Topical Discussion T3: Pumping system, valves sectorization and bakeout

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What's on the menu today….

- **Passing thorough a possible layout to trigger discussion**
- **Valves and sectorization**
- **Bake-out and insulation system**
- **Gauges and RGA**
  - *Possible Agilent Presentation*

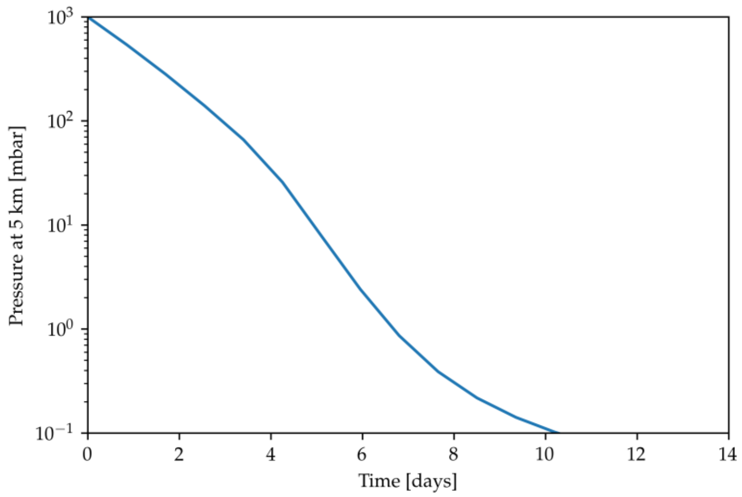
  We did not have time to discuss it, but we got some "indirect" inputs
- **Coffee break (30')**
- **Pumping system for H_2, CO, CO_2 and CH_4**
  - Roughing and turbo molecular pumping
  - Final pumping system
    - *SAES Presentation*
    - *Agilent Presentation*
- **Tower Vacuum** *(If time allow)*

  We did not have time to discuss it, unfortunately
- **Wrap-up** -> Now

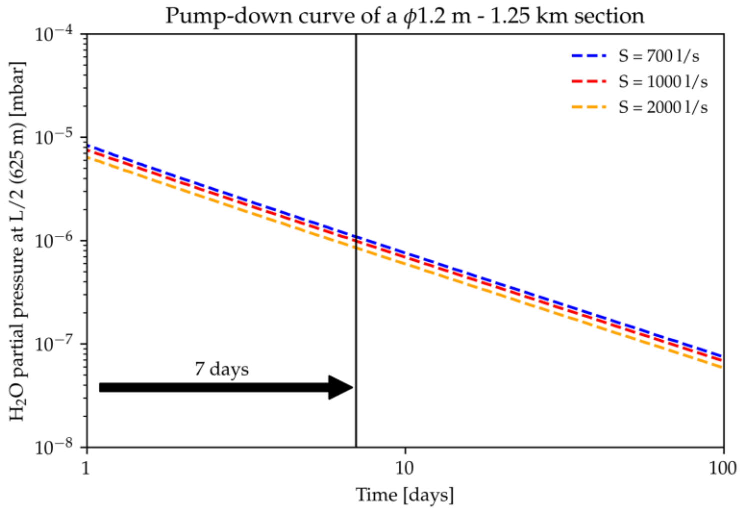
Simplified overview of pumping stages

$P_{ET}(H_2O) = 2 \cdot 10^{-11}$ mbar

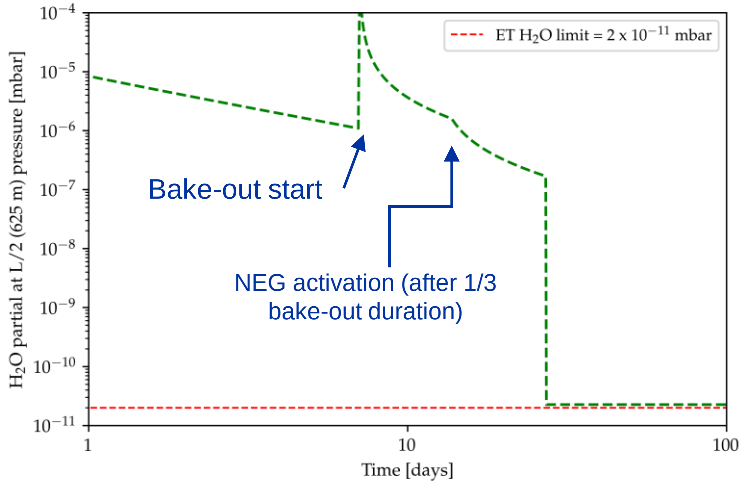
1 – Rough pumping



2 – Intermediate pumping



3 Bakeout & Steady state



8-10 days

20 days

5-7 days

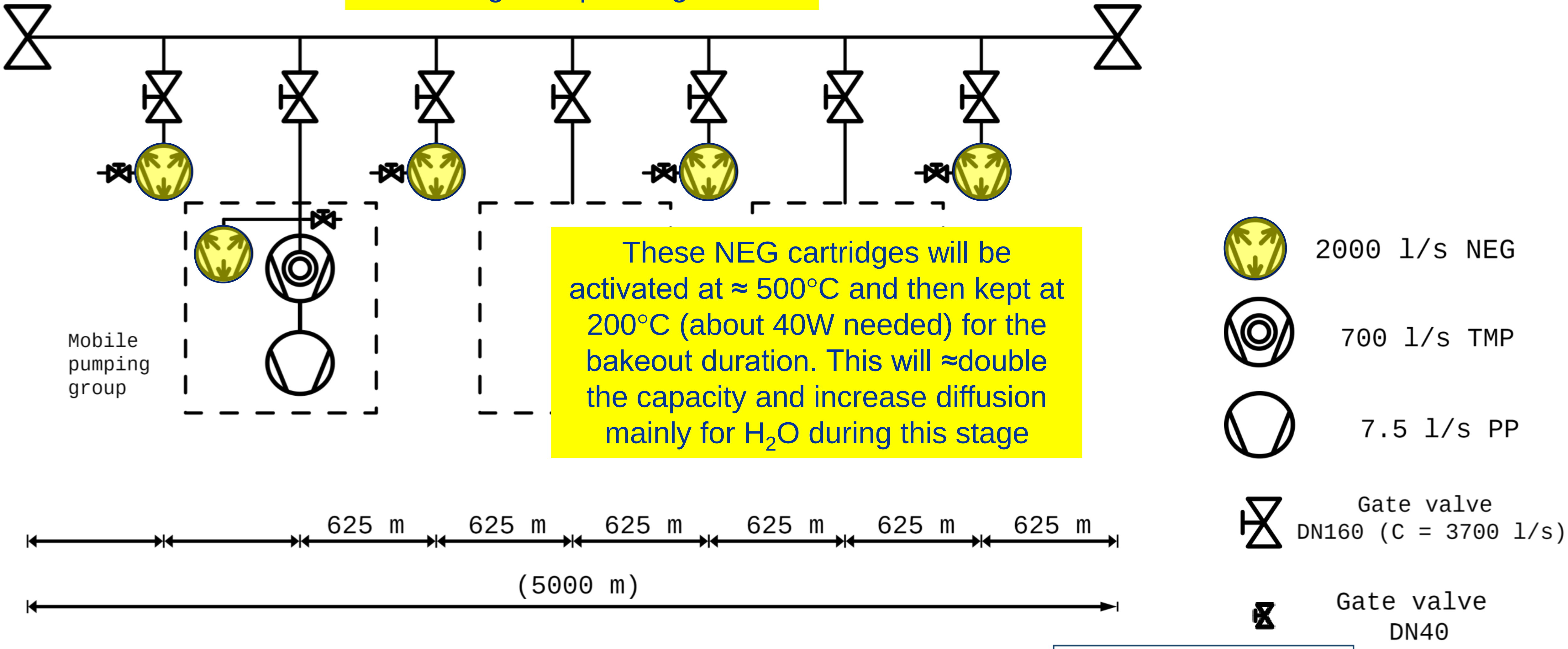
About 5-6 weeks to fully commission 5km of beam pipes -> Furter optimization, mainly on the bakeout ($P(H_2O)$ requirements, bakeout temperature, insulation thickness) could even reduce the time to ≈ 4 weeks (?)

Close to one year to commission all the vacuum system: Which parallel activities could be allowed in the tunnel?

From C.Scarcia presentation

HV pumping: Mobile group to be used during the bakeout cycle

NEG at high temp during the BO



These NEG cartridges will be activated at ≈ 500°C and then kept at 200°C (about 40W needed) for the bakeout duration. This will ≈double the capacity and increase diffusion mainly for H_2O during this stage

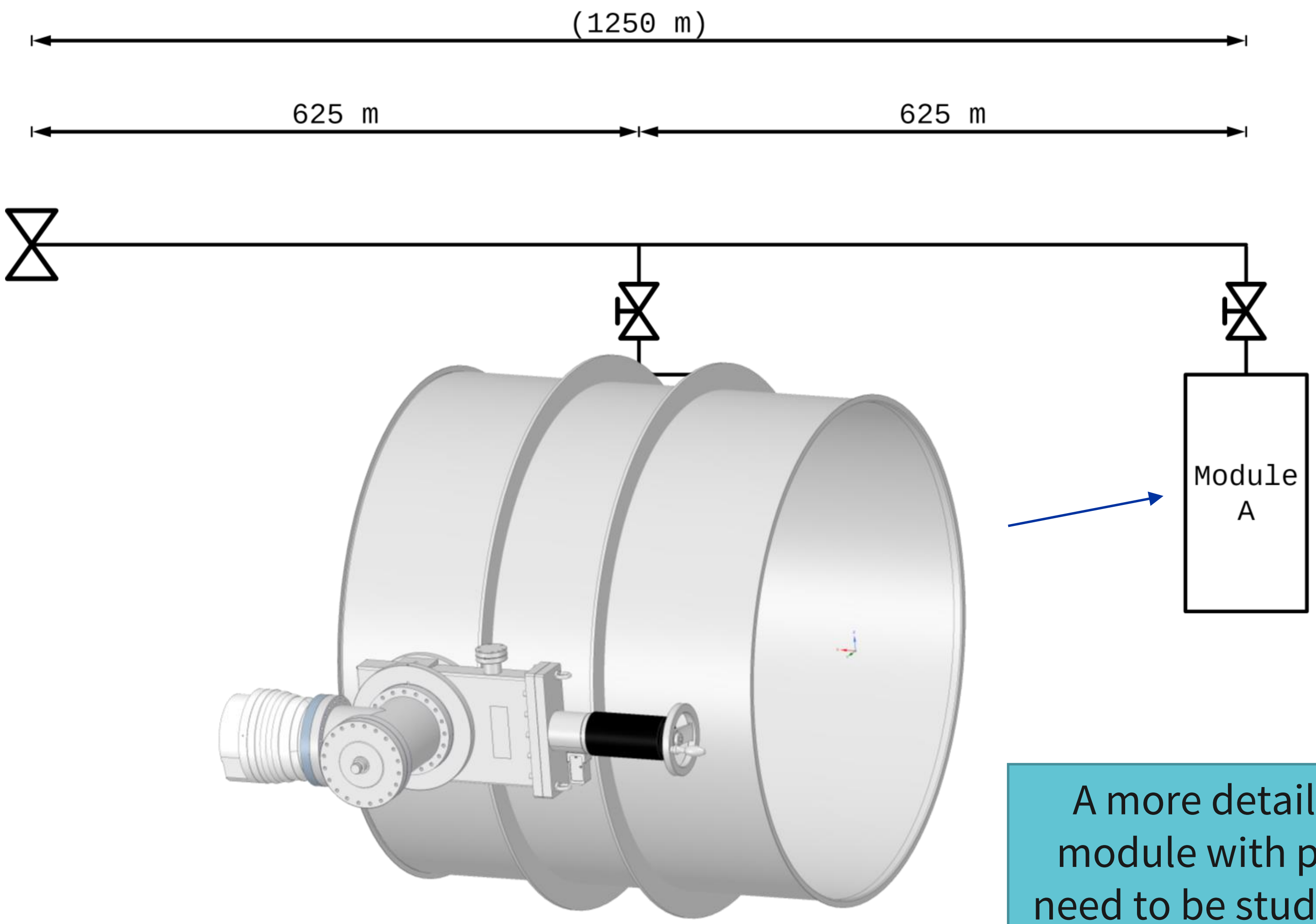
From C.Scarcia presentation

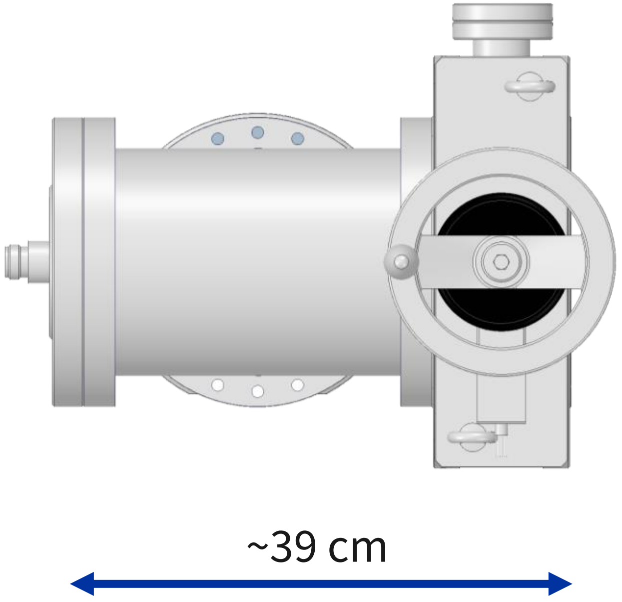
HV pumping: vacuum layout

NEG at high temp during the BO

Module A (mobile):

2000 ls^{-1} NEG + 700 ls^{-1} TMP

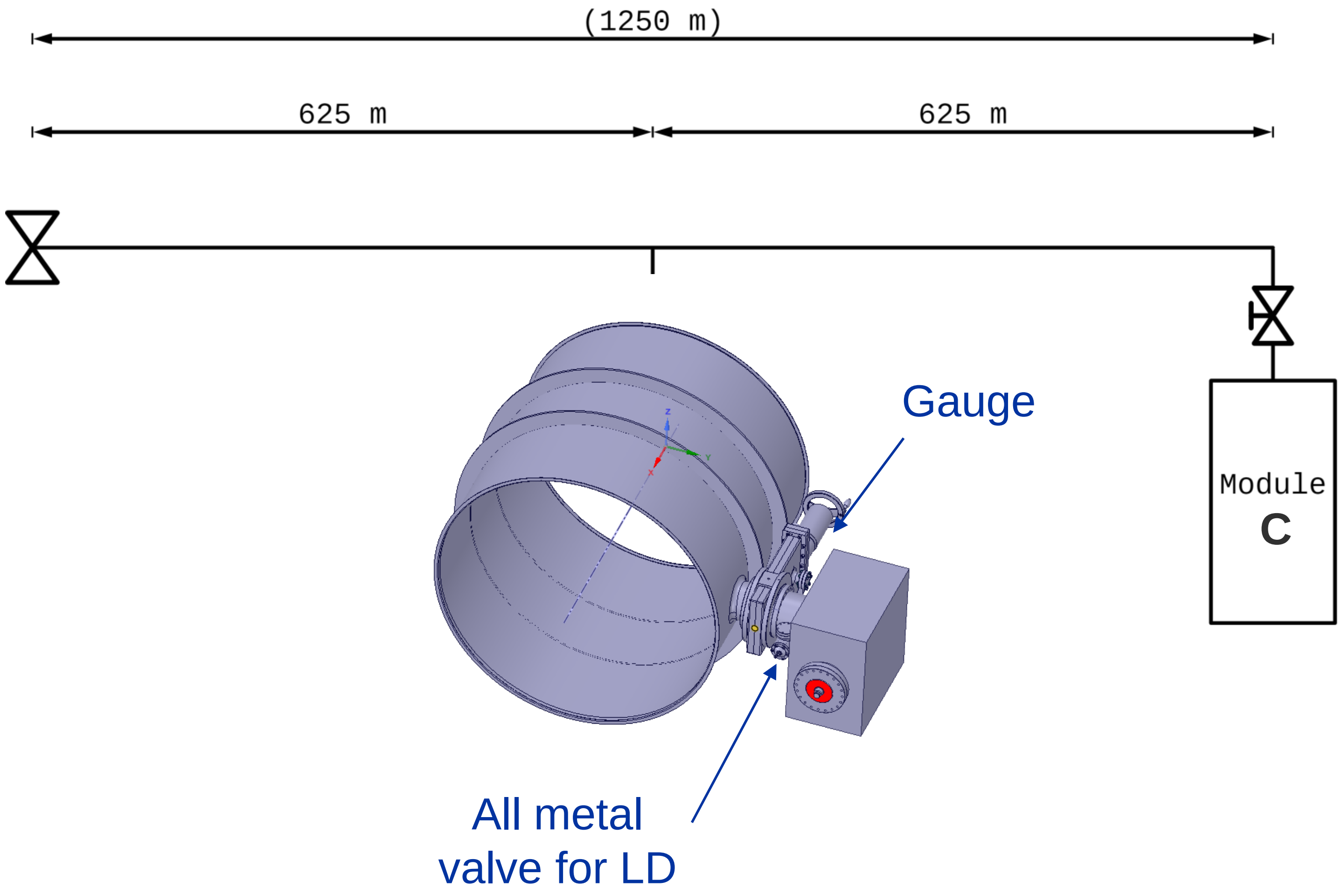




A more detailed design of the module with possibly an elbow need to be studies and integrated

From C.Scarcia presentation

HV pumping: vacuum layout



Module C

Will replace the module A mobile turbo

2000 ls^{-1} NEG + 500 ls^{-1} Ion Pump

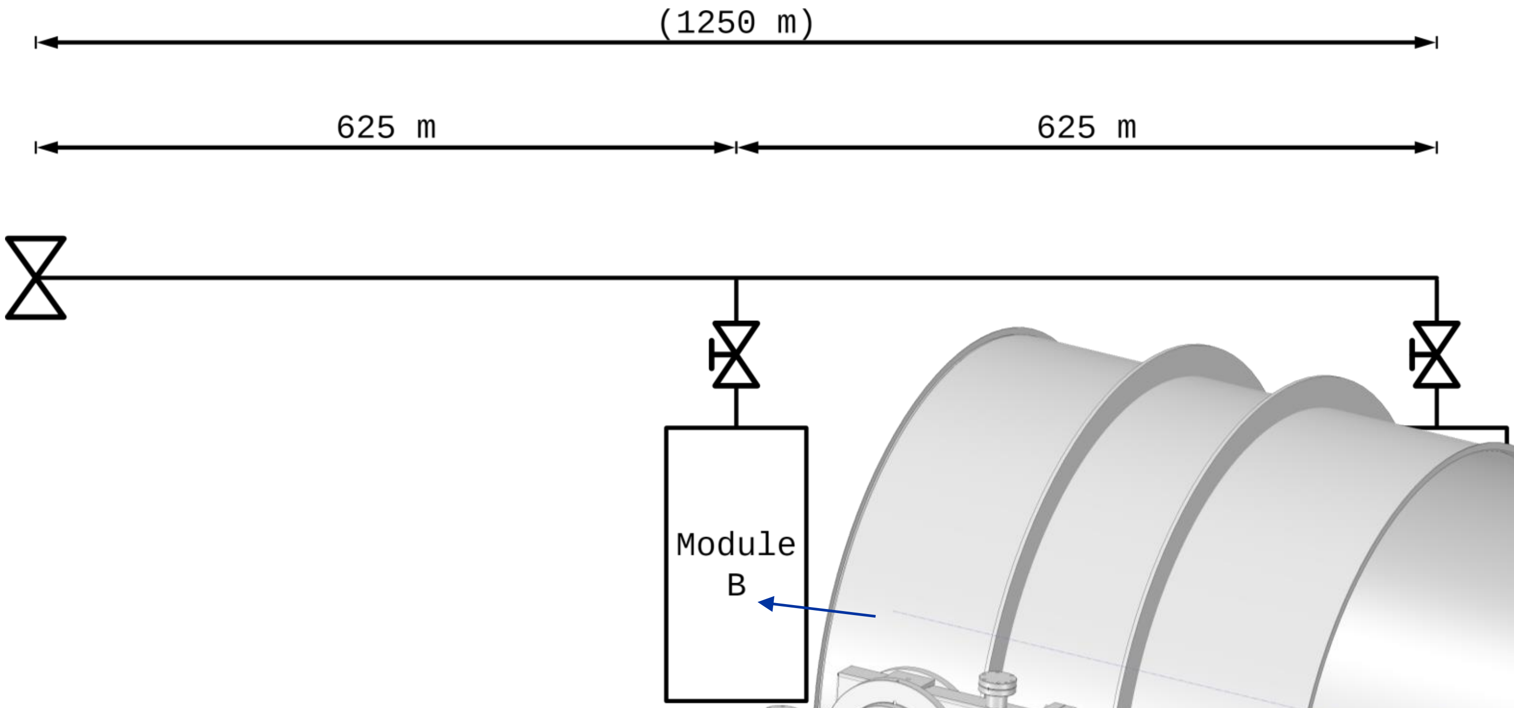
Final configuration after bakeout

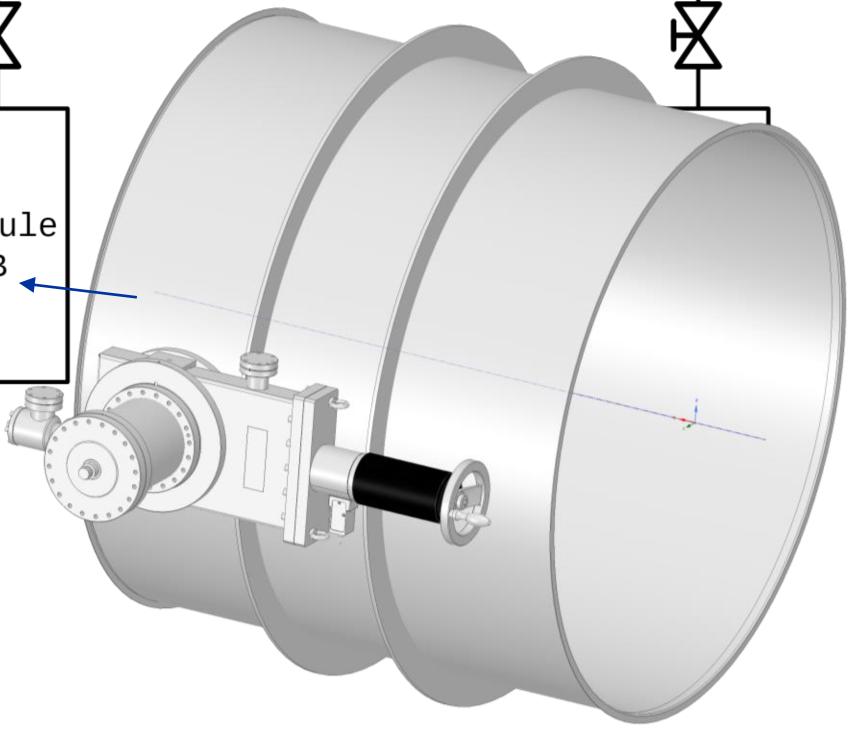
From C.Scarcia presentation

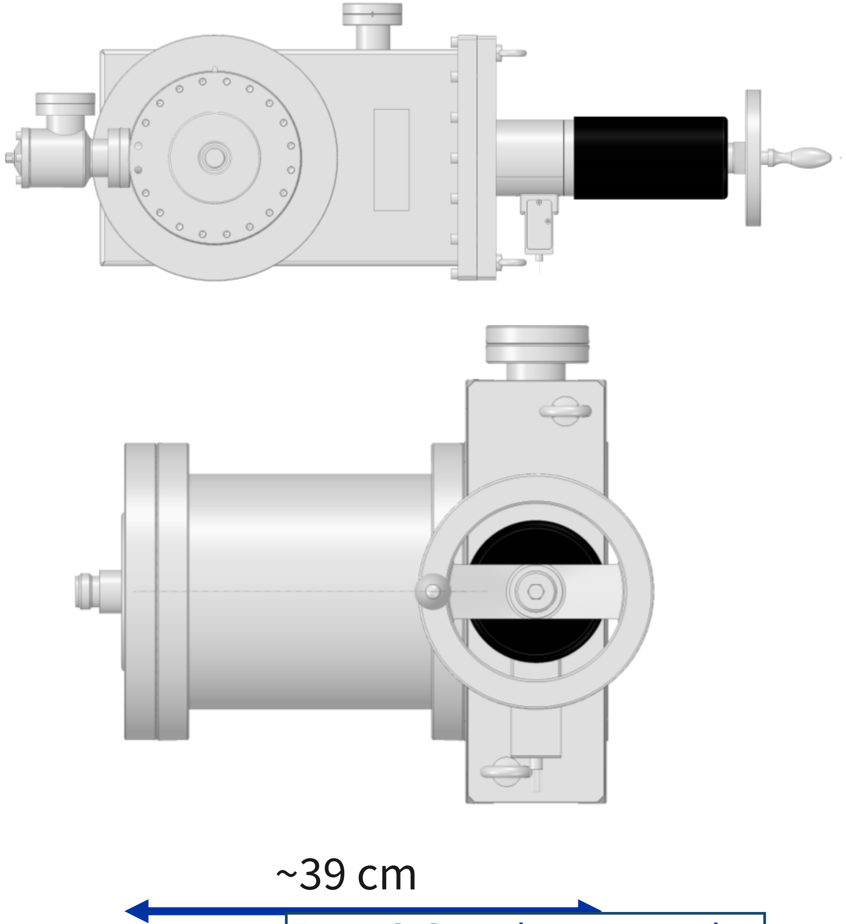
HV pumping: vacuum layout

Module B:

2000 ls^{-1} NEG



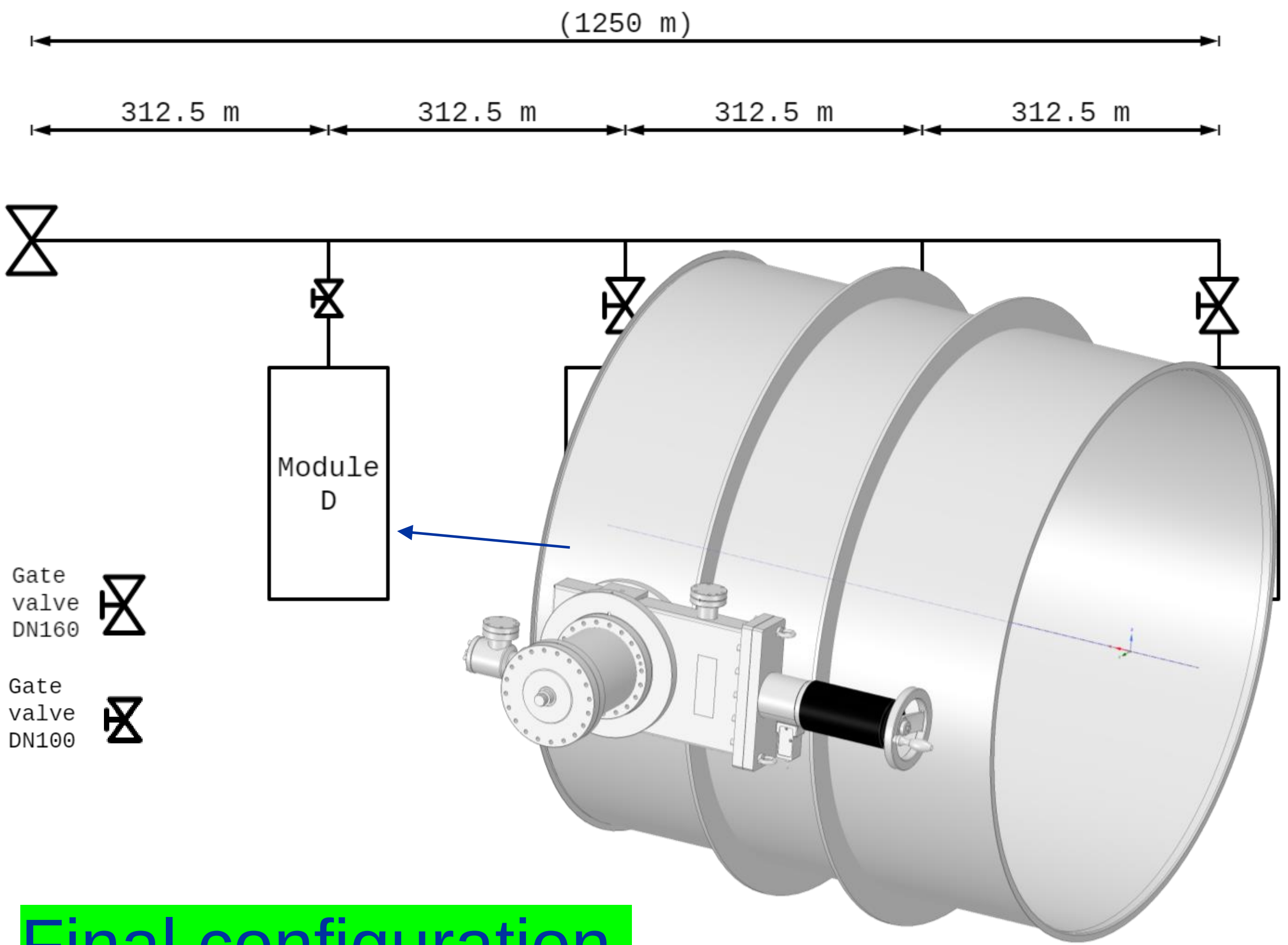




NEG at high temp
during the BO

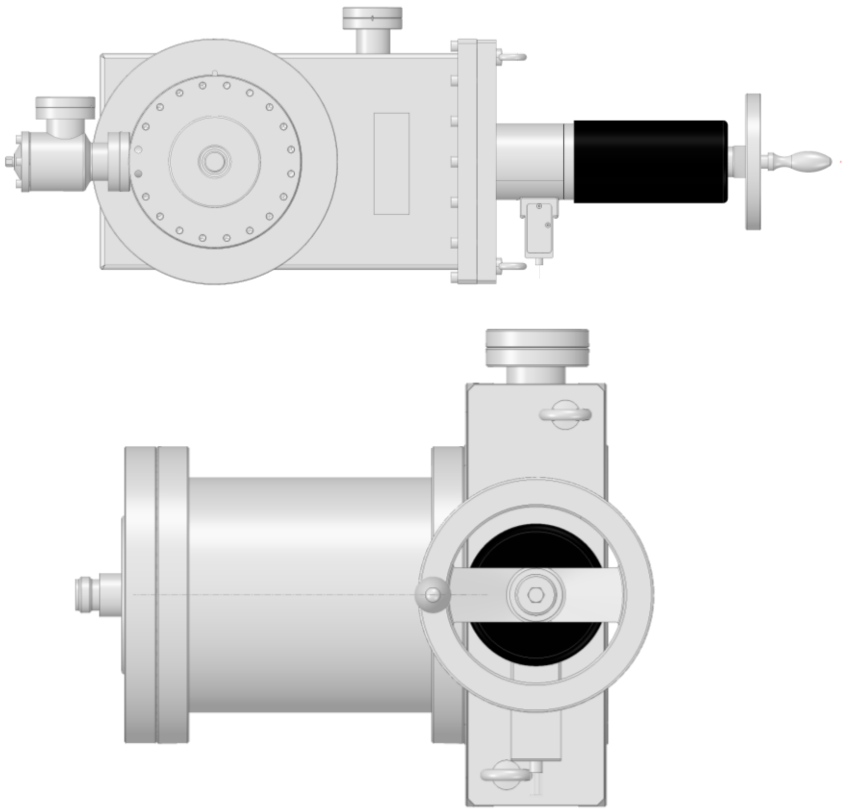
From C.Scarcia presentation

UHV pumping at RT: vacuum layout



Module D:

1000 ls^{-1} NEG or similar



~ 25 cm

From C.Scarcia presentation

Final configuration after bakeout

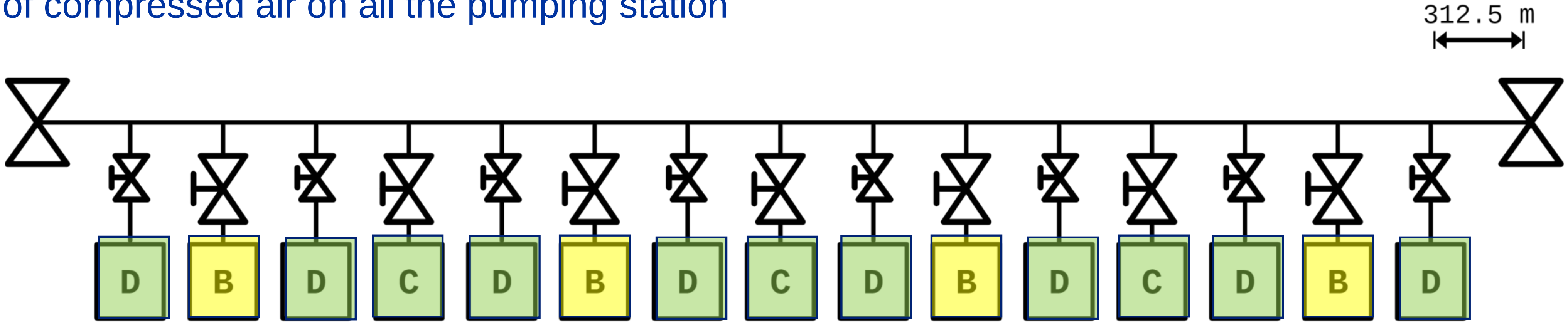
UHV pumping at RT: vacuum layout

Whenever possible the beampipe experts should try to finalize the design of the tunnel, which conditions the spaces and positions of the other elements of the system (cryosystems, towers,)

5000 m

Very Important:

- Need of power 220V on all the pumping station
- Need of compressed air on all the pumping station



From intermediate phase → **B** 2000 l/s NEG

D 1000 l/s NEG

C 2000 l/s NEG + 500 l/s IP

Gate valve DN100 (C = 1400 l/s)

Gate valve DN160 (C = 3700 l/s)

Working @ RT

Working @ High temperature

From C.Scarcia presentation

UHV pumping at RT: vacuum layout
Some further considerations

1. **It was said that all the valves of the pumping modules should be electropneumatic with control system to increase reliability and remote intervention if needed**

2. **It was proposed to even add every 125m some additional angular metal valve/flanges to give the option in case of problems of:**
   1. Add additional pumps Ti sublimation filaments on a “sleeping” mode”: See slide afterward
   2. To add some RGA if needed
   3. To perform more precise leak detection

UHV pumping at RT: vacuum layout
Some further considerations

1. **The DN1250 gate valves should be installed horizontally to the beam line:**
    1. In case of failure you will not block the aperture

2. **They will need in any case some dedicated space for a “clean” installation in the tunnel with a design tent and gas flow**

3. **The DN1250 gate valves are a major concern in case of failure based on existing experience. It was proposed to possibly double at least the one at 5km and have a sort of buffer small sector that in case of need could be easily dismounted and allow access to the mechanism of the valve**
    - Need a list of risks and benefits. Also risks associated with the addition of the valves themselves (e.g. leaks).

- **We should know if a DN1000 or even smaller is a real option at 5km because would decrease a lot the cost**

Venting system & Leak test (or anticipate leaks problem)

1. **It was proposed to use some purified dry air compressor**
    1. LIGO experts suggest dry air @ 77K level with sort of purifying filters : Can we have some detailed information about that? Thanks

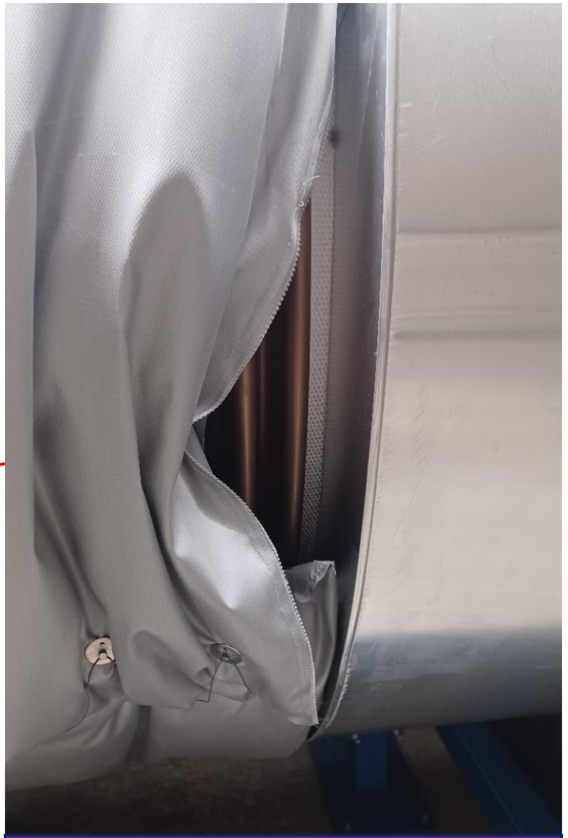
2. **Leak test: during the installation, an overall check of 'total leak rate' shall be done by accumulation and may save some effort with the He LD procedure**
    1. Also, more RGAs shall help for leak localization issues: At least 3 RGA combined with the routine check described below
    2. As a routine check an accumulation should be done to measure that the pressure level is conform and that no “hidden” air leak are present on the system
        1. Important to have a proper RGA signal and every 1-3 year a kind of calibration with an Argon calibrated leak should be done on the pumping ports to be sure we have a proper and precise signal

Bake-out and insulation system

Bake-out via ‘Joule effect’

The support system of the beam pipe should take in consideration the need of bakeout

Some details



II. more heat generated in thinner sections (top/bottom unequal)

I. Electrical isolation of beampipe stands & covers

Bake-out via ‘direct Joule effect’

Some details

III. Pumping stations @ ≈ 0 V

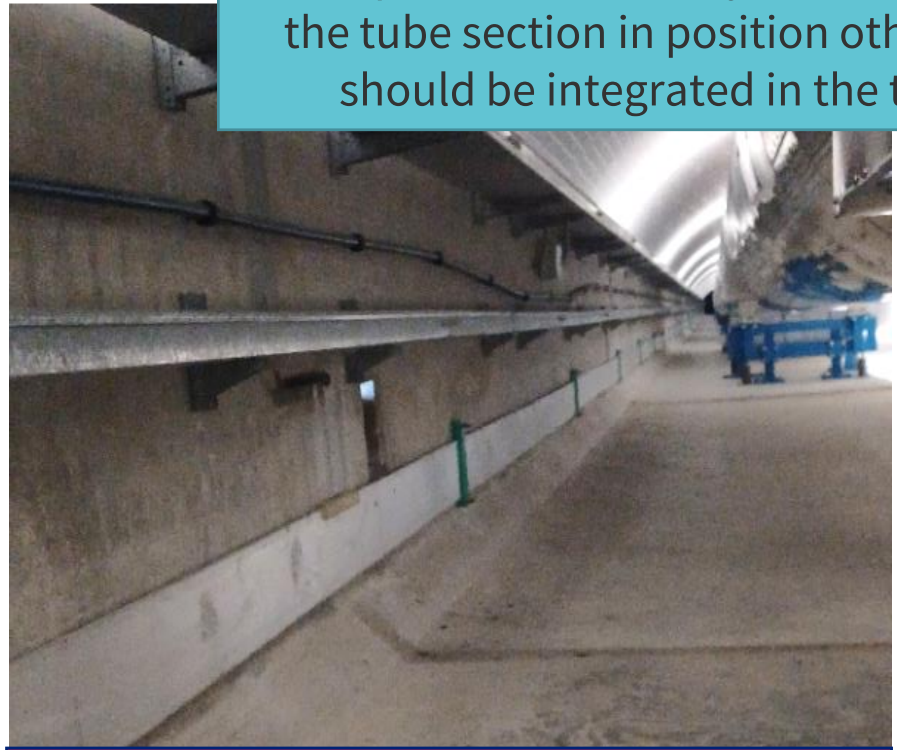
to be designed on purpose

Bake-out via ‘direct Joule ef

We need to study this in detail with the technology now available

Some details II

Like for GEO600 the return conductor could be the possible rail (If any) used to transport the tube section in position otherwise it should be integrated in the tunnel



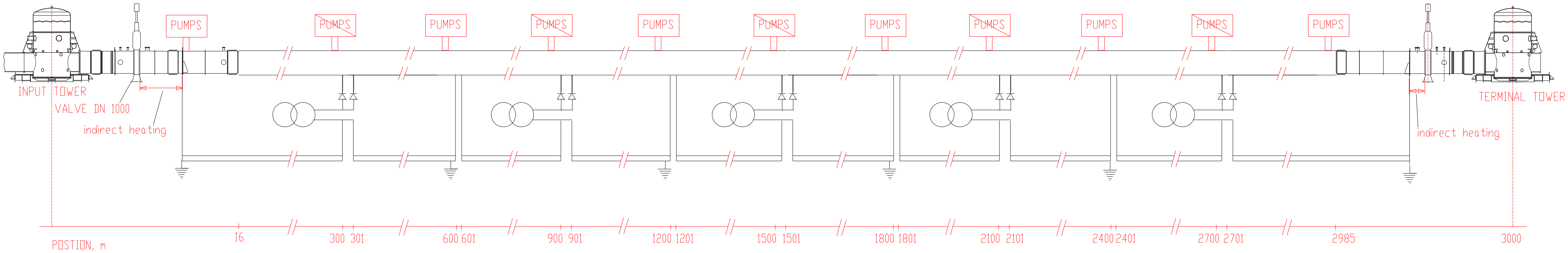
IV. Return conductor

V. DC converters: room & cooling

Bake-out via ‘Joule effect’

Some details

It was done for 3km length, and it could be implemented for 5km. Longer sector length start to be very difficult from all point of view



VI. 60 V DC ‘limit’ (?) & safety aspects: possible impact on layout of bake-out pumping

Insulation material & bakeout consideration

H_2O pressure requirements should be carefully defined because they could have an important impact on the bakeout temperature, insulation thickness and needed time for the bakeout

If HF or LF beam pipe have different requirements should be included already on the design because it could easier the full commissioning and installation: Possible different insulation thickness, different bakeout length, different pumping system, etc…

- Heat to be exhausted during bakeout: forced ventilation sems not to be needed. Consequently, there seem to be no impacts with respect to sectorization. A real case of experience would be helpful. It is an important point that now needs to be defined in order to finalize the design.
- Insulation: Easy to install and to de-install in case of leak
  - Is it worth looking at a solution with dismountable insulation system: Gain on cost of material but more labor cost: TBD.
- Are we searching an as much as possible dust free insulation?
  - Mineral wool or glass fibers or aerogel insulation (etc..) will produce a lot of dust in the tunnel: Coactivates? Blocking point?

Insulation material & bakeout consideration

- Bakeout with joule effect is the only option at the moment, but needs to be developed in detail for the ET project and the CERN pilot sector

- What if a major problem happening?
  - Venting with dry air
  - Exchange the part under air flux to limit retro-diffusion of water
  - Use the "spare" port with Ti sublimation to limit the bakeout of the exchanged part: Limited bakeout with standard heating tape to 100-150m already done at CERN and could save time and money in case of problem
    - "Crazy" idea but it could/should work if analyzed in detail, on a small diameter and with NEG coated beam pipe already implemented at CERN and could be developed for ET: Safety FIRST!

Pumping system

Pressure requirements for ET

Pressure requirements for ET

HF><LF?

Gas species	Outgassing rate	Pressure max	Noise LF	Noise HF
	$mbar\, l/s\, cm^2$	mbar	$1/\sqrt{Hz}$	$1/\sqrt{Hz}$
H_2	1.9×10^{-14}	1×10^{-10}	2.9×10^{-26}	2.4×10^{-26}
H_2O	2×10^{-15}	2×10^{-11}	2.9×10^{-26}	2.3×10^{-26}
N_2	2×10^{-17}	2×10^{-13}	3.7×10^{-27}	2.8×10^{-27}
CO_2	1.5×10^{-16}	2×10^{-12}	1.6×10^{-26}	1.2×10^{-26}
C_2H_4	1×10^{-17}	1×10^{-13}	6.3×10^{-27}	5×10^{-27}

Assuming a margin of 9 for ET-HF and 20 for ET-LF

Are these average value of pressure along 10km? On which length can you accept to a have higher pressure? What is the limit?

At first stage we consider the average pressure along the 10 km arm. To further optimise the analysis, we shall then consider the actual pressure profile in relation to the expected beam profile

Final pumping system for H_2 and CH_4

Turbo molecular pump
- Maintenance
- Vibration
- Single local power supply
- Control system: PLC

CH_4

Cryogenic pumps
- Maintenance
- Vibration
- Single local power supply
- Control system: PLC

CH_4

Ion pumps
- Weight
- Integration
- Single local power supply
- Control system: PLC

CH_4

Sublimation pumps
H_2
- Low cost
- If well designed: High pumping speed and high capacity
- Sublimation process very fats: few minutes
- No local controller and could be easily remotely operated
- Not possible to use during the bakeout phase

NEG based pumps
H_2
- No local controller and no power needs
- Activation cycle relatively short (30-60 min)
- High capacity and possible custom made design

NEG cartridge based pumps
Some consideration & Open questions

- Custom made shape? What is the maximum pumping speed?
  - External vs Internal solution

- Capacity for different gases @ RT vs @ 200°C

- Is there any problem of dust or particles production during the activation cycle?

Pro and cons of different solution: Cost vs Performance

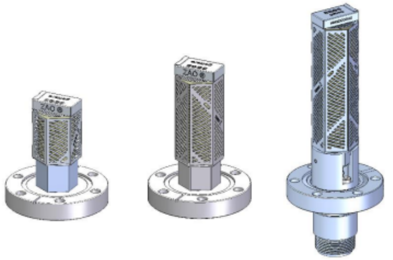
- Why and when using the ZAO?
- Why not capacitor?
- Why not the NEG Strip

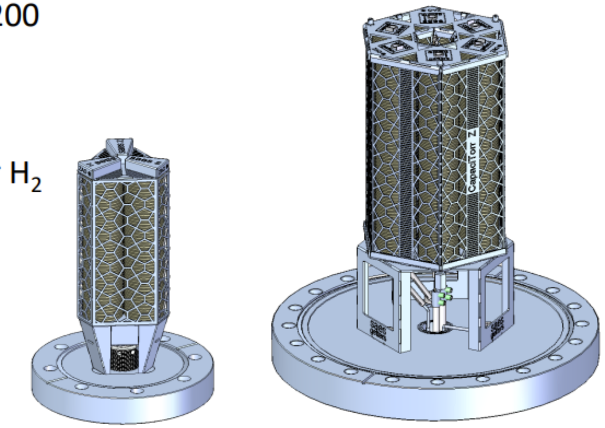
SAES presentation: External solution

Working @ RT

CapaciTorr

- NEG Pump only
- CapaciTorr «Z» family → **UHV application**
- Getter alloy: *ZAO* - ***UHV*** (sintered)
- Flange from CF40 to CF200
- Nude configuration
- Working @RT
- From 100 to 3500 l/s for H_2





Working @ High temperature

CapaciTorr

- CapaciTorr «HV» family → for **HV application**
  - Higher capacity;
  - In-body (or nude) solution
  - Working @ 200°C (or RT)
- Getter alloy: *ZAO* - ***HV*** (sintered)
- Flange from CF40 to CF200
- From 200 to 2100 l/s for H_2

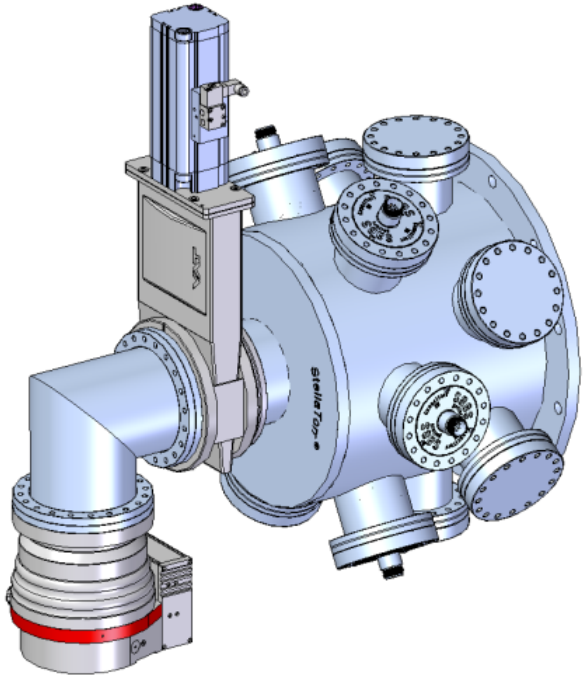
SAES presentation: External solution –Custom made

40 x CapaciTorr Z 200 Cartridge/CF350

- Pumping speed target 7500 l/s for H_2
- Customer's CF350 special body design;
- n. 40 cartridge CapaciTorr Z 200
- n. 2 feedthroughts 4 pin 10 A

StellaTorr 2x6xC2100HV/DN400

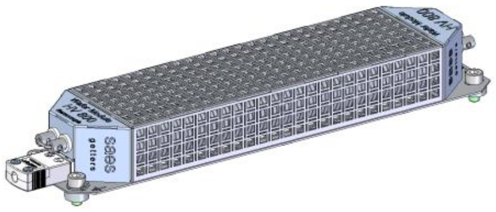
- The solution allows the installation of 6 or 12 C 2100 HV o CT HV NBI cartridges.
- Body geometry discussed with the customer
- Gate valve, TMP e accessories could have been supplied by SAES or not.



SAES presentation: Internal solution & Custom made

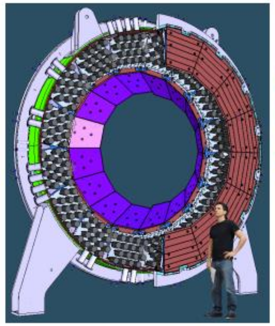
Wafer Module

- NEG Pump without flange
- HV/UHV application (*ZAO* ***HV***/***UHV*** sintered getter alloy)
- Feedthrough flange and in-vacuum cabling available
- Models with thermocouple available
- From 400 to 1400 l/s for H_2

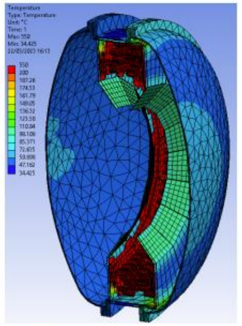


SPIDER

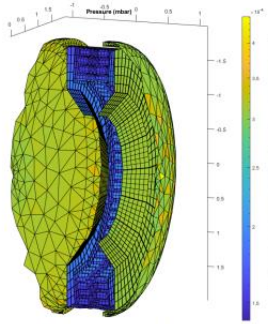
- Pumping system for SPIDER Neutral Beam Injector experiment at RFX for ITER
- Up to 512 NEG cartridges installed → pumping up to 330 m3/s for H2 @e-4 mbar
- Largest NEG pumping system in the world
- Several studies to determine optimal positioning of the pumps
- Thermal and vacuum studies closely linked
- Power supply, electronics and SW integrated within the overall experiment control system



CAD model



Thermal analysis

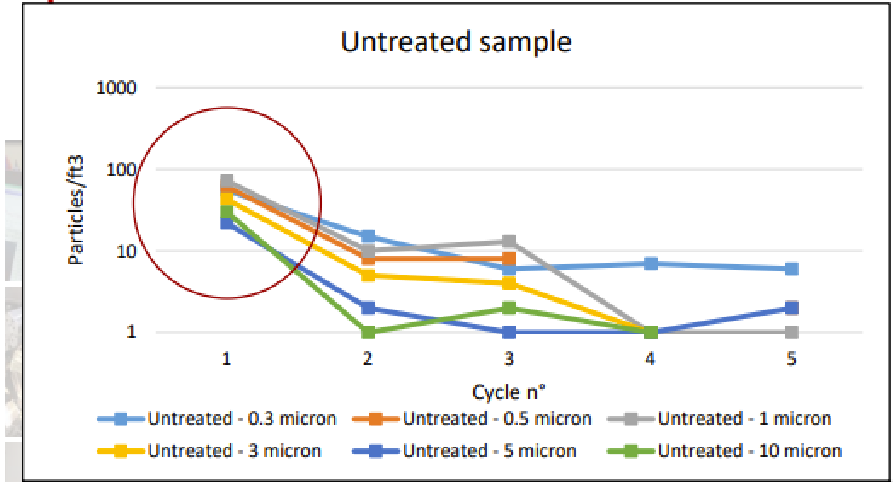


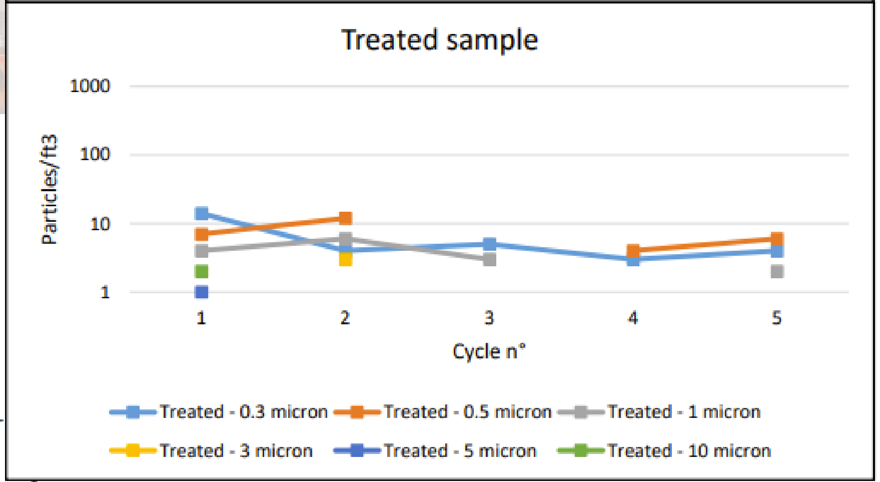
Vacuum analysis

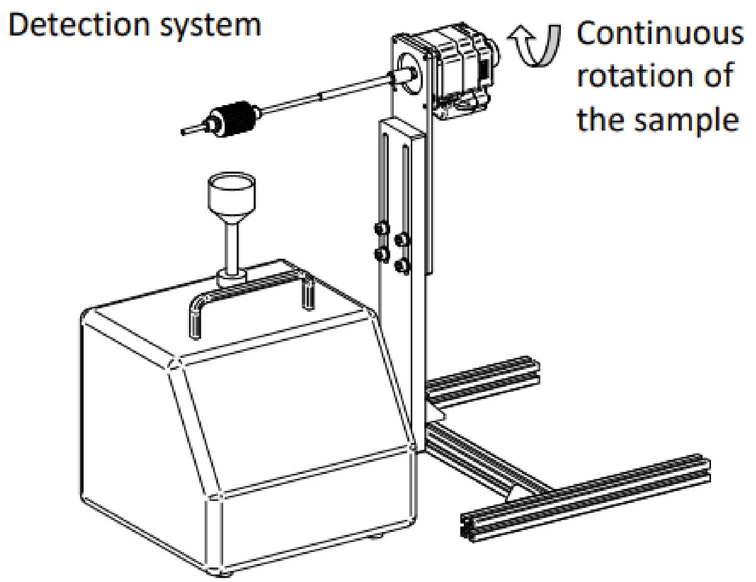
Lab Validation Tests on a sector

SAES presentation: Particle detection

Checking the effectiveness of cleaning treatments







Example of countings for 11 dsk NEG stacks (ZAO UHV):

- **Treated stack: background-comparable;** masses > 5 micron below 2 units at the first minute, then they are not detected anymore.
- **Effectiveness of cleaning treatment.**

Ion Pumps
Some consideration & Open questions

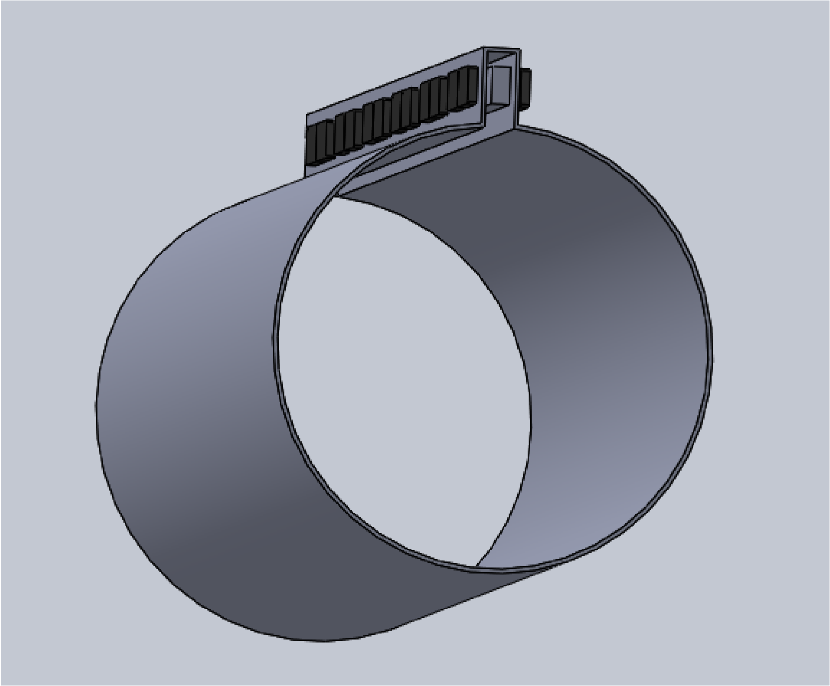
- CH4 Pumping: How efficient at this pressure level?
  - Internal vs external solution.

- Powder and particle production? Can they migrate in the beam tube?

- HV Feed through robustness? Can we drop the idea of the manual gate valve? Pro and cons

- How many ion pumps can be piloted with a single power supply? Power and cable needs? Ethernat or Profibus connection?

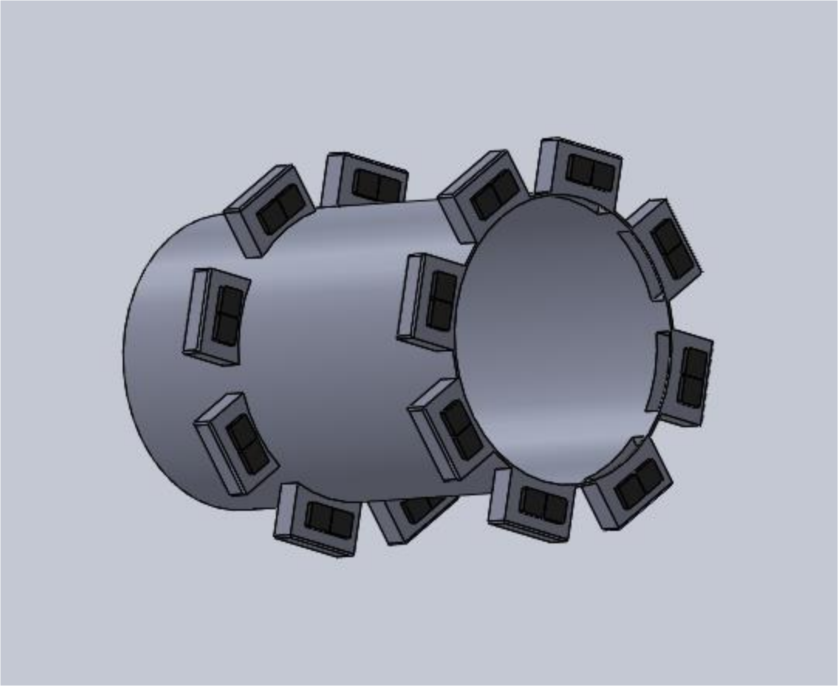
Agilent presentation: Internal solution & Custom made



Slot dimensions: 160mm x 130 mm x ???

160 mm Diameter increase

Overall dimensions, including magnets & Pole pieces



Slot dimensions: 160 x 130 X 300 mm

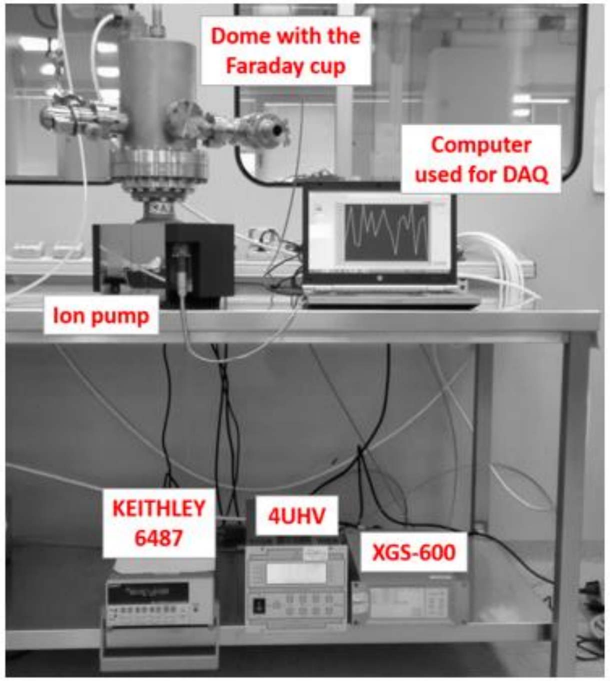
160 mm diameter increase

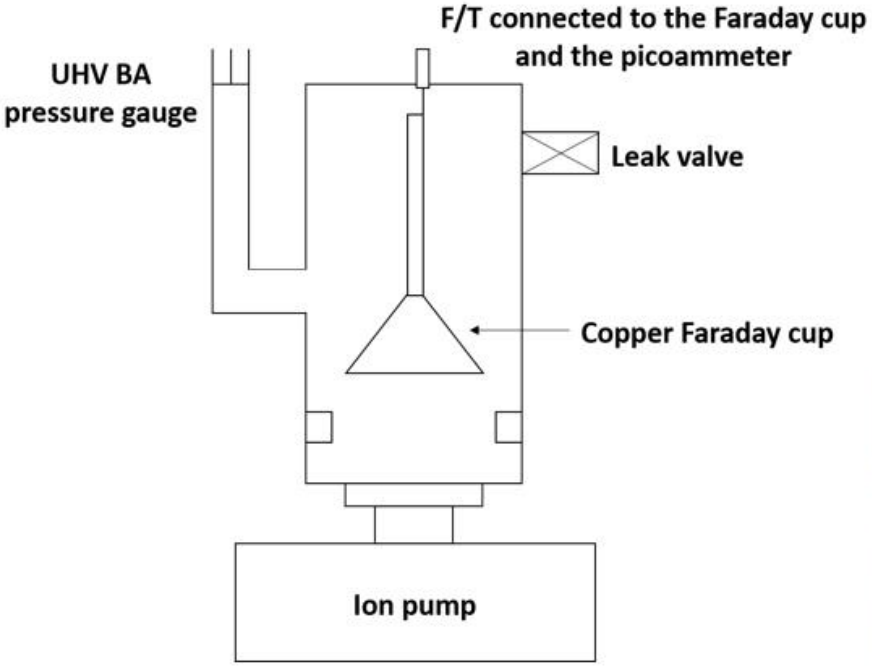
Overall dimensions, including magnets & Pole pieces

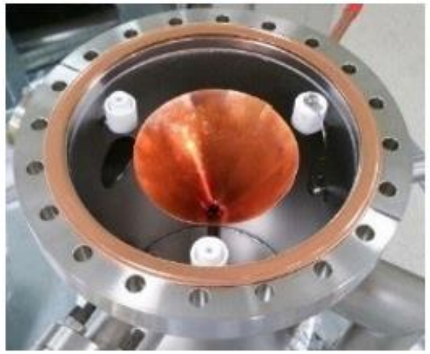
Agilent presentation: Particle emission

Experimental setup

Particle Emission



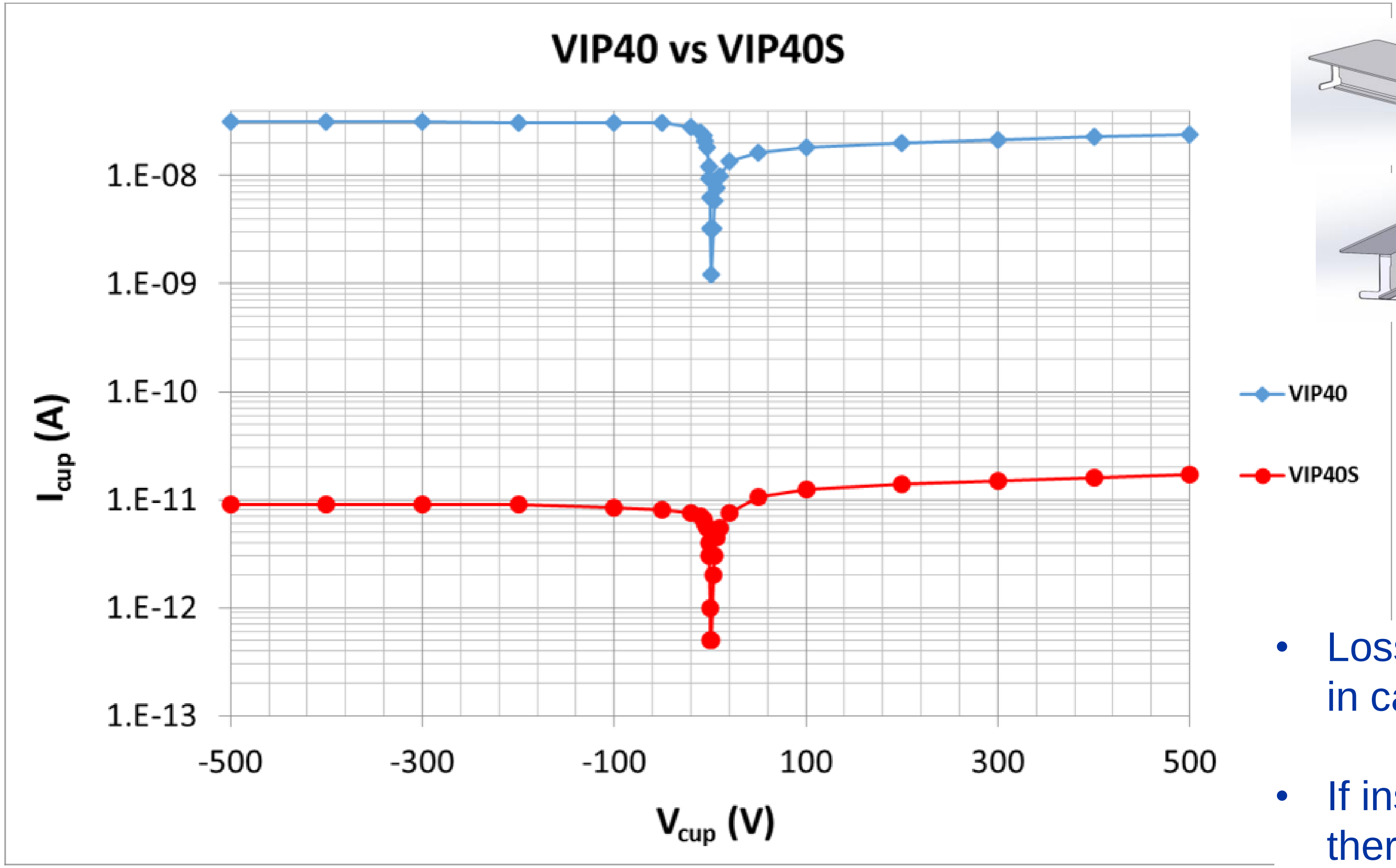


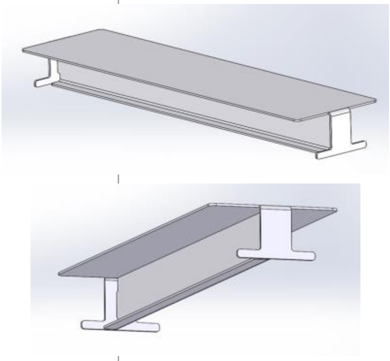


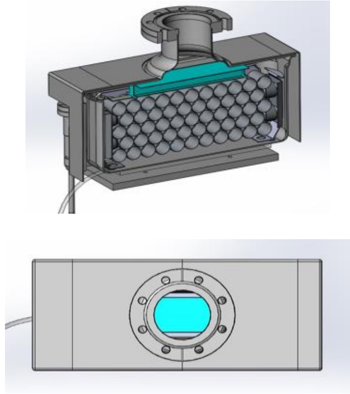
Tests at P= 5 E-7 mbar and V = 5KV unless otherwise specified

Agilent presentation: Particle emission

Not Shielded vs New Shield , DN 40 flange







More than three orders of magnitude particle reduction

- Loss of about 25% of pumping speed in case of shield
- If installed with elbow most probably there is no need of shielding

Agilent presentation: CH_4 Pumping

Methane «behaves» like a Noble Gas

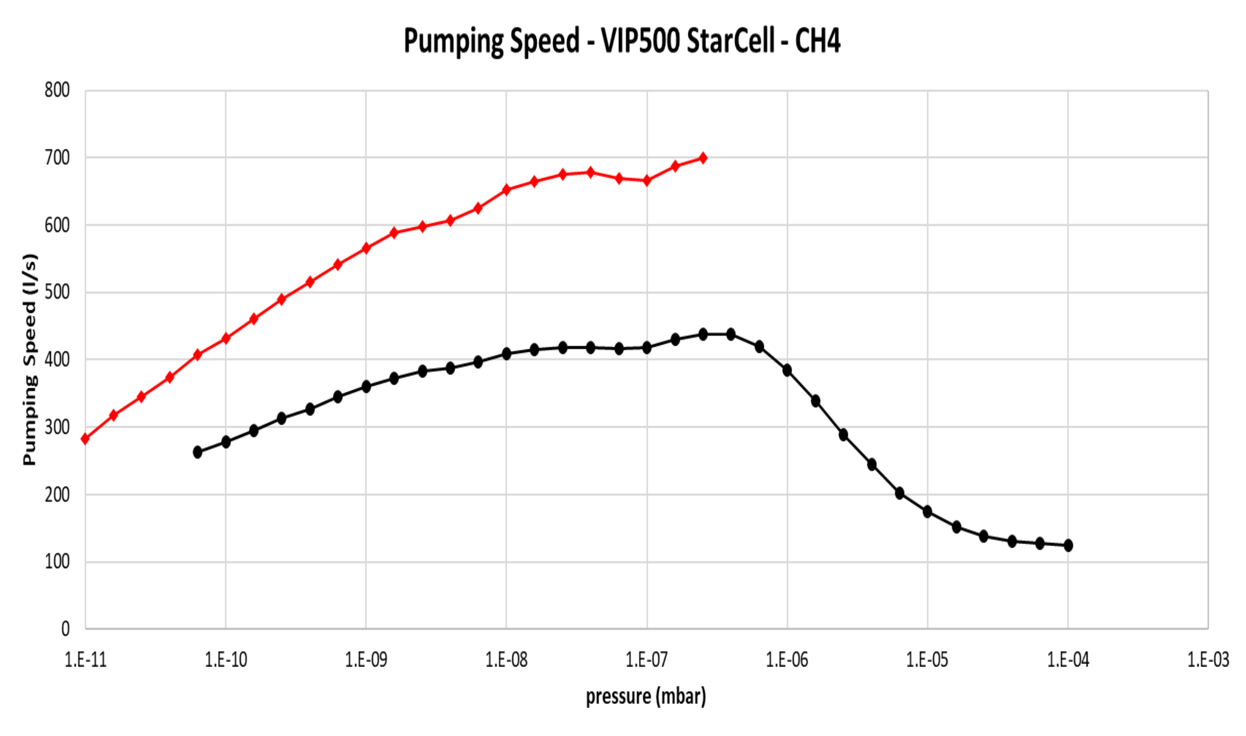
Main pumping mechanism is CH4 ions bombarding the cathode , and then either implanted there (unstable pumping) or being neutralized and reflected , and embedded into the anode and covered by sputtered cathode material (stable pumping)

StarCell performance best for CH4 , highest reflection rate

Phisycal burying , not chemical reaction

Ion pumps do crack Methane and Hydrogen and CHx are pumped as «getterable» gases

Overall efficiency almost comparable to the one for Nitrogen



- Starcell is the best solution in any case

Agilent presentation:
Corrosion free ION Pumps HV Feedthrough

Corrosion free feedthrough

HV feedthrough and connector are subjected to corrosion

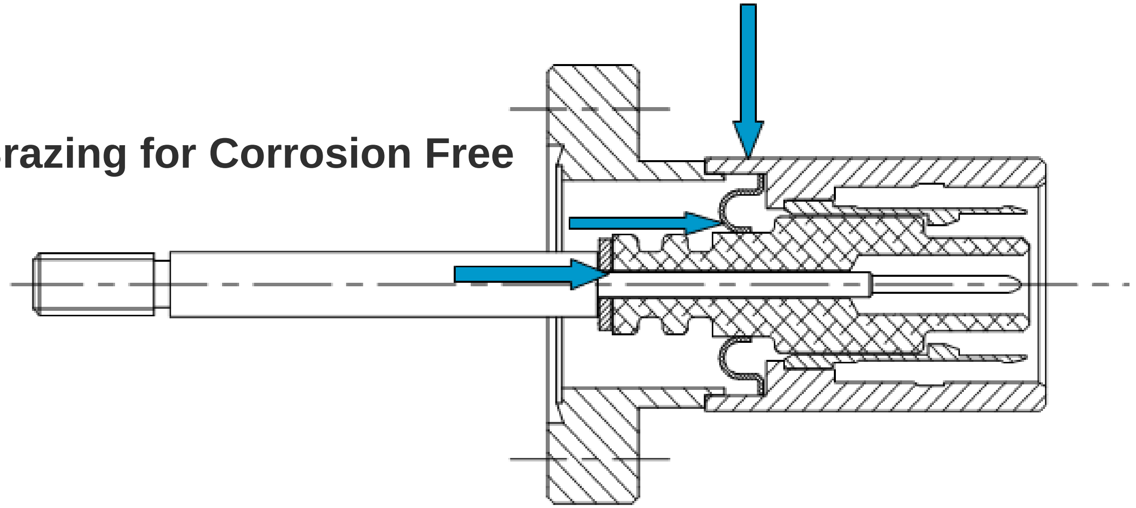
Transition metal to Kovar (or similar) to ceramic is critical

Temperature cycling , humidity , high electric field gradient may cause corrosion

Water vapor trapped in between the connector and the feedthrough may cause oxidation

Specific design to minimize air trapping and criti

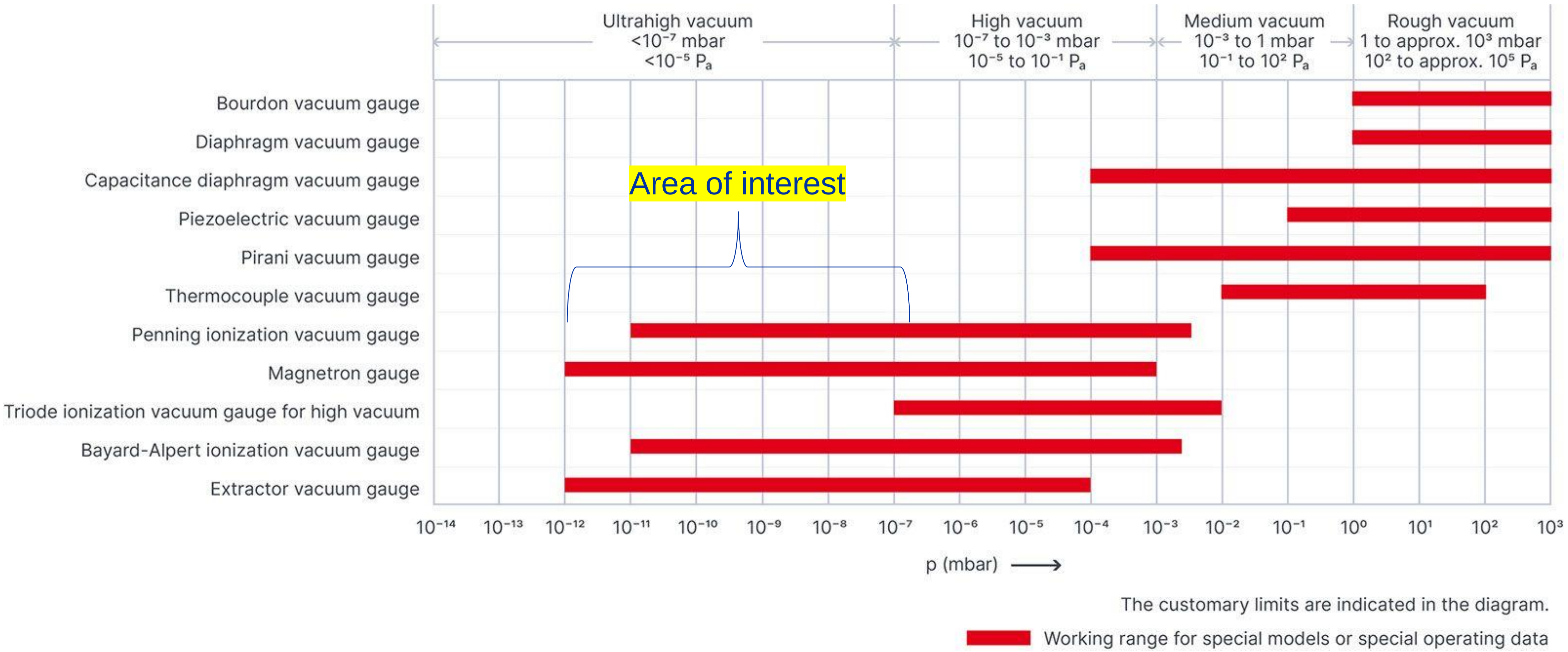
Vacuum Side Brazing for Corrosion Free



Gauges

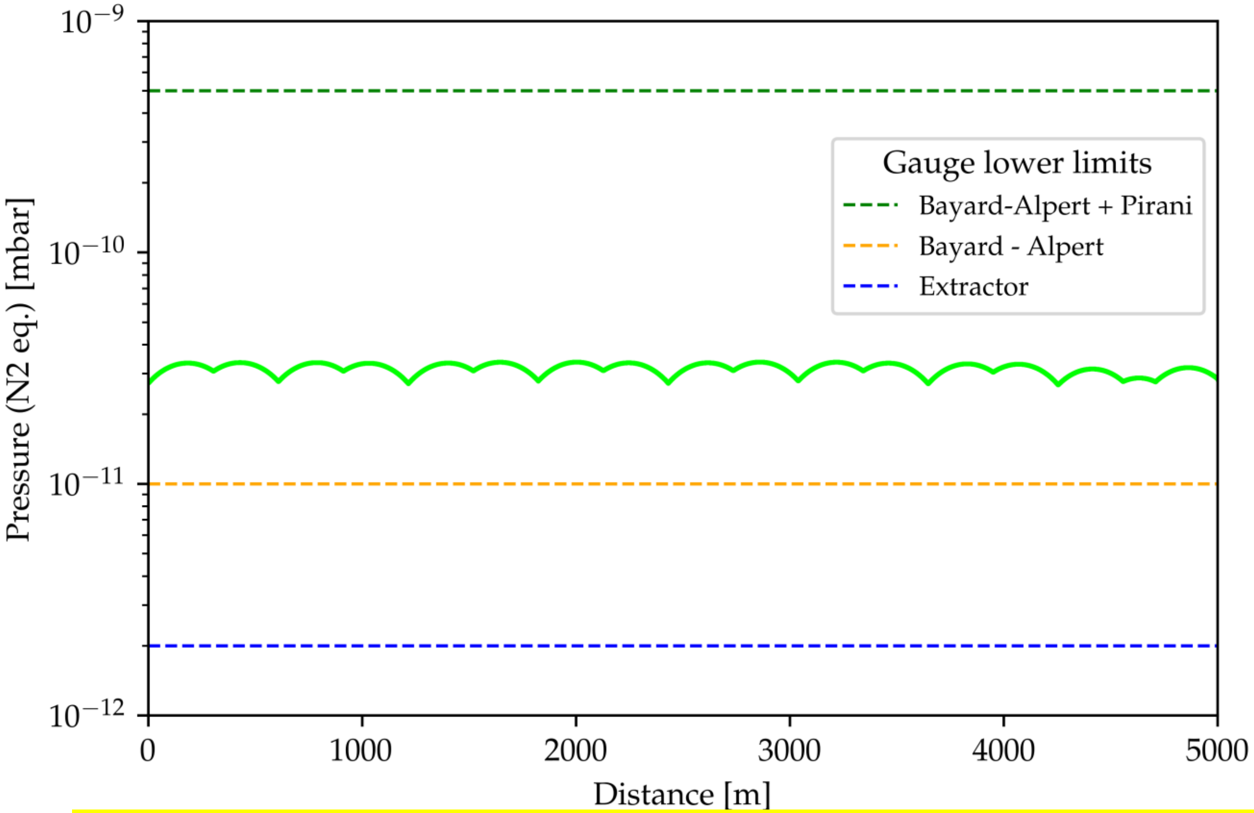
Do not manged to properly discuss but we got some "indirect" inputs

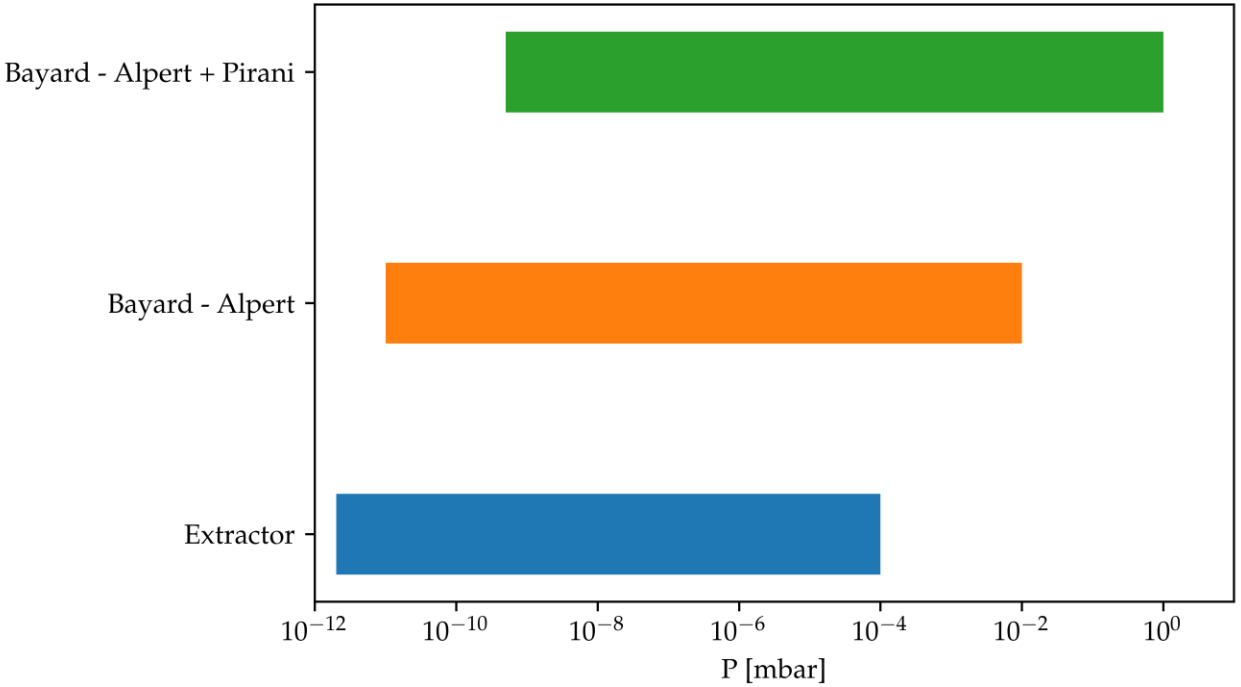
Which choice do we have for vacuum gauge?



FROM: https://diavac.co.jp/english/products/keisokuki/index.html

Pressure monitoring: total pressure profile vs. gauge limits





- From the discussion it seems that BA gauge are the best option and should be analysed and its integration studies in details
  - Installed on elbow or with shield to limit charged particles production

From C.Scarcia presentation

Thank you for your attention