HIE-EBIS Workshop
Vacuum Aspects and Recommendations

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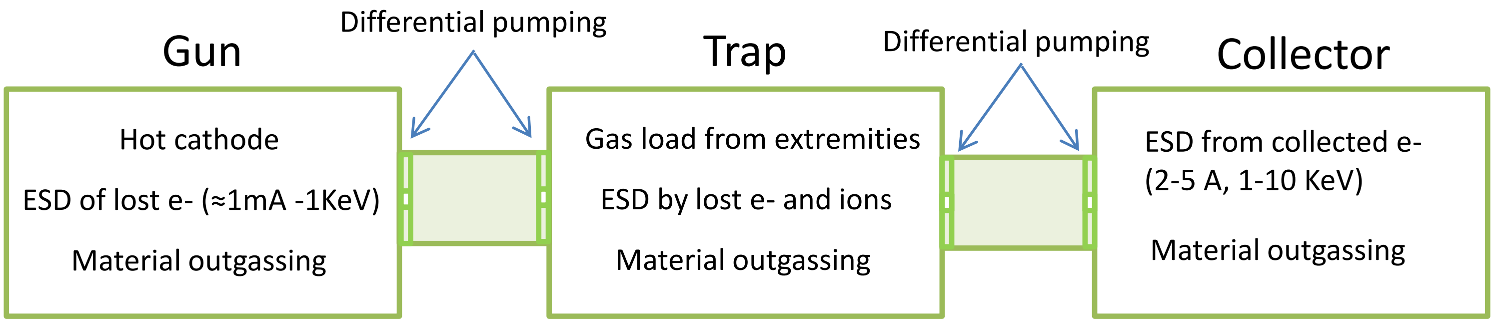
Request to vacuum system



Pressure requirements		
- Protection of cathode - Reduced gas transmission	- Lowest possible gas density	- Reduced gas transmission
10^{-9} mbar	10^{-13} mbar Is this value mandatory also for H_2?	10^{-8} mbar

Gas load in the trap from collector chamber without differential pumping:

$$Q = P_C C_{C\to T} \sim 10^{-8}\ \text{mbar}\ \frac{\ell}{s}\ \left(C_{C\to T} \sim 1\ \frac{\ell}{s}\ \text{for cylindrical tube D=1 cm, L=10 cm}\right)$$

Necessary pumping speed in the trap:

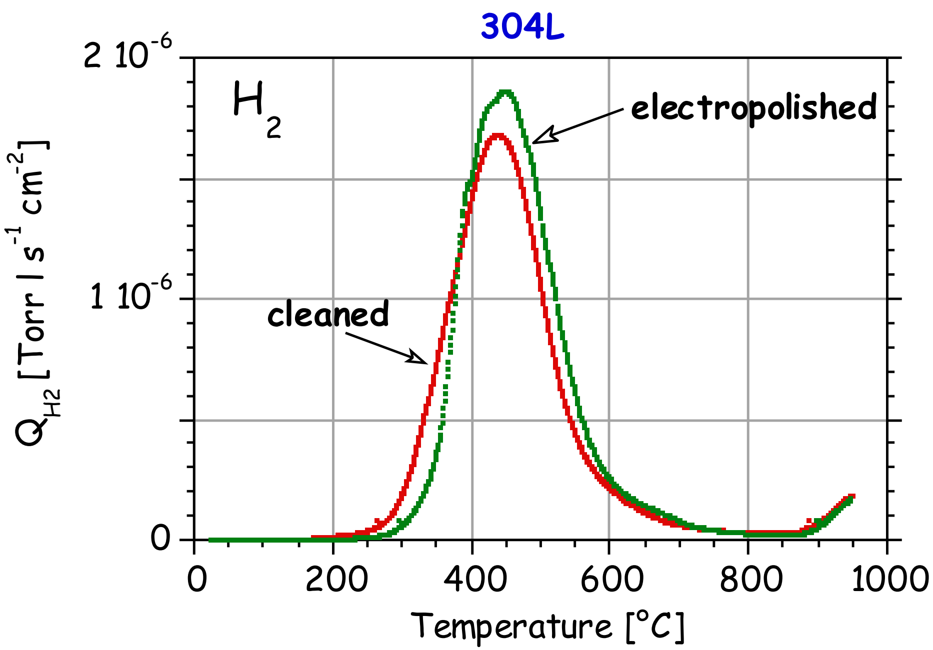
$$S_T = \frac{Q_{C\to T}}{P_T} \sim \frac{10^{-8}}{10^{-13}} = 10^5\ \frac{\ell}{s} \to \text{irrealistic}$$

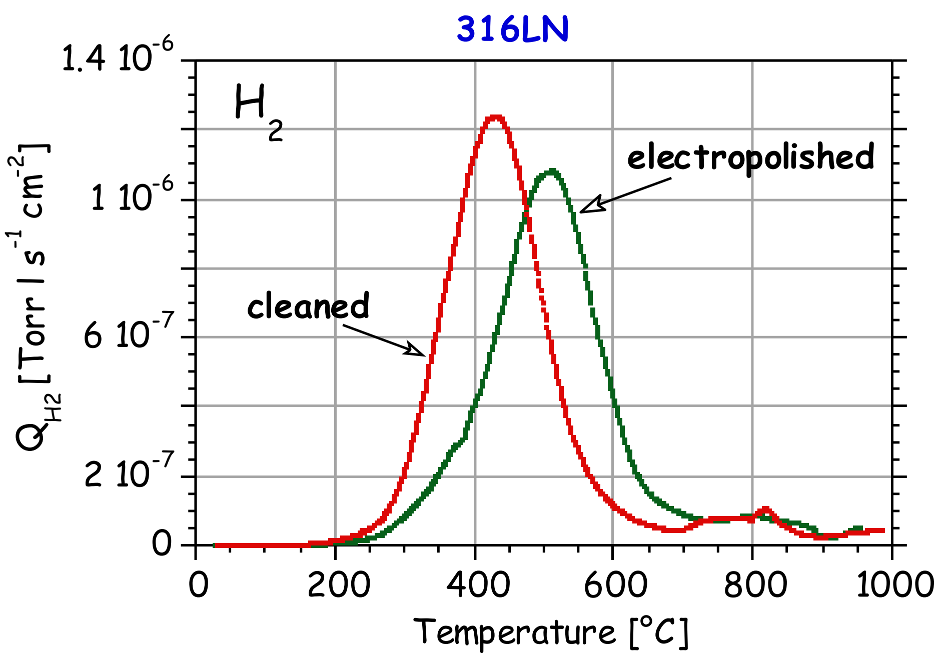
→Differential pumping is necessary

Thermal outgassing for traditional vacuum materials after bakeout:

$$P = \frac{Q}{S} + P_0$$

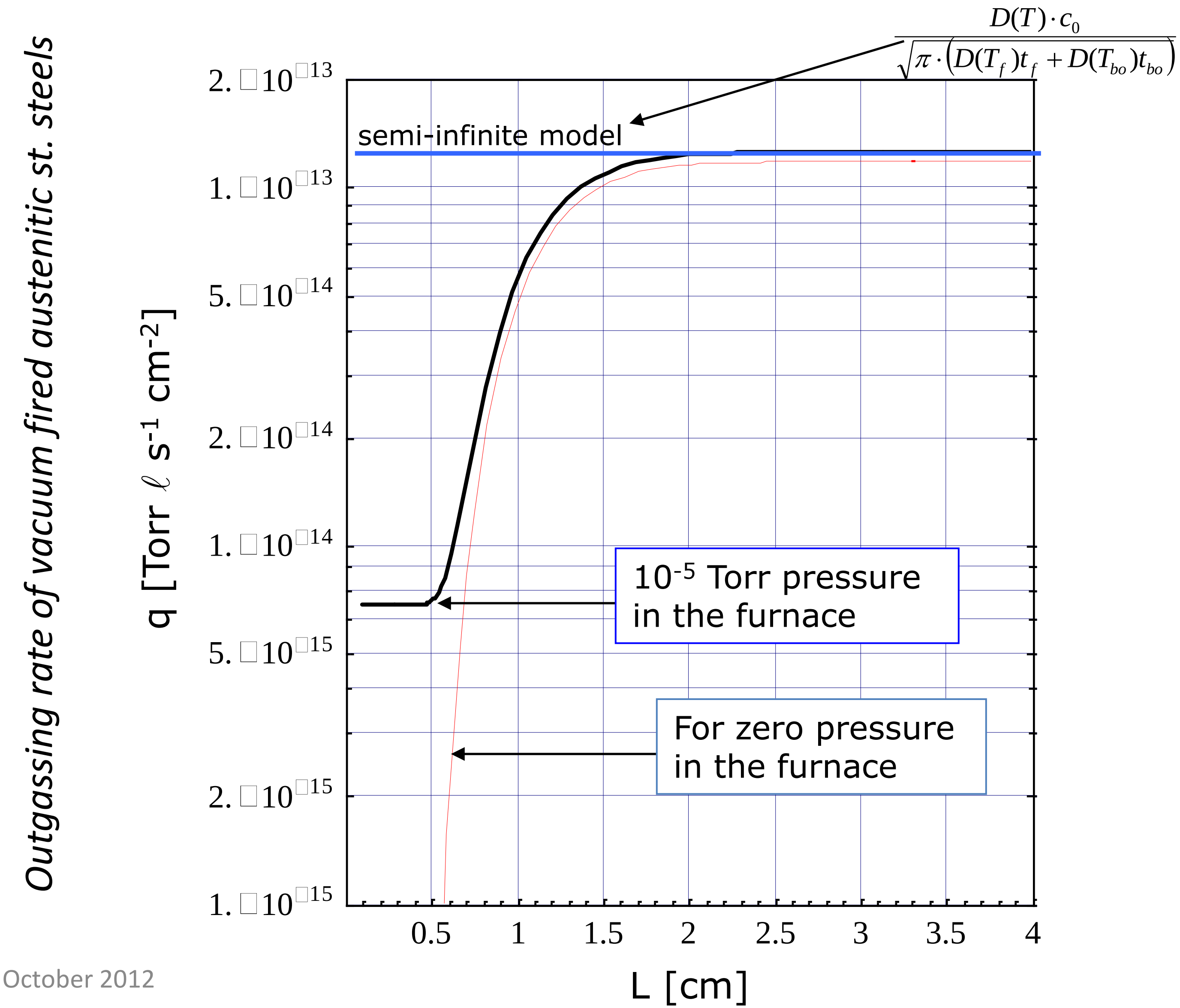
- **Mainly H_2**, except for porous solids (ceramics and graphite)
- Low T (<200°C) bakeout: **10^{-12} mbarℓs^{-1}cm^{-2}** for stainless steel and copper, lower for Al alloys
- **Chemical and electrochemical** treatments have **minor effects** on H_2 outgassing rate.





Thermal desorption measurement: 1 mm thick ribbons, heating rate 5 K min^{-1}, bakeout temperature 150°C (15h)

- Stainless steel vacuum fired at 950°C (2h): **2 10^{-13}-7 10^{-15} mbarℓ$s^{-1}$$cm^{-2}$**



Effect of temperature on outgassing rate

$$Q \propto e^{-\frac{E_D}{k_B T}}$$

Example: outgassing rate of stainless steel

$$\frac{Q_T}{Q_{RT}} = e^{-\frac{0.52}{k_B}\left(\frac{1}{T}-\frac{1}{T_{RT}}\right)}$$

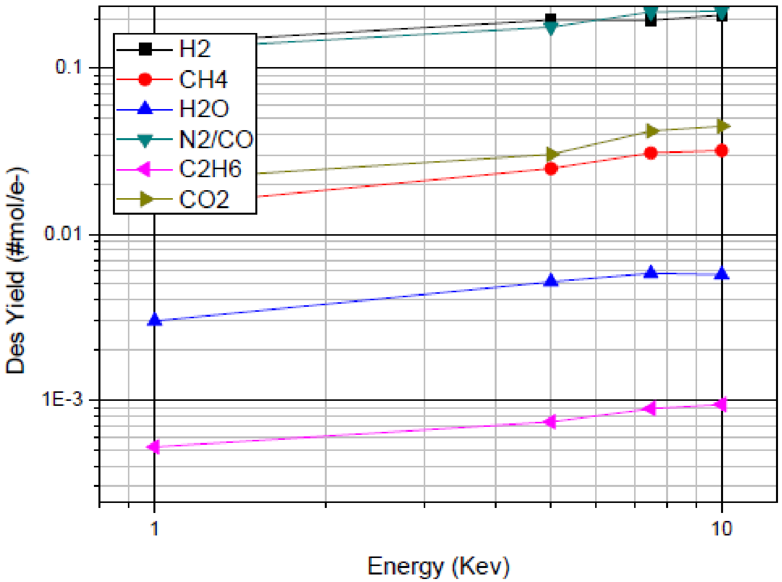
T = 100 K → $\frac{Q_T}{Q_{RT}} = 4\ 10^{-18}$

T = 300°C → $\frac{Q_T}{Q_{RT}} = 21000$

$$P = \frac{Q}{S} + P_0$$

Desorption yields as a function of electron energy at dose 1.6 10^{15} e^{-} cm^{-2}

Chiara Pasquino, Master degree thesis, Politecnico di Milano



In general: the electron energy has a minor effect on η for electron energies higher than 2 KeV.

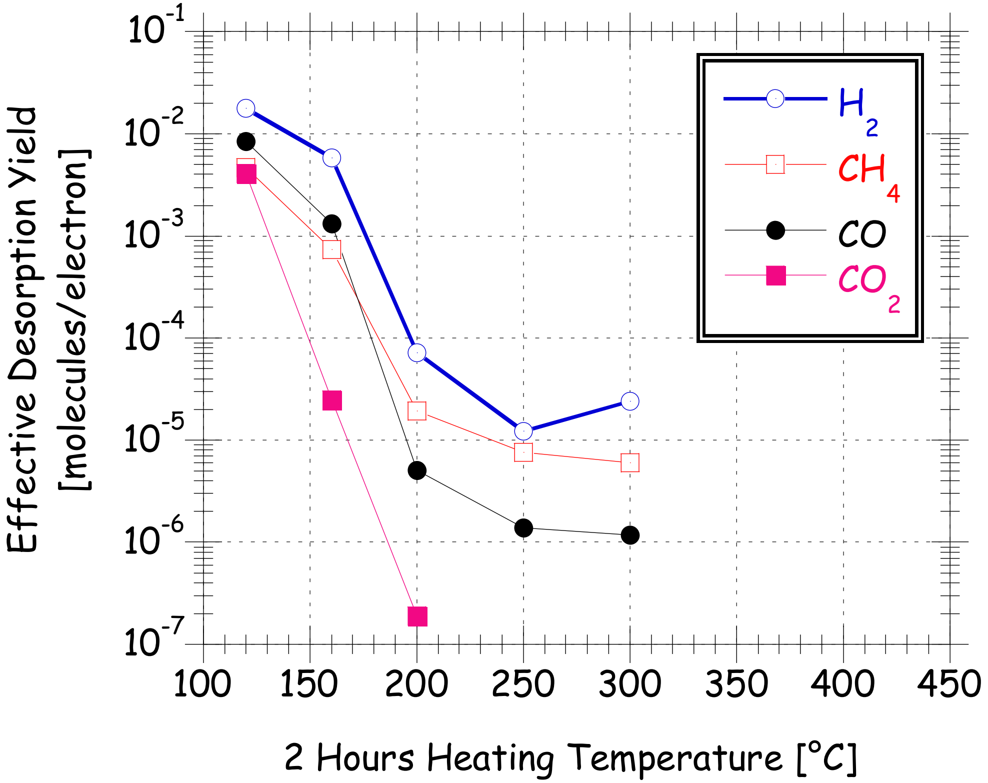
$$\eta = \eta_0 D^{-\alpha} \qquad 0.6 < \alpha < 1$$

Example:

- $\eta = 10^{-1}$ at 10^{17} e^{-} cm^{-2}
- $\alpha = 0.6$ and electron current 3.5 A
- Electron energy ~ KeV

Conditioning time	1 day	10 days
Desorption yields	1.6 10^{-5}	4 10^{-6}

- The desorption yield is only slightly affected by chemical and thermal treatments.
- Only TiZrV thin film coating may provide low effective desorption yields without conditioning



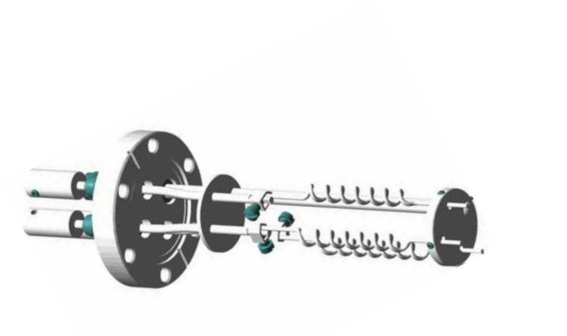
$$P = \frac{Q}{S} + P_0$$

Pumps with P_o lower than 10^{-12} mbar are needed

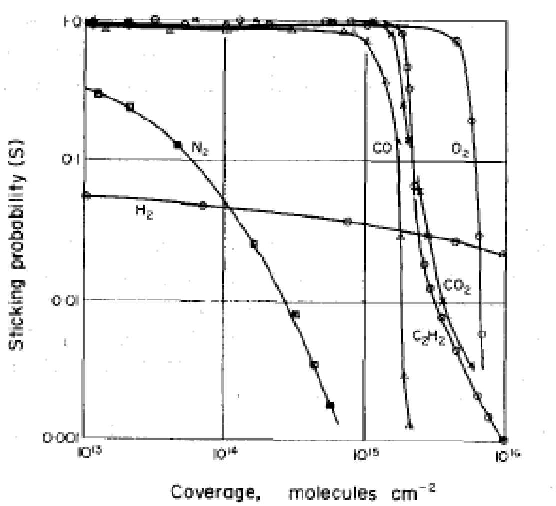
Getter pumps → hydrogen dissociation pressure.
Hydrogen is pumped reversibly. In an isolated system an equilibrium pressure is obtained.
It is never a problem in the UHV range.

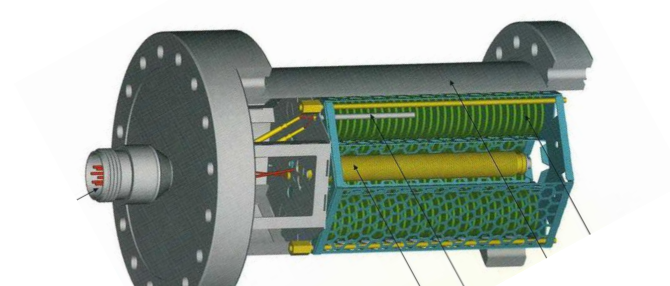
Cryopumps → saturated vapour pressure
Vapour pressure below 10^{-12} mbar for all gases, except He, may be produced at a temperature of 2.3 K, which may be obtained by means of a liquid He bath at reduced pressure (about 50Torr).

Lump getter pumps

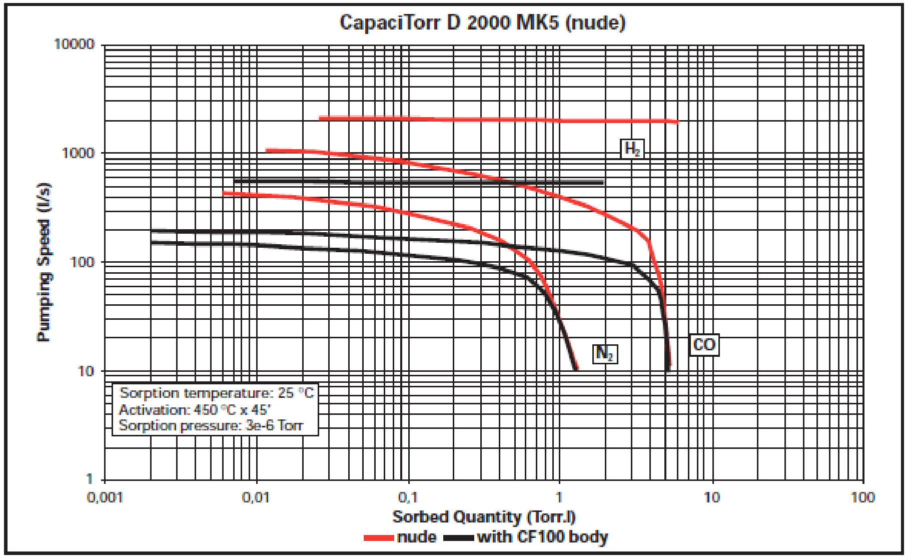


A K Gupta, J H Leck, Vacuum, 1975





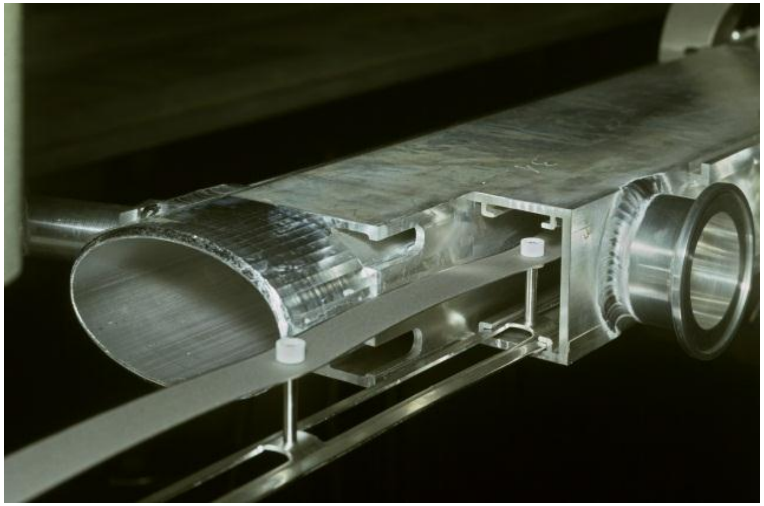
Courtesy of SAES Getters



- Saturated after the adsorption of one monolayer (3.3×10^{-5} Torr l cm^{-2}) of CO.
- Already tested at 10^{-13} mbar

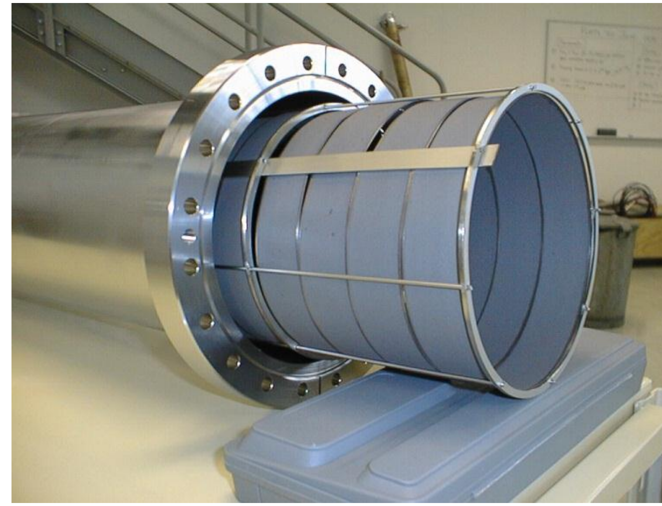
- Q_{sat}= 5 Torr ℓ equivalent to 15 m^2 of smooth getter surface.
- Already tested at 10^{-12} mbar

Getters do not pump rare gases and CH_4: they always need auxiliary pumps



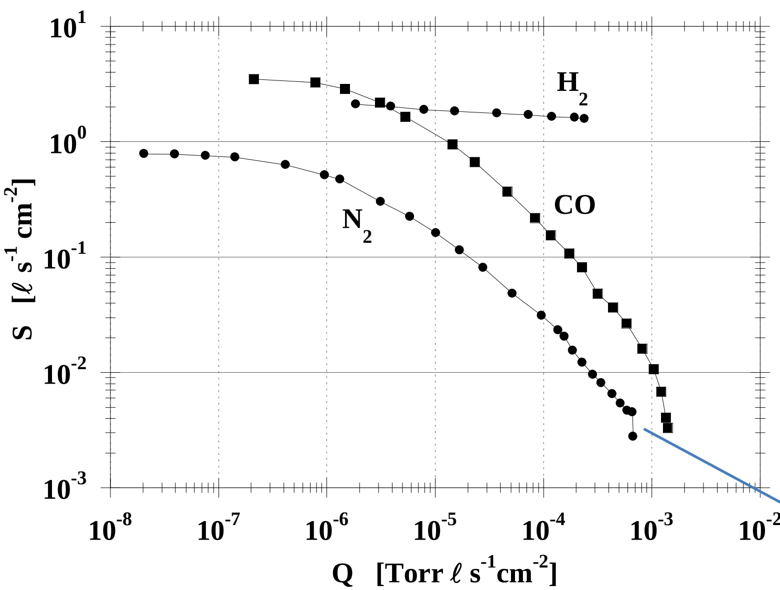
St 101

In LEP, it was activated by ohmic effect



St 707

This alloy may be activated at temperatures as low as 300°C (24h): passive activation may be applied



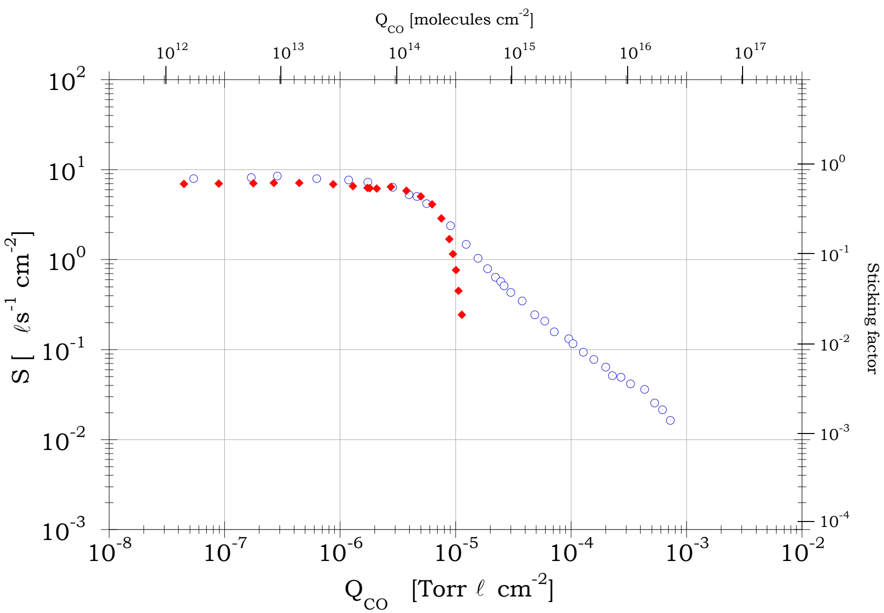
Both solutions may be used when distributed pumping is needed, however:

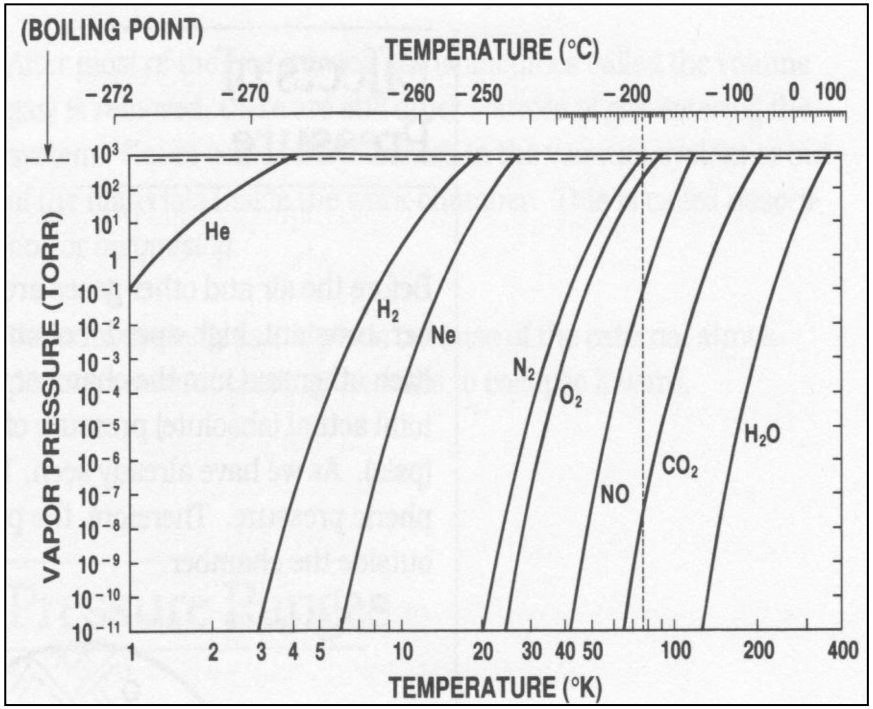
- High temperature needed for activation (T>300°C)
- Space needed for supports
- Gas sources not reduced
- Potential risk of dust production

Equivalent to 50-100 cm^2 of smooth getter surface

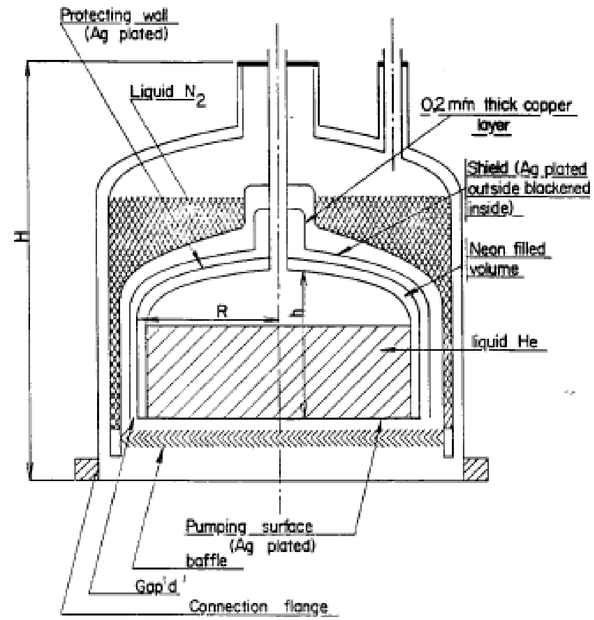
Getter pumps: NEG thin films

- TiZrV is deposited by sputtering onto the inner wall of vacuum chambers.
- It may be activated at 180°C (24h). It is the main pump of the warm LHC's LSS.
- Typical S at zero coverage: 0.3-0.5 ℓs^{-1} for H_2.
- The pumping capacity may be increased by coating rough coatings on rough substrates
- Very large surfaces may be coated
- The outgassing rate of the substrate surfaces is suppressed
- No experience in pumping at cryogenic temperature, but we are eager to start…





- **Cryocondensation**: surfaces cooled at temperature lower than 3 K are needed to achieve vapour pressures lower than 10^{-11} Torr for H_2.



C. Benvenuti, Vacuum 1979

- **Cryosorption:** submonolayer pumping → pressures much lower than the vapour pressure are achievable.

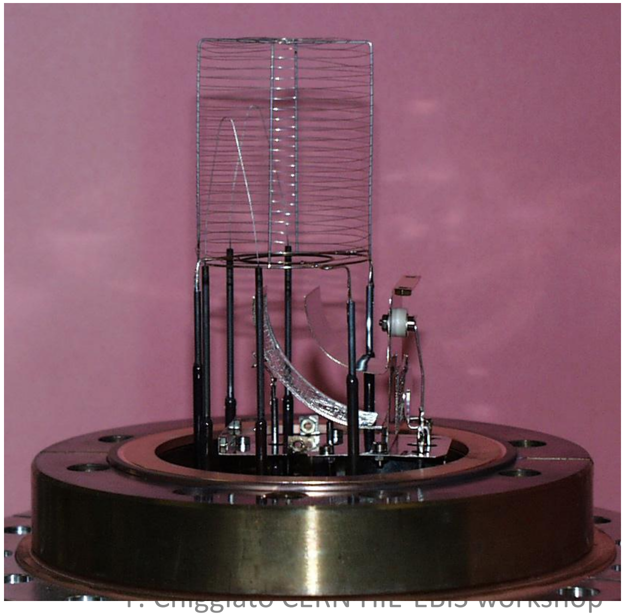
- **Porous materials** are used; for example, in one gram of standard charcoal for cryogenic application, about 1000 m^2 of surface are available for adsorption.

- Significant quantities of **H_2 and He may be pumped at 20 K and 4.3K**, respectively.

Cryo vs NEG pumps

	NEG pumps	Cryosorption pumps
Pumping selectivity	No pumping for rare gas and CH_4; need of auxiliary pumps	No selectivity
Regeneration/Condi -tioning	Full bakeout for passive activation of NEG films or St707 ribbon	Auxiliary pumps to remove desorbed gas.
Maintenance	No maintenance	Regular and expensive for refrigerators
Power cut	Continue pumping, no need of power supply	Desorption; need of an auxiliary pump.
Bakeout issue	Temperature of NEG surfaces > 180°C	Need for bakeable cryosorbers
Cost	Lower	Higher
Dust production	Not excluded a-priori for ribbons	No problem
Safety issues	Pyrophoricity, except for NEG films	No problem for refrigerators
Space needed	Negligible	Integration of refrigerator
Inlet valve for lump pumps	No need	Necessary for regeneration -> €
Operational incidents	Strongly affected by contamination (F, Cl, hydrocarbon)	Unduly gas charge on porous surface

- Nowadays, no commercial vacuum gauges can measure 10^{-13} mbar at room temperature
- At CERN, a Bayard-Alpert gauge developed in the ‘70th is currently used.
- It has a x-ray residual pressure of about 2 10^{-12} Torr; pressure measurement in the 10^{-13} Torr range is possible by modulation.
- The modified Helmer gauge gave reliable results in the low 10^{-14} Torr: but it is not anymore available at CERN. A development programme is going to be launched in 2013 in collaboration with an industrial partner.



Conclusions

- The pressure requirement in the HIE-EBIS's trap is so challenging that every **single** material must be selected, treated and checked with the highest precaution.

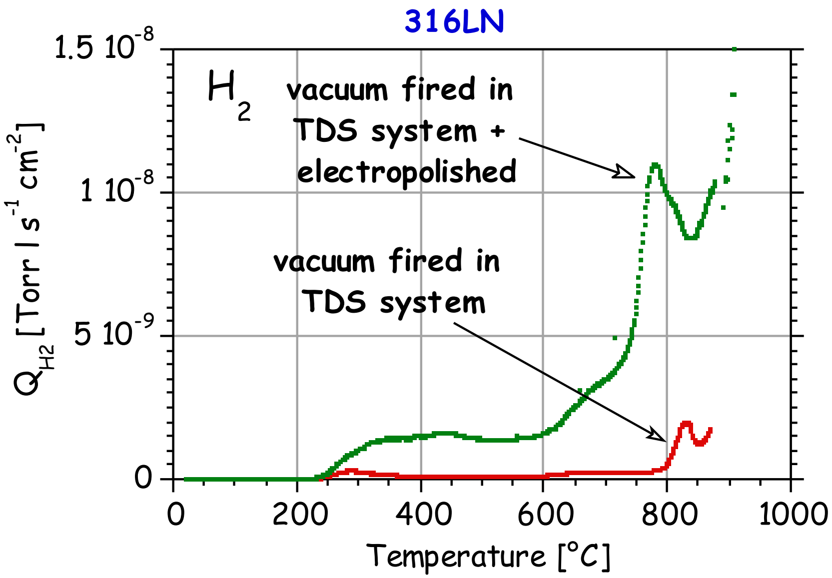
- If a getter based solution is selected, be sure that:
  - the coated surface is the largest possible;
  - the design allow a uniform temperature bakeout;
  - during the activation, the coated surface is not unduly charged by gas desorbed by uncoated areas ;
  - no F contamination is present (for example Teflon in primary pumps)
  - the NEG is activated after the full conditioning of the collector and cathode.

- If a cryosorption solution is selected, be sure that:
  - all parts are bakeable;
  - the cryosorber is strongly fixed and can withstand several bakeout cycles;
  - consider a scenario that include power cut;
  - cool the cryosorber surface as late as possible after the beginning of the pumpdown.

- As devil is in the details, work closely with your vacuum experts in any step of the project, especially design, and ask for vacuum validation tests as soon as possible.

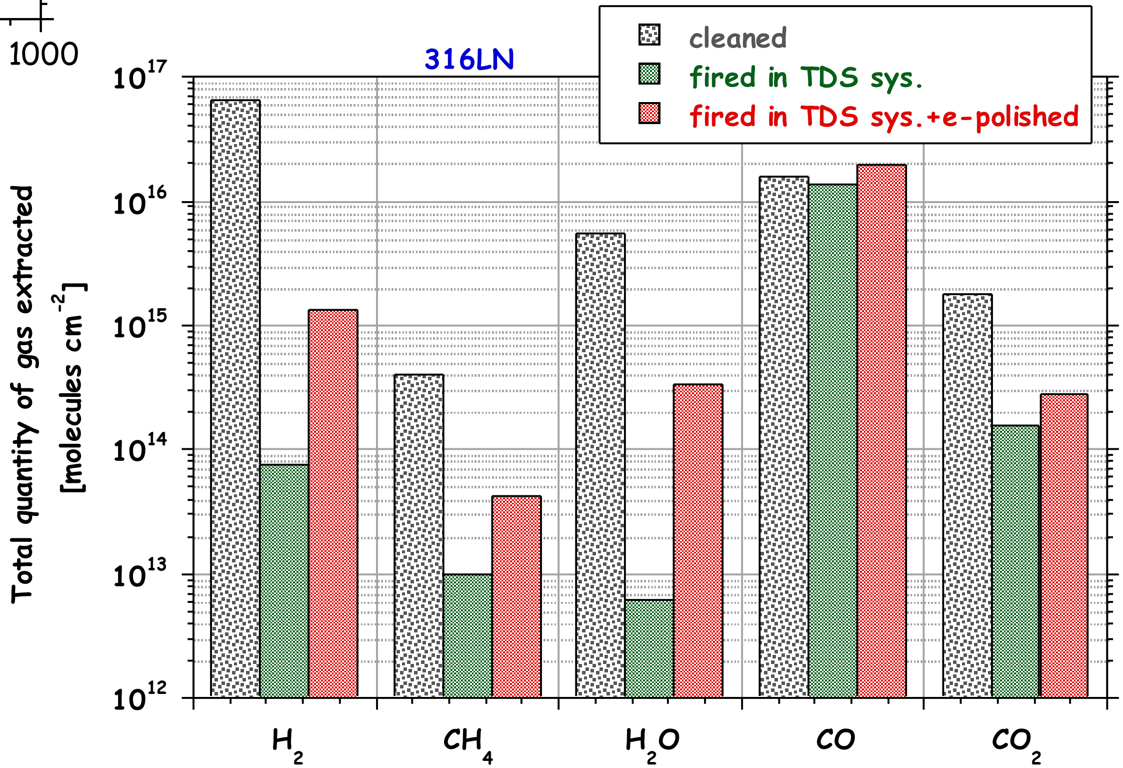
Additional slides

Gas sources: outgassing

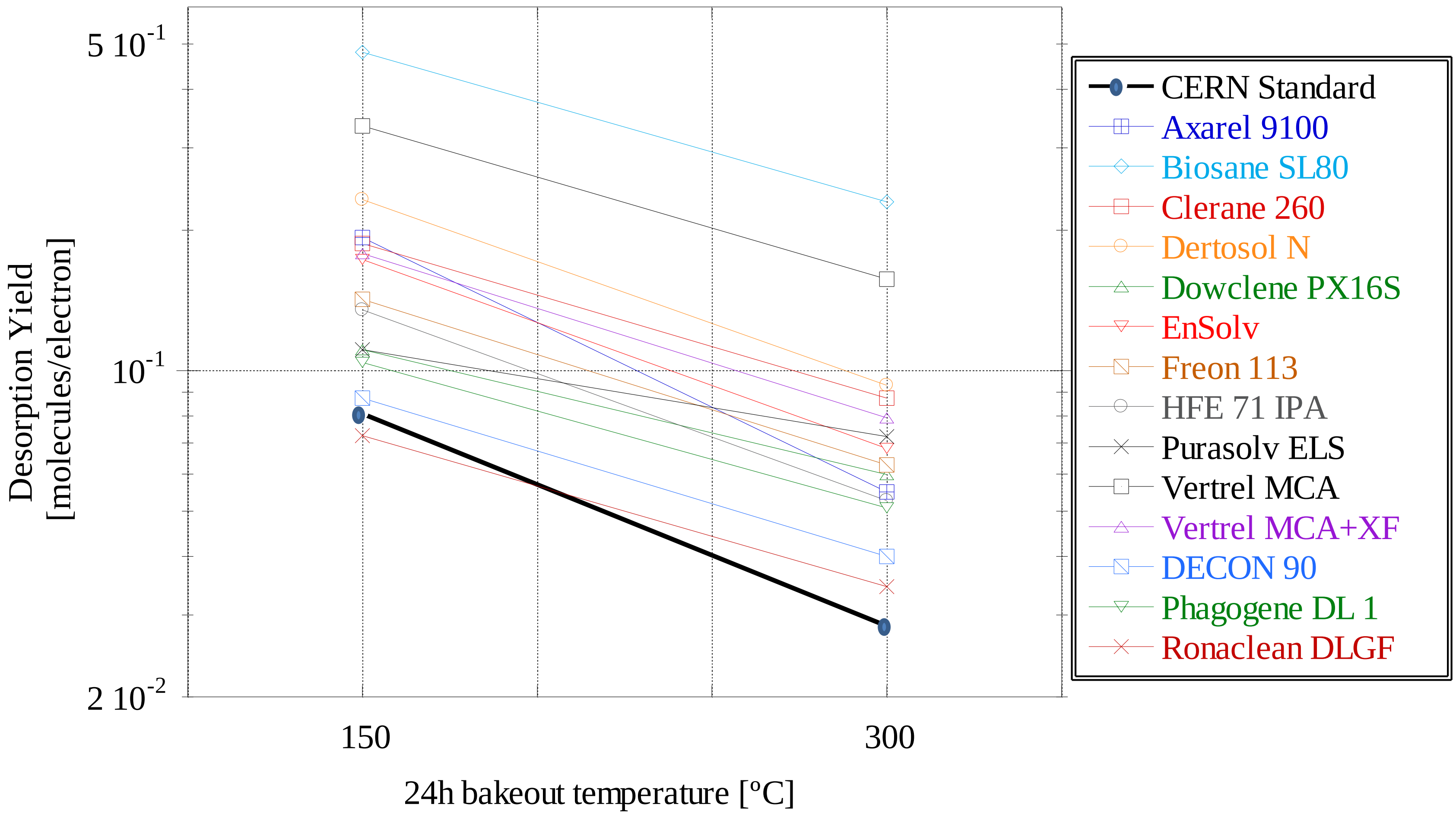


Thermal desorption measurement: 1 mm thick ribbons, heating rate 5 K min^{-1}, bakeout temperature 150°C (15h)

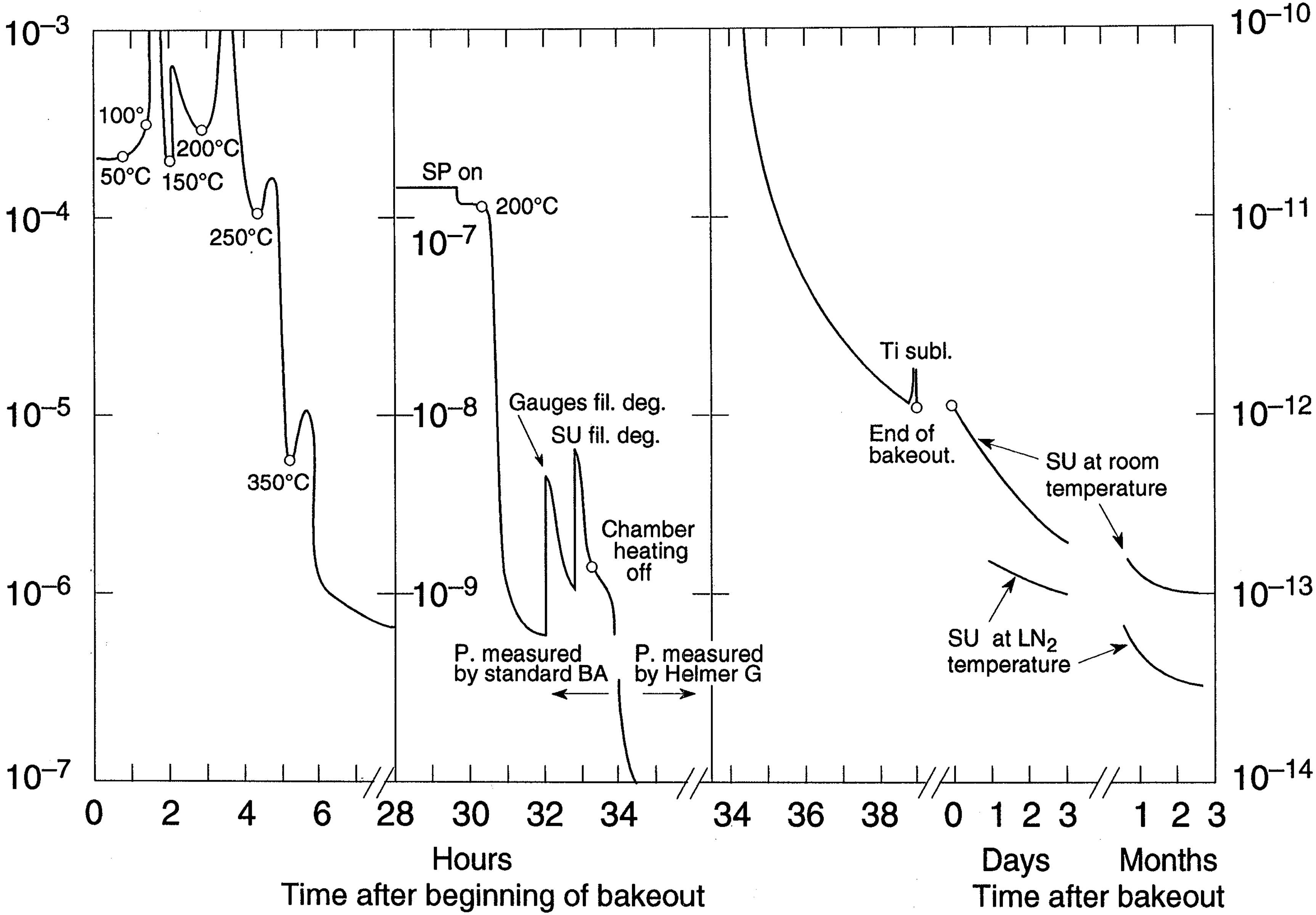
Electropolishing reintroduces about 1/50 of the quantity of H initially present in the sample.

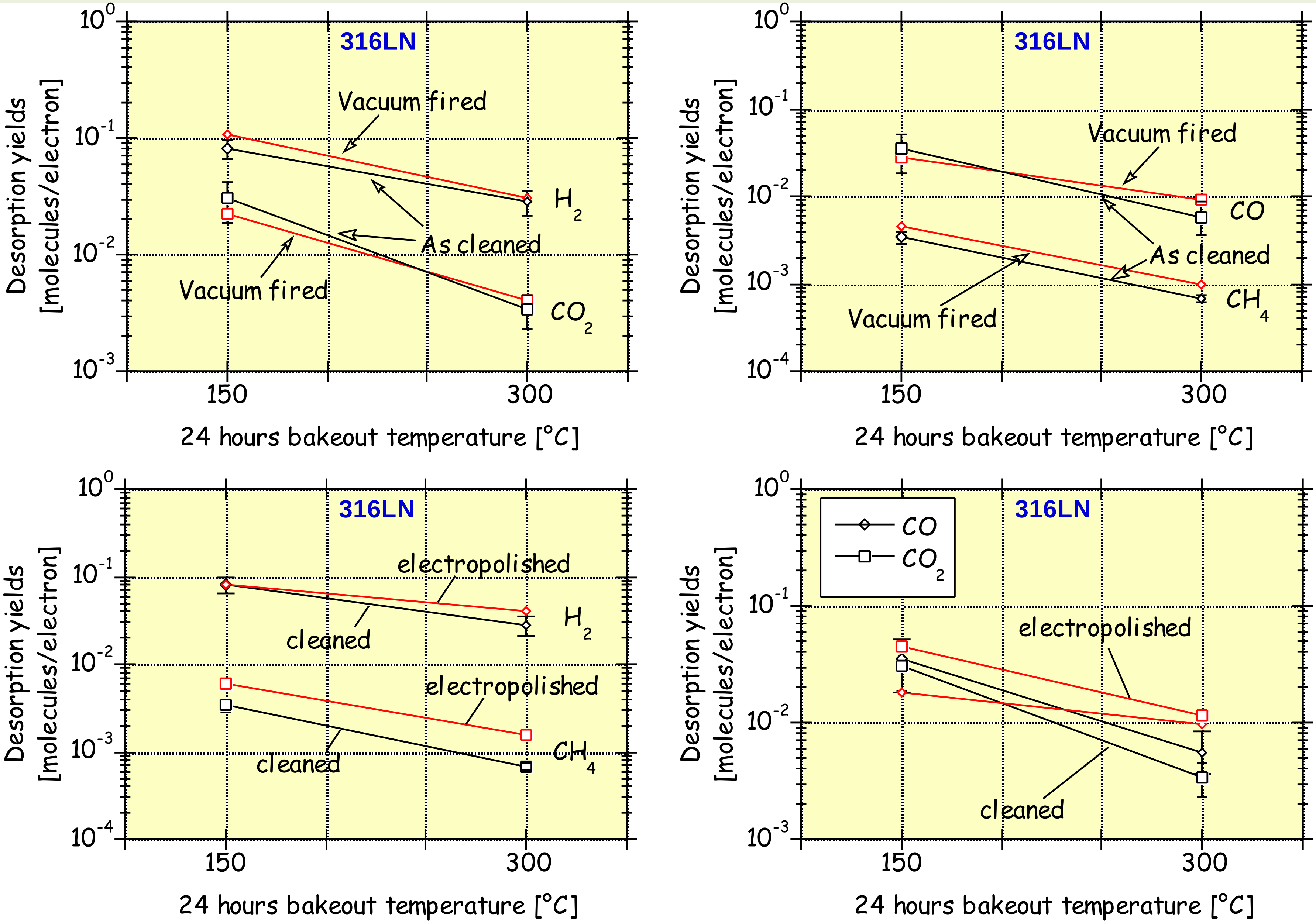


Effect of bakeout temperature and cleaning product



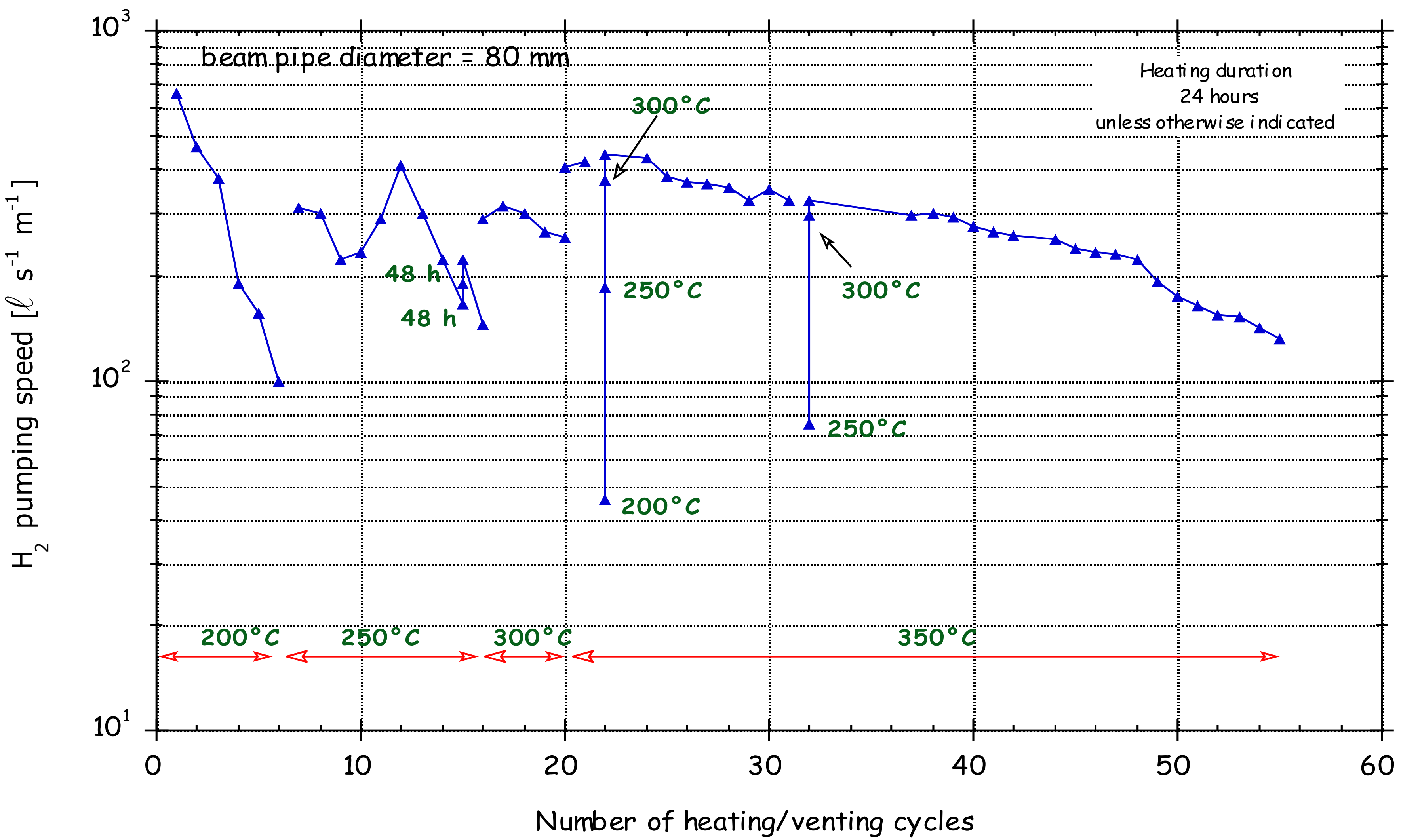
Operational issues



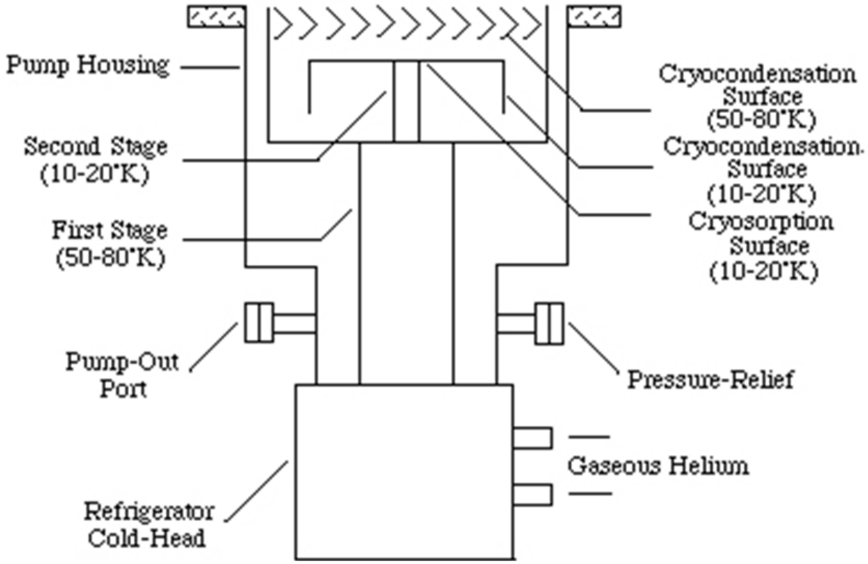


500 eV electrons, no conditioning

NEG coating performance deterioration



Cryopumps



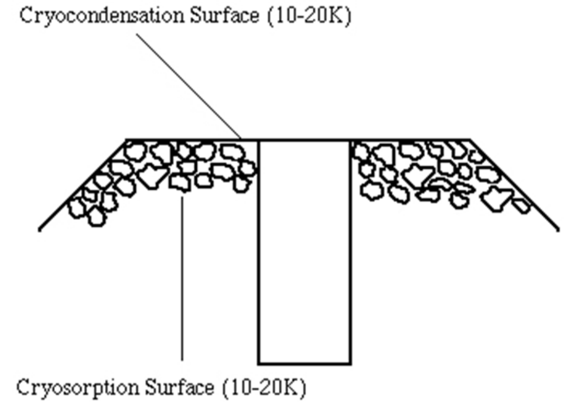


Table 13: Pumping speeds and maximum gas capacities of a commercial cryopump (Oerlikon-Leybold 800 BL UHV); the pump inlet diameter is 160 mm. Courtesy of Oerlikon-Leybold

	H_2O	N_2	Ar	H_2	He
S [ℓ s^{-1}]	2600	800	640	1000	300
Capacity [Torr ℓ]		225000	225000	3225	375

Very high pumping speeds

Cryosorption and cryocondensation are used for distributed pumping, in particular in vacuum chambers installed in superconducting magnets.