Towards final validation of new temperature of BS for triplets

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https://indico.cern.ch/event/742082/contributions/3072177/

OUTLINE

1. Introduction
2. Operating in the 40-60 K range
3. Operating above 60 K
4. Conclusions

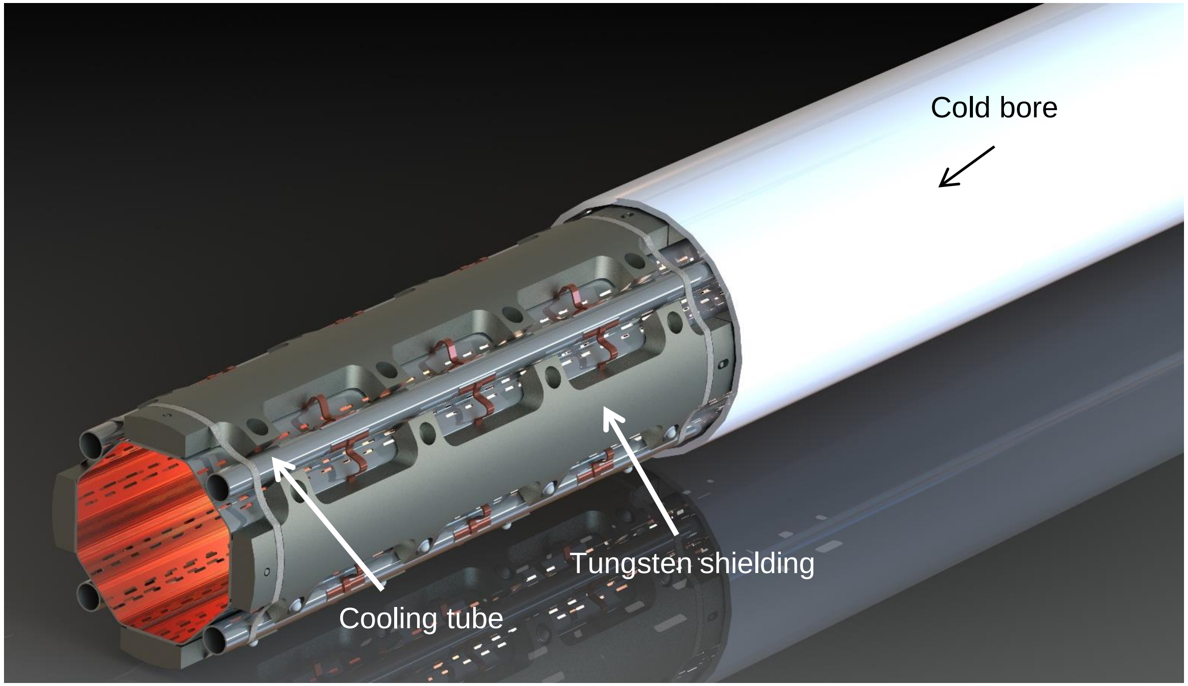
1. Introduction

Triplet beam screens

- Triplets beam screens are shielded with tungsten to intercept the debris produced at the interaction point, protecting thus the cold mass

- Nominal heat load on the beam screen = 15 W/m

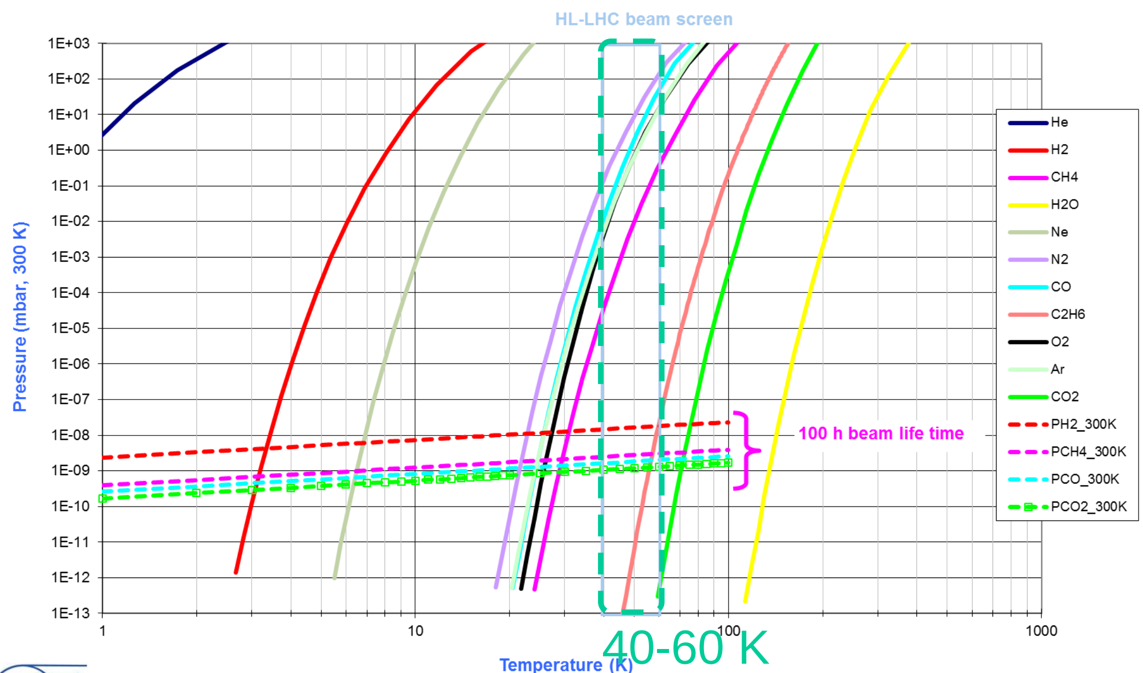
- Four cooling tubes extract the beam induced heating and maintain the beam screen temperature along the Triplet string in the 40-60 K temperature range



Why is the actual base line 40-60K ?

- Objectives are:
  - To optimize the cryogenic cooling scheme.
  - To increase the pumping speed of the beam screen's (BS) holes and minimize the gas physisorption onto the BS.
- Based on the saturated vapor pressure (SVP) curves of a smooth surface (pressure over liquid or solid phase for many monolayers of condensed gas), the temperature window 40-60 K was proposed
- In this temperature window:
  - The gases which have a SVP larger than 10^{-5} mbar are not condensed on the BS.
  - Other gases are condensed on the BS (*i.e.* CO_2, H_2O)

Saturated vapour pressure from Honig and Hook (1960) (C2H6 Thibault *et al.*)



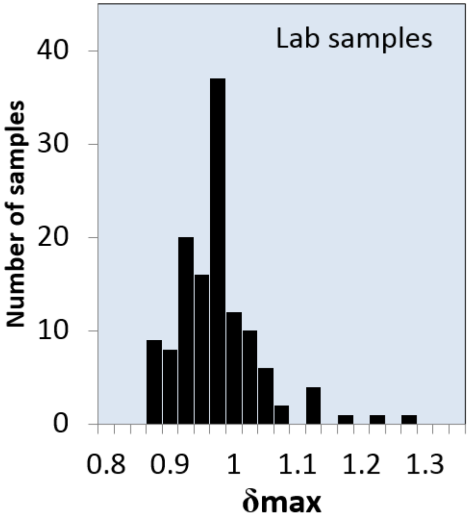
a-C coating on HL-LHC beam screen Cu surface

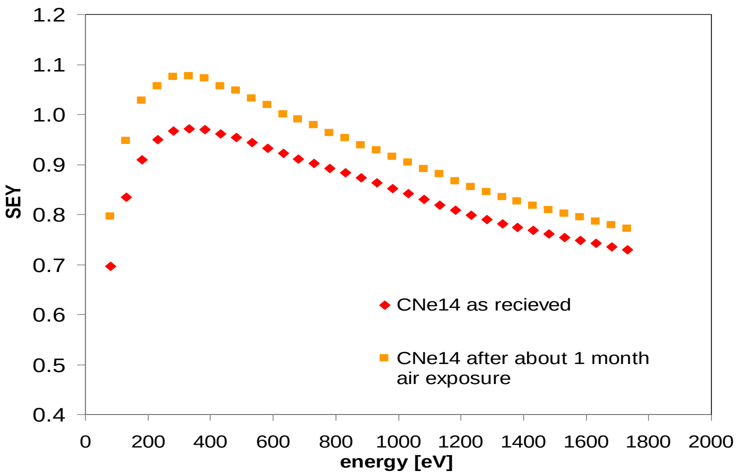
- a-C coating is proposed to mitigate electron multipacting to reduce the heat load on the beam screen and the background to the experiments.

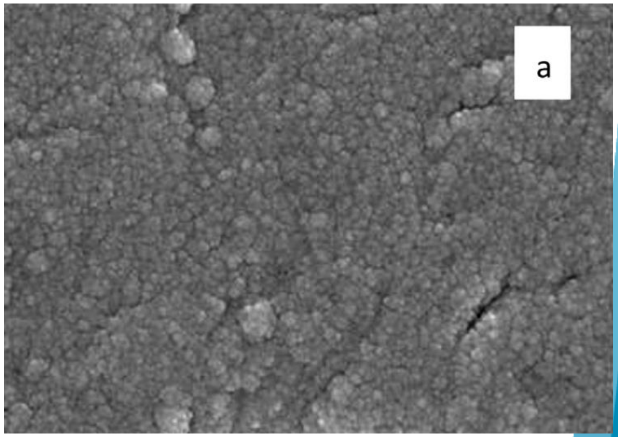
- It has a maximum SEY of 1 +/- 0.1 ==> no or little multipacting is expected

- The coating is under evaluation at cryogenic temperature in the laboratory and with LHC type proton beams.

- Performance at cryogenic temperature of a-C shall be compatible with HL-LHC parameters, in particular with the BS operating temperature of the triplets (40-60 K)







P. Costa Pinto et al. Vacuum 98 (2013) 29-36

2. Operating in the range 40-60K

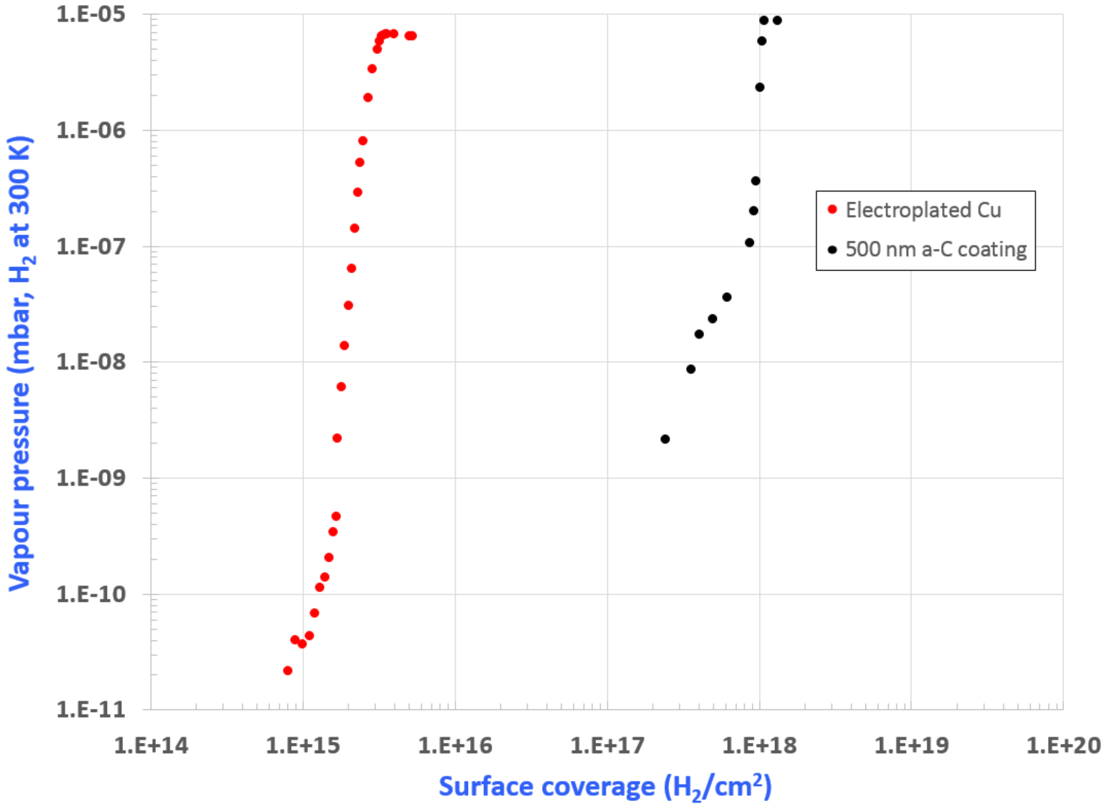
Adsorption Isotherms at 4.2K of Cu and a-C coating

- The H_2 saturated vapour pressure is reached when more than one monolayer of gas is physisorbed
- Samples:
  - Electroplated Cu
  - ~ 500 nm thick a-C coating on Cu

- At 4.2 K, the monolayer capacity of a-C is much more than one on Cu (10^{15} H_2/cm^2)

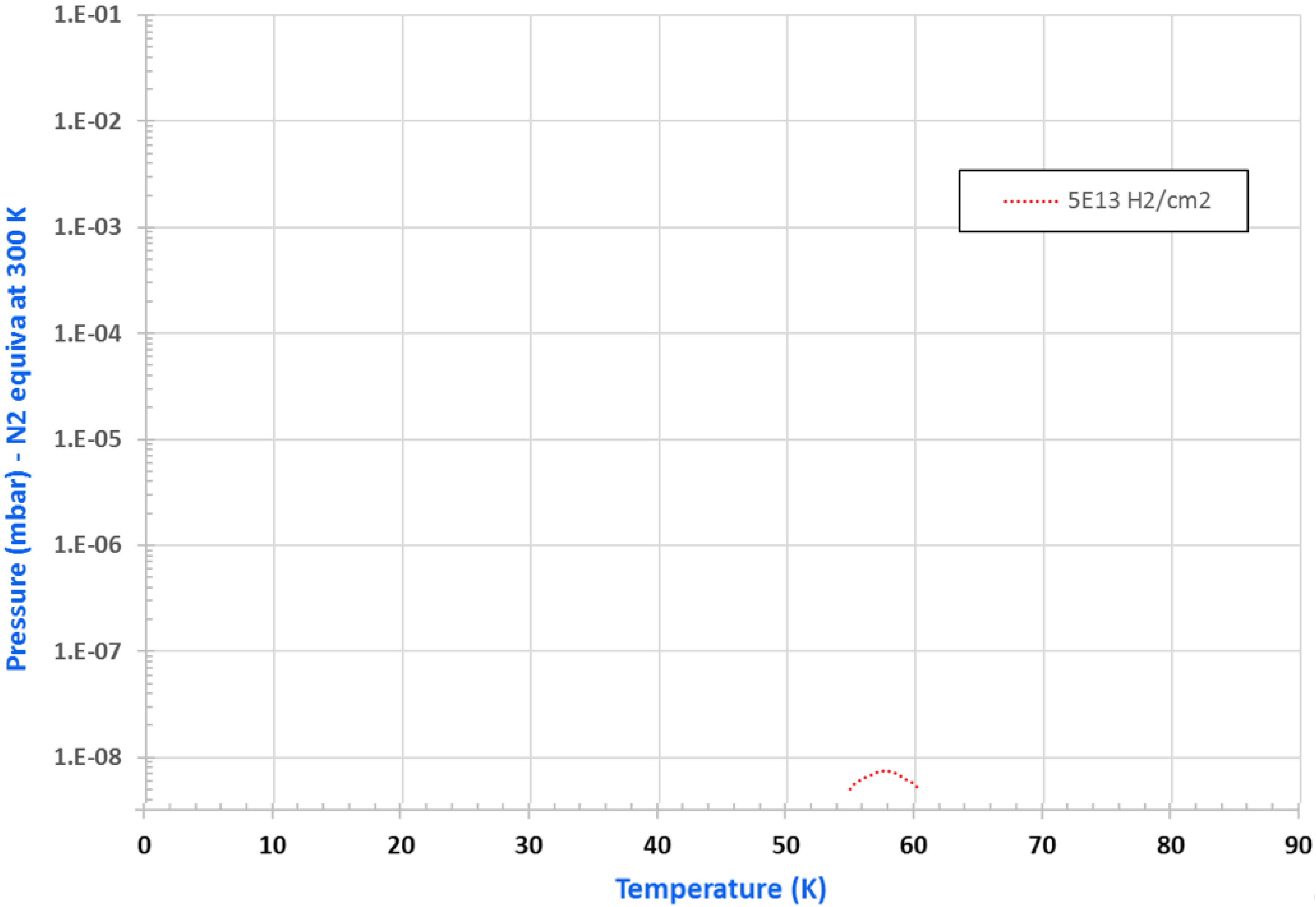
- The coating is **porous**
- Capacity ~ 100 x Cu

➔ What is the impact of the porosity on the BS optimal temperature?

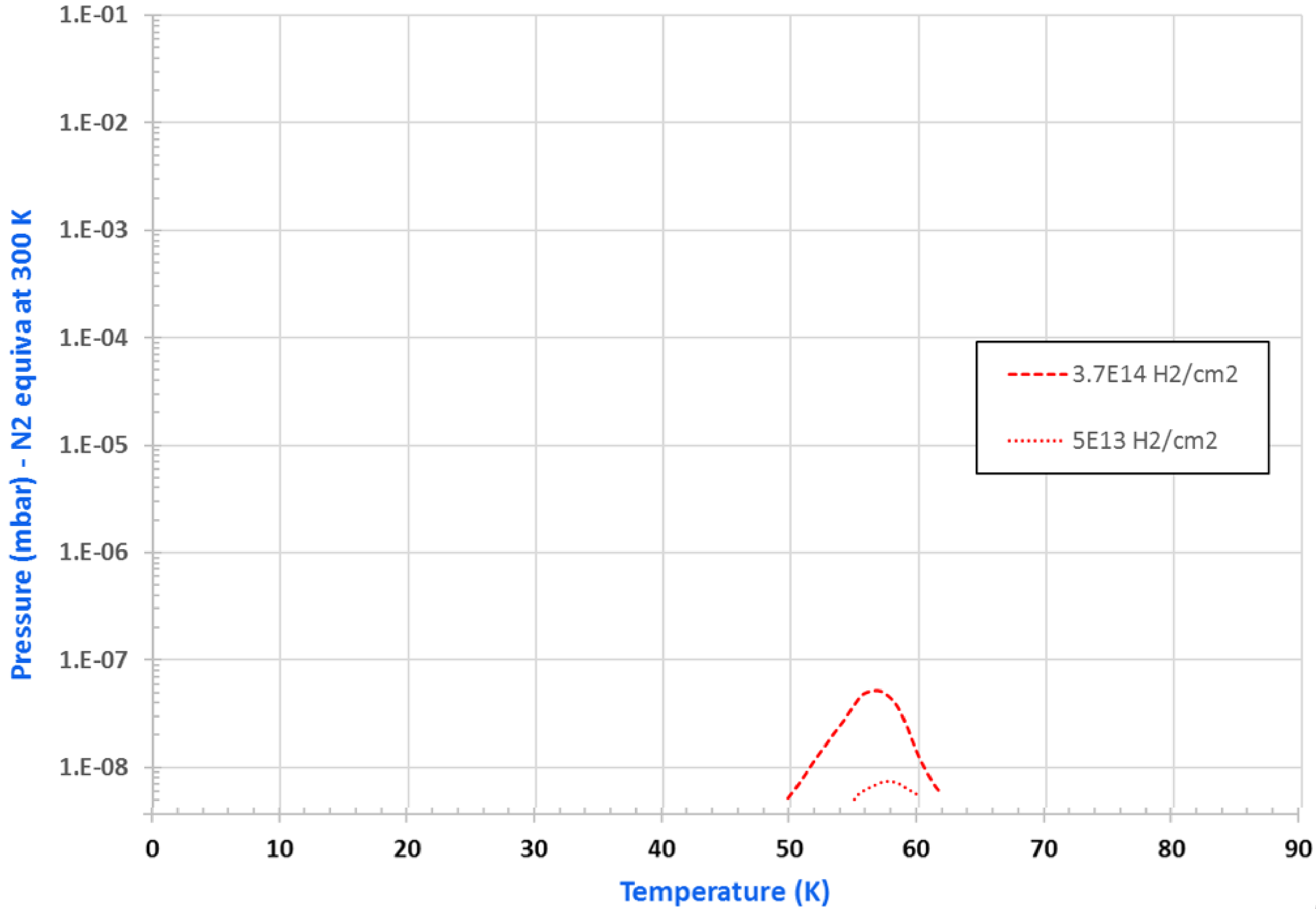


H_2 thermal desorption of 5 10^{13} H_2/cm^2

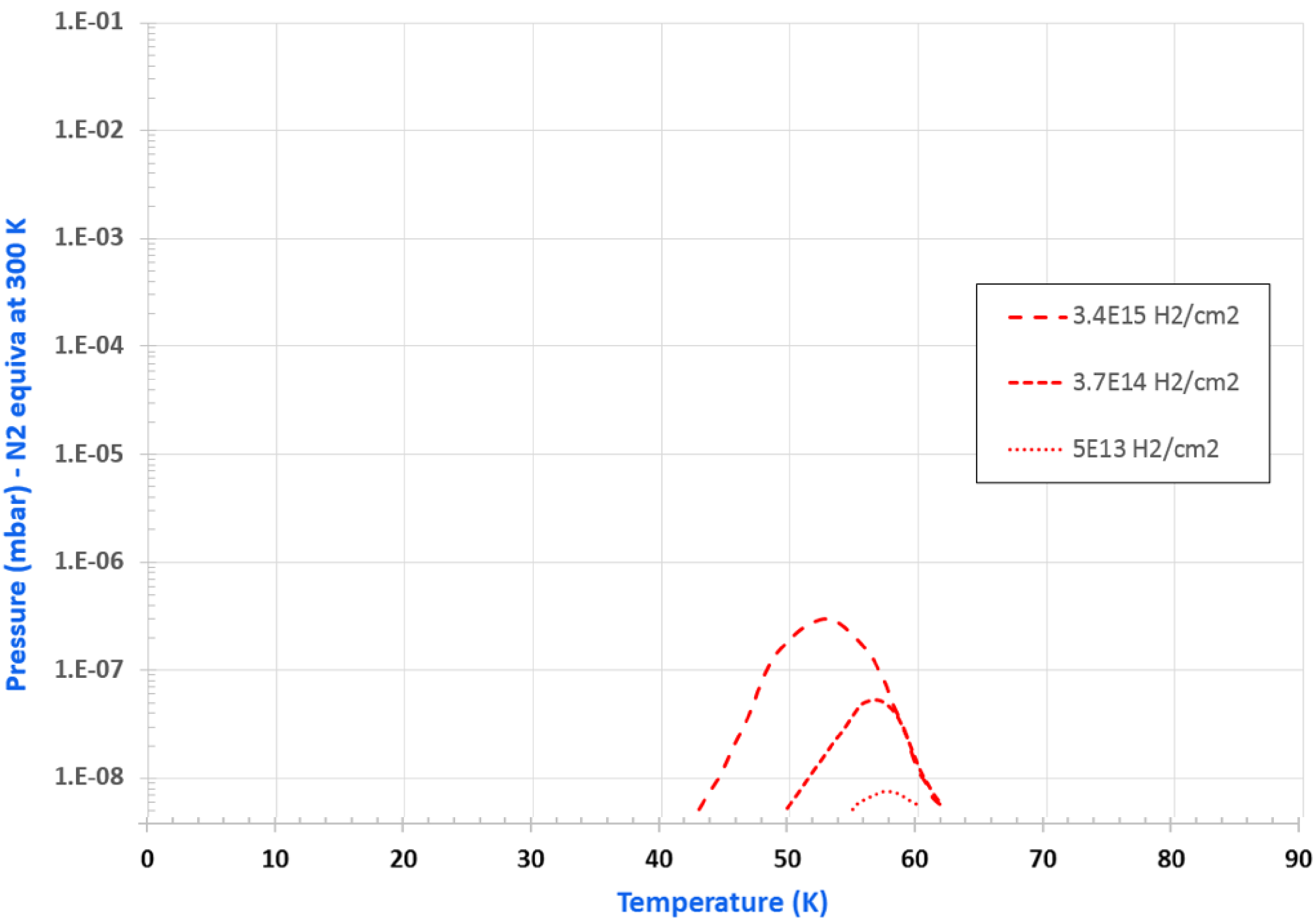
- H_2 desorbs in the range 40-60 K



H_2 thermal desorption of 3.7 10^{14} H_2/cm^2

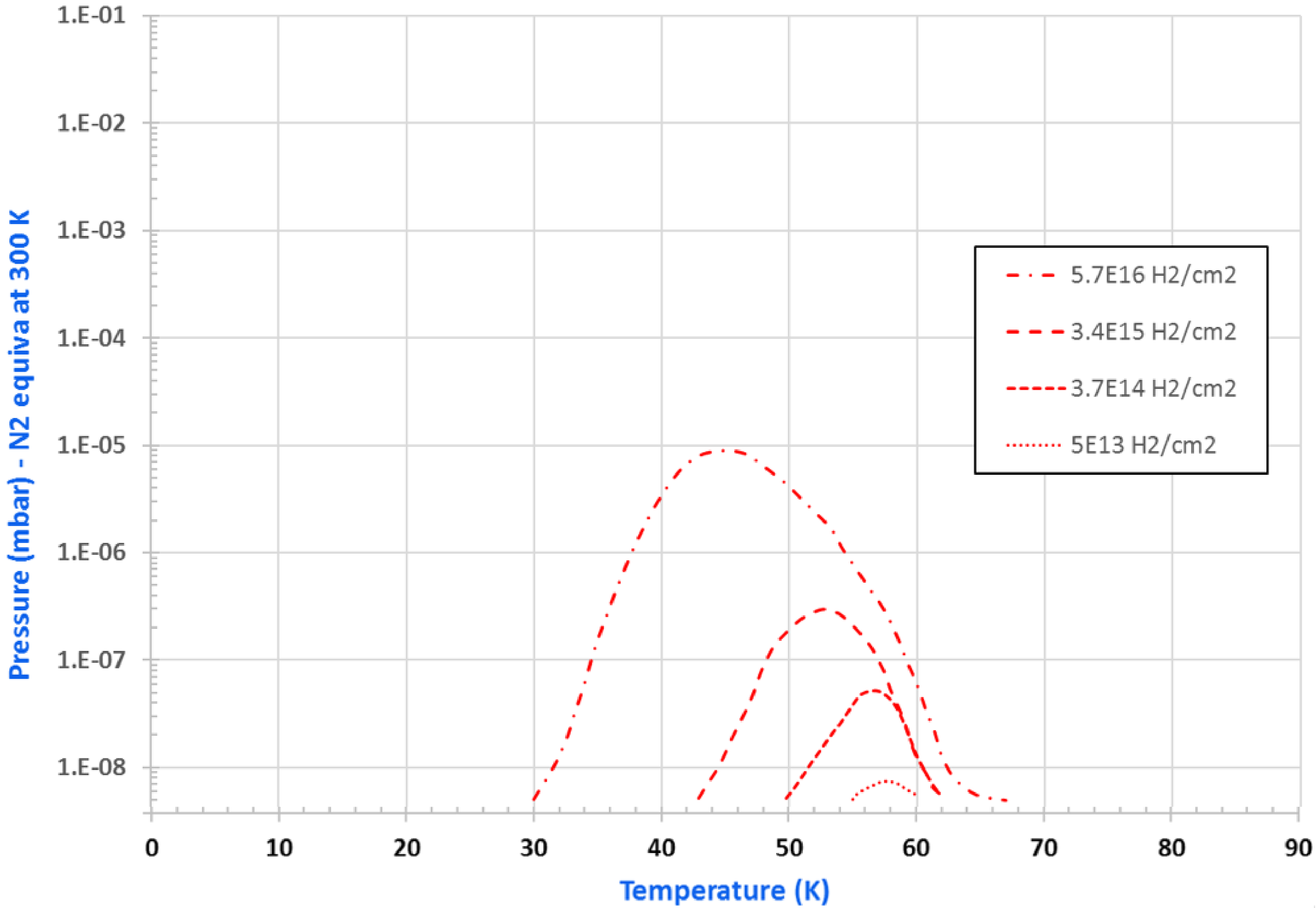


H_2 thermal desorption of 3.5 10^{15} H_2/cm^2

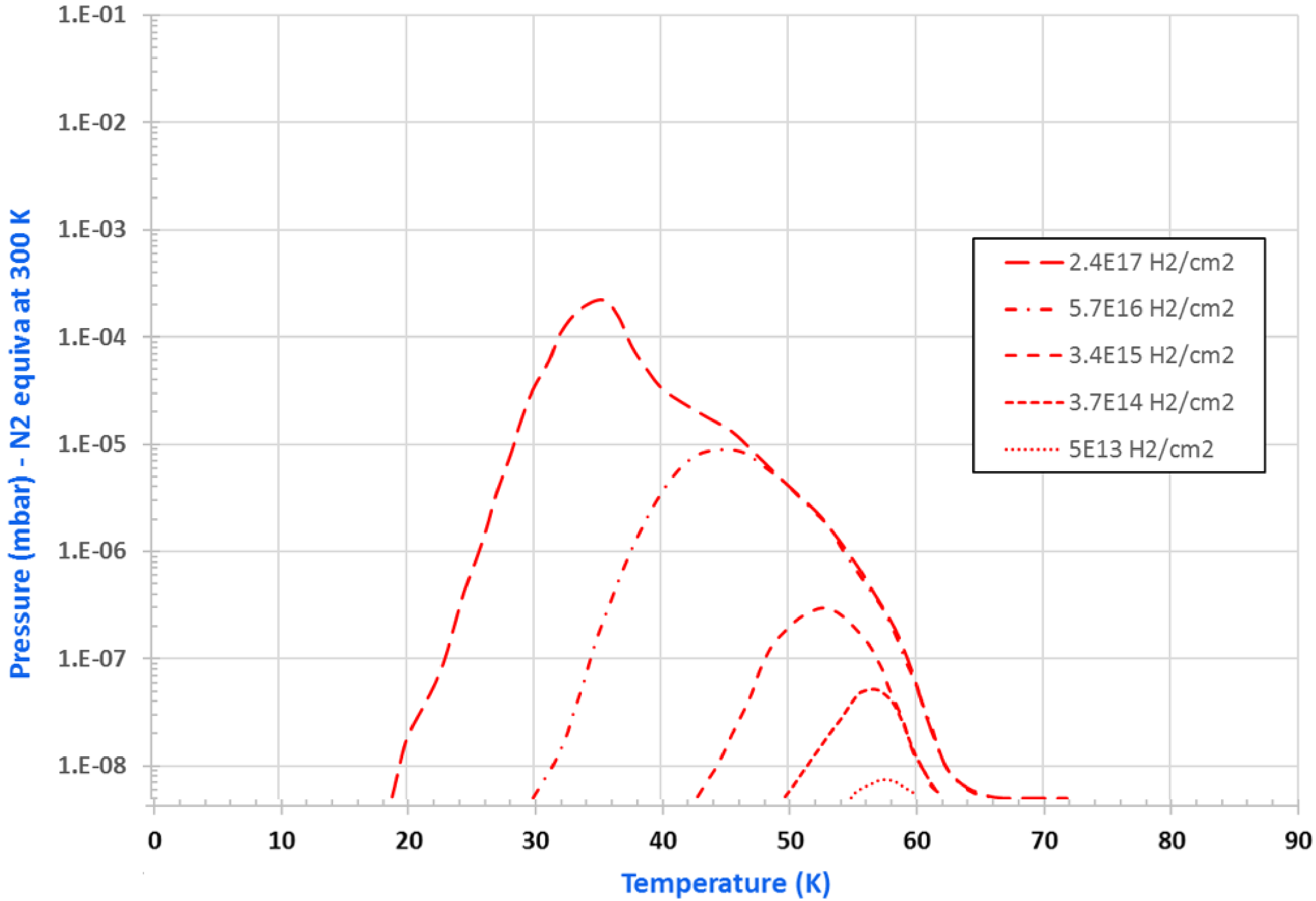


H_2 thermal desorption of 5.7 10^{16} H_2/cm^2

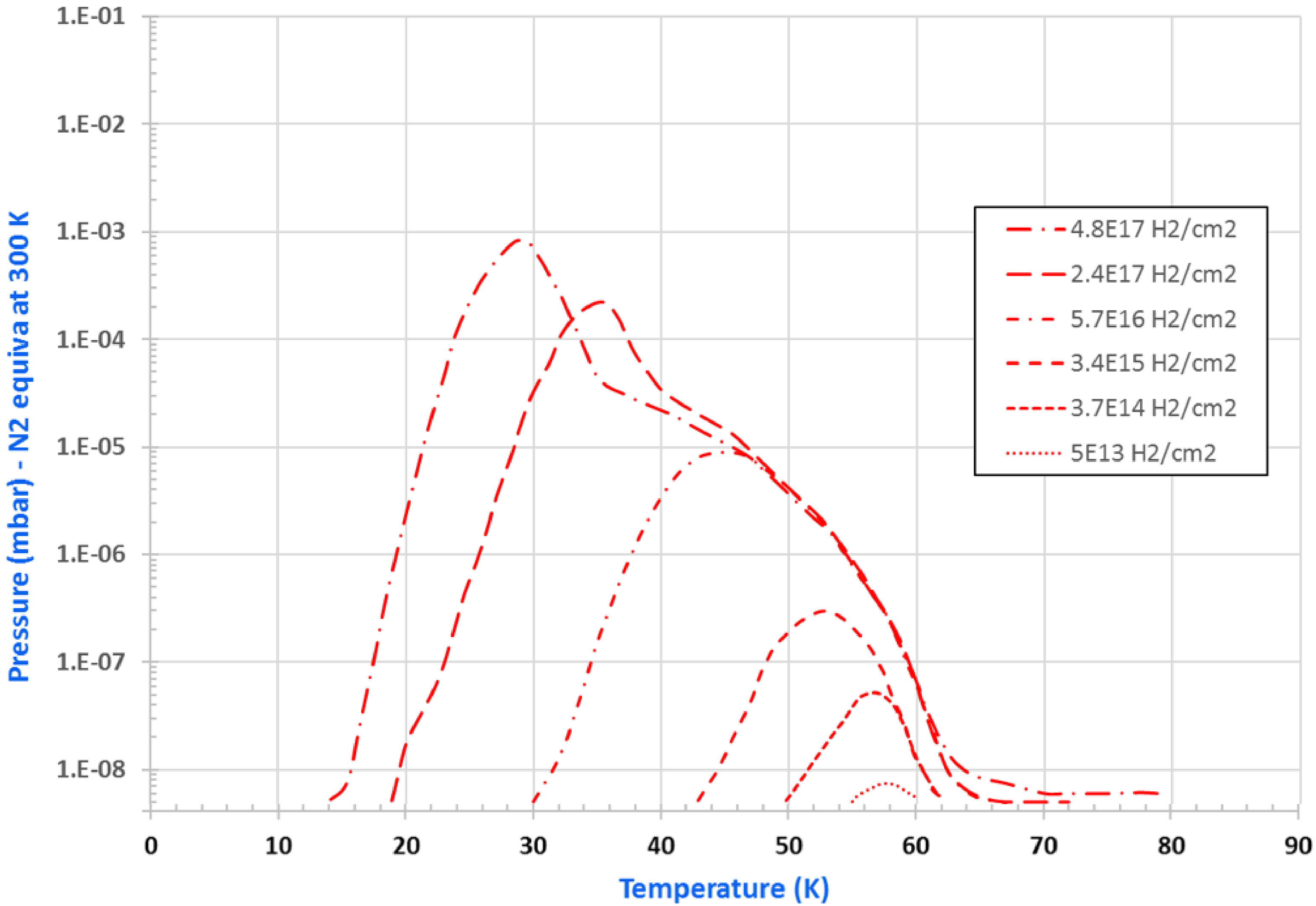
- While increasing the H_2 surface coverage, the desorption peak is shifted to lower values



H_2 thermal desorption of 2.4 10^{17} H_2/cm^2

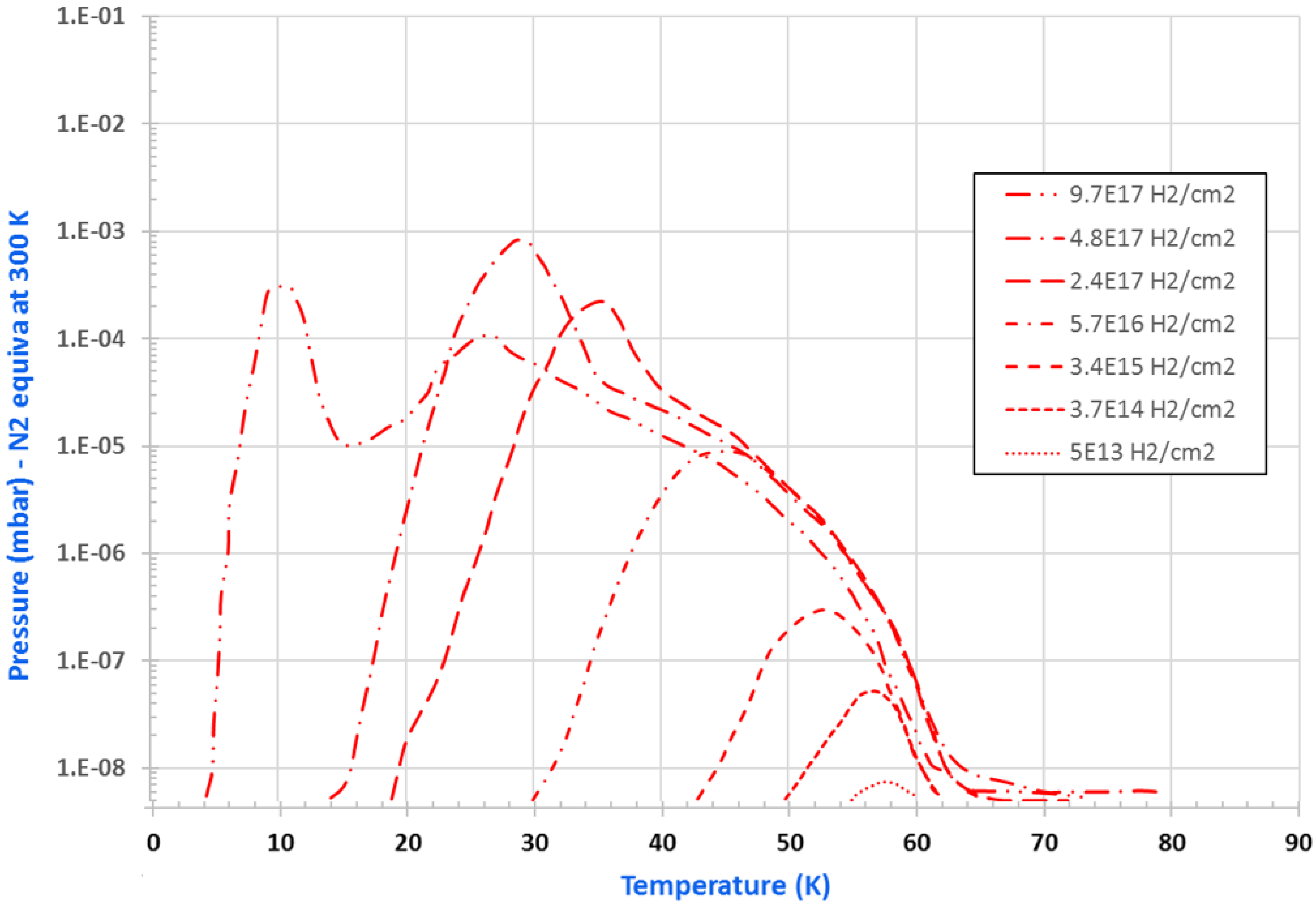


H_2 thermal desorption of 4.8 10^{17} H_2/cm^2



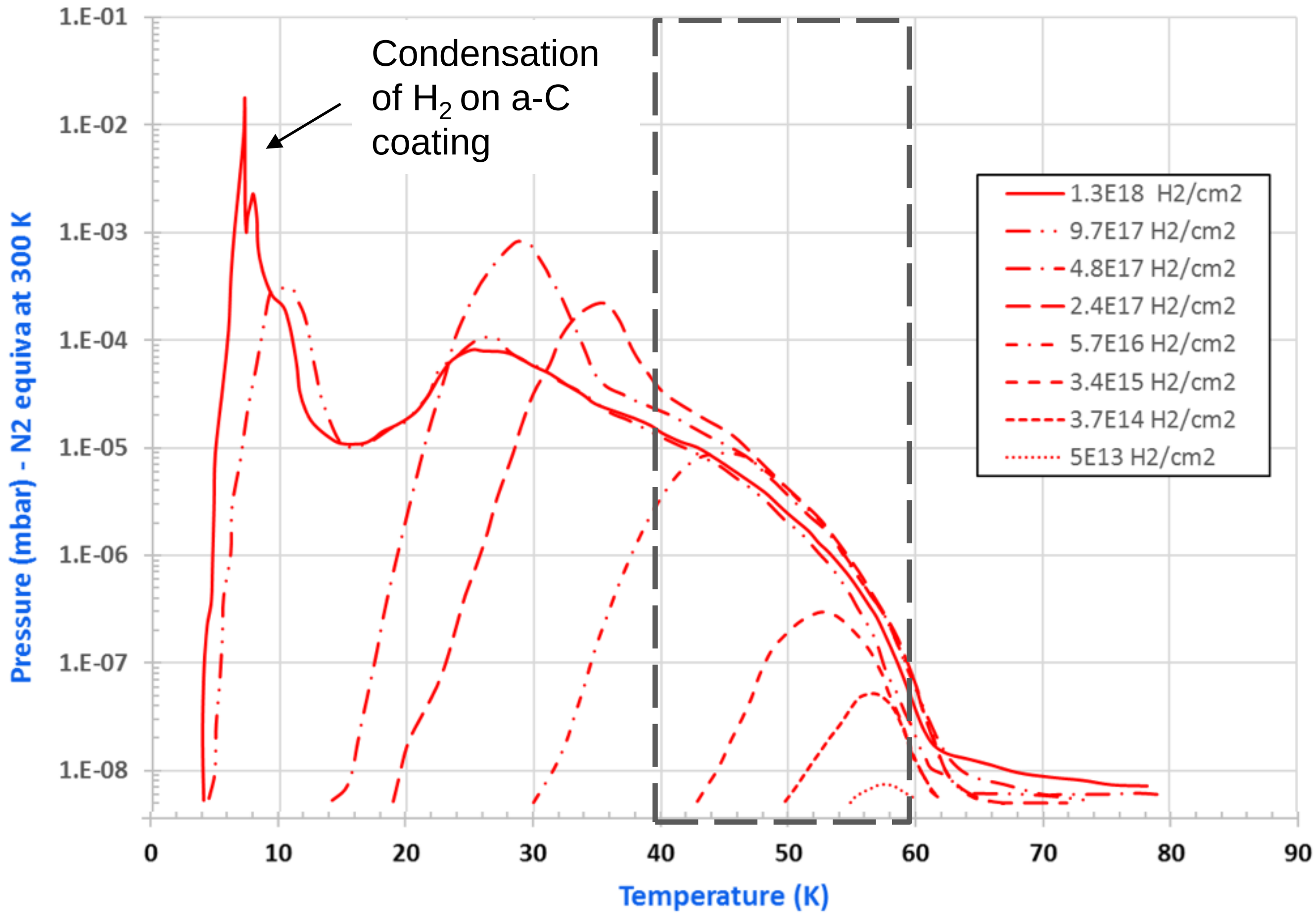
H_2 thermal desorption of 9.7 10^{17} H_2/cm^2

- While increasing the H_2 surface coverage, the desorption peak is shifted to lower values:
  ➔ high binding energy sites are occupied first



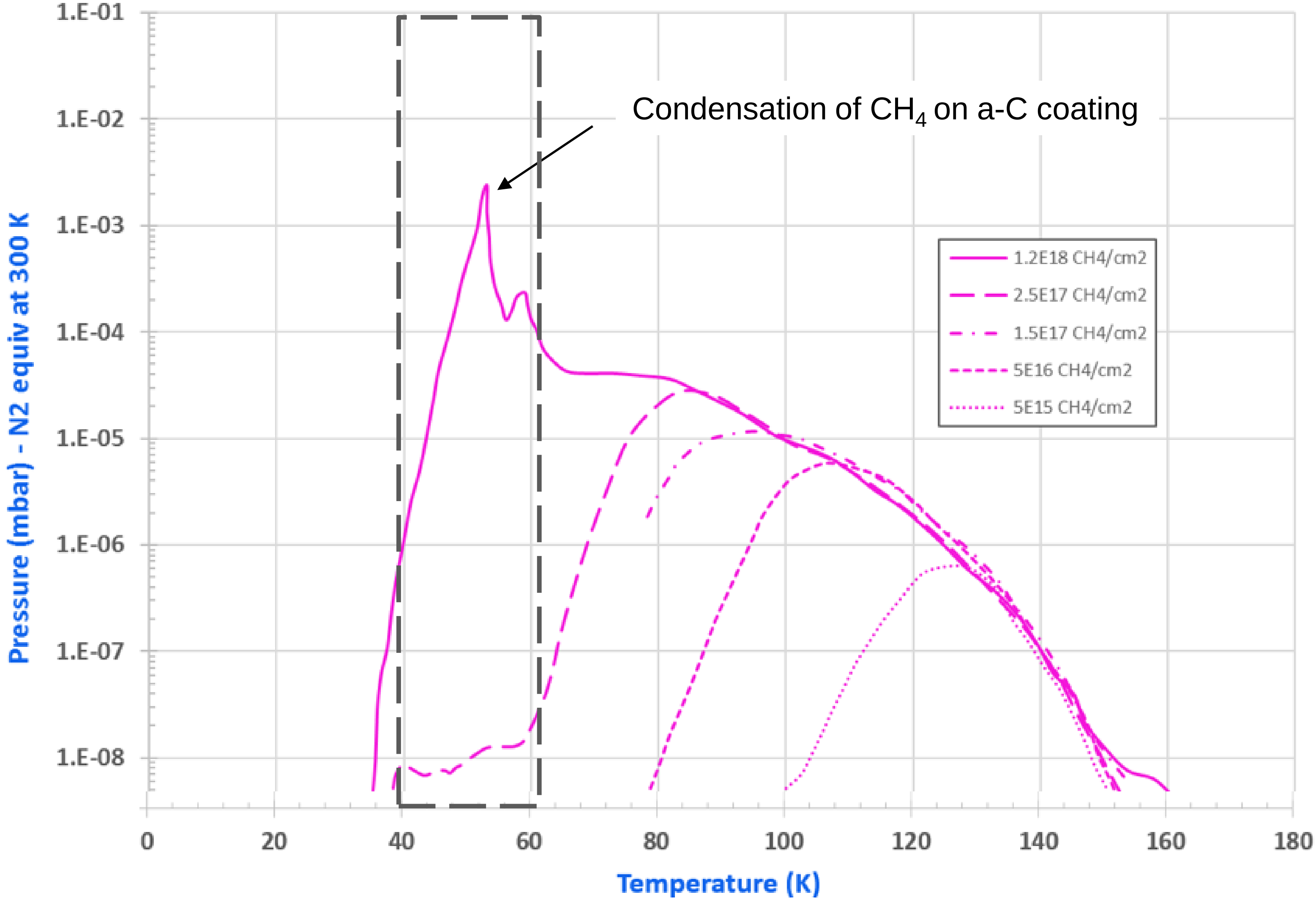
H_2 thermal desorption of 1.3 10^{18} H_2/cm^2

- H_2 desorbs in the range 40-60 K
- While increasing the H_2 surface coverage, the desorption peak is shifted to lower values:
  ➔ high binding energy sites are occupied first
- When the surface is covered by several monolayers of hydrogen, the binding energy equals the heat of vaporisation (9 meV for H_2).



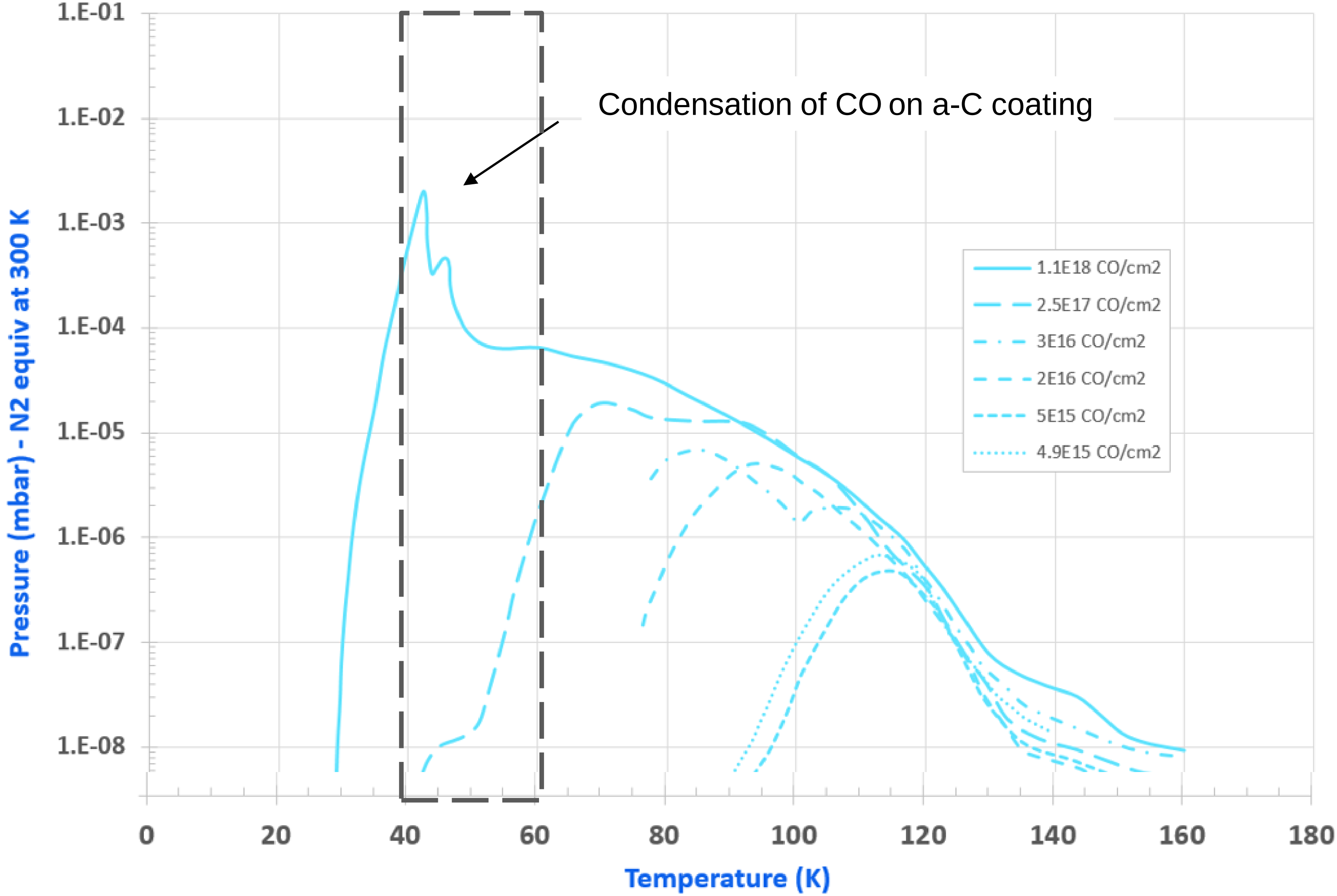
CH_4 thermal desorption

- Heat of vaporisation of CH_4 equals 0.09 eV



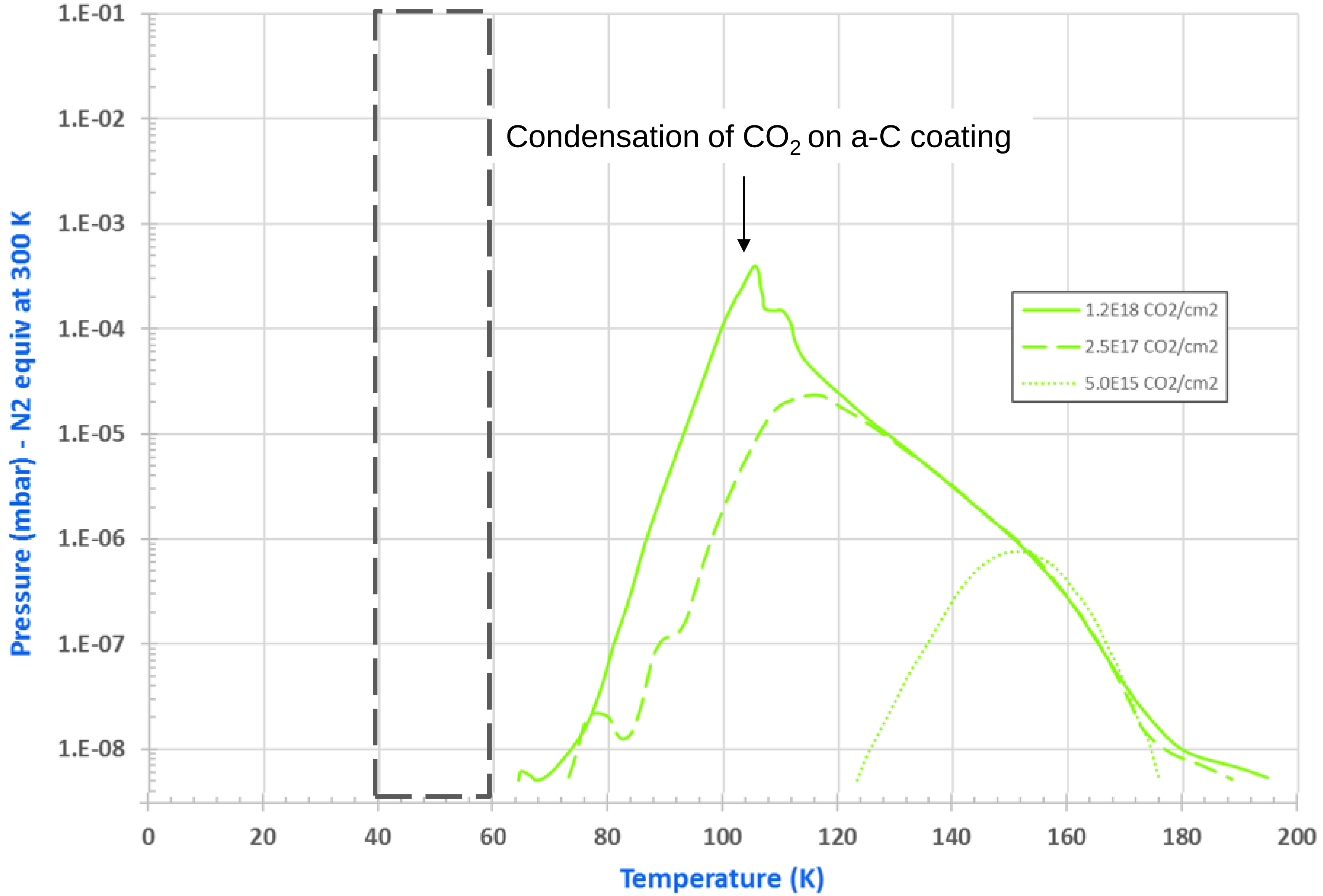
CO thermal desorption

- Heat of vaporisation of CO equals 0.06 eV



CO_2 thermal desorption

- Heat of vaporisation of CO_2 equals 0.16 eV

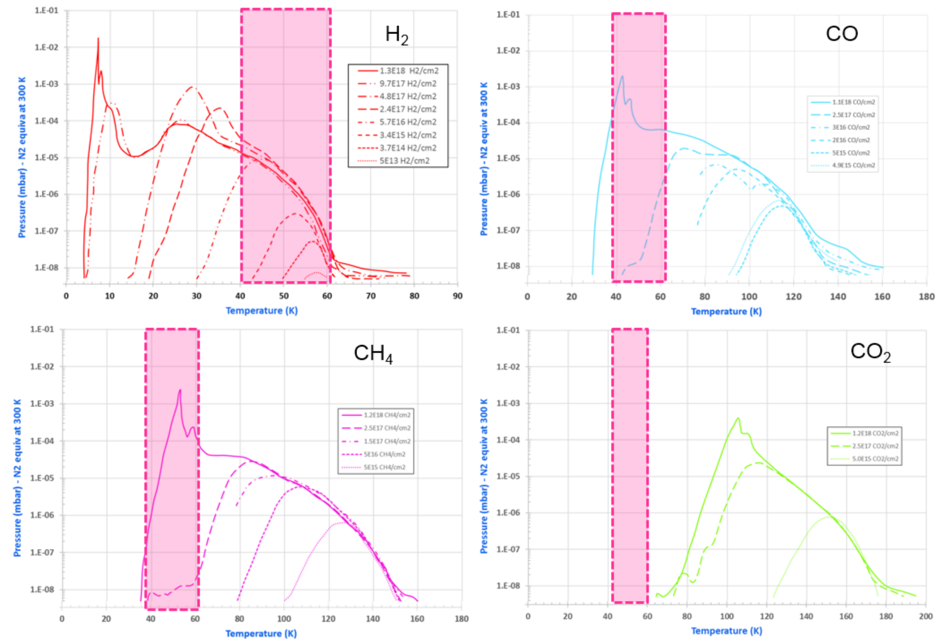


Impact on BS temperature

- H_2 is desorbed in the range 40-60 K

➔Modification of the baseline operating temperature of the BS for the triplets

➔Proposed operating temperature 60-80 K



	H_2	CH_4	CO	CO_2
Peak in 40-60 K	Any coverage	For coverage > 10^{17} CH_4/cm^2	For coverage > 2 10^{16} CO/cm^2	For coverage > 10^{18} CO_2/cm^2
Peak in 60-80 K	No coverage	For coverage > 5 10^{16} CH_4/cm^2	For coverage > 5 10^{15} CO/cm^2	For coverage > 10^{17} CO_2/cm^2

- Similar results were obtained with COLDEX

3. Operating above 60 K

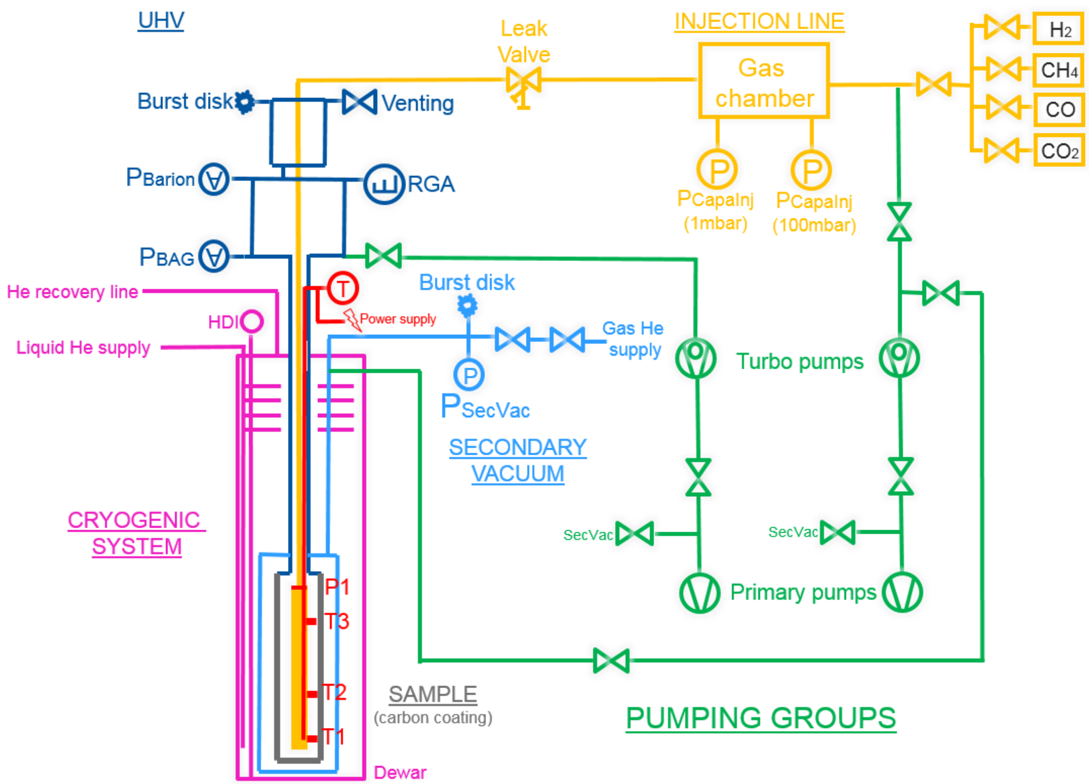
CISTM experimental set-up

- Cryogenic ISotherms and Thermal desorption Measurements (CISTM)
- A set-up to study adsorption/desorption of gas on surfaces in the 4 to 100 K range

- ~ 350 nm thick a-C coating
- Sample:
  - L=0.7 m , D=0.08 m
  - Surface area 1730 cm2

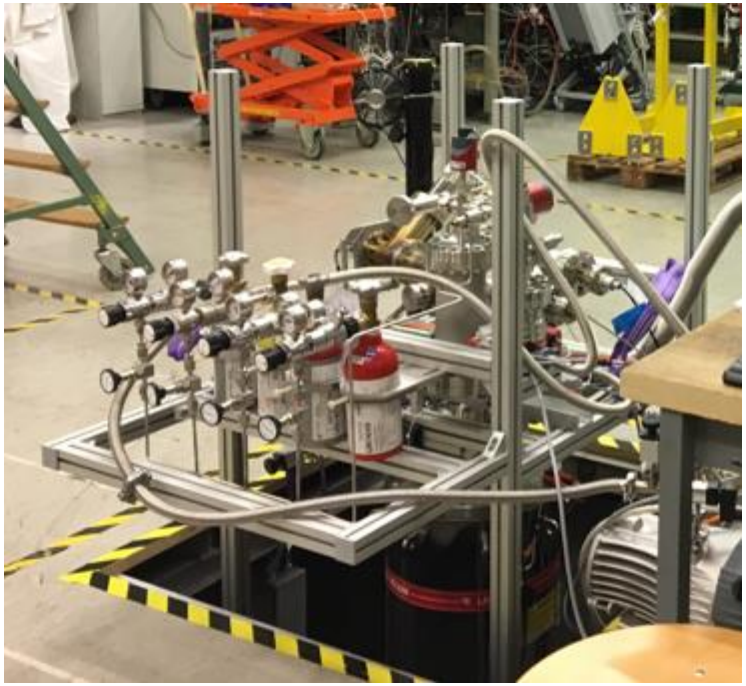
- Gas is injected into the sample

- Secondary vacuum & heater to control the sample temperature



CISTM system

Sample before insertion in secondary vacuum and cryostat

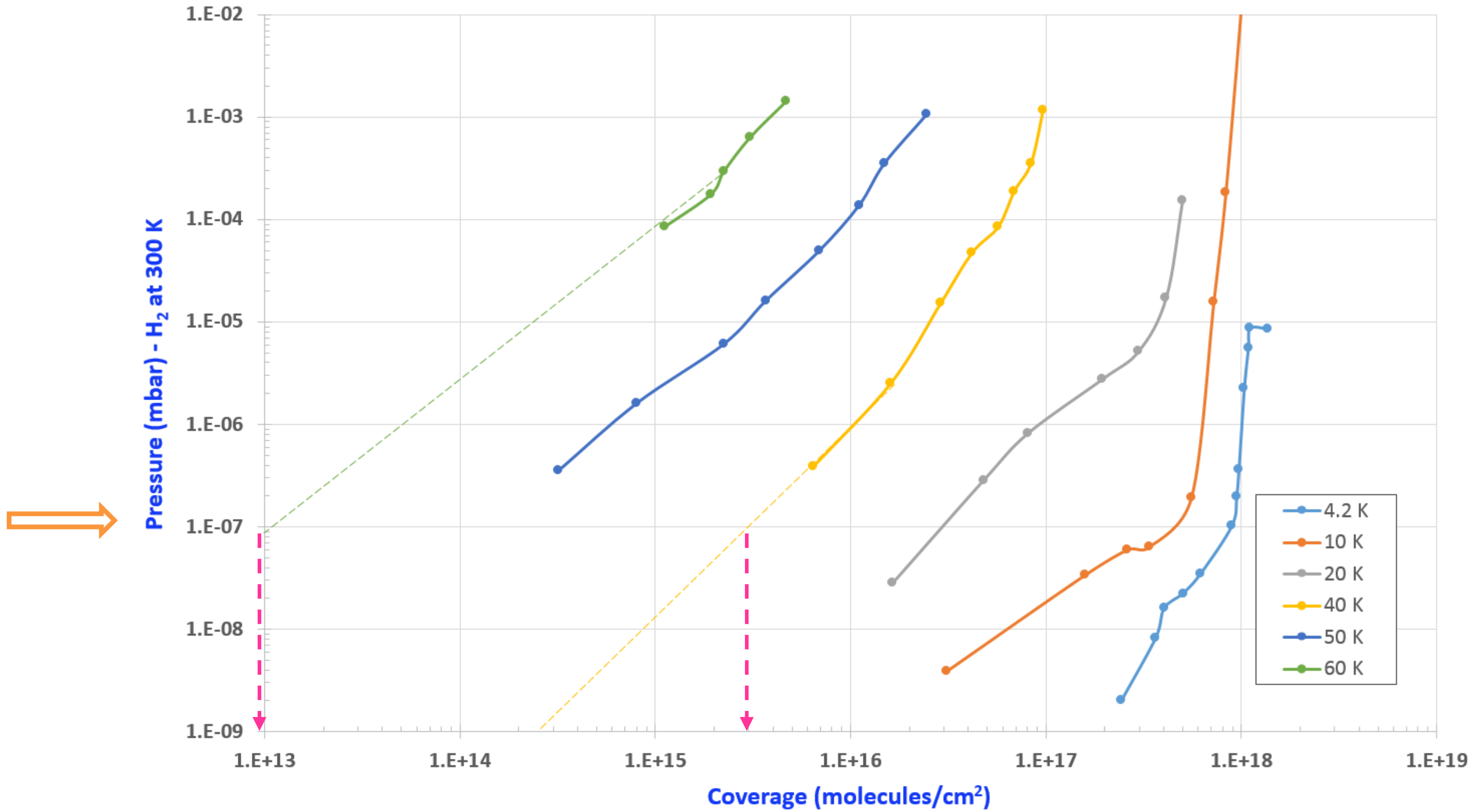


Operating condition

H_2 adsorption isotherms on a-C coating

- In ultra-high vacuum regime, below 10^{-7} mbar,
  - In the range 40-60 K, the surface coverage can be as large as $5\ 10^{15}$ H_2/cm^2
  - Above 60 K, the surface coverage is below 10^{13} H_2/cm^2

➔ the beam screen is almost free of H_2 molecules

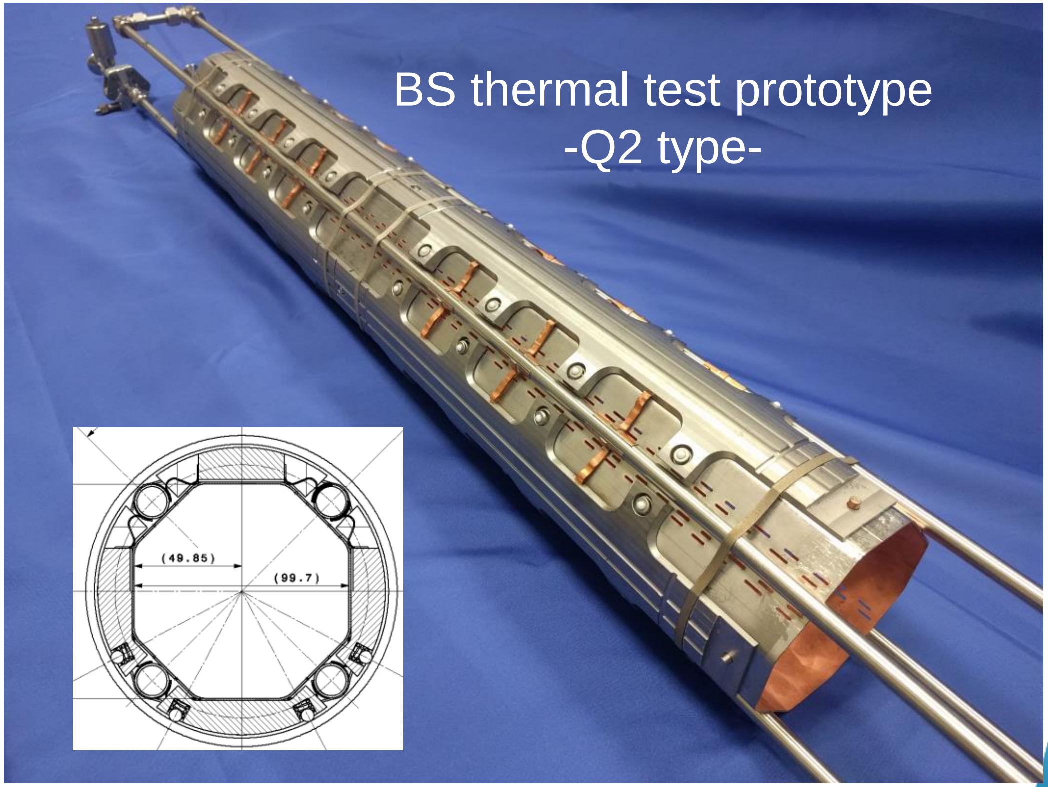


H_2 dynamics in HL-LHC Triplets

- Photons generated by D1 will irradiate the Triplets at grazing angle
- Photon flux ~ 10^{17} ph/m/s at 30 eV critical energy:
    - PSD yield ~ 4 10^{-5} molecule/ph (see BINP results)

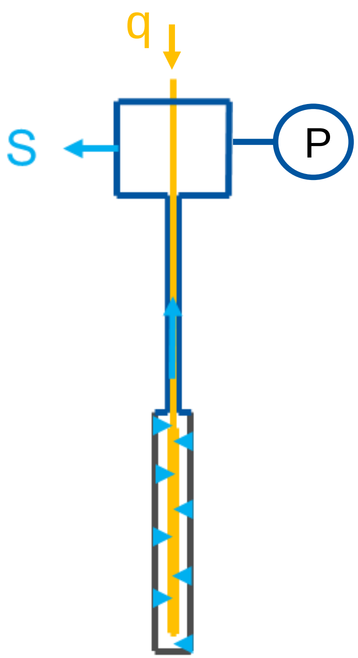
  ➔ Corresponding gas load in CISTM ~ 2 10^{-7} mbar.l/s

- HL-LHC beam screens:
    - Surface area:
        - 3200 cm^2/m
    - holes surface:
        - 60 cm^2/m
    - Transparency:
        - 2 %



Simulating H_2 dynamic with CISTM

- Gas flow is injected into the system at constant/variable temperature and the pressure, P, is monitored



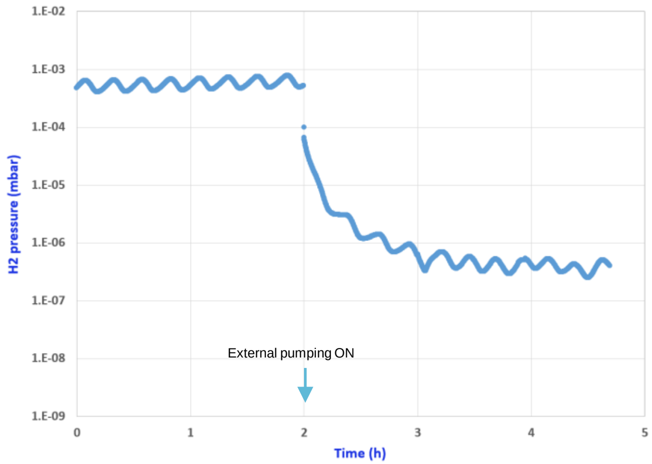
- Typical injection fluxes
  - q = 2 10^{-5} – 2 10^{-4} mbar.l/s
    i.e. 100–1 000 x HL-LHC PSD gas load

- External pumping speed
  - S ~ 80 l/s equivalent to 1.8 cm^2
  - Sample surface area 1730 cm2
    - Equivalent transparency 0.1 %

➔ For comparison with HL-LHC, the measured pressure in CISTM shall be divided by 20

H_2 dynamics

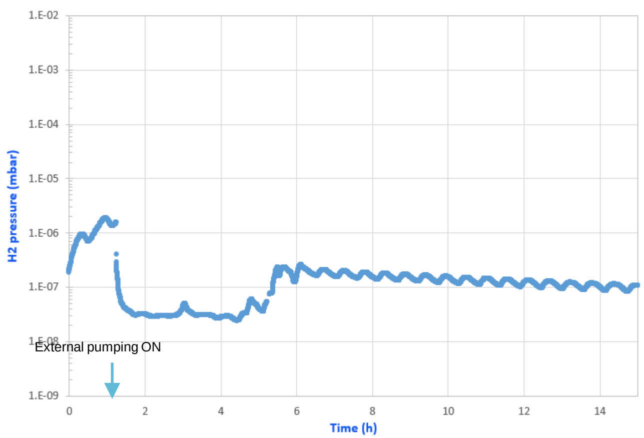
- Preliminary results:



T = 50 ± 0.5 K
Q ~ 2 10^{-5} mbar.l/s

P_{Eq} = (5 ±1) 10^{-7} mbar

➔surface coverage ~ 2 10^{14} H_2/cm^2



T = 60 ± 1 K
Q ~ 2 10^{-6} then 2 10^{-5} mbar.l/s

P_{Eq} = (1.5 ±0.2) 10^{-7} mbar

➔Lower oscillation amplitude than at 50K
➔Lower surface coverage ~ 2 10^{13} H_2/cm^2

4. Conclusions

Conclusions

- The use of materials with large porosity allows to trap:
  - Electron thereby mitigating electron multipactoring
  - Molecules on many adsorption sites spanning a large range of binding energy thereby allowing molecular desorption over a wide temperature range

- 400 nm thick a-C coating is a porous material which allows H_2 desorption till 60 K as demonstrated by adsorption isotherms and COLDEX studies

- A new experimental set-up has been designed & commissioned to study the operating temperature of the beam screens for the HL-LHC triplets

- First H_2 adsorption isotherms in the range 10-60 K have been obtained

- Preliminary H_2 injections to study the HL-LHC beam screen behaviour in the range 50-60 K have been done

- Preliminary results with ~ 400 nm thick a-C coating indicate a possible operating range of 60-80 K for the beam screens

Next steps

- This study must be completed with other gases: CH_4, CO and CO_2, and other temperatures in the range 40-100 K.

- In order to optimise the coating adherence, electron cloud & impedance performance, new coating parameters have been defined:

  50 nm of a-C coated on a 150 nm of Ti layer

- New samples shall be produced for CISTM, COLDEX & BINP experimental systems to study, during LS2 and RUN3, the impact of this new coating parameters on the operating temperature.

Thank you for your attention

Many thanks to A-L Lamure, R. Salemme and R. Cabezas for their significant, valuable and important contributions

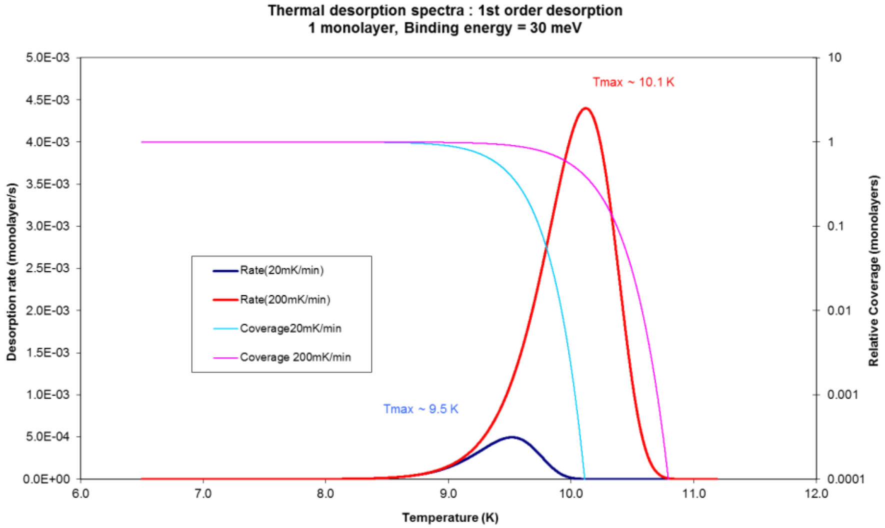
Spare slides

Thermal desorption spectroscopy

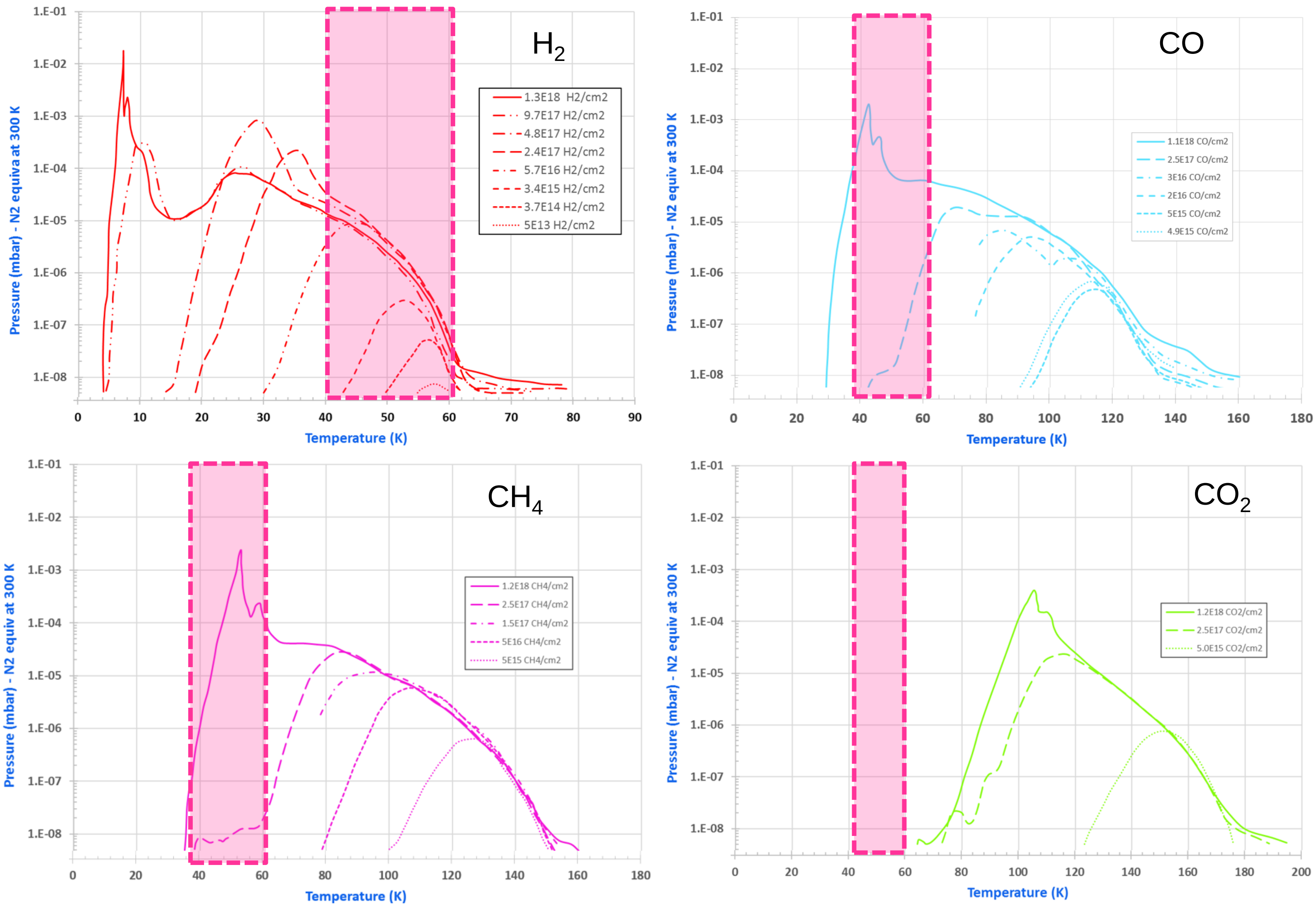
- Allows to characterise a surface against molecular species and surface coverage
- Syn: Temperature Programmed Desorption
- Measurement of the desorbed molecules from a surface while increasing the surface temperature

$$\frac{d\theta}{dt} = -\,\nu_n \theta^n \, e^{-E/_{kT}}$$

- θ surface coverage
- v pre-exponential factor
- n desorption order: n=1 desorption of molecules, n=2 desorption of molecules following recombination of atoms
- E activation energy
- T temperature, k Boltzmann constant

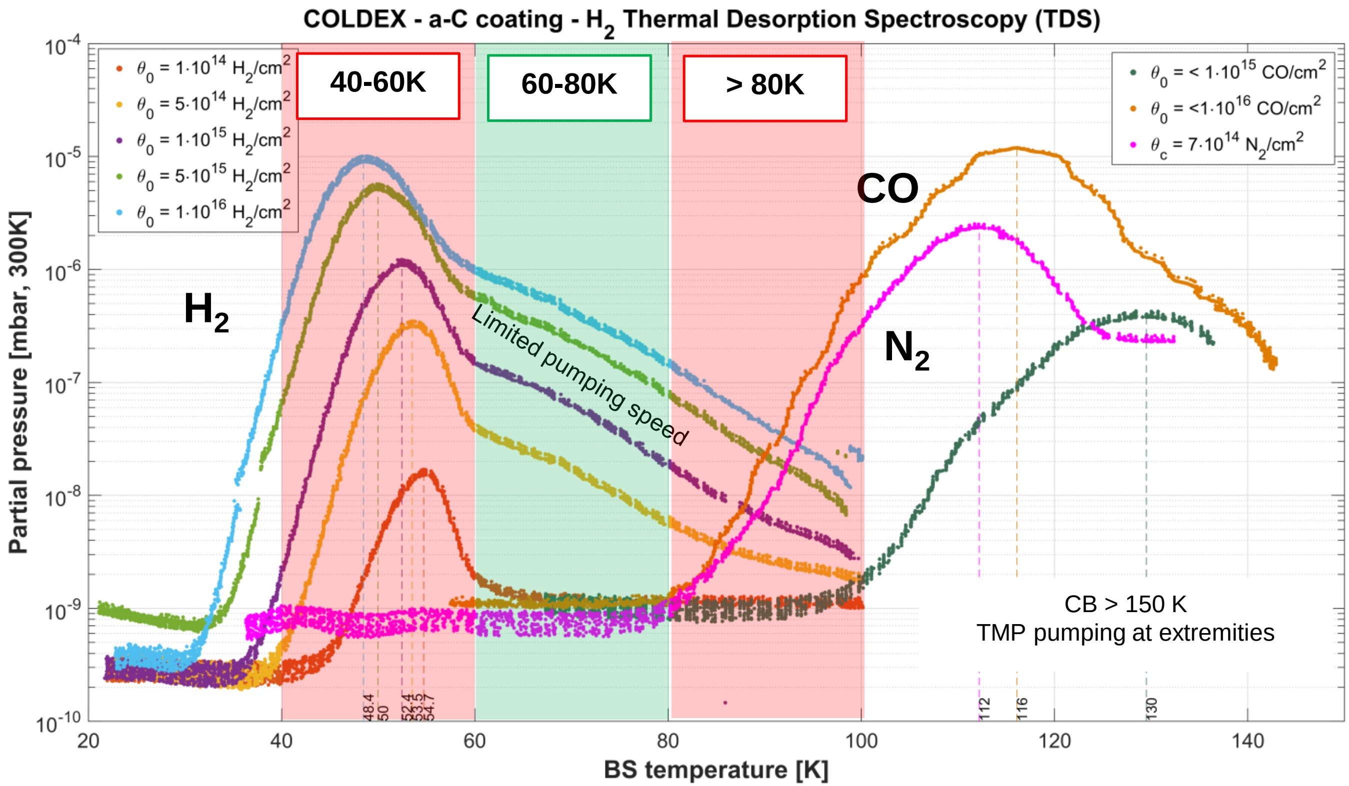


Thermal desorption



COLDEX observations (1)

- The hydrogen desorption phenomenon was also observed with the 2.2 m long a-C coated beam screen of COLDEX
- Similar conclusions could be drawn: 60-80 K as tentative operating temperature



R. Salemme *et al.* Proc. IPAC 2016

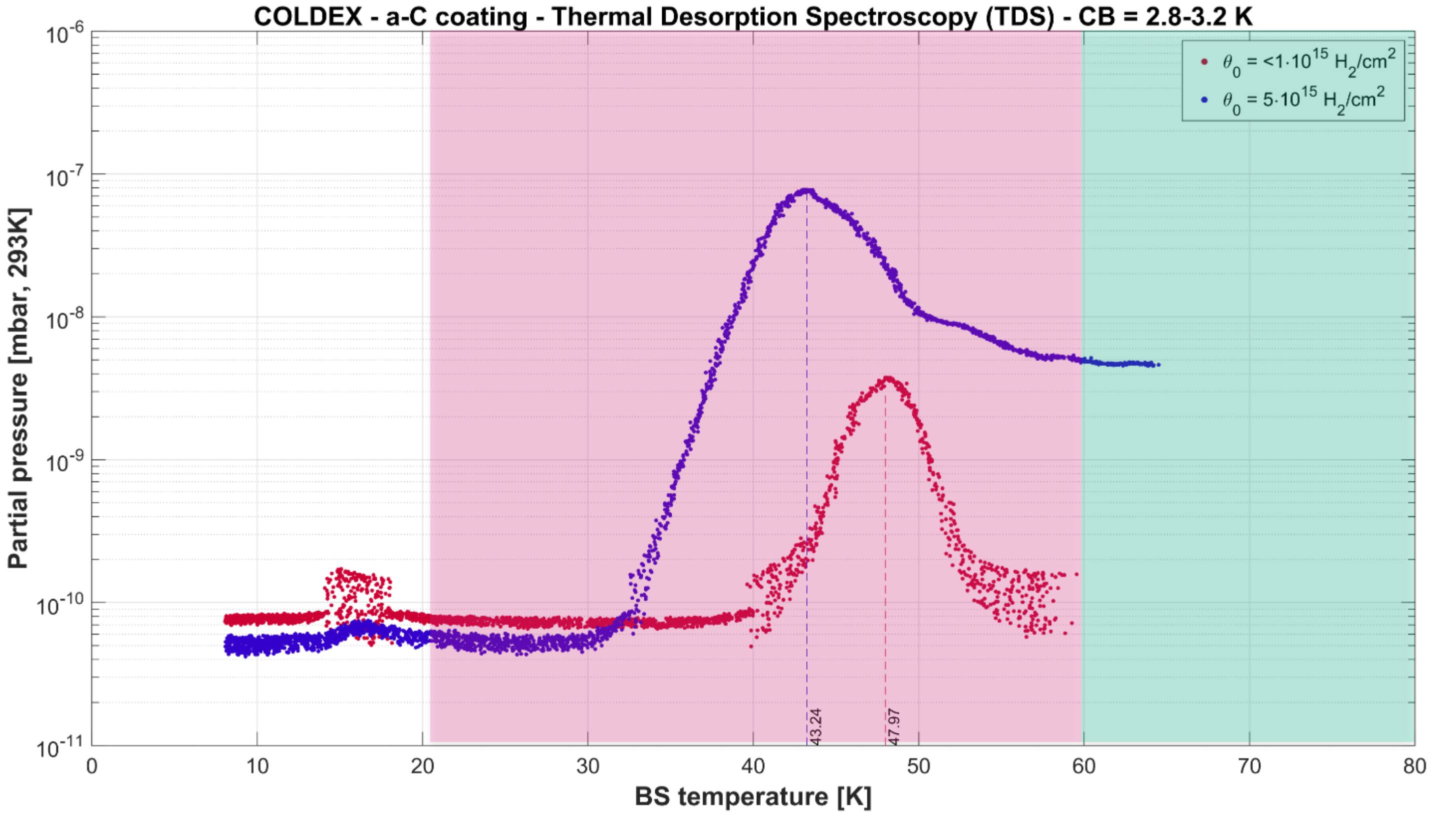
COLDEX observations (2)

- However, in operating conditions, the desorbed gas is pumped by the cold bore trough the beam screen holes

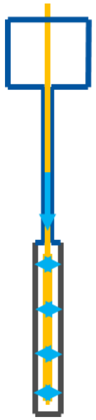
  ➔ this shall mitigate the effect of the desorption

- Observed with preliminary studies conducted in 2016:
  - Peak pressure is reduced by ~ 50

  ➔ more studies are needed with COLDEX during RUN 3 to quantify the effect

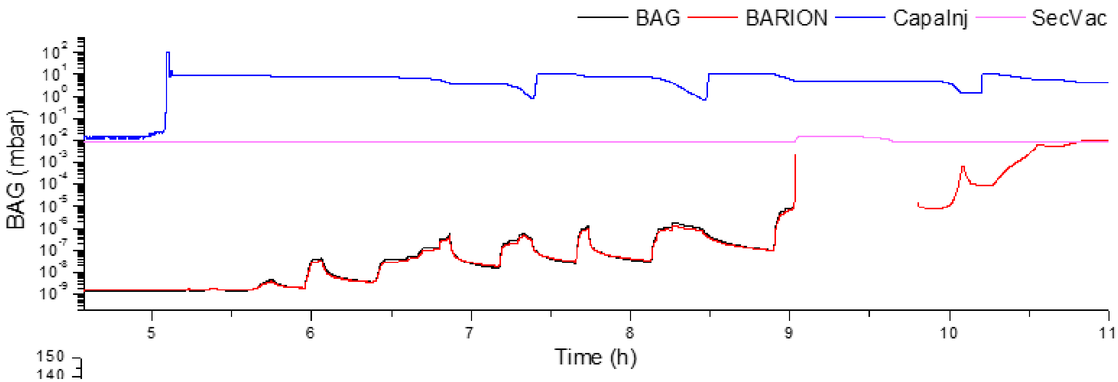


Adsorption isotherm



- Known quantity of gas is admitted into the system at constant temperature
- Equilibrium pressure is recorded as a function of surface coverage
- Typical results:

At 10 K



At 20 K