IRIS detector studies in vacuum: status and plans

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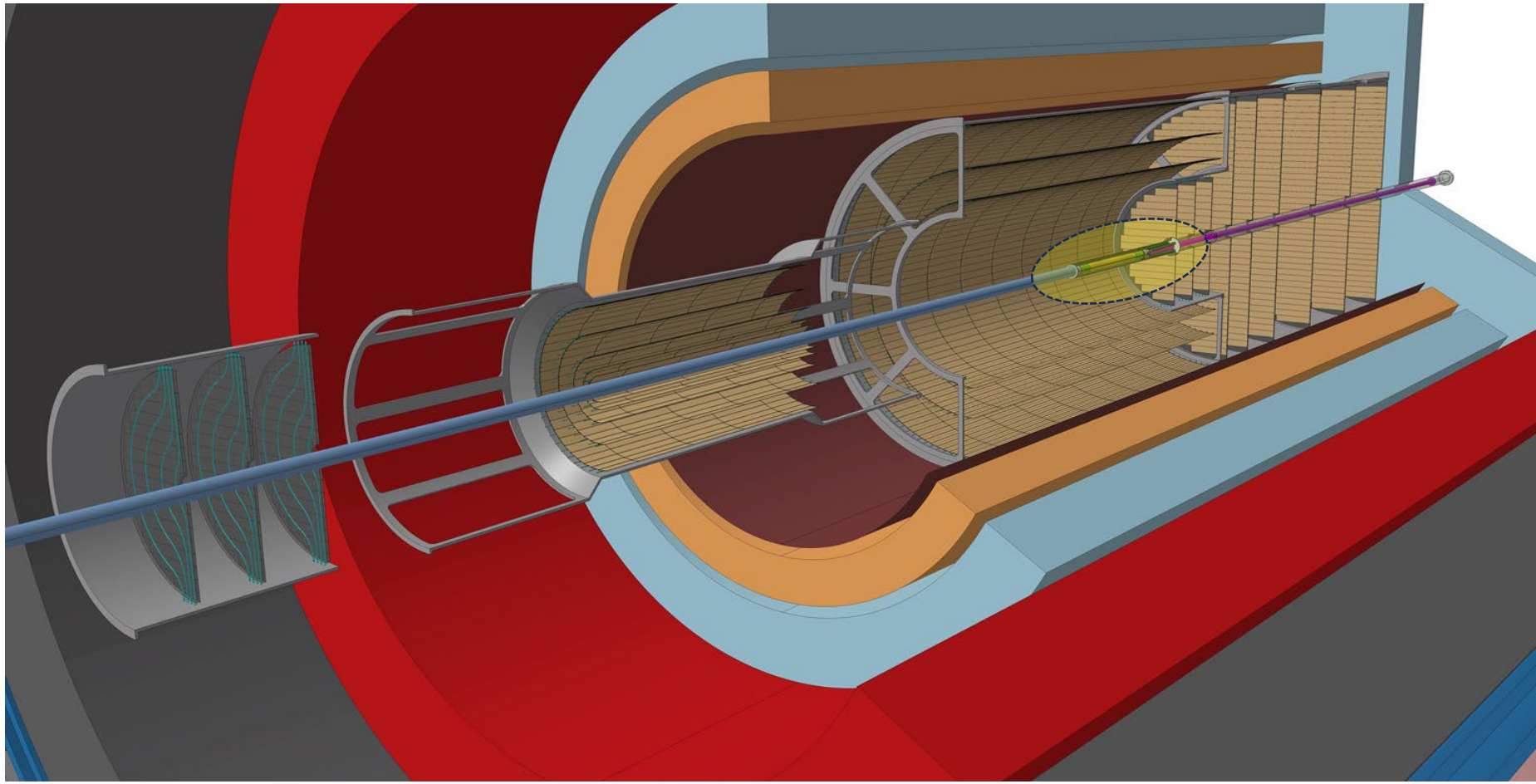
INFN Bari, Bari-Italy

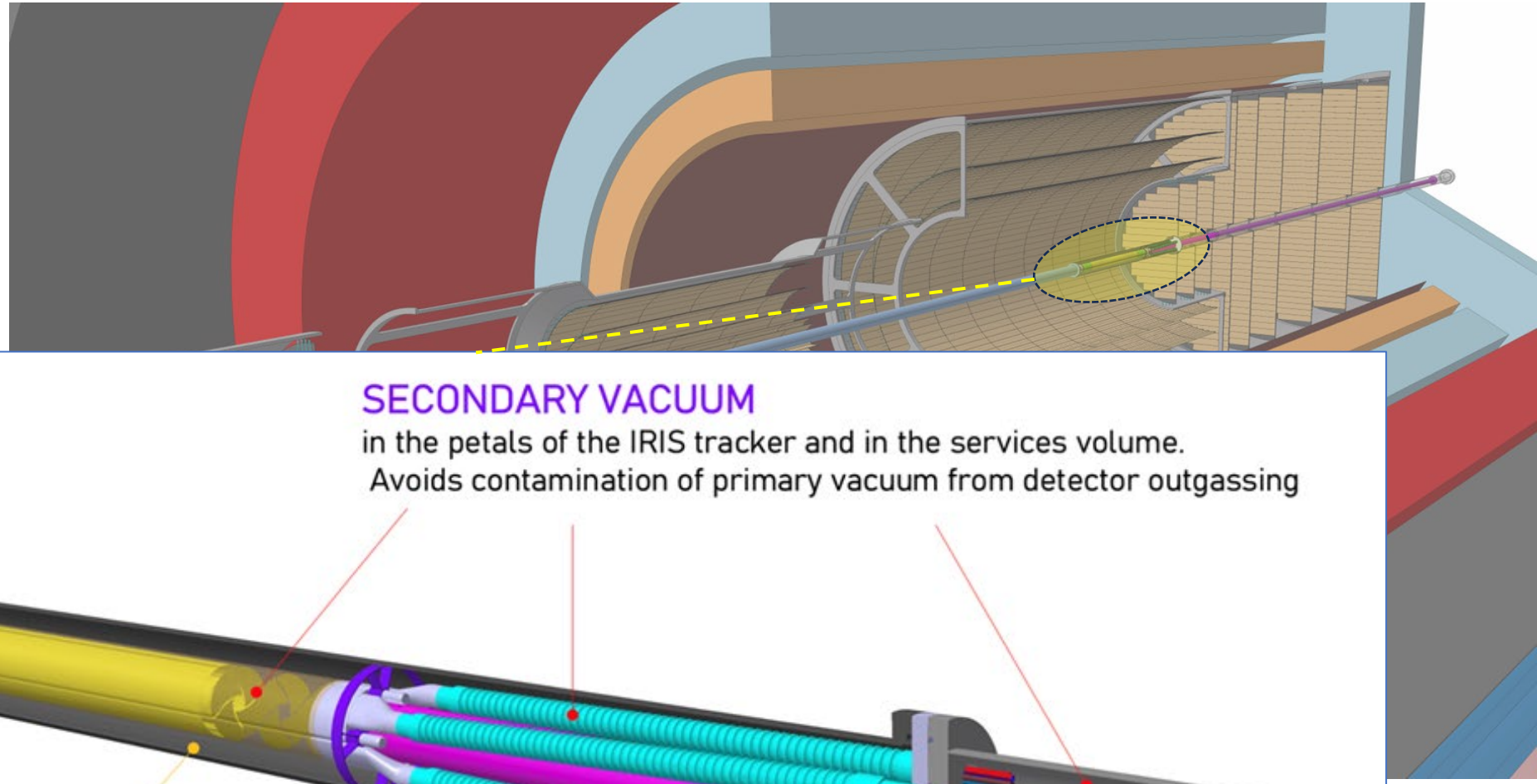
Contents

- Motivation
- Preliminary results
  - Present experimental setup
  - Outgassing study
  - Residual gas atmosphere study
  - Total mass loss (TML) study
  - Wire bonding strength study
- Available experimental facilities
- Future plans

IRIS detector @ ALICE3



IRIS detector @ ALICE3



How to perform outgassing measurement?

There are three ways to perform outgassing measurement:

- Comparing the vacuum level with and without sample
- Comparing residual atmosphere of vacuum chamber with and without sample using RGA
- Comparing the mass of sample before and after pumping

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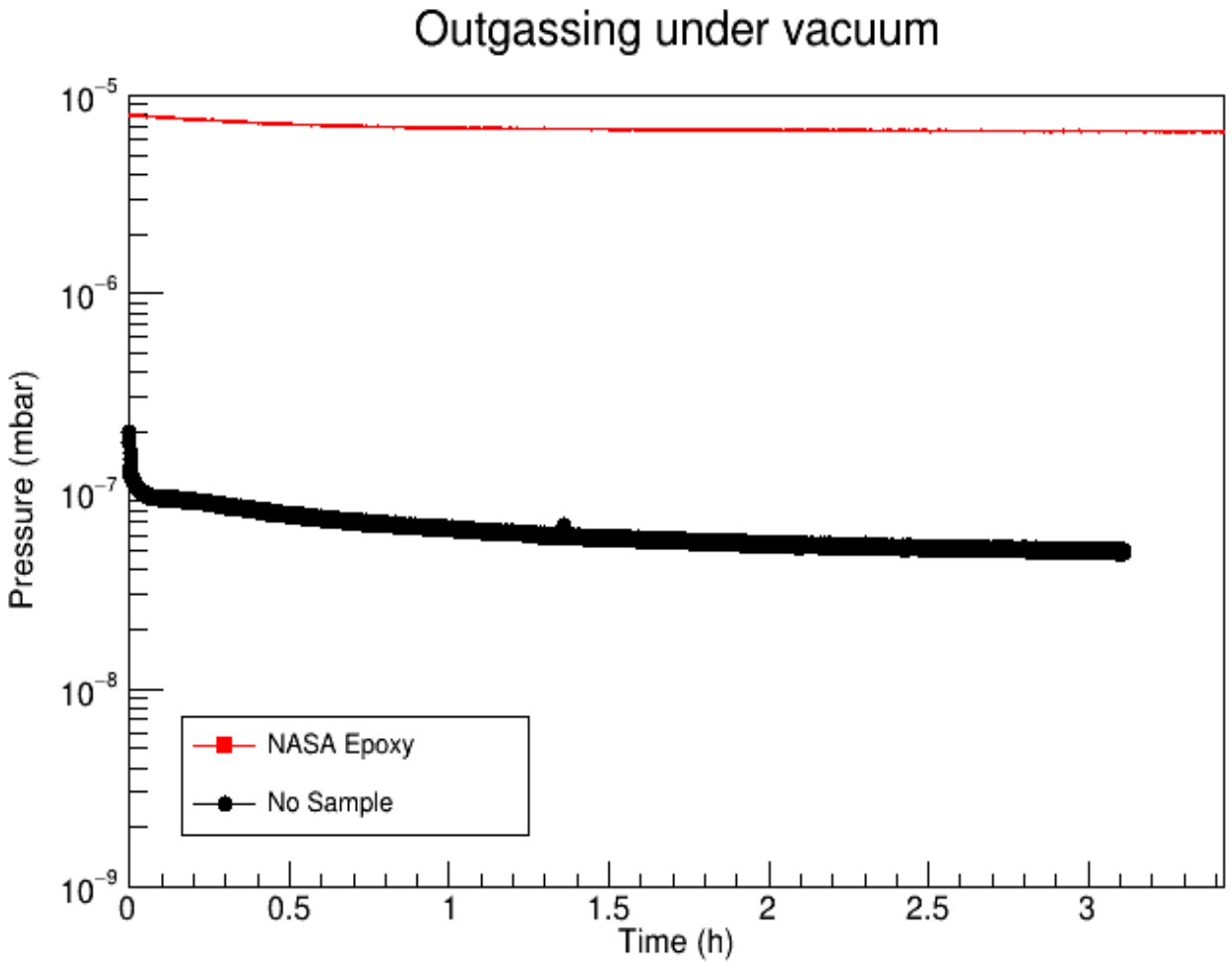

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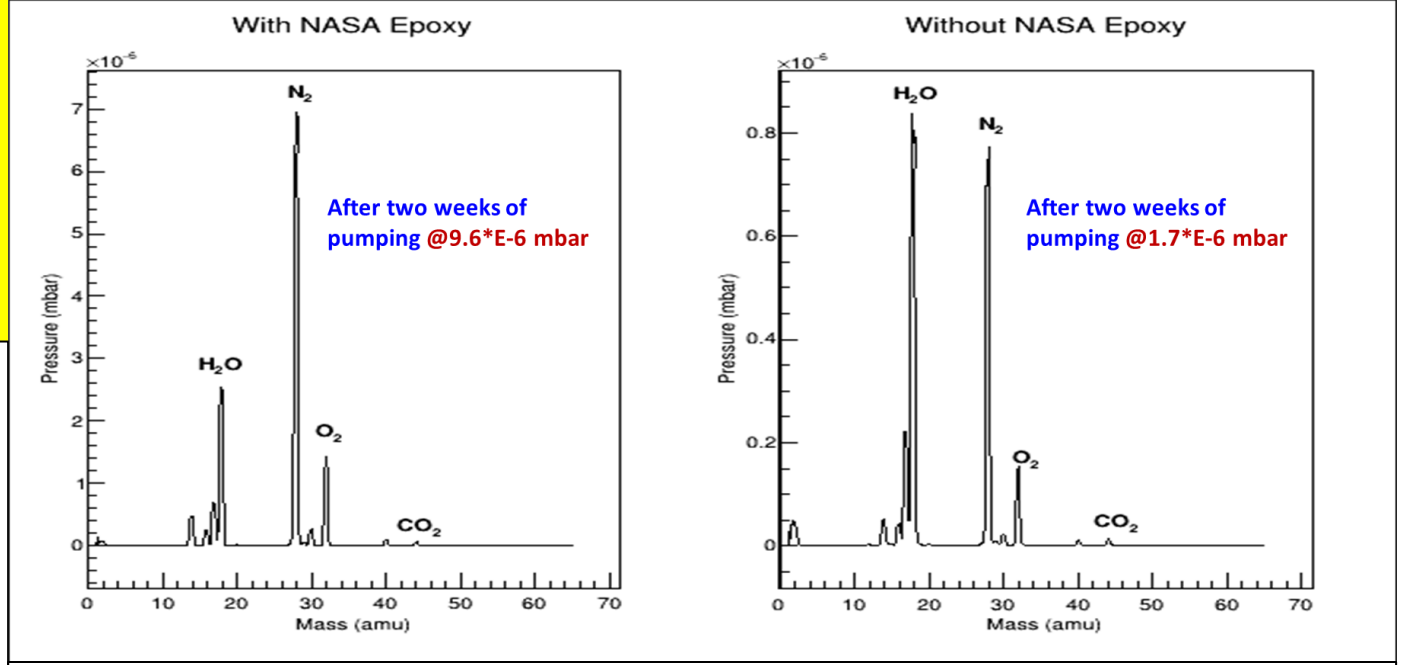

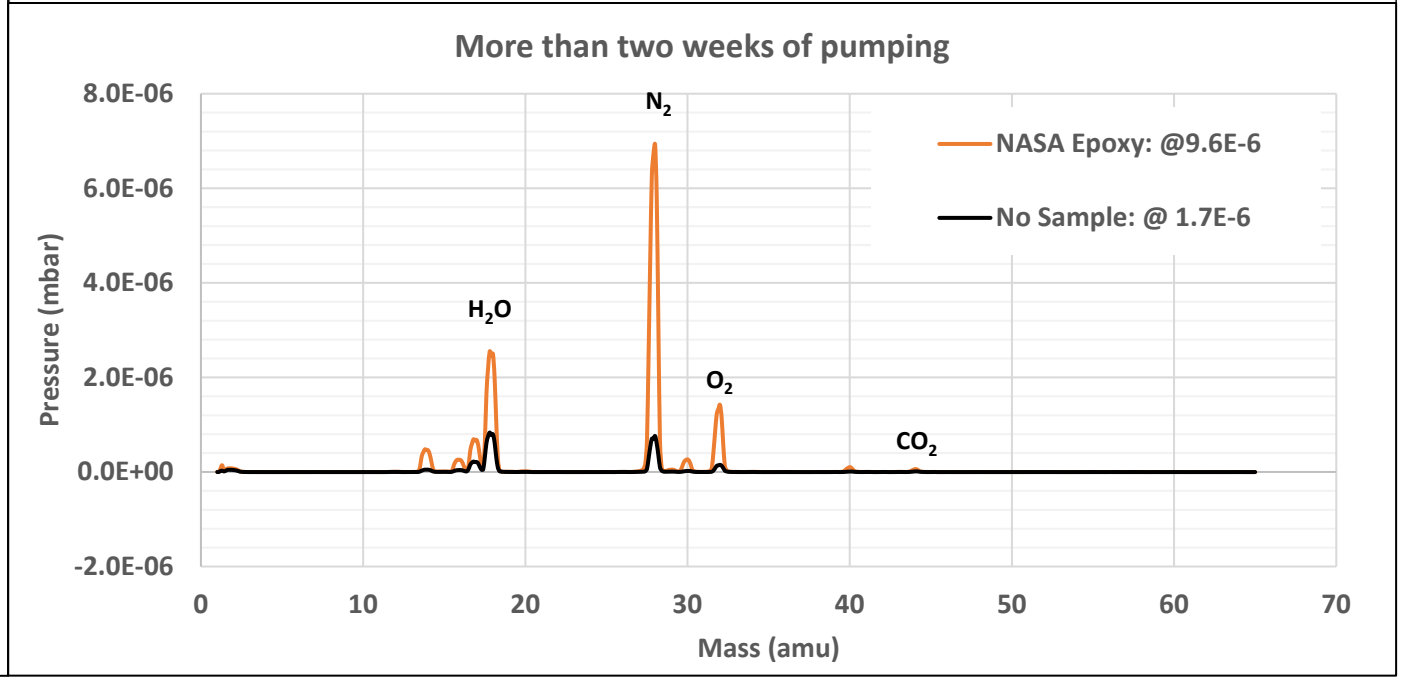

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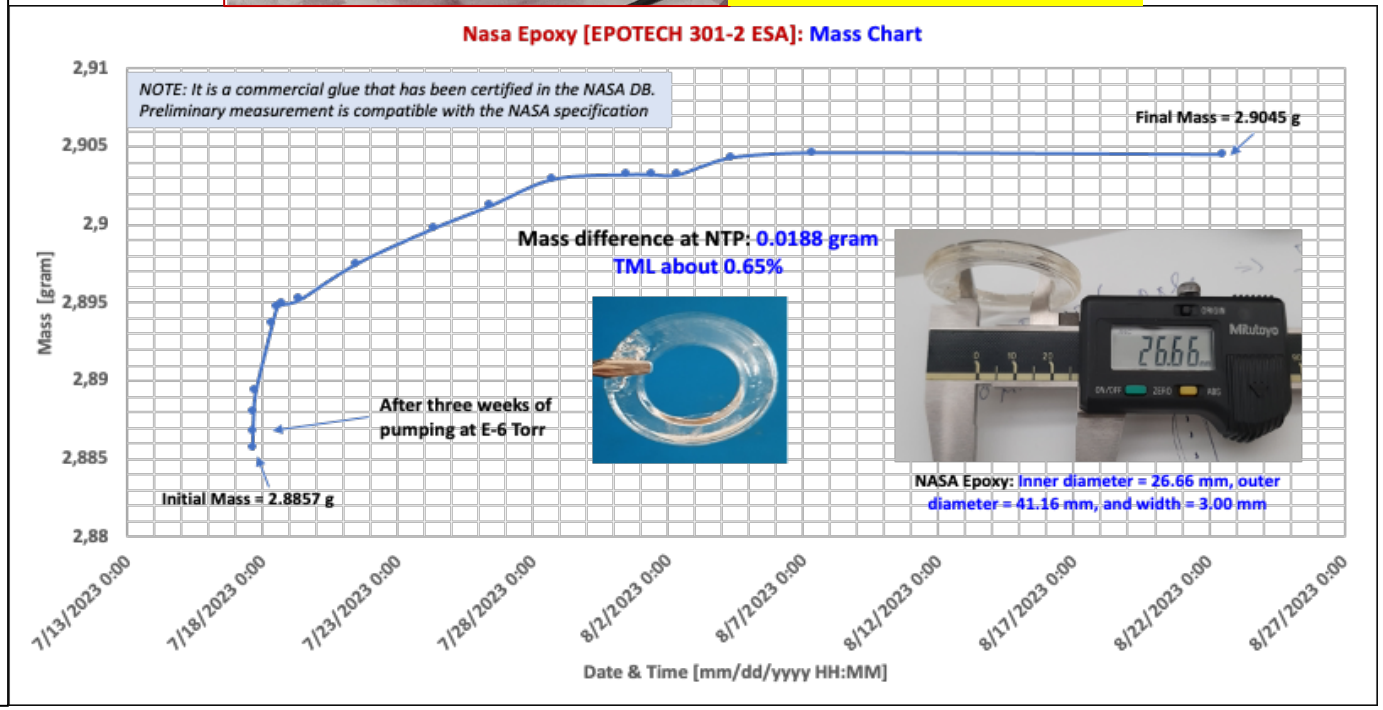
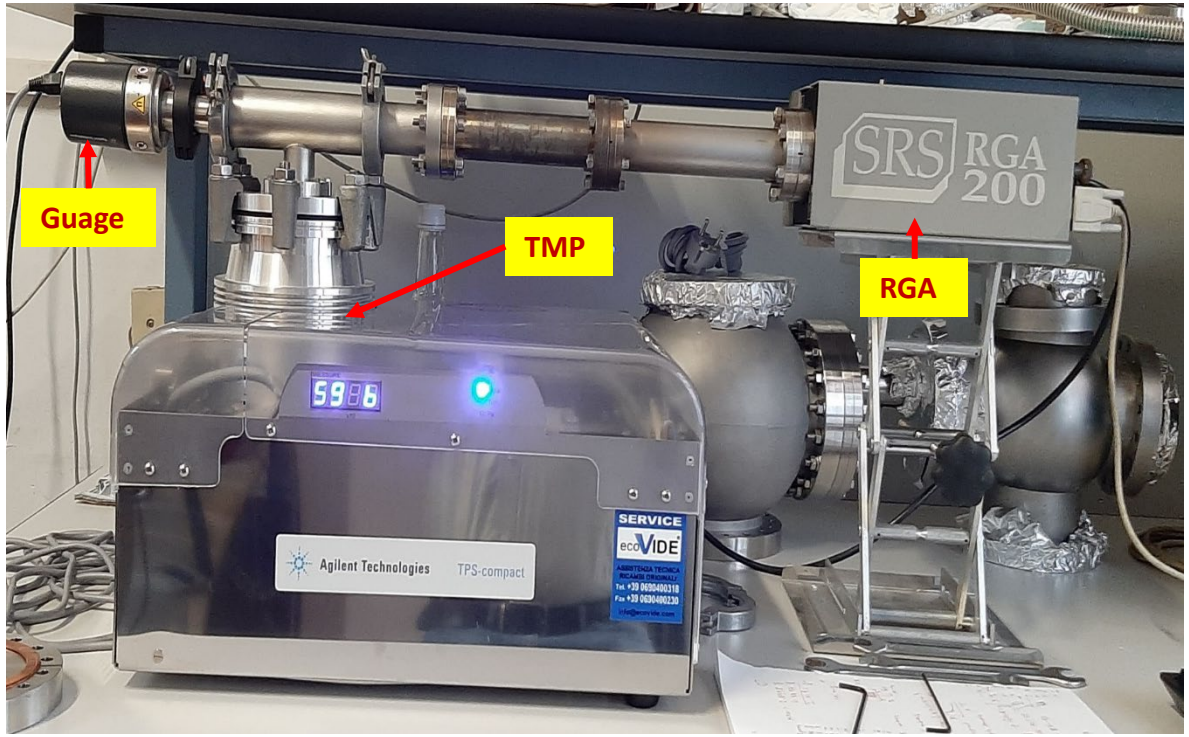
Analytical balance
(Radwag AS 110-R2):
Res 0.1 mg

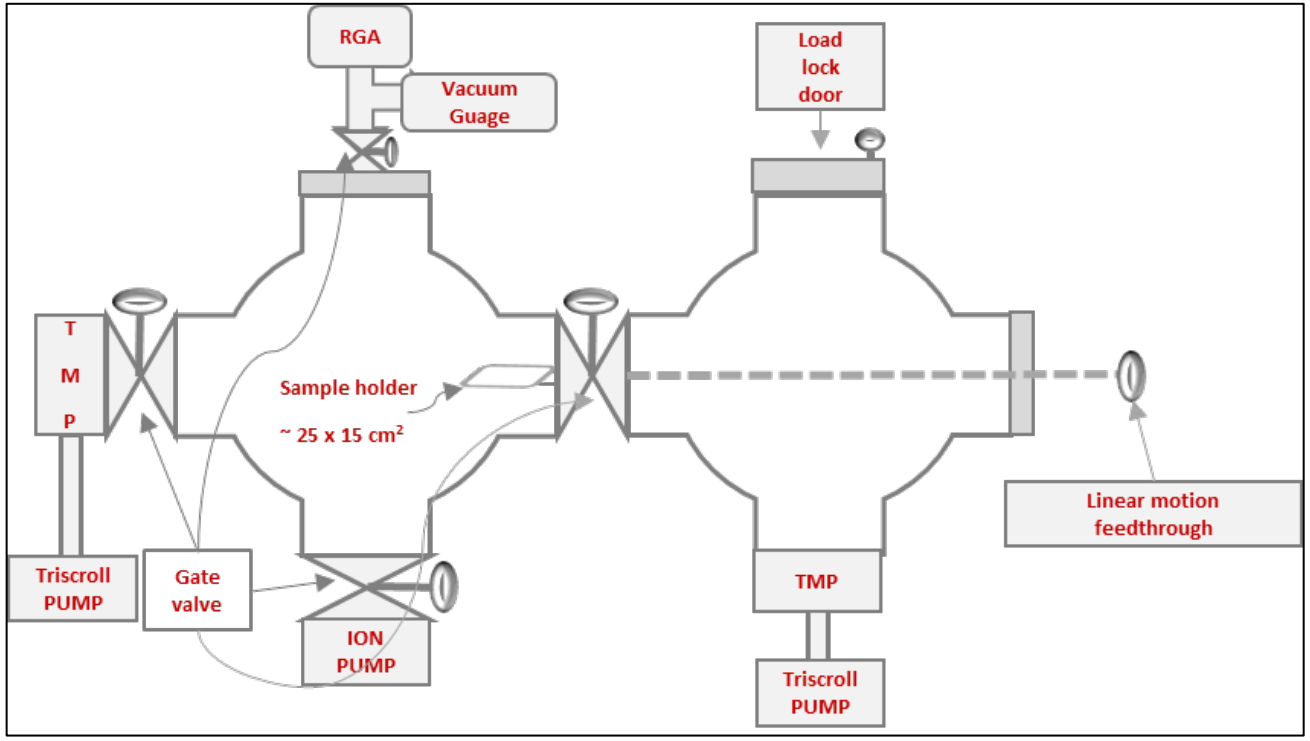


Available experimental facility and plans?

Currently running setup up to 10^{-6} mbar



Future setup up to 10^{-10} - 10^{-11} mbar

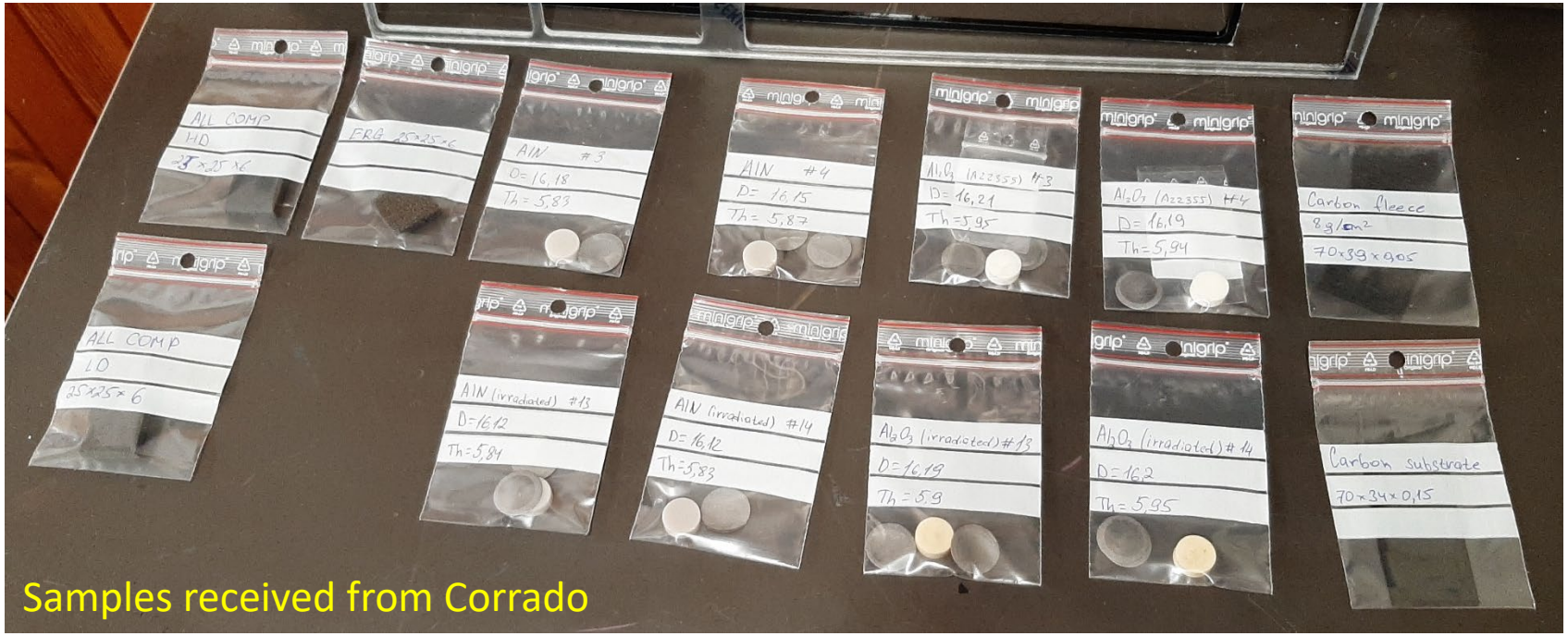


Samples to test in vacuum environment

Samples:

- Carbon (LAYPUS) Substrate of the cold plate
- Carbon Fleece of the cold plate
- Carbon foam All comp high density
- Carbon foam All comp low density
- Carbon foam ERG duocel
- Optical Fiber with connector
- NASA Epoxy
- Si wafer
- Wire bonded Si wafer
- FPC
- 3D printed aluminium nitride (AIN) samples disks
- Al2O3 samples disk: 3D printed alumina (Al_2O_3) samples disks
- 3D printed AlSi samples disks

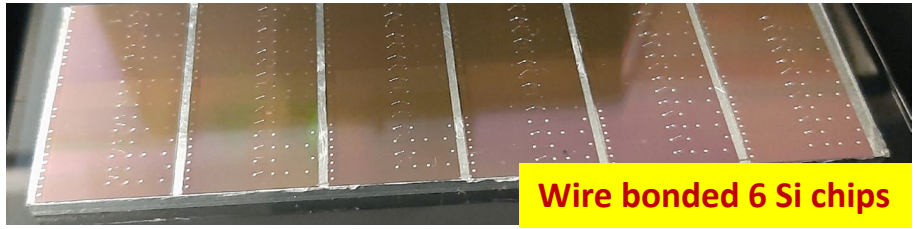

Sample received from Felix



Samples received from Corrado

Preliminary
Experimental Results @10^{-6} mbar

List of components : preliminary studied



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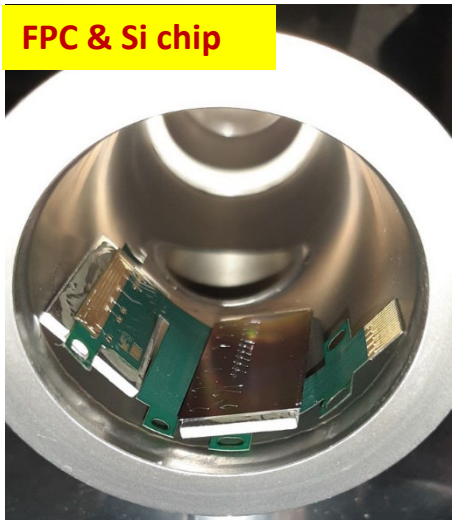
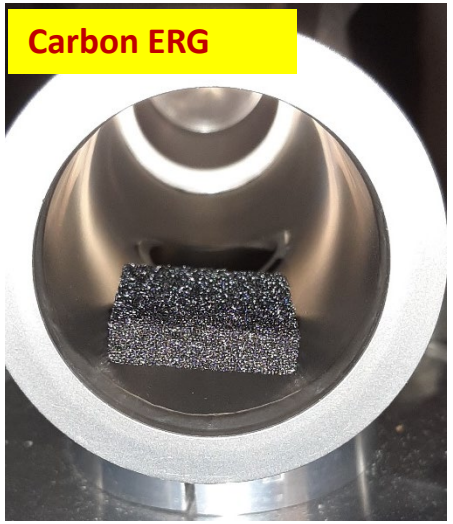
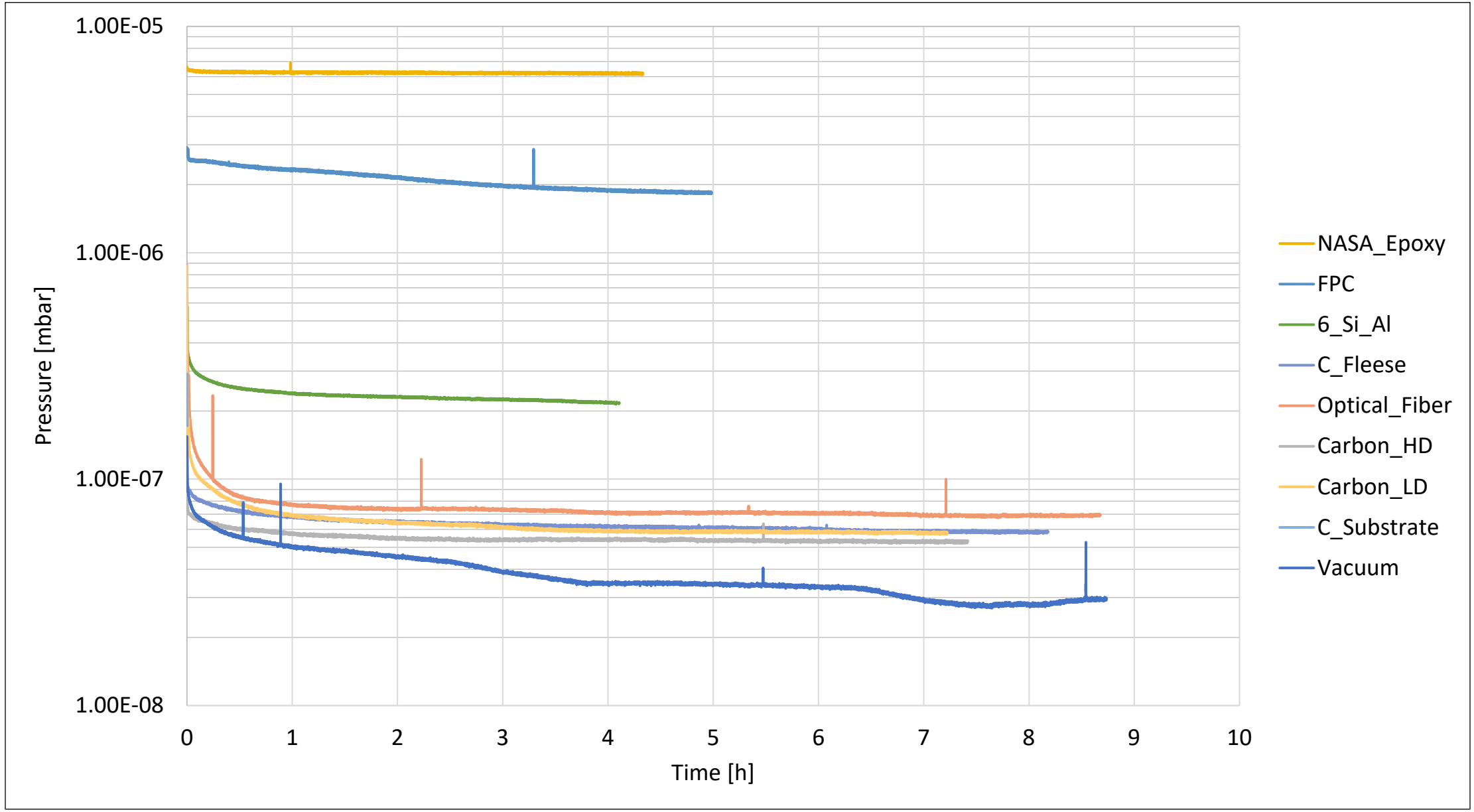
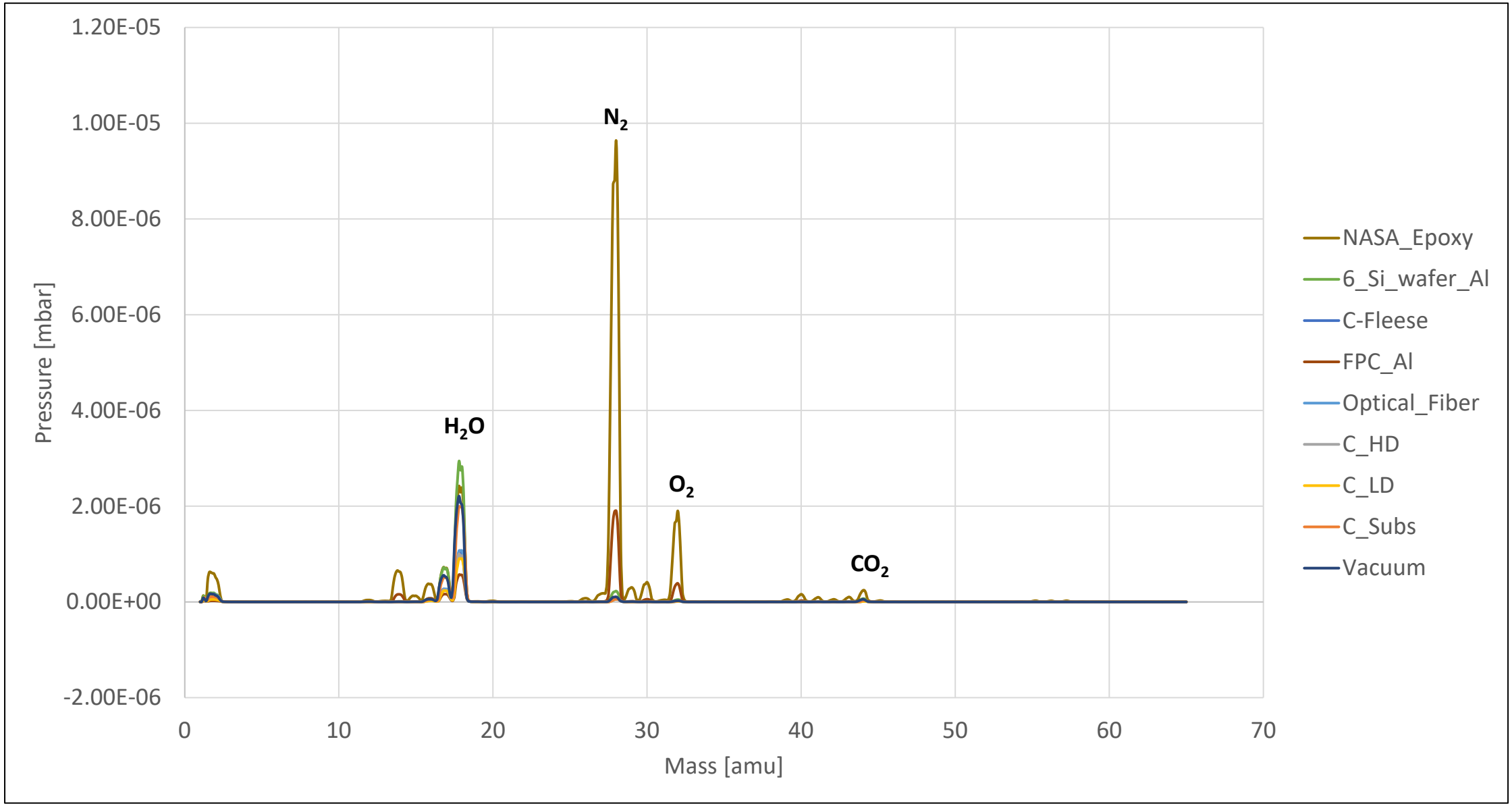




Outgassing under vacuum (1E-6 mbar)



Residual gas compassions: under vacuum (1E-6 mbar)



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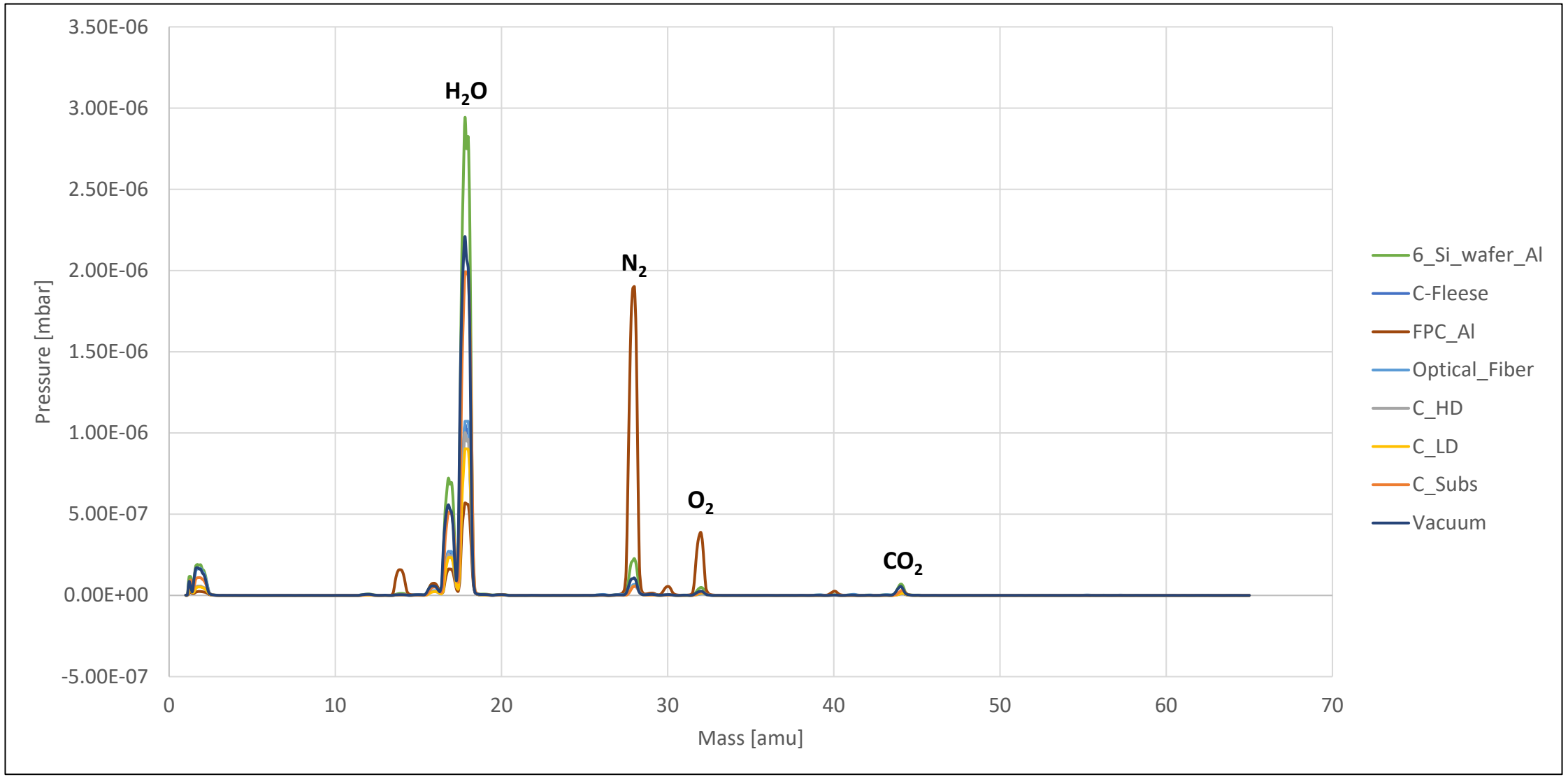

Total mass loss [TML]: under vacuum (1E-6 mbar)

Samples	TML [%] (Just after vacuum treatment)	TML [%] (Regained after vacuum treatment)
NASA_Epoxy	--	0.65
FPC_Al	--	0.05
Si_Wafer_Al	--	0.050
3_Si_Wafer_Al	0.01	0.01
C_Fleese	1.82	0.46
C_HD	0.47	-0.01
C_LD	0.73	0.01
C_Substrate	0.20	0.14
Optical_Fiber	0.32	0.14
C_ERG	11.85	12.23

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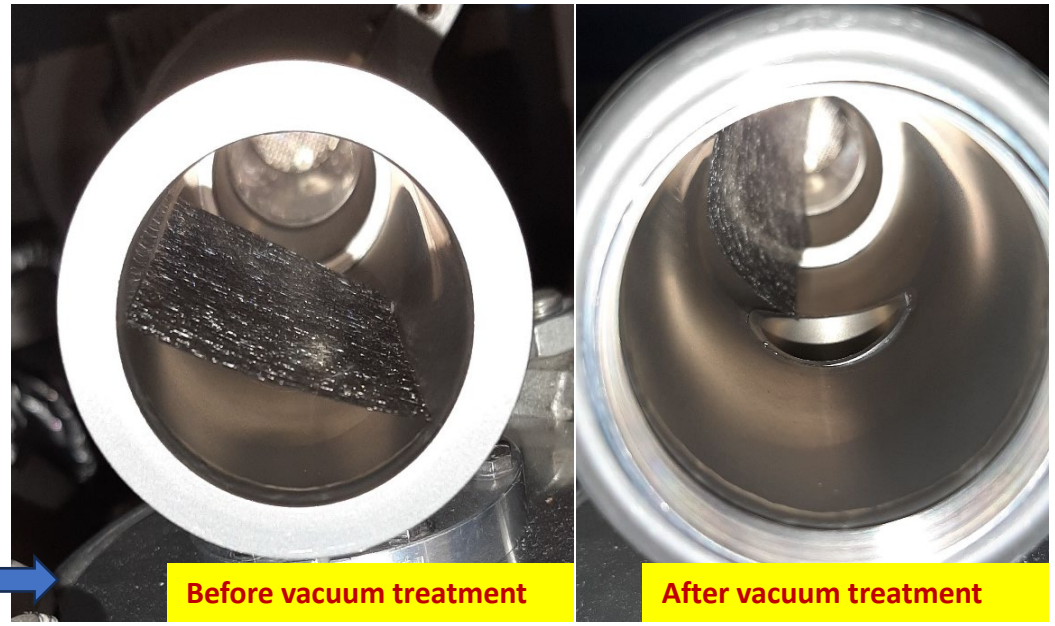

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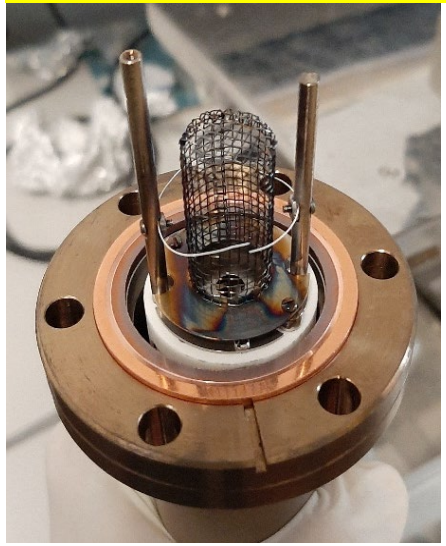
Carbon ERG fibers: after vacuum treatment

Broken filament : after Carbon ERG vacuum treatment

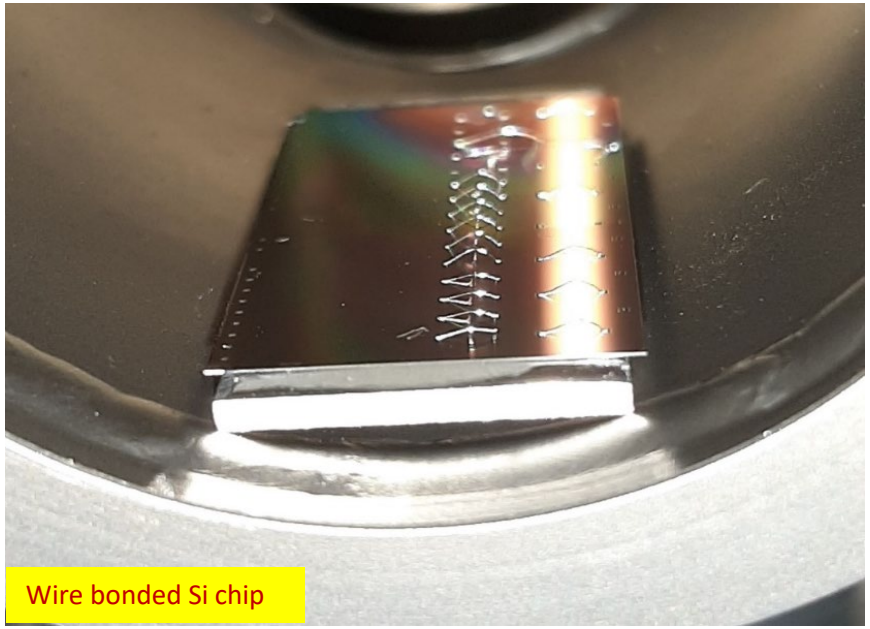


WIRE-BONDING STUDY UNDER VACUUM

wire bonded Si wafers and required setups: Pulling force test

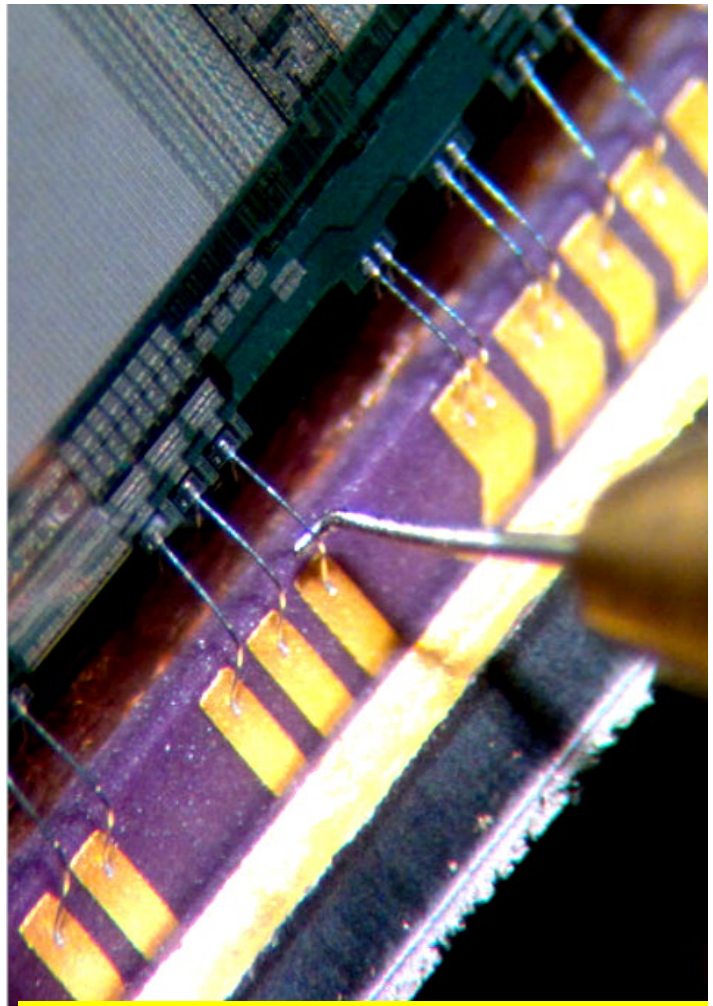
Setup description:

- 6 ALPIDE chips glued on metallic support and wire bonded
- Each chip having 14/15 wires bonded
- To disentangle eventual chip-to-chip variation
  - 44 pull test without vacuum treatment
  - 44 pull test after vacuum treatment



Wire bonded Si chip

wire bonded pulling force test measurement setup

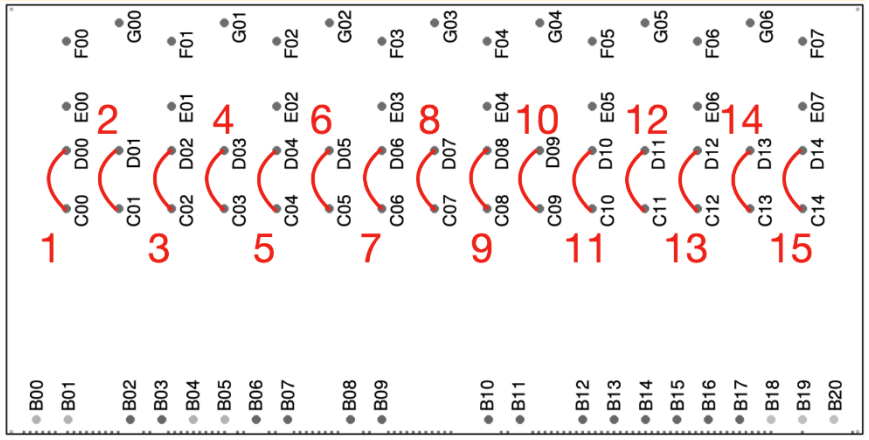


Example of a hook pulling the wire

Experiment execution dates:

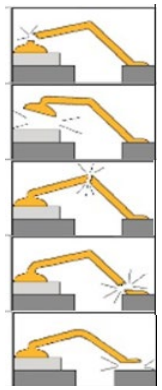
- Chips mounted and pull-force tested on **6/20/2023**
- Samples kept under vacuum (10^{-6} bar) for **~10 days**
- Pull-force measurement after vacuum treatement on **19/20/2023**

wires distribution between the ALPIDE's pads"



CHIP	Without VACUUM Pull-force average ±sigma (min - max) g [# of wires]	Aafter VACUUM Pull-force average ±sigma (min - max) g [# of wires]
#1	8.37 ±1,50 (6,5 - 11.1) [8]	8.23 ±0.95 (6.80 – 9.45) [6]
#2	8.00 ±1.90 (7.08 - 10.67) [6]	7.28 ±2.62 (4.58 - 12.54) [8]
#3	8.92 ±2.11 (6,04 – 12.30) [8]	8.90 ±1.68 (7.14 – 11.39) [7]
#4	8.56 ±2,42 (4.50 - 12,.9) [7]	9,04 ±1.53 (7.02 - 11.06) [8]
#5	9.72 ±0.66 (8.88-10.57) [8]	9.20 ±0.83 (8.12 – 10.88) [7]
#6	7.09 ±1.73 (4,42 – 9.55) [7]	8.32 ±1.12 (6.35 - 9.57) [8]
TOT	**8.49 ±1.87 (4.42 - 12.59) [44]**	**8.50 ±1.66 (4,59 - 12,54) [44]**

CHIP	Without VACUUM (44 wires)					After VACUUM (44 wires)				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
#1	6	1	0	0	1	2	2	0	1	1
#2	2	1	0	0	3	0	1	0	5	2
#3	4	2	0	0	2	1	2	0	4	0
#4	4	0	0	1	2	0	5	0	2	1
#5	7	0	0	0	1	1	3	0	2	1
#6	3	3	0	0	1	0	5	0	2	1
TOT	26	7	0	1	10	4	18	0	16	6



1 – Breakage at the 1st foot
2 – Lift-off at the 1st foot
3 – Breakage at the apex of the loop
4 – Breakage at the 2nd foot
5 – Lift-off at the 2nd foot

- Strong reduction of breakage at the 1st foot
- Clear increase of lift-off at the 1st foot
- Strong increase of breakage at the 2nd foot
- Moderate reduction of lift-off at the 2nd foot

<u>Breakage/Lift-off</u>
BEFORE vacuum: 27/17
AFTER vacuum: 20/24

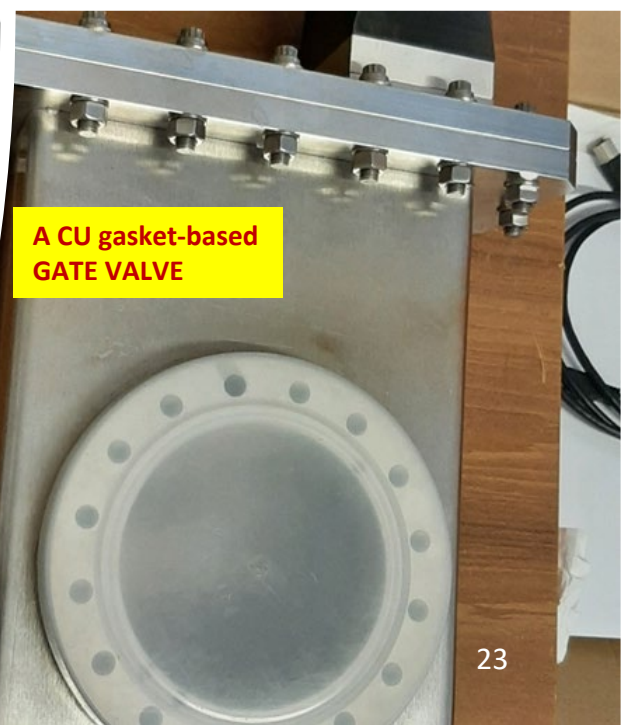
Experimental Facilities @ INFN Bari

- Two SS 4-way cross spherical vacuum chambers
- All kind vacuum pumps (Primary + TMP +ION)
- Gate valves (Cf-150, cf-100, kf-40)
- Display and control units for all types of pumps
- All types of vacuum gauges and display unit


A 4 way-cross SS spherical chambers


HOT Cathode guages

An ION Pump


A CU gasket-based GATE VALVE

Future experimental facilities to be assembled @ INFN Bari

Experimental setup: *vacuum SS chambers with associated equipment to reach 10^{-10} mbar pressure*

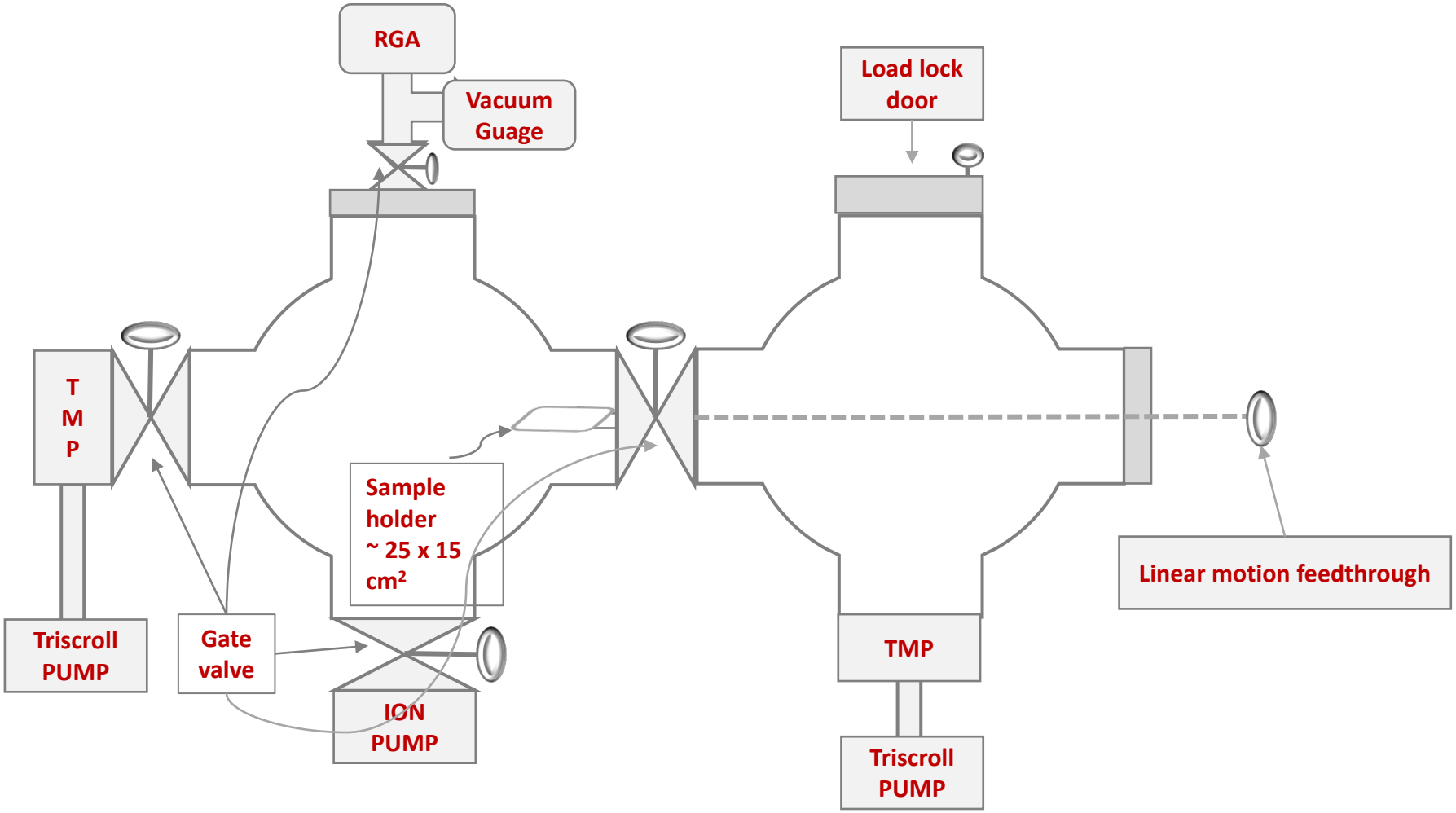


Fig: Schematic diagram of a four-way cross ~20 cm diameter SS spherical chamber are available with all type of pump and RGA

Experimental setup: *vacuum SS chambers with associated equipment to reach 10^{-10} Torr pressure*

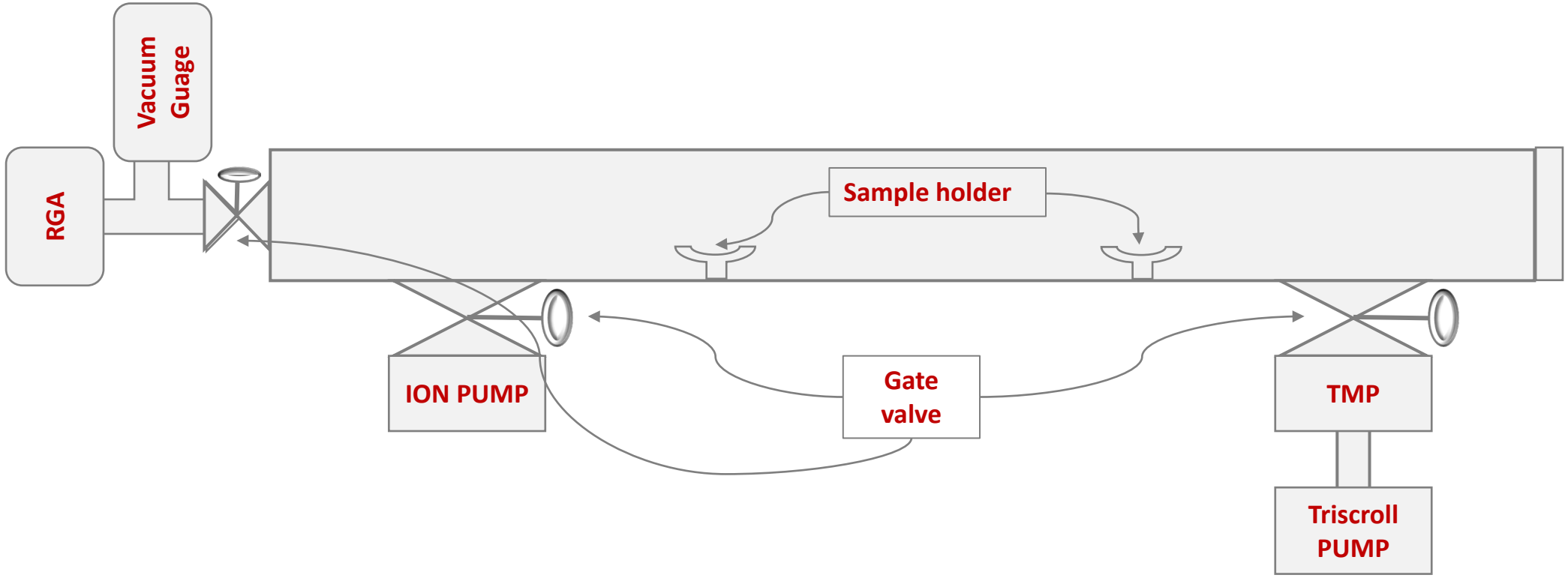
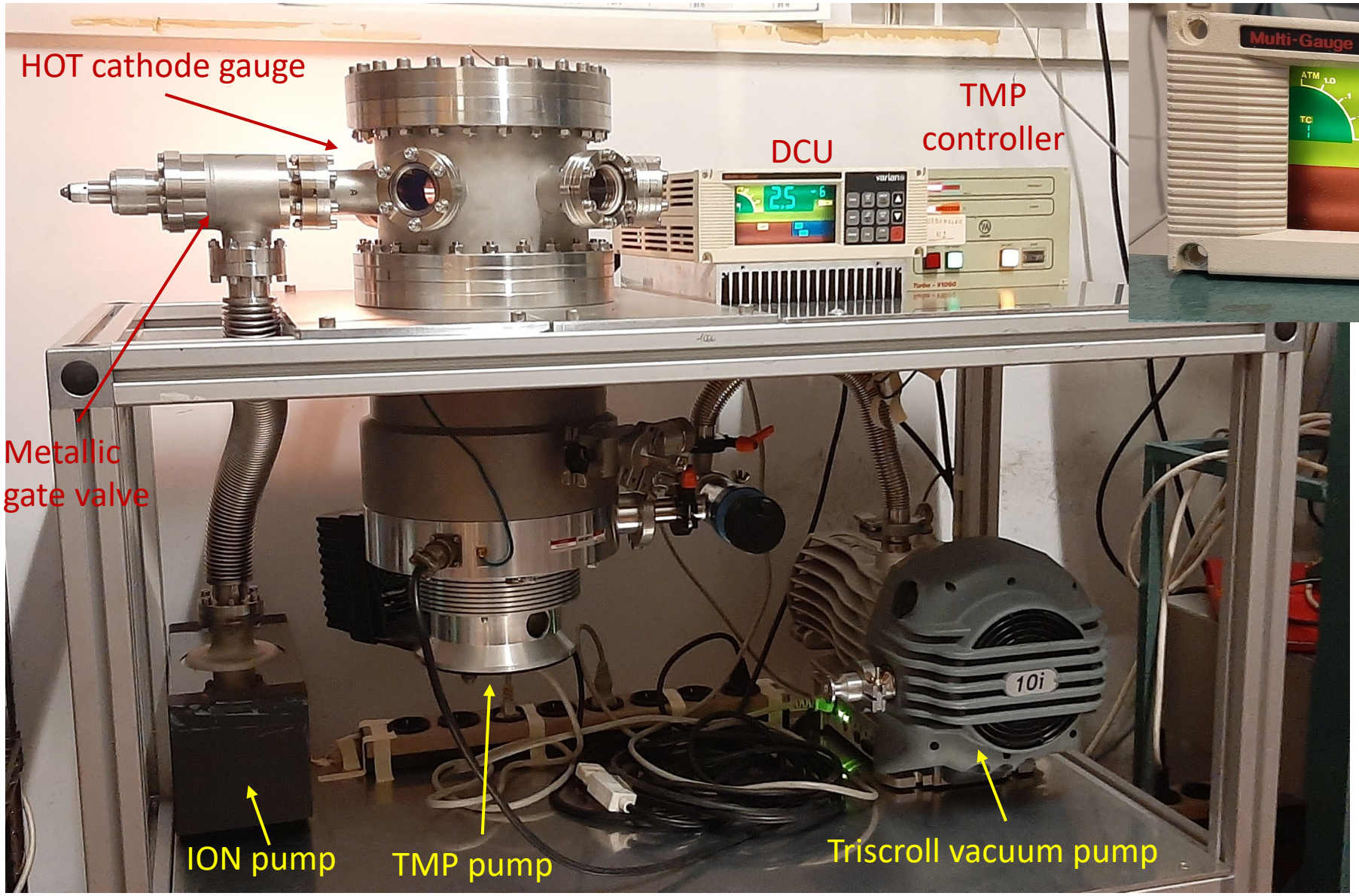
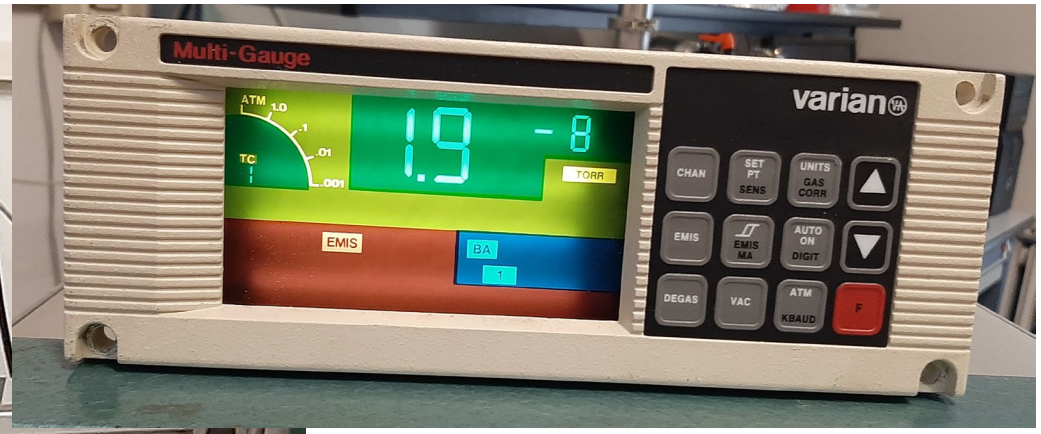


Fig: Schematic diagram of a future SS cylindrical chamber need to build a/c to detector dimension together with required vacuum pumps and RGA

Future plans

- Need to build a vacuum chamber with a vacuum of the order of ~10^{-10} Torr
  - All gaskets and gate valve must be metallic
  - Heating tape and heating lamp are essential
  - Proper cleaning with ultrasonic bath in distilled water followed by alcohol
  - All types of vacuum pumps (primary, TMP & ION) are available
- Measurements to perform
  - Outgassing study
  - Residual gas atmosphere study
  - Total mass loss (TML) study
  - Wire bonding strength study
  - Gluing strength
- Samples to be test
  - All IRIS detector components
  - Glue for IRIS detector
  - Wire bonded Si chips
  - FPC
  - Optical fiber cable

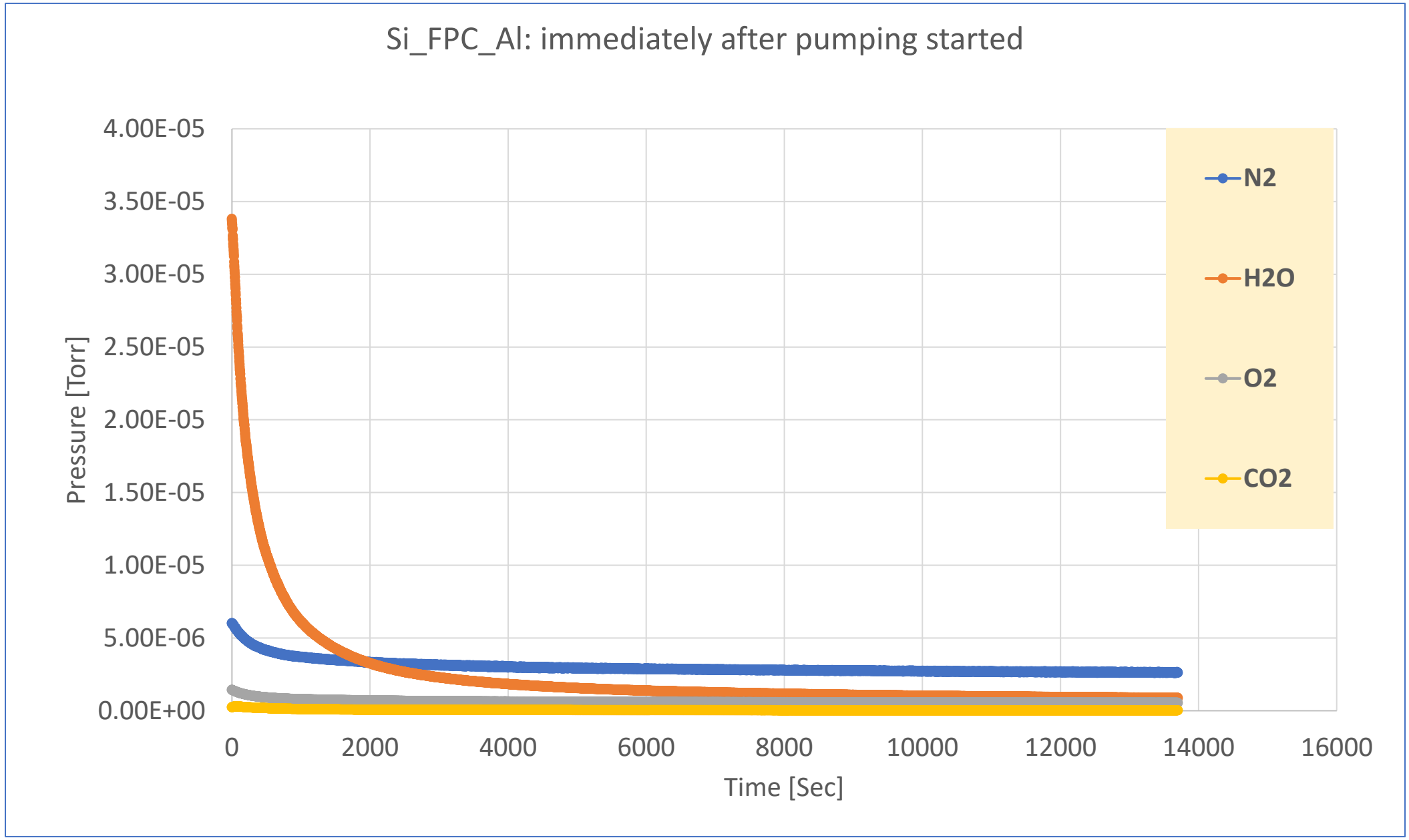


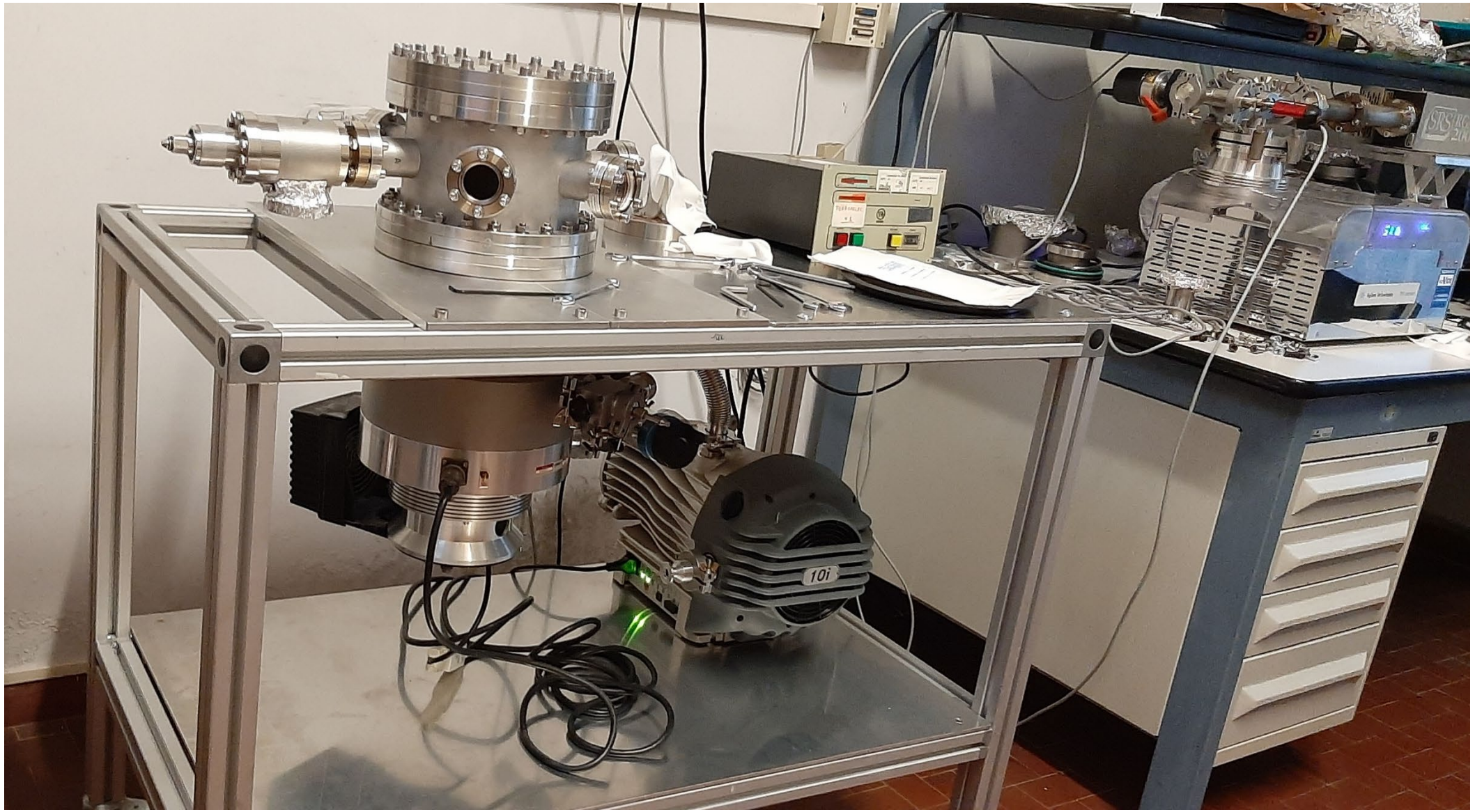


Reached **1.9E-8** Torr pressure in 24 hours of pumping : Without any ION pump and heating tape running

Thank you

Thank you


Si_FPC_Al: immediately after pumping started
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
Pressure [Torr]
0
2000
4000
6000
8000
10000
12000
14000
16000
Time [Sec]
N2
H2O
O2
CO2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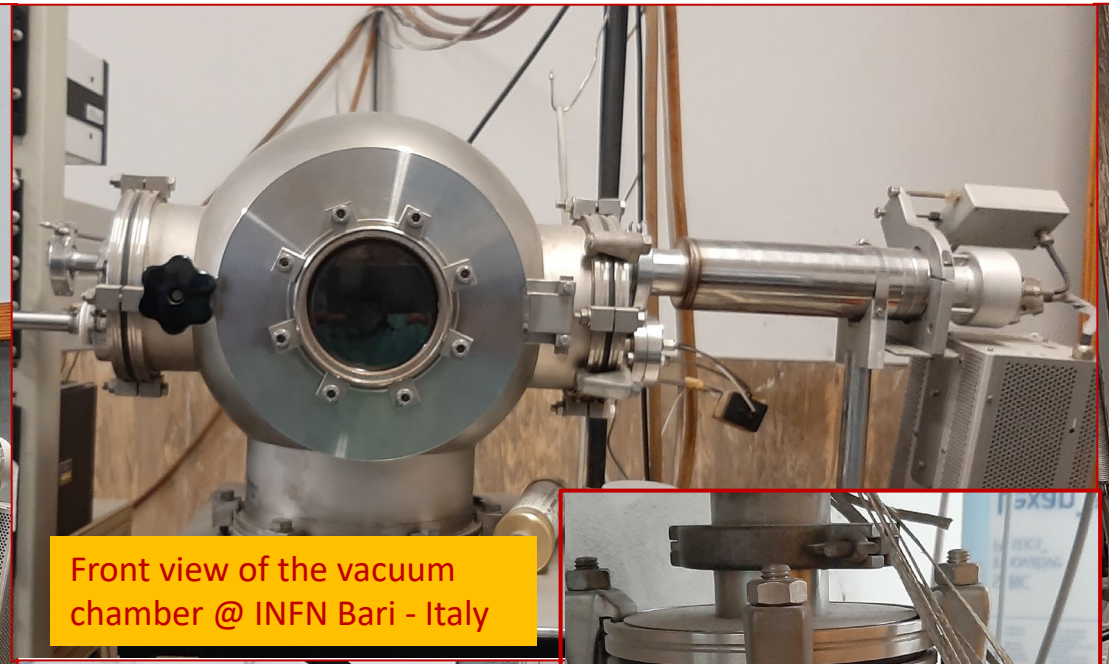
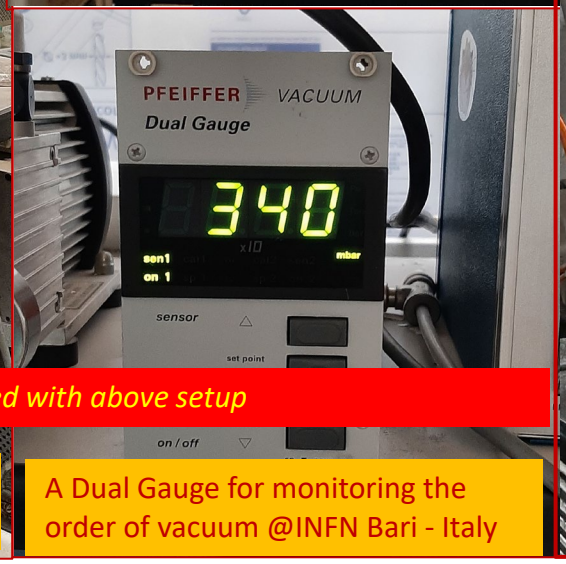
Instruments @INFN Bari – Italy:

Pictorial view of a 5-way cross vacuum chamber @ INFN Bari - Italy



Front view of the vacuum chamber @ INFN Bari - Italy



A Dual Gauge for monitoring the order of vacuum @INFN Bari - Italy

CsI coating for ALICE HMPID have been performed with above setup

An Agilent turbo molecular pump, with pumping speeds of 300 L/s

A RADWAG (AS 110.R2) Analytical Balances machine @INFN Bari -Italy

Available vacuum pumps

Fig: *Primary vacuum pumps*

Fig: *Turbo molecular pump*

Fig: *ION pumps*

Display and control units

Available vacuum gauges and display unit

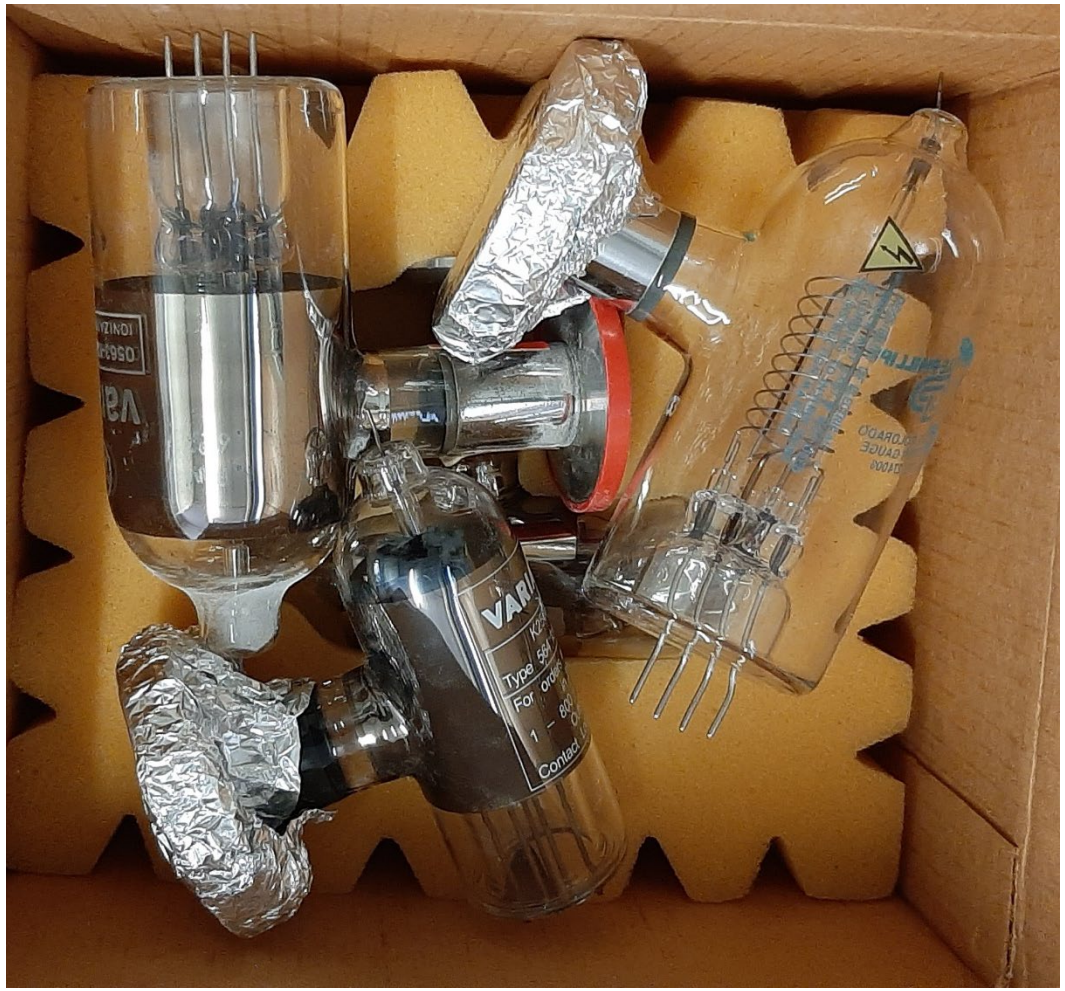
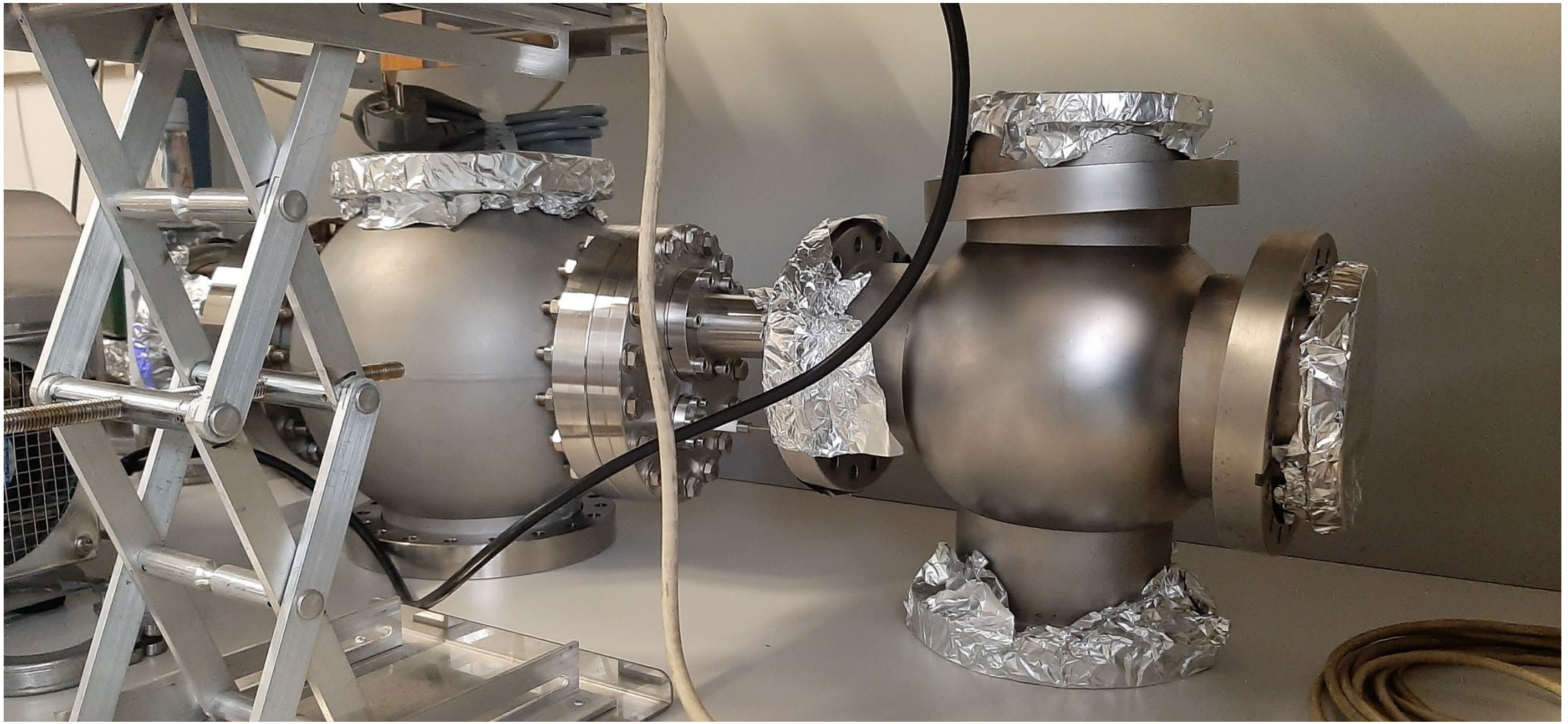
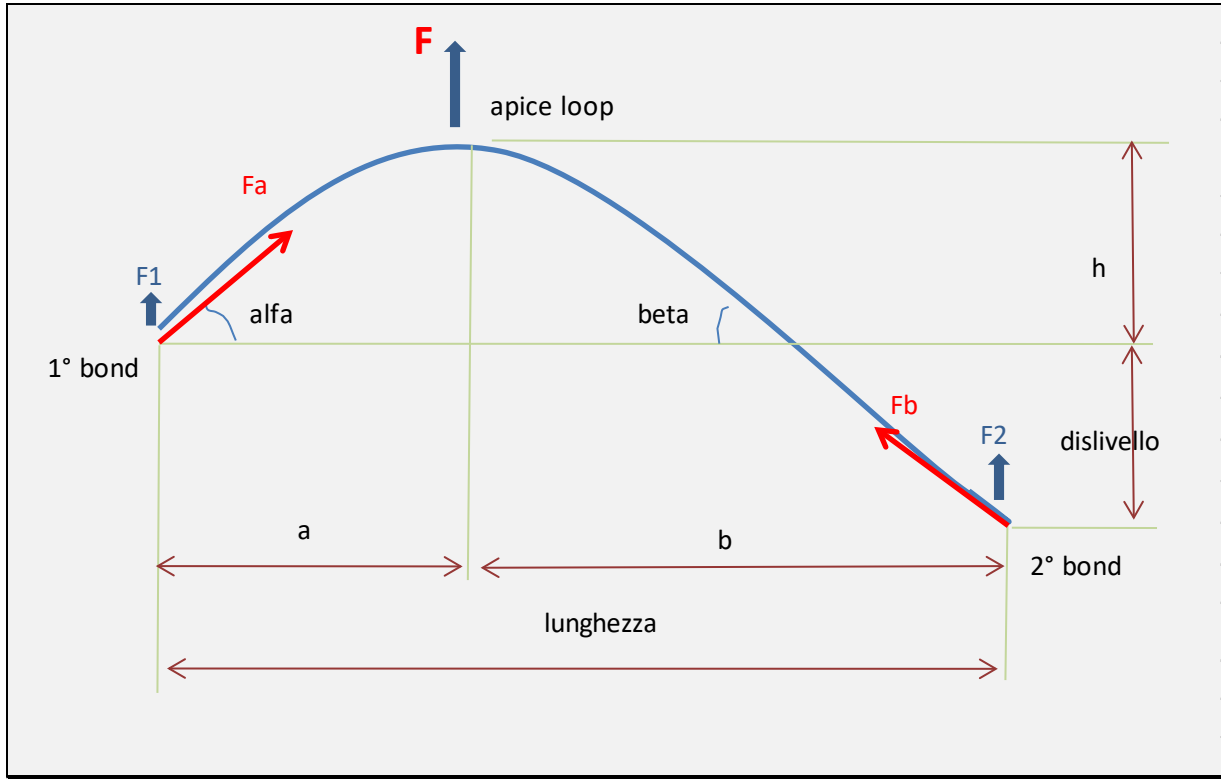


Fig: Vacuum gauges and display unit

Available vacuum chambers

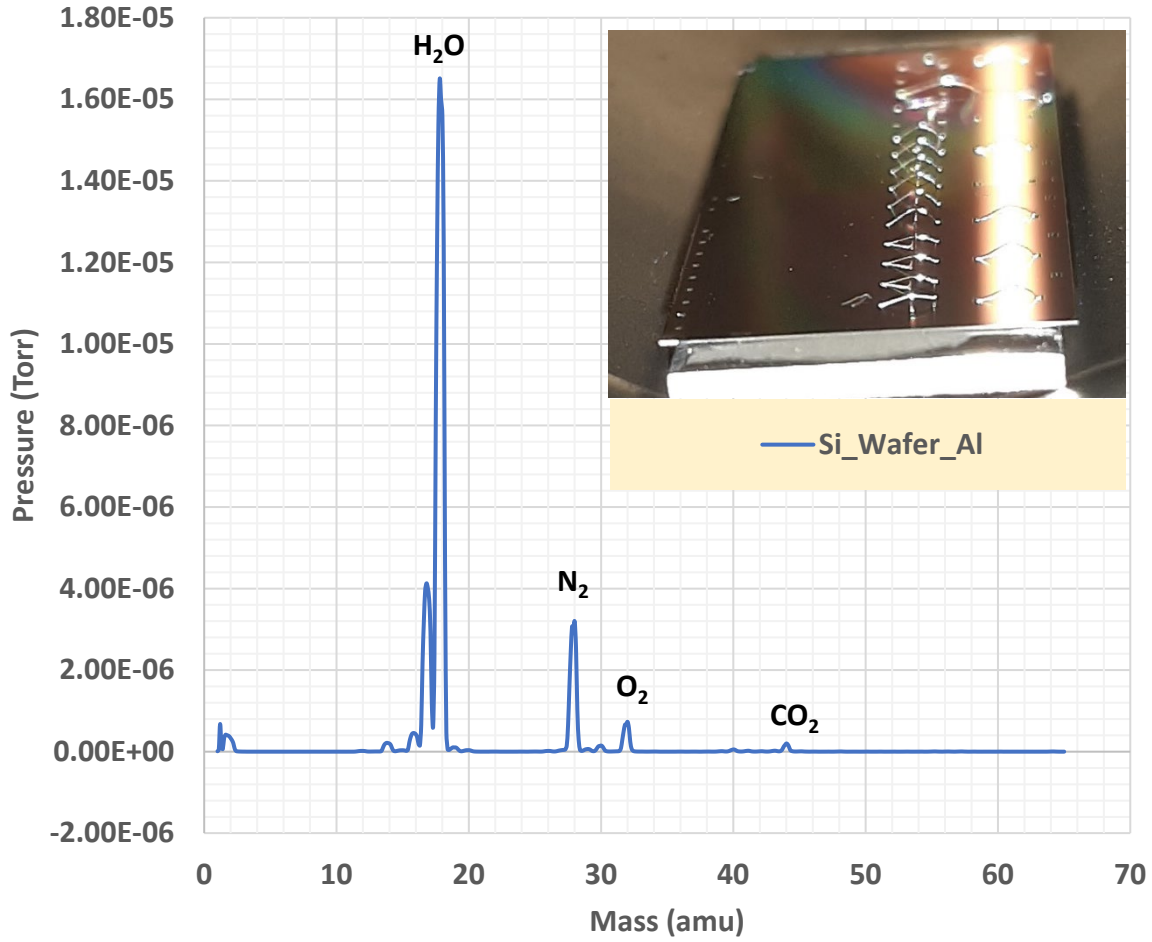


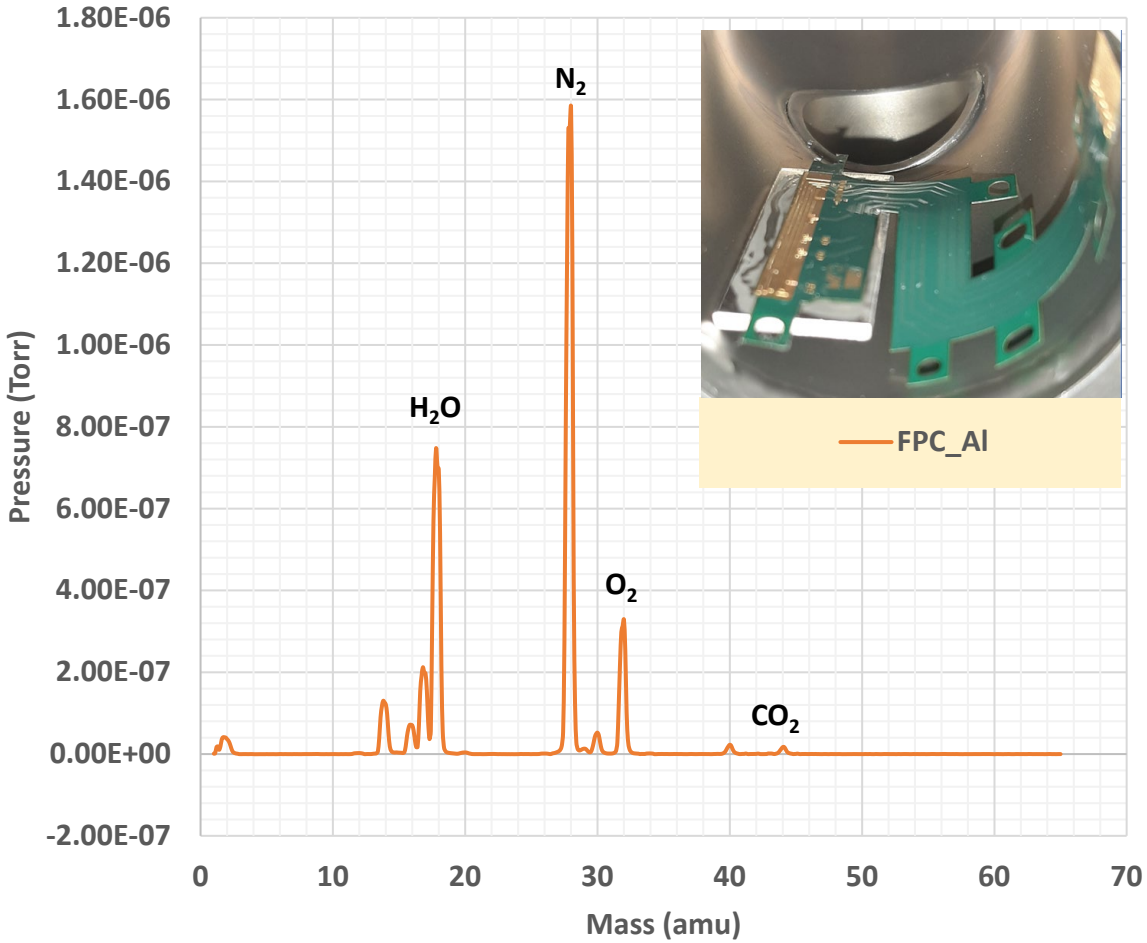
Available gate valves



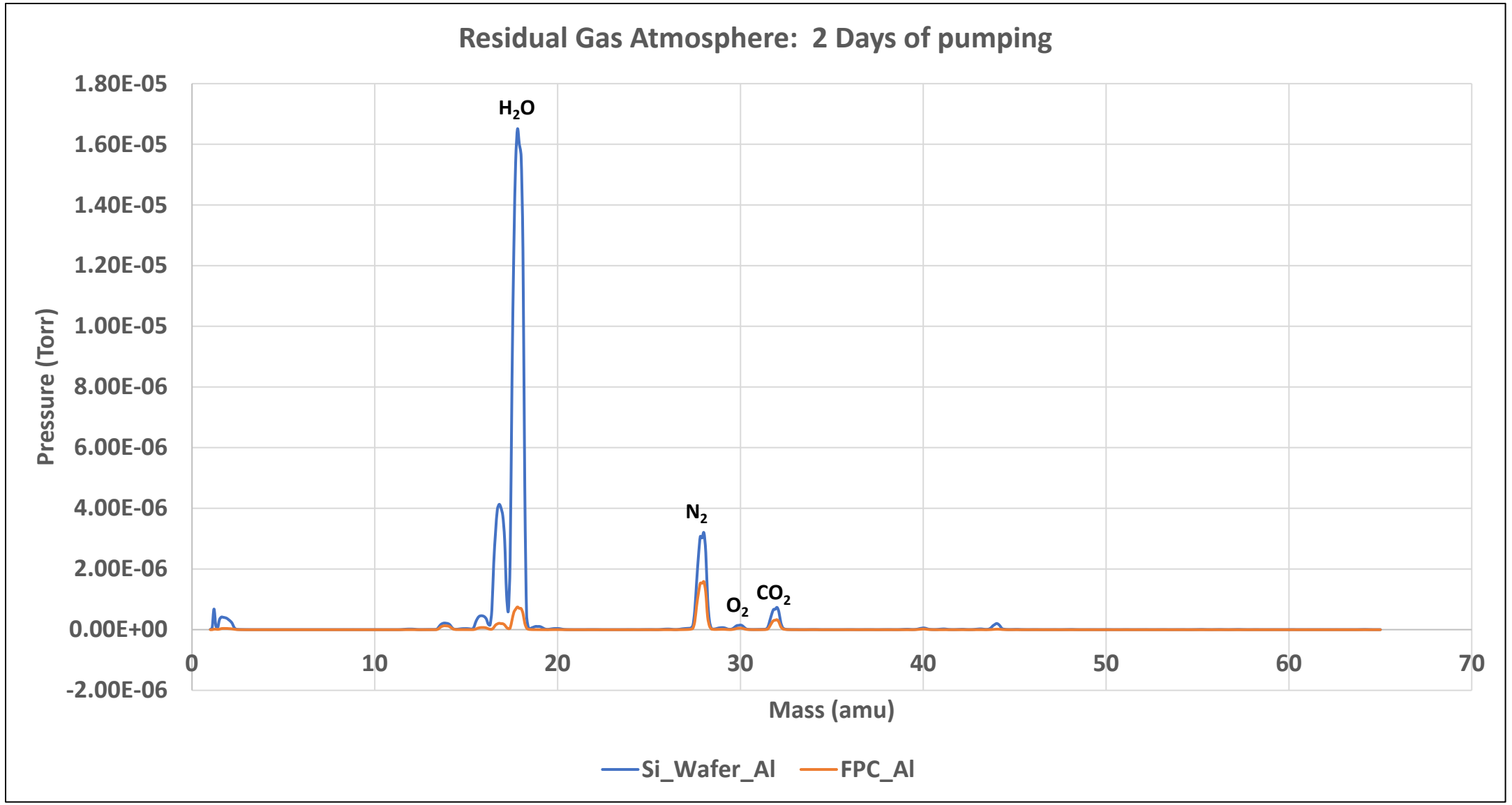
	1° bond	2° bond	apice loop	
X	21140	21126	21140	
Y	85014	82988	84001	
bond height e/o focus	11795	11795	11225	
Length	2026		forza	9.46
height difference	0			
h	570		Fa	9.8
a	1013		Fb	9.8
b	1013			
angolo alfa	29		F1	4.8
angolo beta	29		F2	4.8
angolo strappo dinamometro	0			

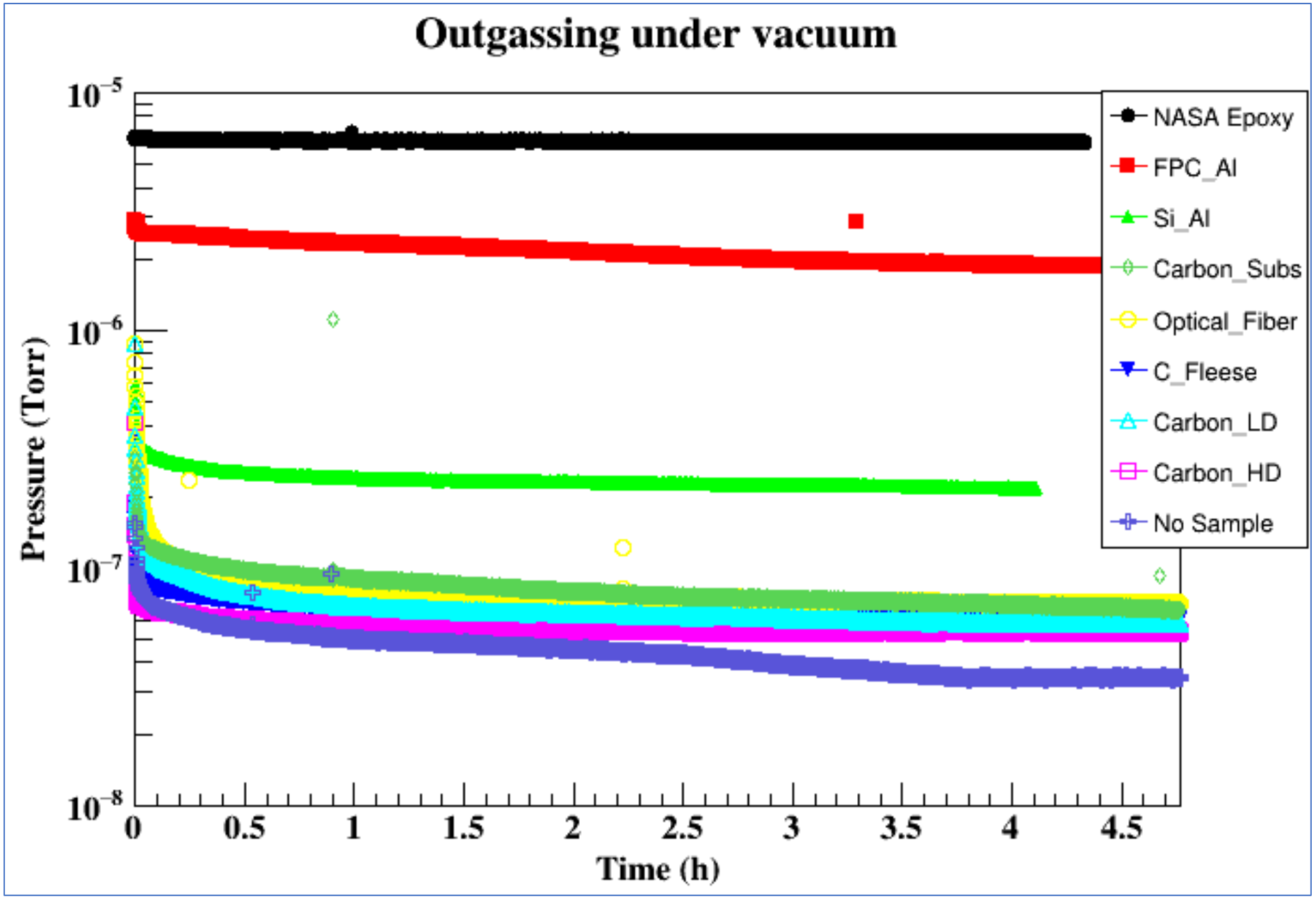
Si wafer and FPC: Residual gas atmosphere study

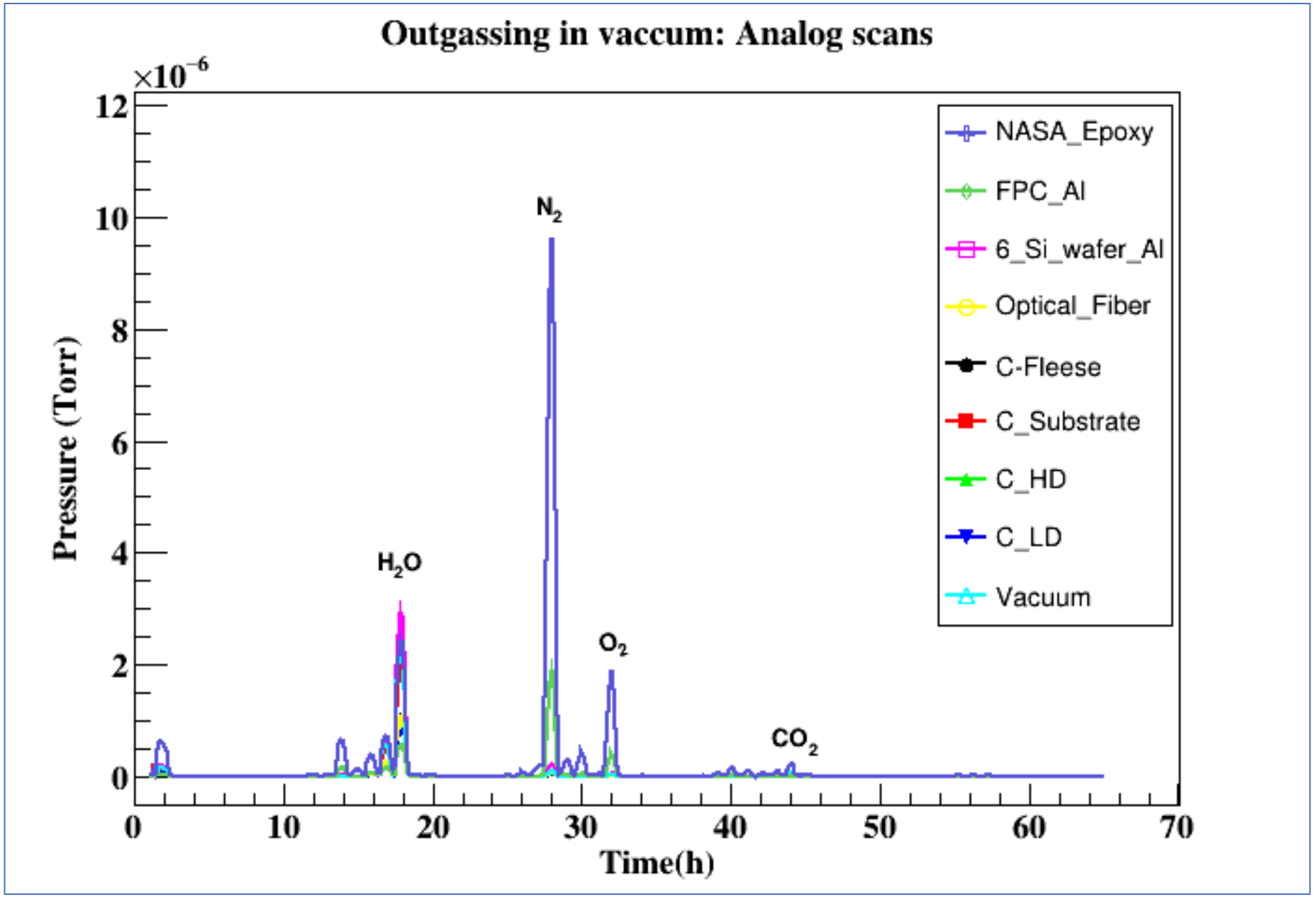




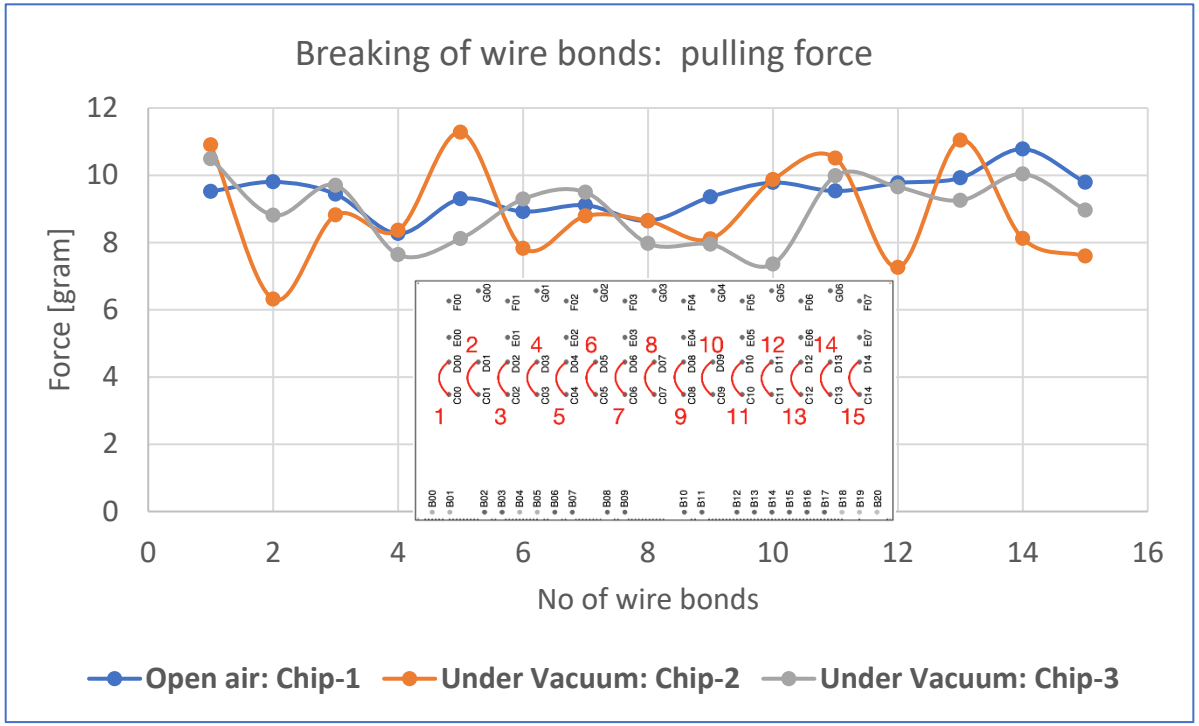
Si wafer and FPC: Residual gas atmosphere study



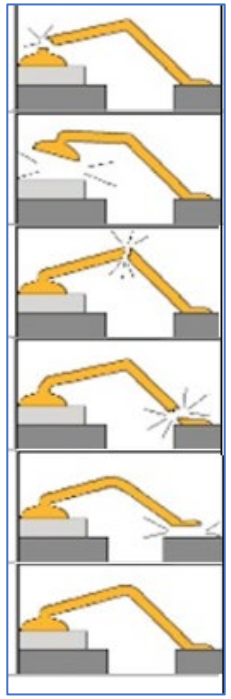

Outgassing under vacuum
Pressure (Torr)
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Time (h)
NASA Epoxy
FPC_Al
Si_Al
Carbon_Subs
Optical_Fiber
C_Fleese
Carbon_LD
Carbon_HD
No Sample


Outgassing in vaccum: Analog scans
×10⁻⁶
Pressure (Torr)
Time(h)
N2
H2O
O2
CO2
NASA_Epoxy
FPC_Al
6_Si_wafer_Al
Optical_Fiber
C-Fleese
C_Substrate
C_HD
C_LD
Vacuum

Pulling force test: preliminary results



Pulling force	chip 1: As received	chip 2: 11 days in vacuum @ E-6	chip 3: 11 days in vacuum @ E-6
Minimum	8.27	6.32	7.36
Maximum	10.78	11.28	10.49
Medium	9.46	8.90	8.98
Sigma	0.59	1.50	0.97



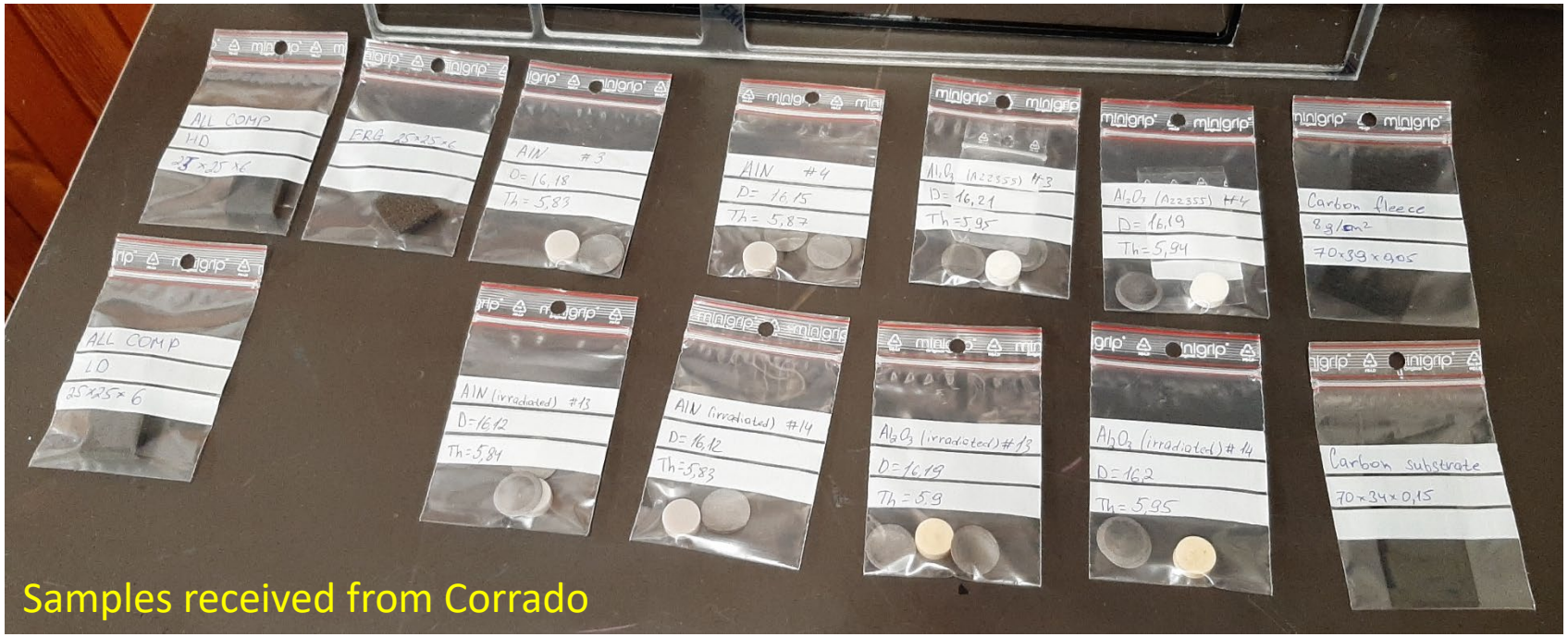
Failure modes	Chip 1	Chip 2	Chip 3
Breakage at the first foot	12	7	9
Lift off at the first foot	0	5	5
Breakage at the apex of the loop	0	0	0
Breakage at the second foot	0	1	0
Lift off at the second foot	3	2	1
Ddouble loop hooked	0	0	0

- Pull force before and after vacuum treatment: compatible within statistical error
- Lift off failure increased after vacuum treatment
- *More statistics will be added for clear understanding*

Samples to test in vacuum environment

- Sample received from Corrado Gargiulo
  - 3D printed aluminium nitride (AIN) samples disks
  - Al2O3 samples disk: 3D printed alumina (Al_2O_3) samples disks
  - 3D printed AlSi samples disks
  - Carbon (LAYPUS) Substrate of the cold plate
  - Carbon Fleece of the cold plate
  - Carbon foam All comp high density
  - Carbon foam All comp low density
  - Carbon foam ERG duocel
- Sample received from Felix Reidt
  - Optical Fiber with connector
- Samples tested in Bari
  - NASA Epoxy
  - Si wafer
  - Wire bonded Si wafer
  - FPC


Sample received from Felix



Samples received from Corrado