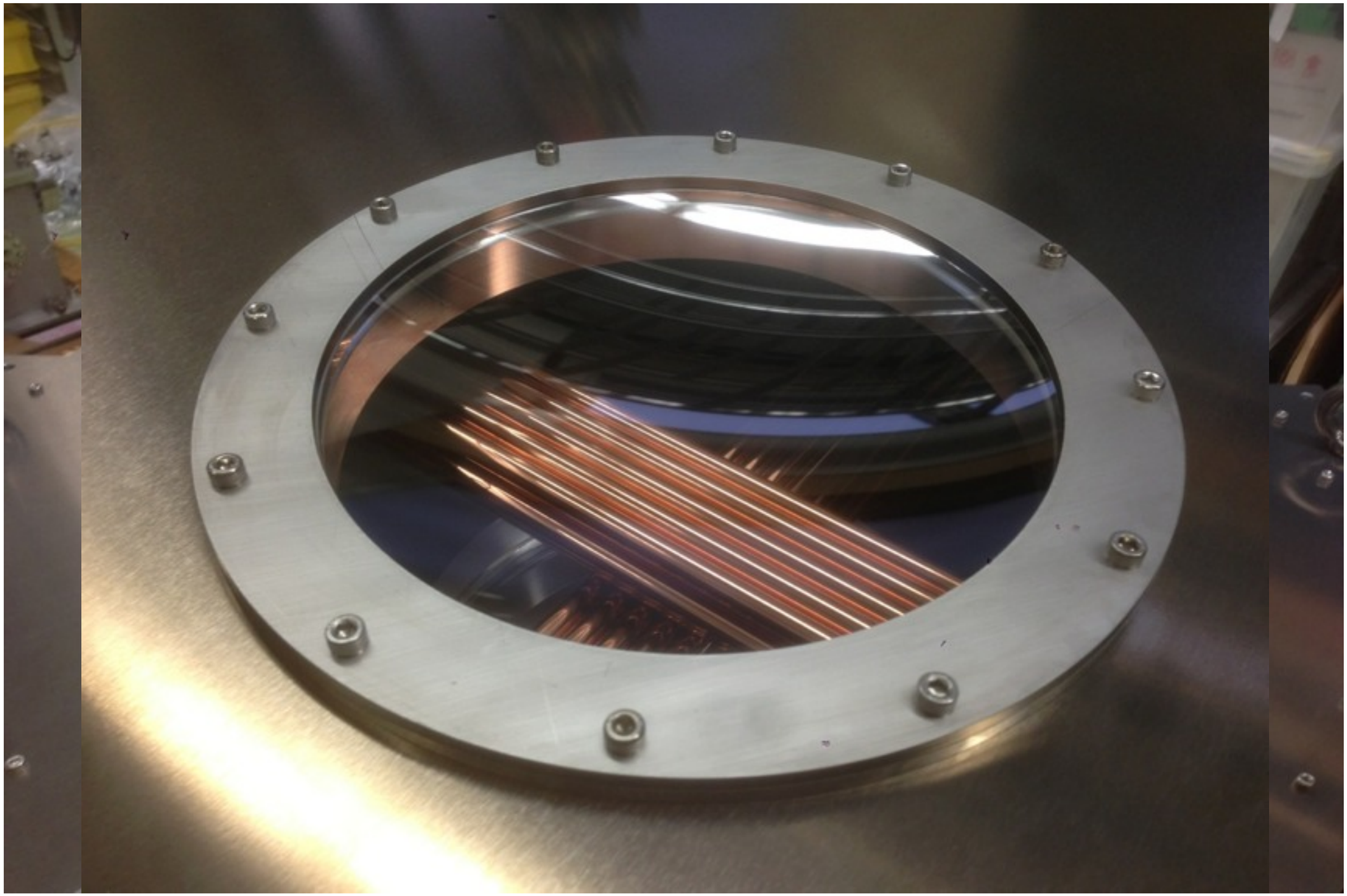

Final prototyping strategy and schedule

	FY2014			FY2015	FY2016
assembly prototype	fundamental study		straw test in vacuum → final decision on straw choice		
straw trial	1st	2nd			
front-end development	prototype-2		final design	mass production	
manifold design	optimization				
real detector	design finalize by the end of FY2014			construction	

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Poster-157
"ROESTI: A Front-end Electronics for Straw Tube Tracker in COMET"
by Kazuki UENO

Conclusions

- **Straw Tracker development for COMET is ongoing.**
  - **Searching for $\mu^- N \rightarrow e^- N$, Lepton Flavour Violation, at J-PARC**
  - **Should be operational in vacuum, Should be made by light material**
    - **Good momentum resolution (<200keV/c) for 100MeV electron**
- **To improve the material budget, straw development is ongoing.**
  - **1st trial (20μm + Al-cathode) was successfully done.**
  - **2nd trial (12μm) is ongoing**
- **Assembly prototype (*1-to-1* size) is constructed with NA62 straws**
  - **assembly technique development / gas manifold optimization**
  - **replacing the NA62 straws by COMET straws (1st/2nd), technical decision will be done by straw mechanical studies in vacuum**
- **Aiming to finalize the design by FY2014, and to complete the construction by FY2016.**

appendices

COMET Experiment - Overview -

High Intensity Muon

Pion capture and muon transport by superconducting solenoids would provide high beam intensity.

Pulsed Muon Source

Beam pulsing is very important in order to suppress prompt BG.
Pulse Separation should be ≳ 1μsec.

Special Muon Transport

A muon beam line should be sufficient long to eliminate pions in a muon beam, and dedicated to reject DIO electrons.

High Resolution Detectors

Endpoint of spectrum of DIO electron comes to the signal region. Good σ_E is mandatory.

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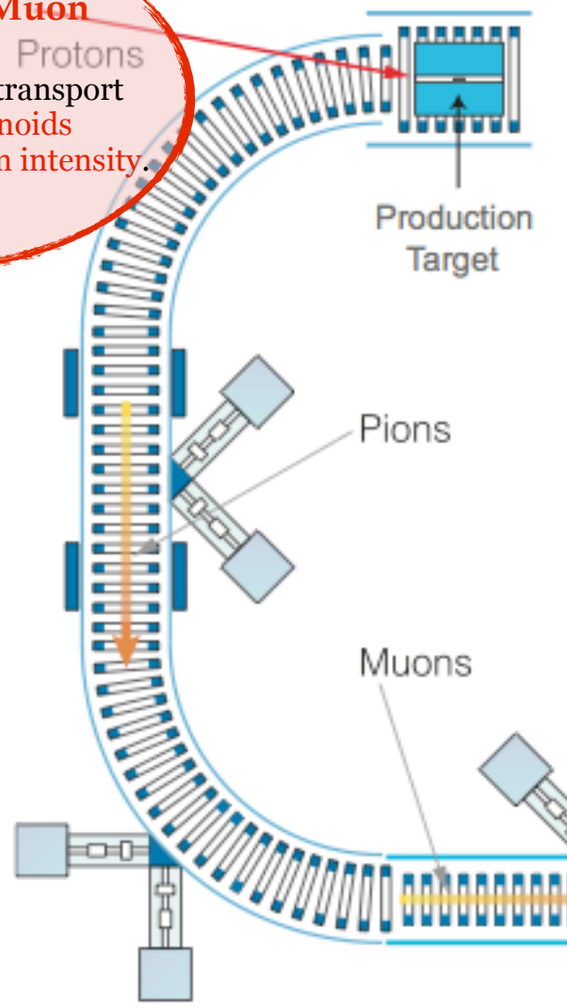
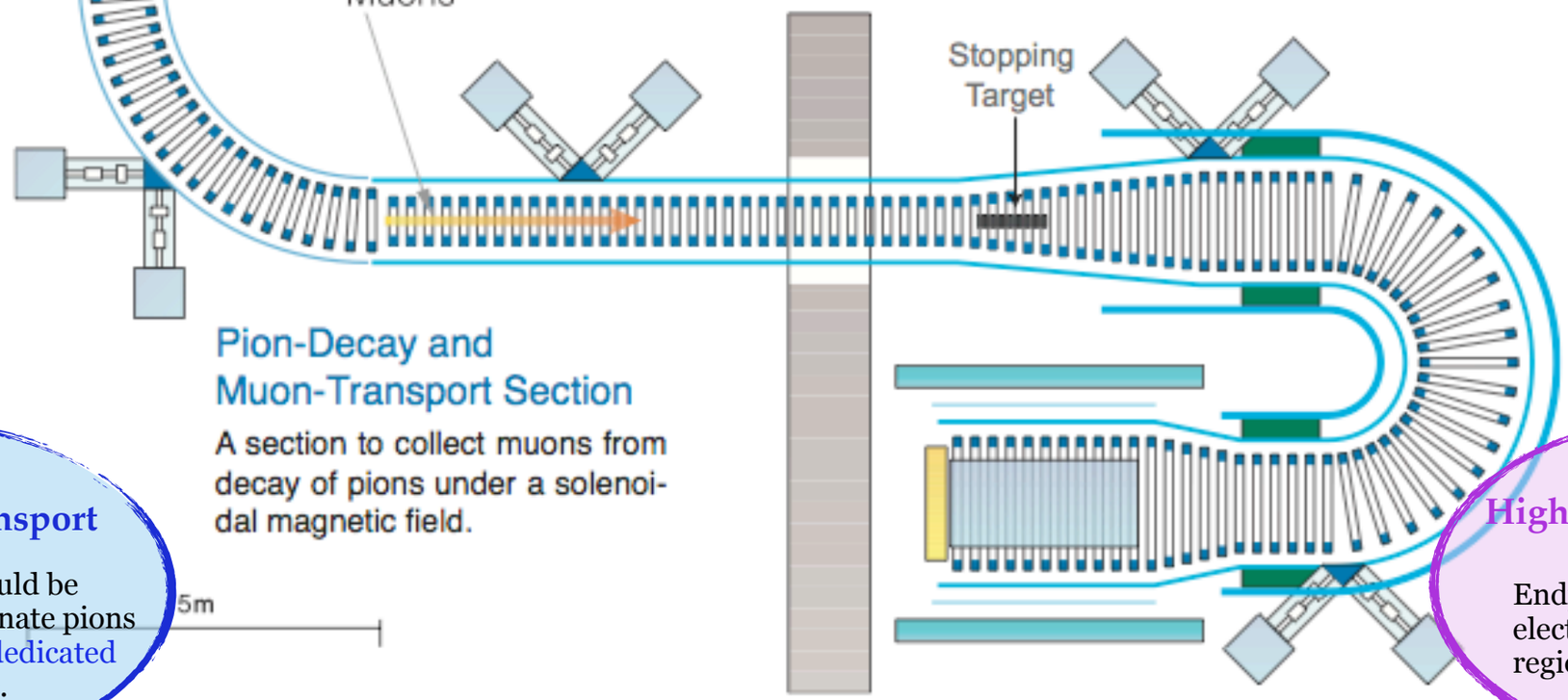


Pion Capture Section

A section to capture pions with a large solid angle under a high solenoidal magnetic field by superconducting maget

Detector Section

A detector to search for muon-to-electron conversion processes.



Pion-Decay and Muon-Transport Section

A section to collect muons from decay of pions under a solenoidal magnetic field.

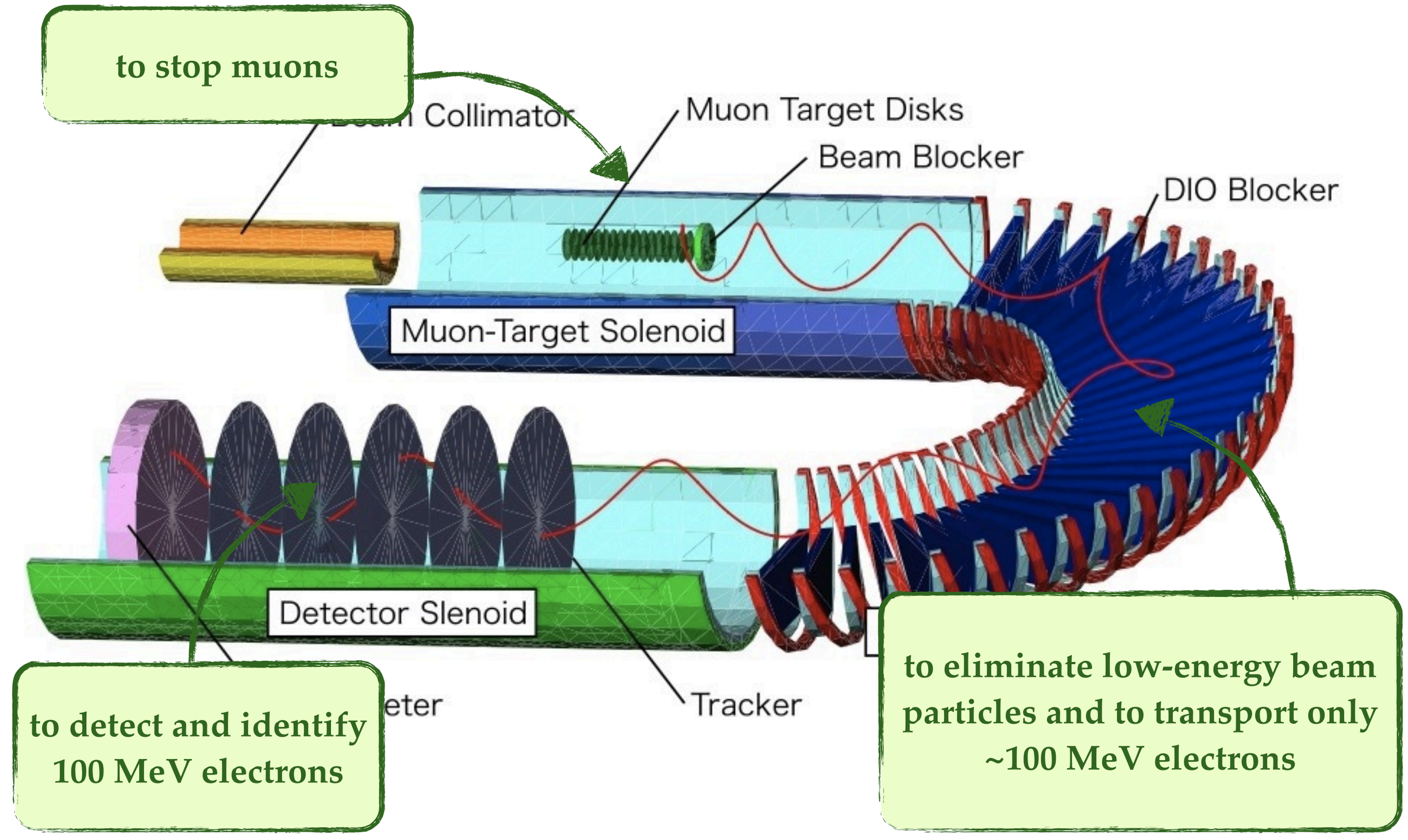
Special Muon Transport

A muon beam line should be sufficient long to eliminate pions in a muon beam, and dedicated to reject DIO electrons.

High Resolution Detectors

Endpoint of spectrum of DIO electron comes to the signal region. Good σ_E is mandatory.

COMET Detector Apparatus



COMET Expected Sensitivity

- Single Event Sensitivity (2×10^7 sec running):

$$\mathcal{B}(\mu^- + \mathrm{Al} \to \mathrm{e}^- + \mathrm{Al}) \sim \frac{1}{N_\mu \cdot f_{\mathrm{cap}} \cdot A_\mathrm{e}}$$

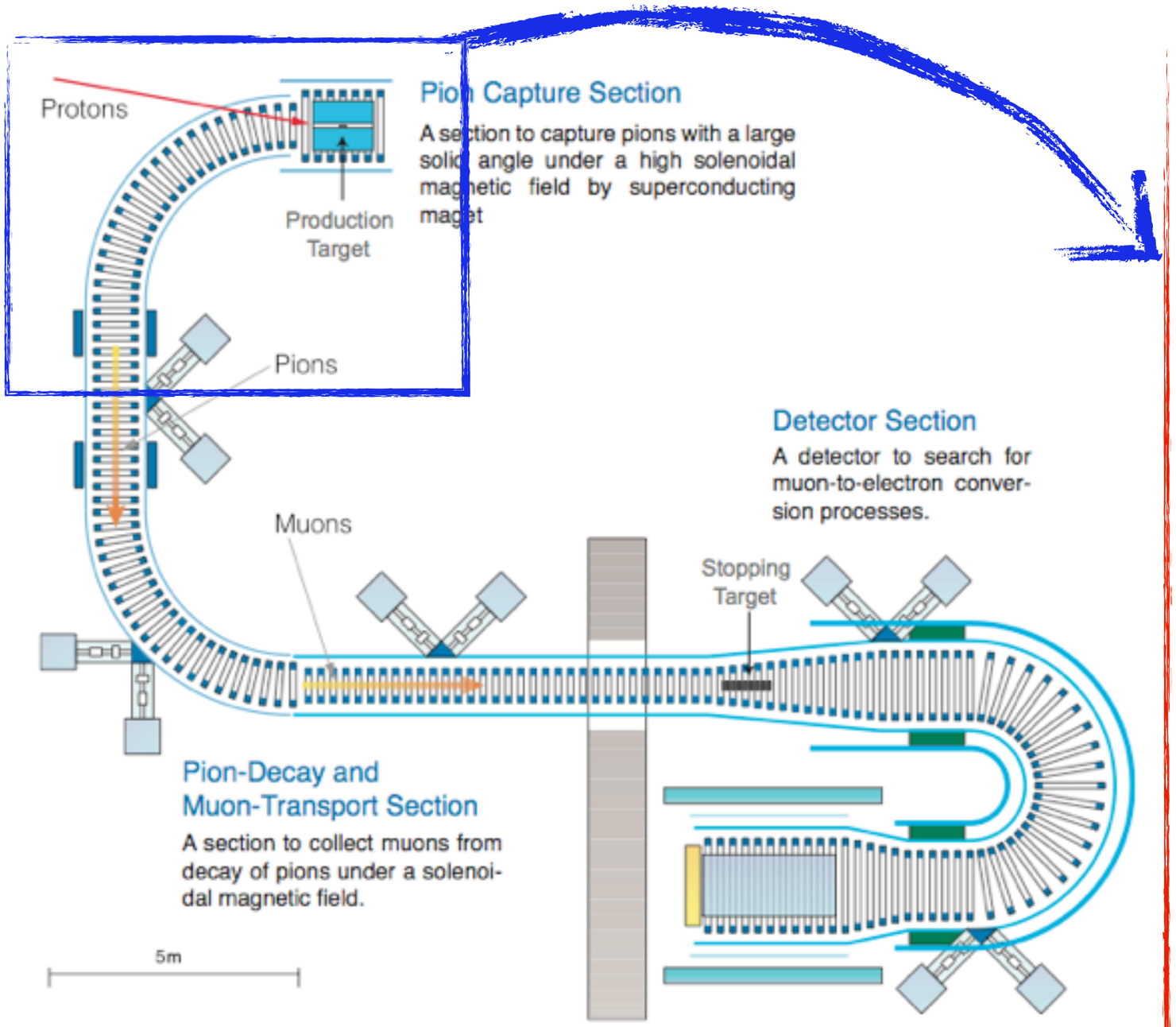
  - N_μ is a # of stopped muons
    - 2.0×10^{18} muons
  - f_{cap} is a fraction of muon capture
    - 0.6 for aluminum
  - A_e is the detector acceptance
    - 0.031

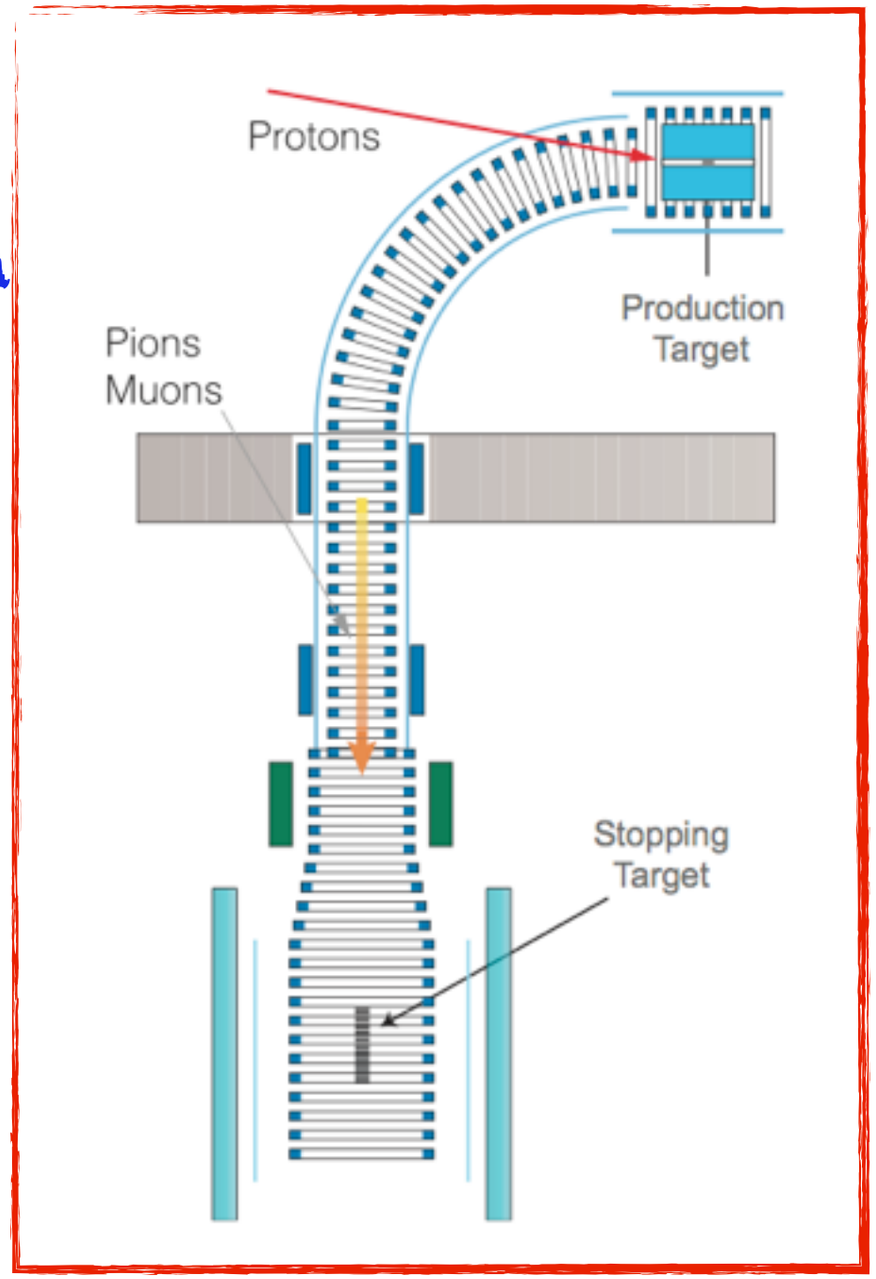
total # of p's	**8.5×10^{20}**
μ yield / p	**0.0035**
μ stopping ε	**0.66**
# of stopped μ's	**2.0×10^{18}**

Single Event Sensitivity
2.6×10^{-17}

Upper Limit (CL.90)
6.0×10^{-17}

Staging Approach for the COMET Realization



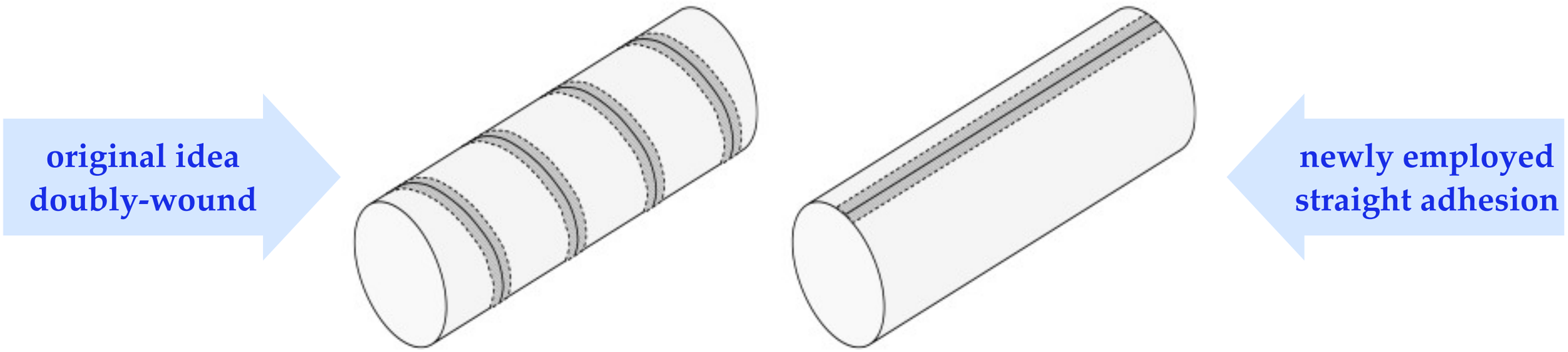


full COMET (phase-II)

(phase-I)

Straw tube

- Original design (CDR) employed the “doubly-wound” straw tube.
  - Changed to the new straw : “straight-adhesion” straw tube.

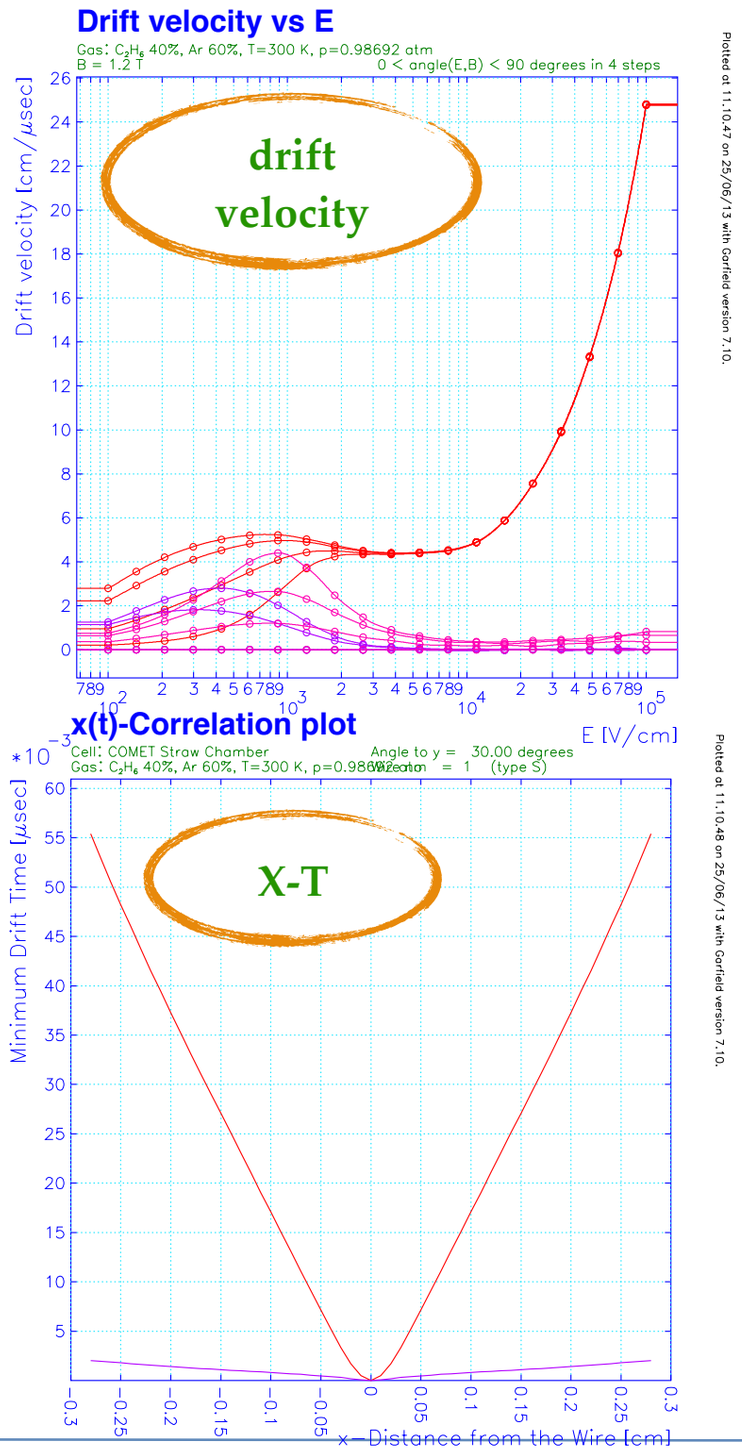


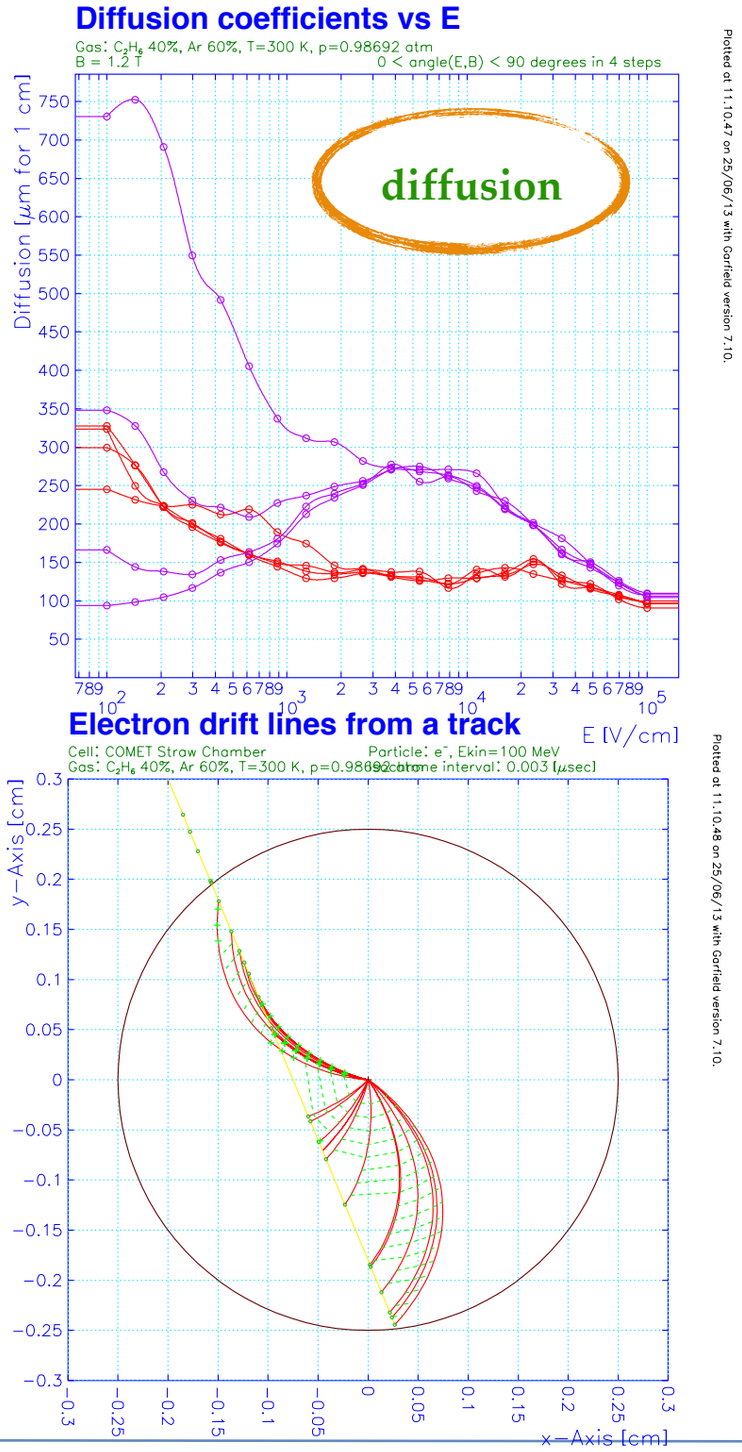
- New adhesion style has been developed by JINR group for NA62 experiment at CERN, enabled by ultrasonic welding method.
- **Ads**.: Small gas leakage due to short length of seam, small amount of material due to no glue is needed, possibly make it thinner, mass-production by JINR group in house → Big advantage for cost
- Issue; Straw-wall thickness and material
  - NA62 straw ; 9.75mm diameter / 36μm-thickness mylar + Cu deposition

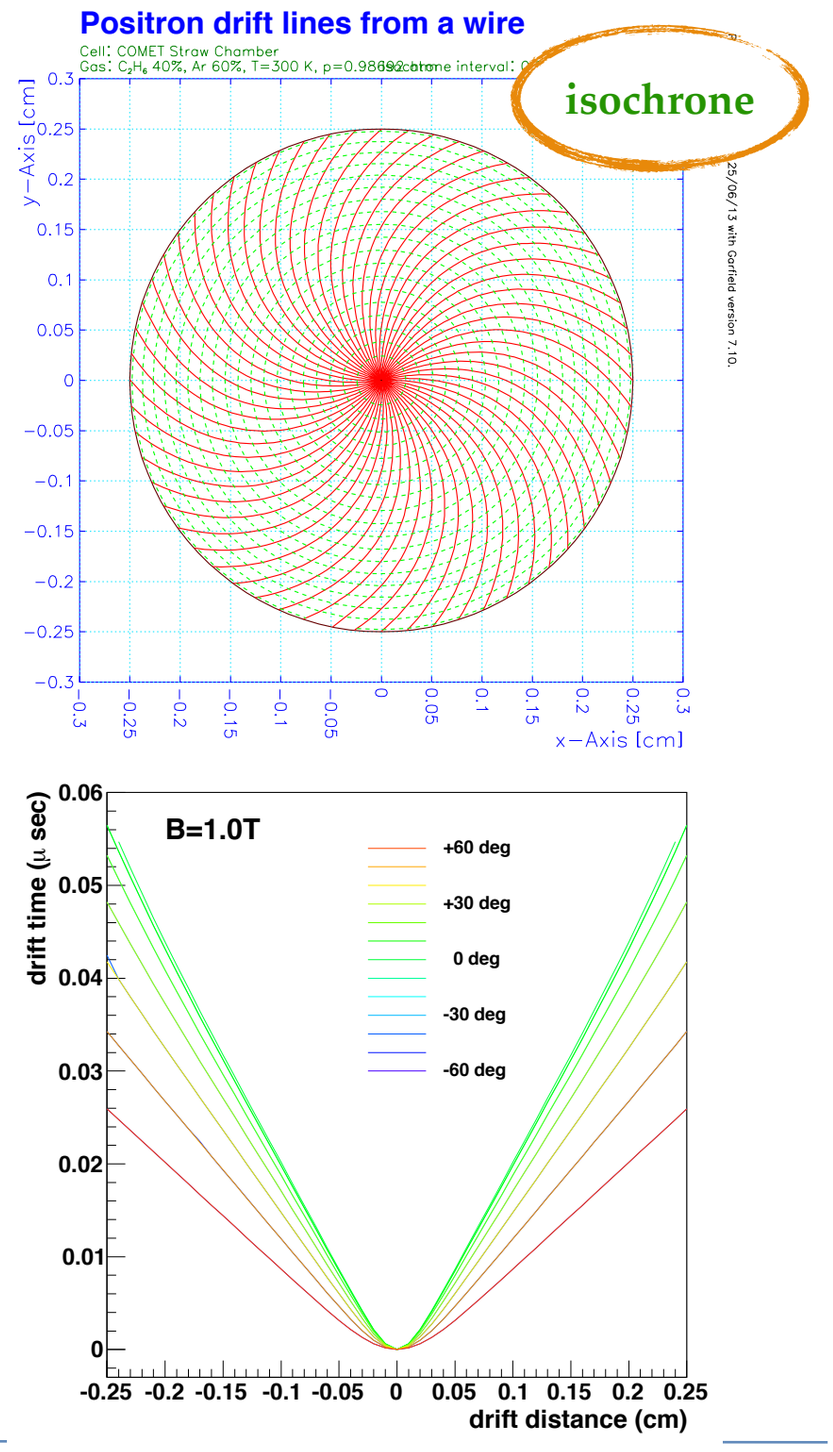
    → Thicker and heavier than our requirement, Not acceptable

Chamber active gas

- **Ar-C_2H_6 (50:50)** is employed as default gas mixture.

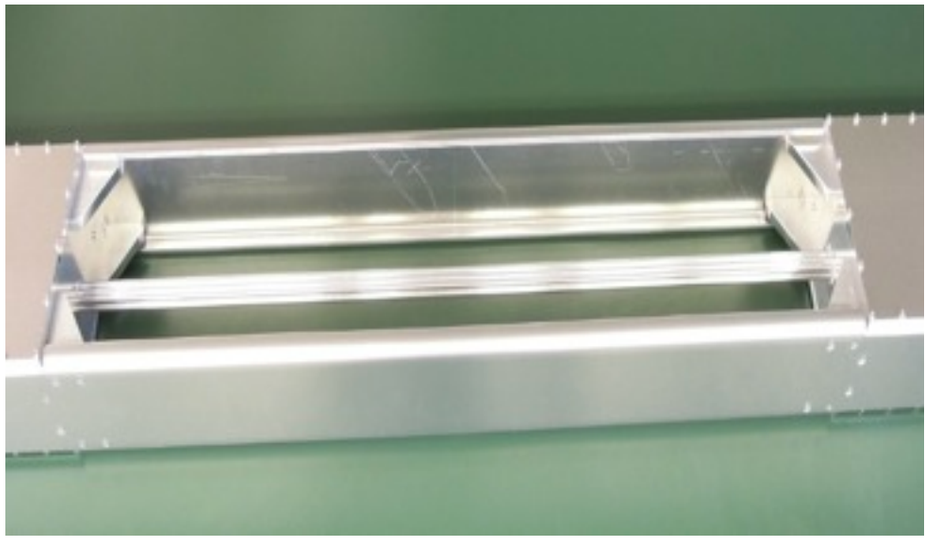


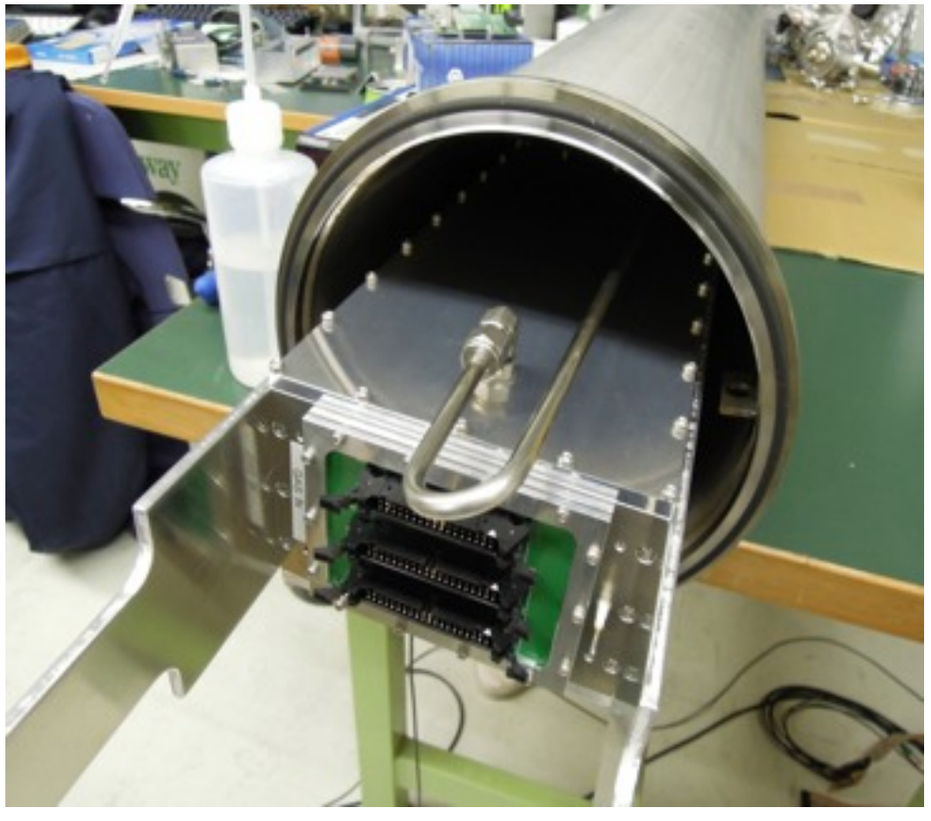


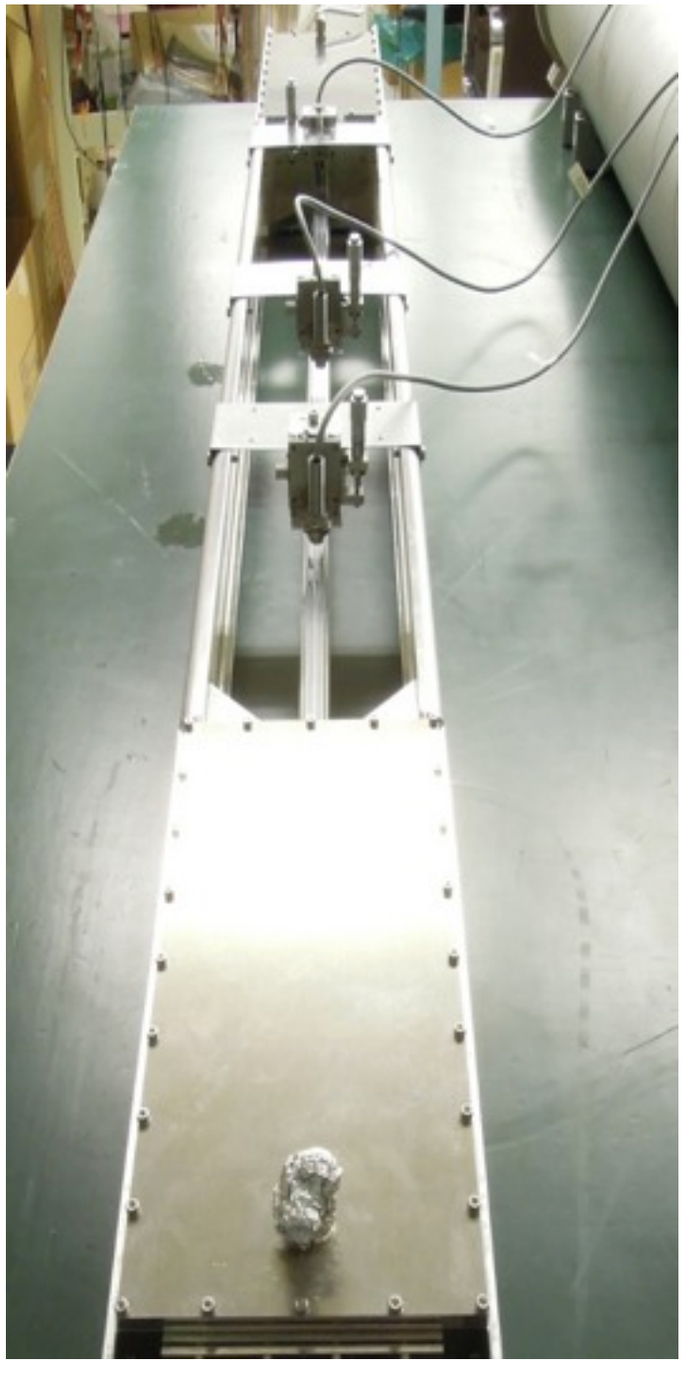


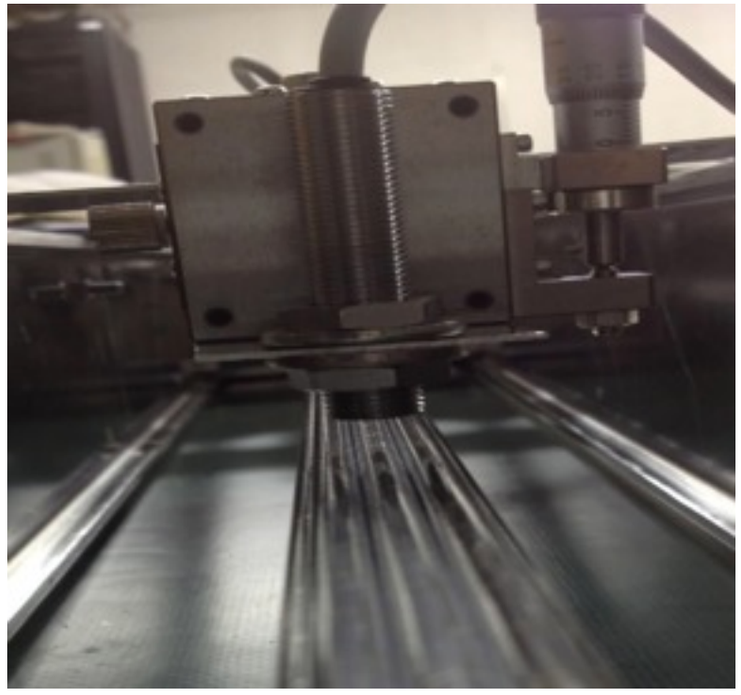
Straw Operation in Vacuum

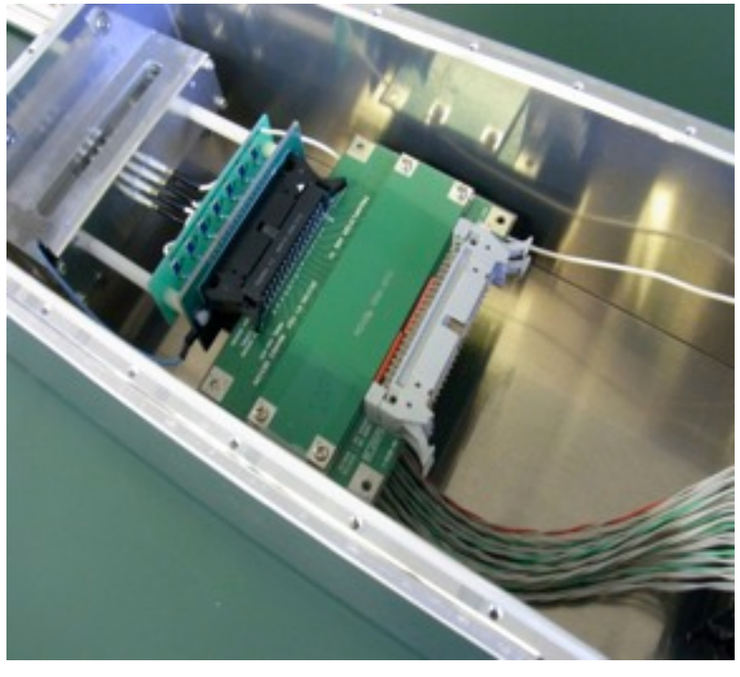
- **1-*to*-1** (but doubly-wound straw) length prototype test was done





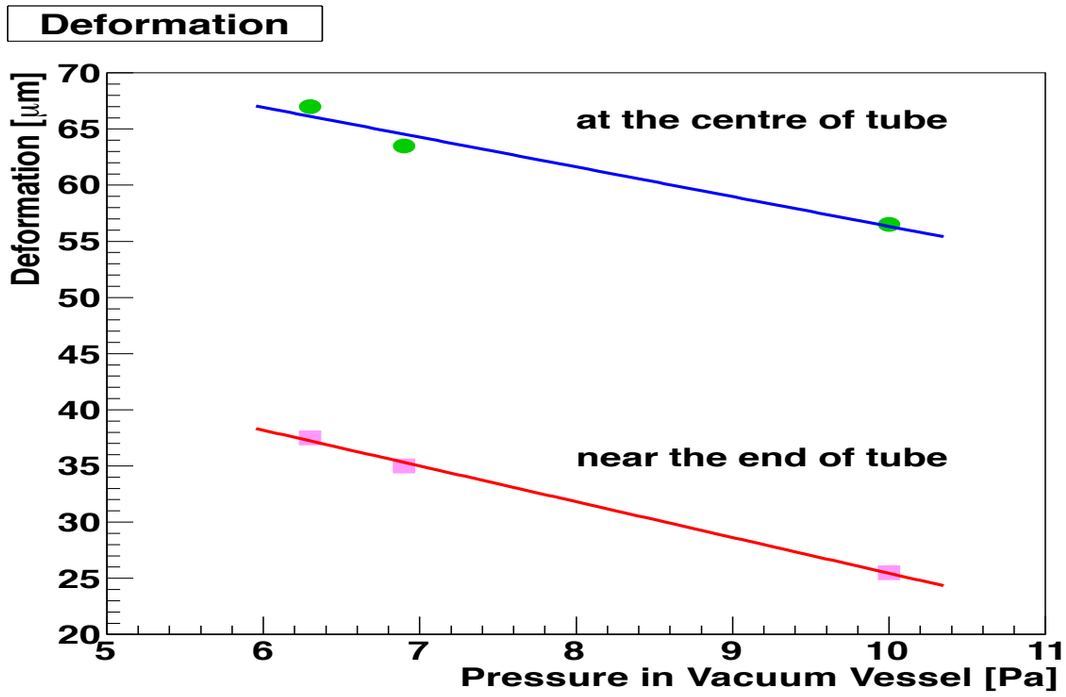






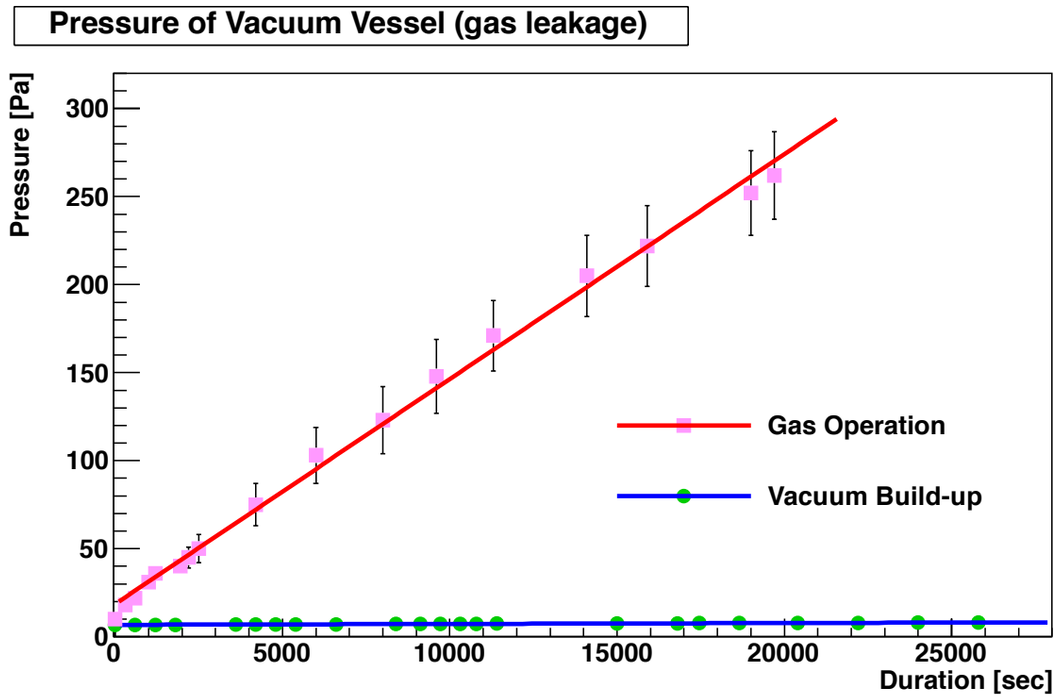
Straw Operation in Vacuum

Deformation Study



- Surface deformation is measured by over-pressurizing by 2 bar in air.
- Same measurement was done by 1 bar operation in vacuum.
- Both results are in good agreement, and 67 μm of max. deformation was found → enough small

Gaseous Leakage Study



- Pressure build-up in vacuum is measured as a function of duration after pump closed.
- Same measurement was done by measuring the pressure drop after 2 bar over-pressurized.
- 0.3 cc/sec of leakage → enough small