# Study of vacuum stability at cryogenic temperature

*WP4 - Activity at LNF*

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# Beam Screen Temperature

## Working Pressure ⟷ BS Temperature Range

(<$10^{-11}$)

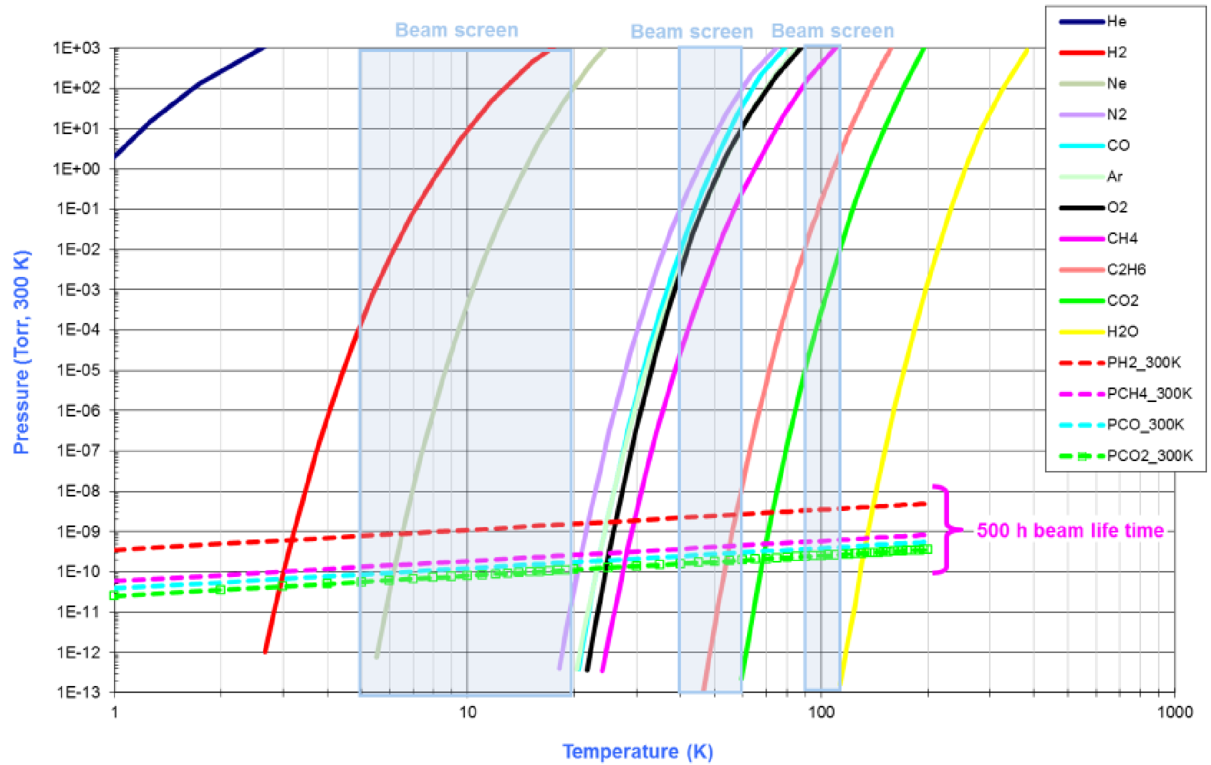
### LHC

SR Power = 0.13 W/m

### FCC

SR Power = 40 W/m

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

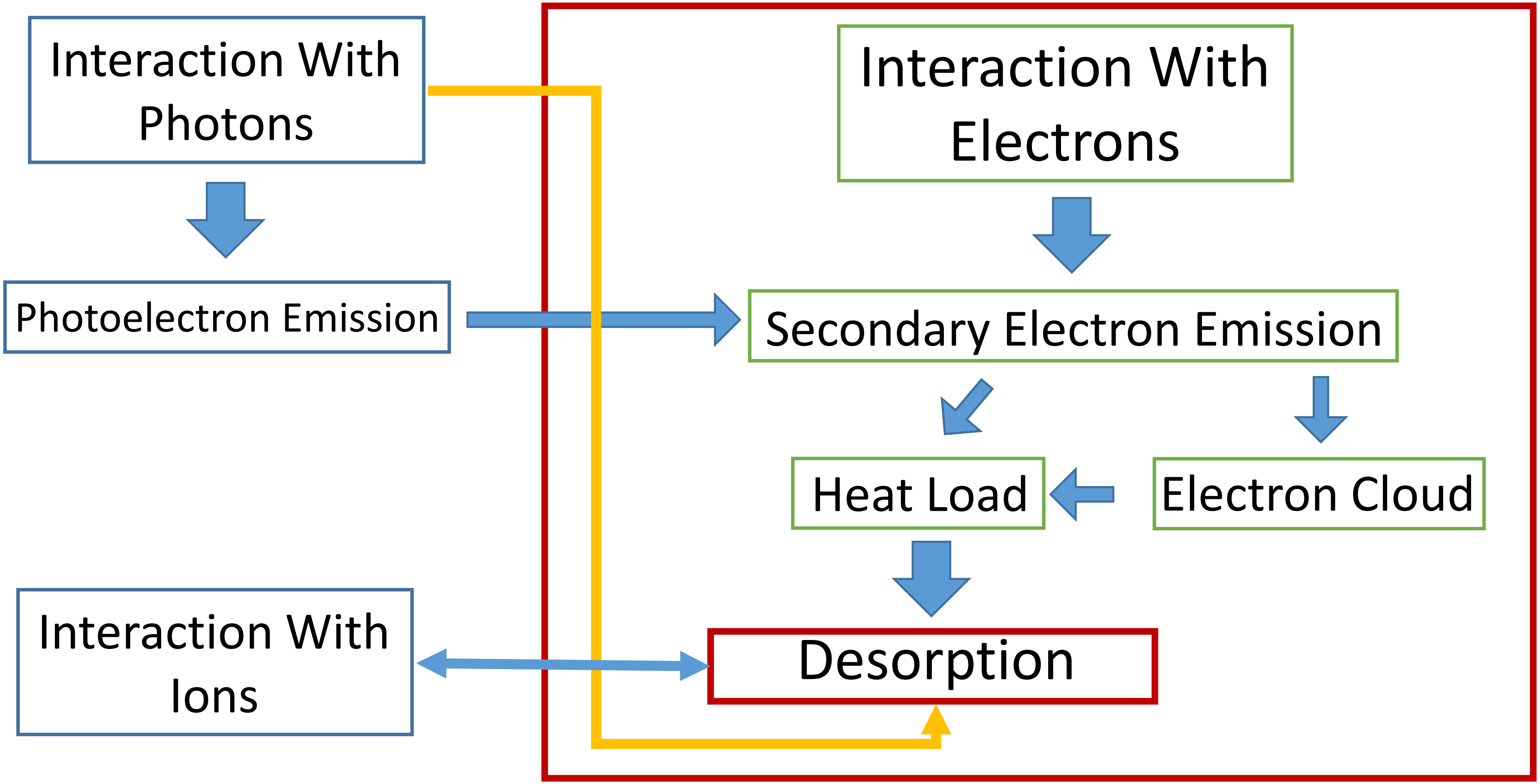


# Temperature

- Find right working temperature is a fundamental point for vacuum stability.
- Work near a gas desorption temperature could generate great pressure oscillations.

Study of adsorption/desorption behaviour near critical temperature is mandatory to understand vacuum stability

# Vacuum Stability



# Studies

- Surface Quality

- X-Ray / UV Photoemission
- Secondary Electron Yield (SEY)

- Adsorbed atoms and molecules

- Cryogenic temperature
- Atoms/Molecules Adsorption/Desorption process

# LNF-Lab Now

Two Different Ultra-High Vacuum Systems equipped with:

- Low Energy Electron Diffraction
- Secondary Electron Yield Spectroscopy
- Surface Preparation
- Gas-Line

- X-Ray/UV Photoemission
- High Temperature Manipulator

- Low Temperature Manipulator (≈ 9 K)

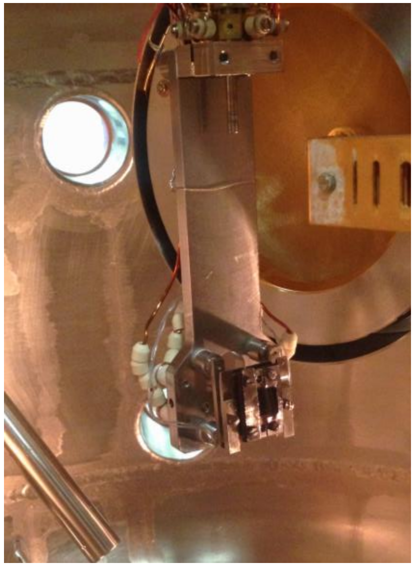
Raman Spectroscopy

Scanning Tunneling Microscopy

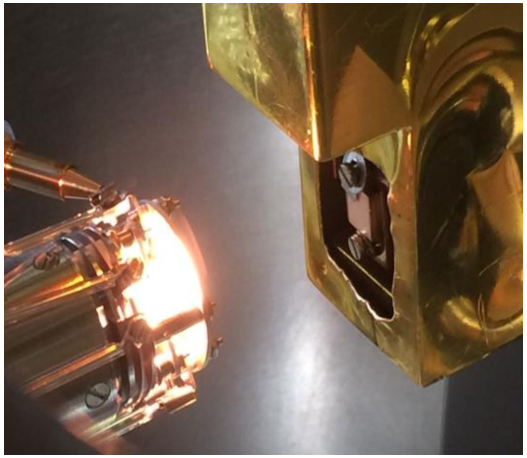
# LNF-Lab Now

Gas-Line

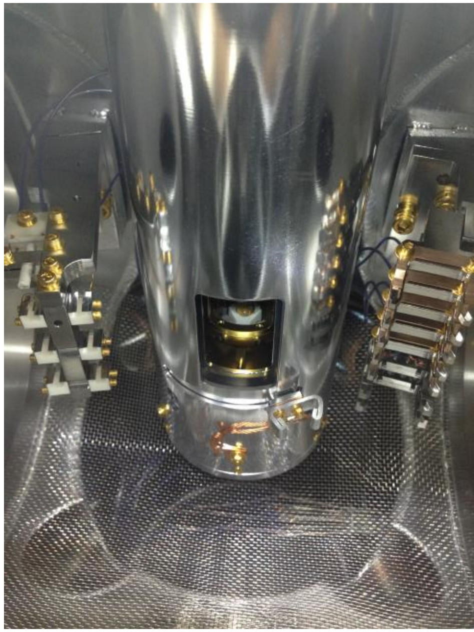
HT Manipulator



LT Manipulator



LT STM



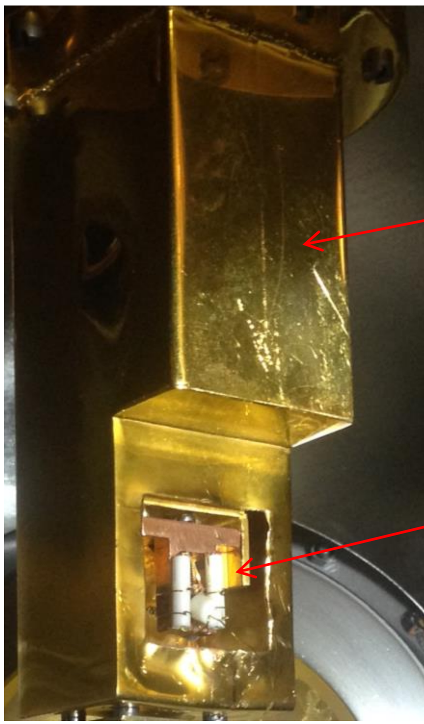
# LNF-Lab Activities I

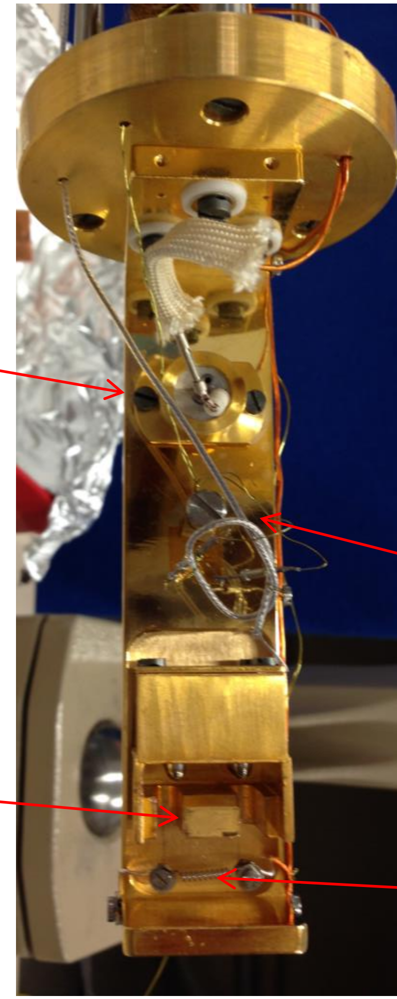
Maintenance of Low Temperature System

Fixed some problems with Low Temperature manipulator, working on compressor of cryogenic system (≈5 months)

Now Low Temperature = 10 K

# LNF-Lab Activities I



# LNF-Lab Activities II

First **Preliminary** Results

Adsorption/Desorption process of Atoms and Molecules (Argon, CO) at cryogenic temperature measured with:

Secondary Electron Yield (SEY) and

Temperature Programmed Desorption (TPD)

# LNF-Lab Activities II

- Adsorption process of Argon (Ar) and Carbon-Monoxide (CO) on atomically sputtered Cu surface at low temperature (with SEY)
- Desorption process of Ar and CO from heated Cu sample (with SEY and TPD)
- Interaction between electrons and Ar films (SEY)

# LNF-Lab Activities II

## Working Parameters:

- Basic Pressure ≤ $1x10^{-10}$ mbar
- Electron Beam Current < $1x10^{-7}$ Ampere (A) (Max Current @ max electron energy)
- Electron Beam Energy from 75 to 1000 eV
- Sample Bias 75 V
- Single Spectra Acquisition Time ≈ 120 sec
- Beam Radius < 1.0 mm

- 1 Langmuir (L) = 1 sec @ $1x10^{-6}$ mbar
- 1 L = 1 Mono-Layer (ML) (with sticking coefficient = 1)

- Temperature range: form 10 to 300 K

# LNF-lab Activities II

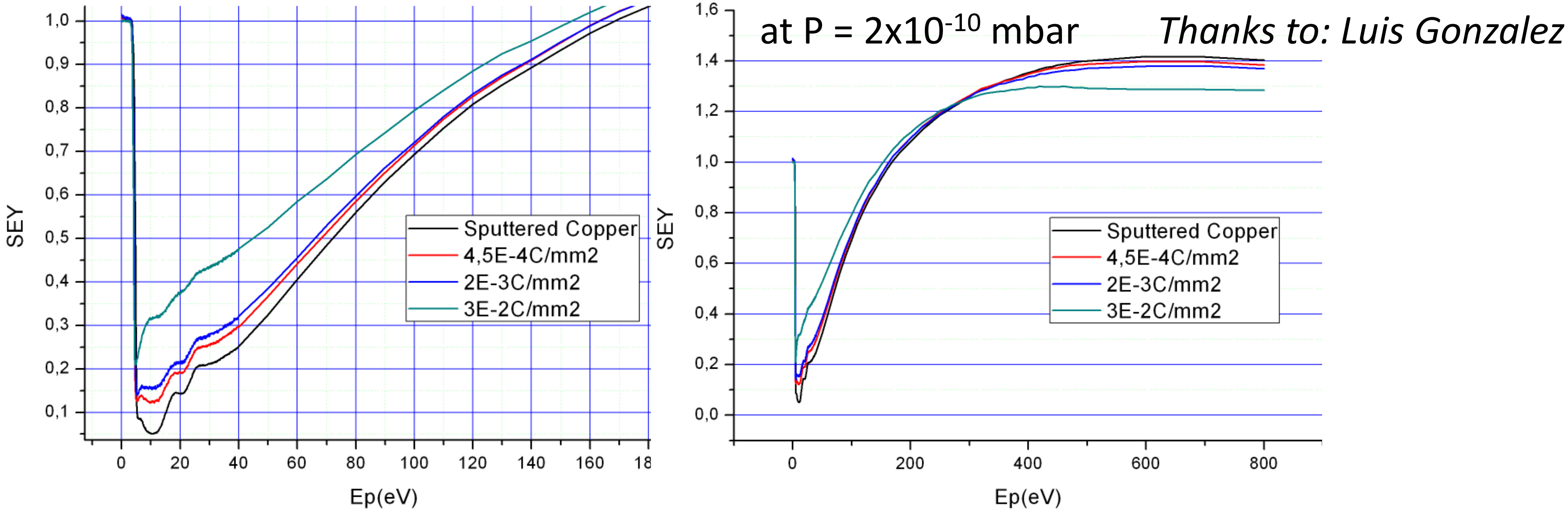
- Why start with Atomically Sputtered clean Copper?

  Electron Beams have not effect on a clean surface so any modification to the SEY can be attributed to atoms and molecules on surface.

  - easy to single out contamination (sample pumping) from experimental.
  - easy to eliminate spurious and otherwise occurring scrubbing effects from real non-clean surfaces.

# LNF-lab Activities II

## Experimental Test with Atomically Sputtered Copper




- First observable changes (blu) after 0.02C/mm$^2$ ➔ more than 6 h SEY measurements
- More significant changes (green) needs more than 60 h continuous measuring
- Our standard SEY lasts 120s!

# LNF-lab Activities II

- Why Argon and Carbon-Monoxide?

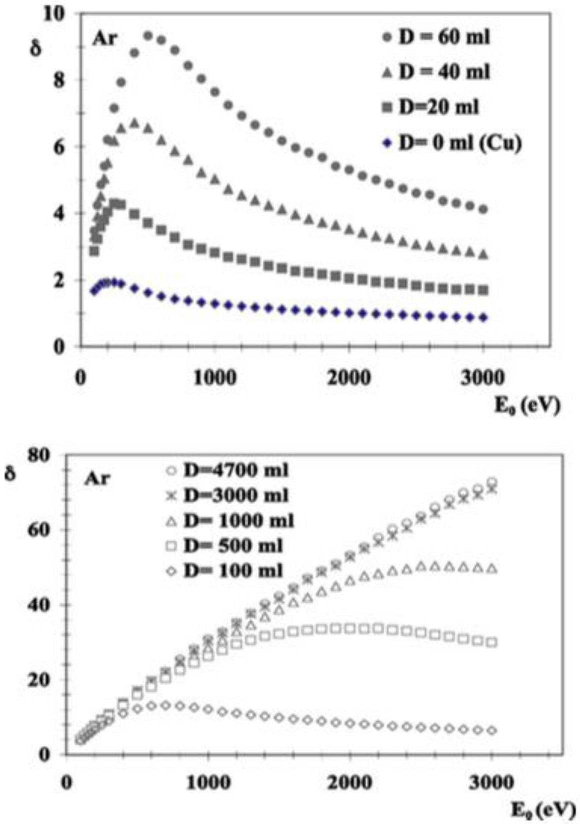
  ① Argon is a inert gas and it's the best starting point to study SEY al Low Temperature

  ① Carbon-Monoxide is a gas of great interest for accelerator physics

# LNF-lab Activities II

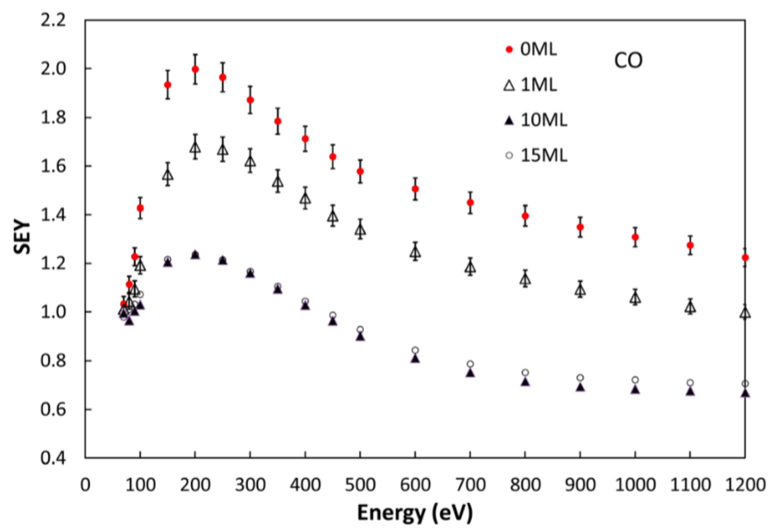
## Reference Literature spectra of Argon and Carbon-Monoxide SEY

Argon




J. Cazaux et al.:
Phys. Rev. B 71 (2005) 035419

Carbon-Monoxide

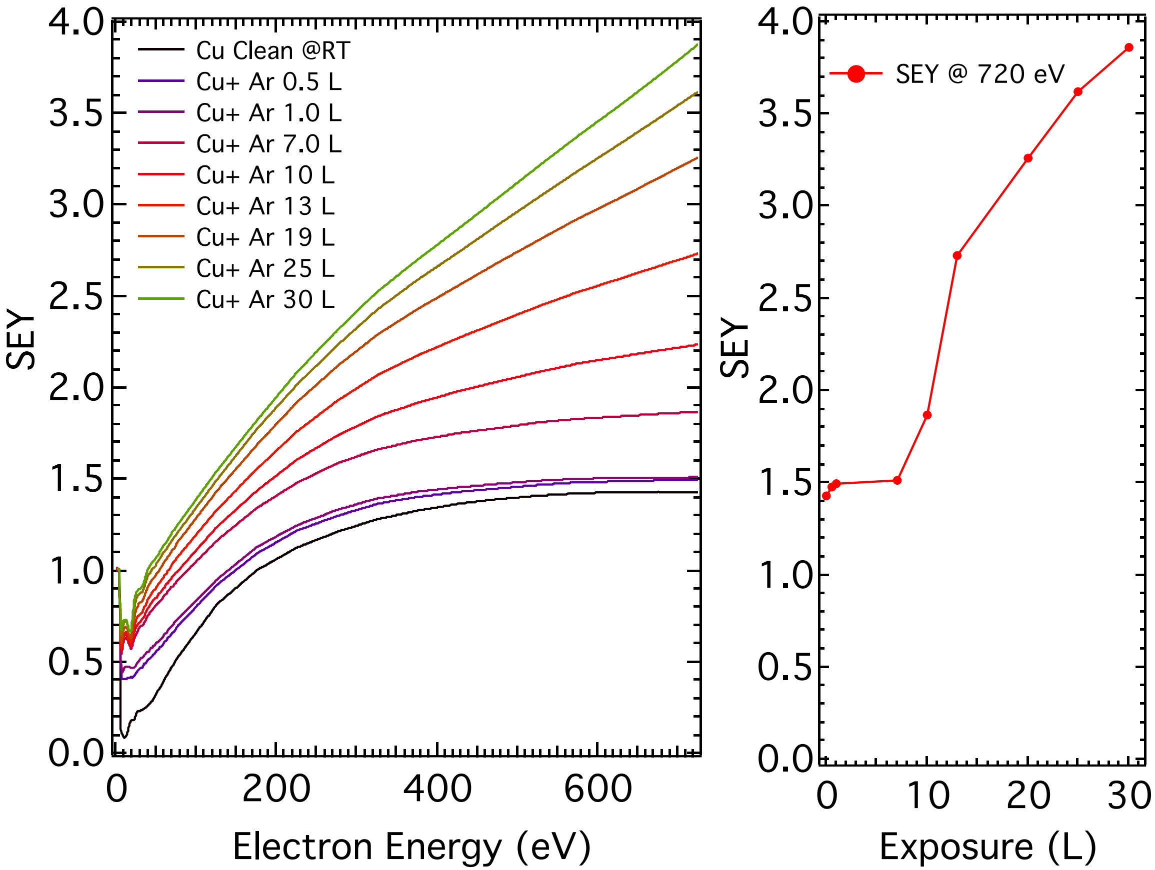



A. Kuzucan et al.:
J. of Vacuum Sci. & Tech. A 30 (2012) 051401

# First Preliminary Experimental Results

# Argon Adsorption (SEY)

## Adsorption process of Argon on Cu sample at 10 K
## General behaviour



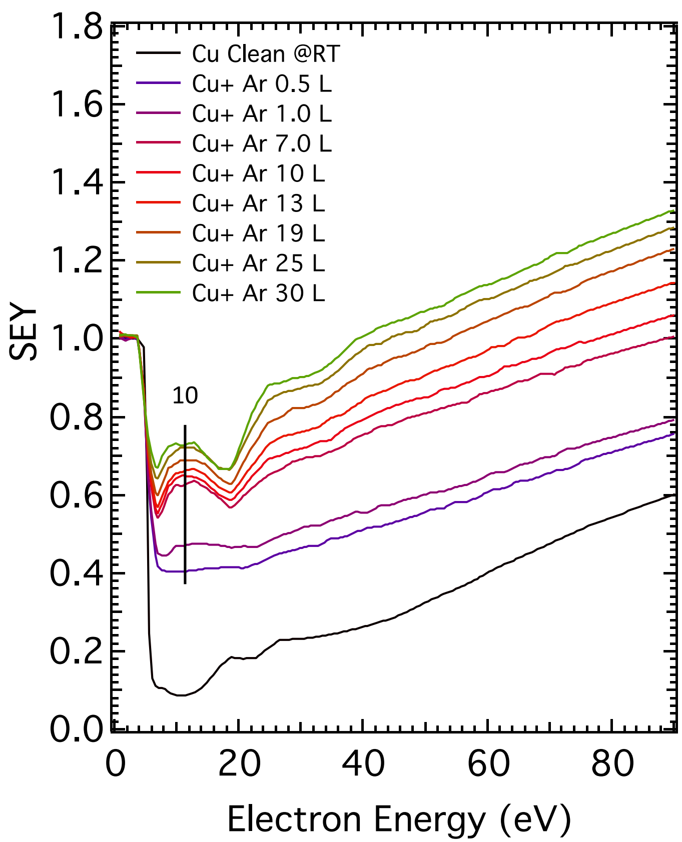

Two different regions

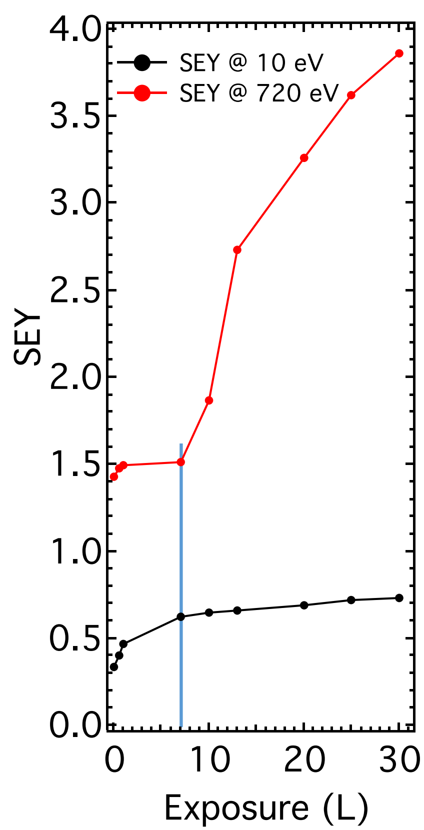
| High Energy (>50 eV) | Low Energy (<50 eV) |
|---|---|

- SEY at 720 eV increases during adsorption from 1.4 to 3.9
- Formation of Argon Thick Film (TF)

# Argon Adsorption (SEY)

## Adsorption process of Argon on Cu sample at 10 K
## Low Energy behaviour




### Two different regions

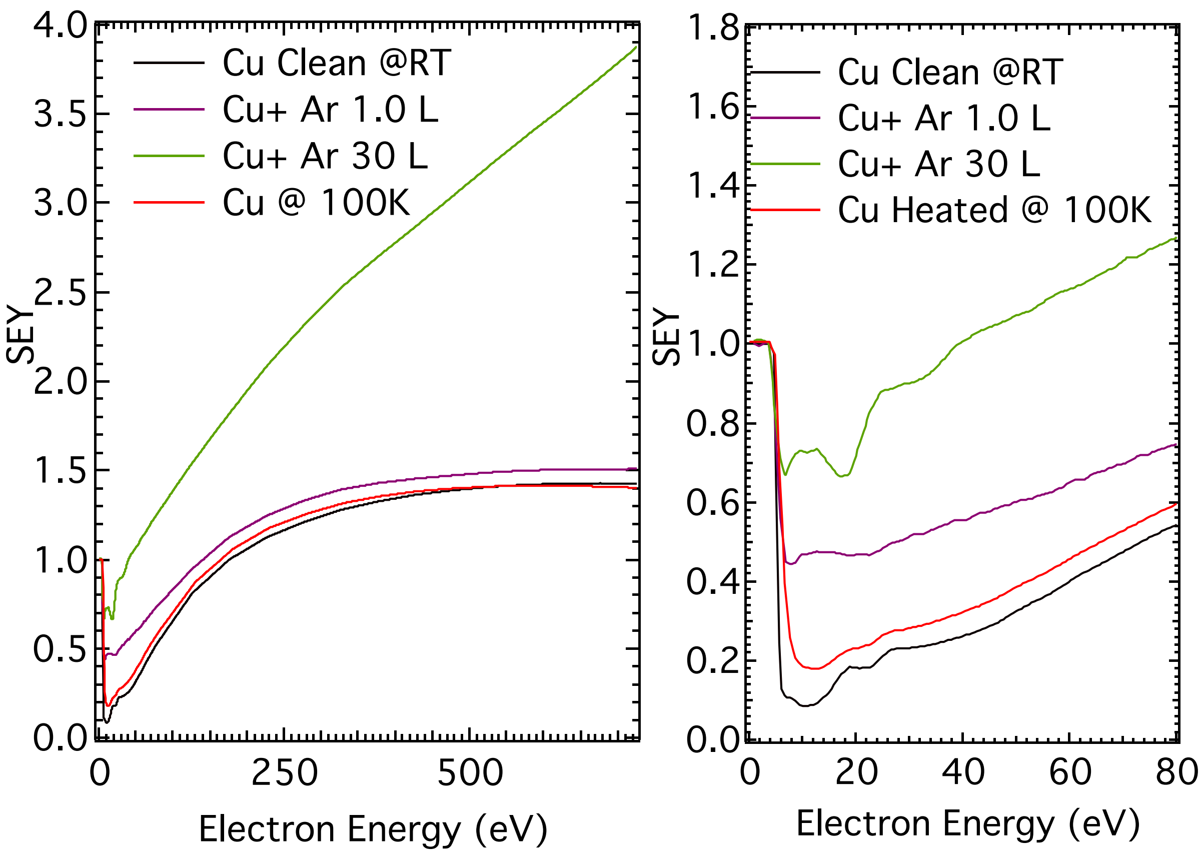
High Energy (>50 eV)

Low Energy (<50 eV)

- SEY increases during first steps and reaches saturation
- Formation of Argon Single Layer (SL)

# Argon Desorption (SEY)

Desorption process: Cu sample heated up to 100 K

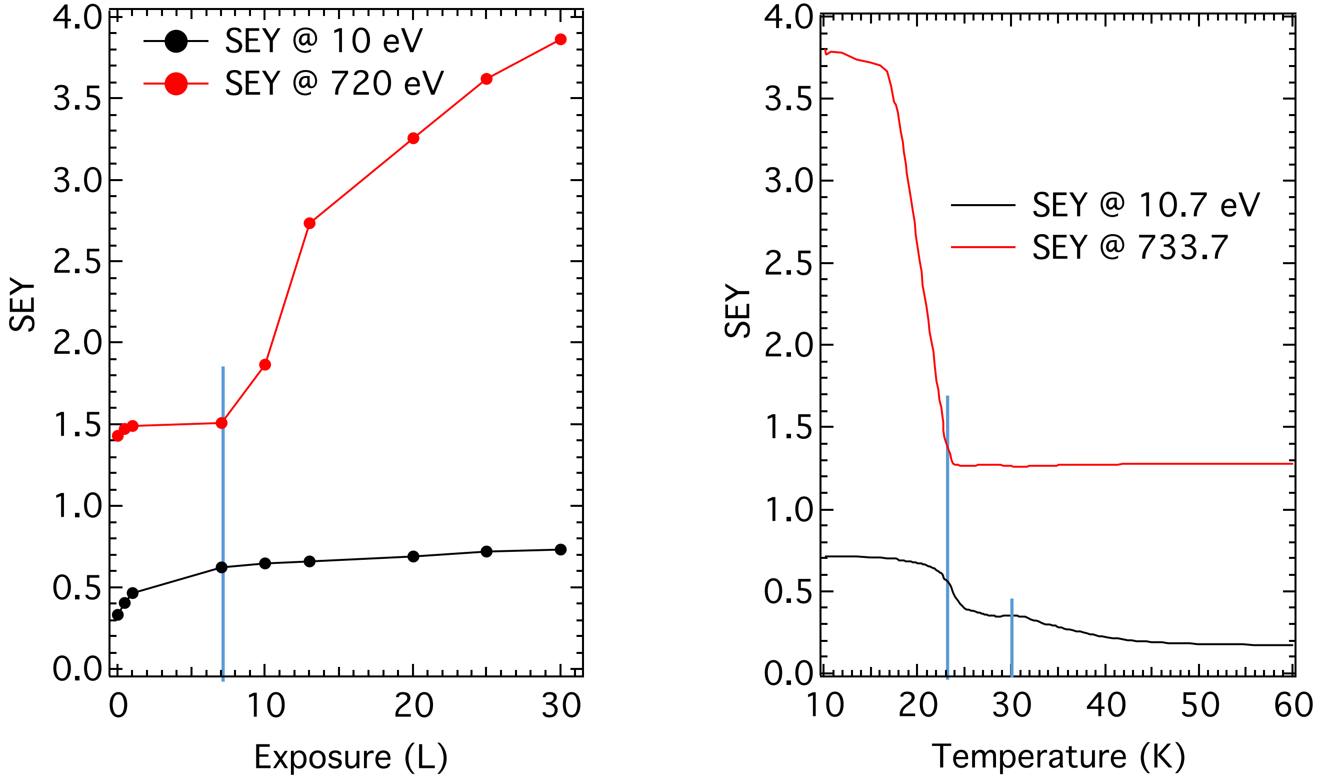



Sample *"Cleaned"*
SEY returns to the initial value

Slight differences due to possible residual impurities on the surface

# Argon Desorption (SEY)

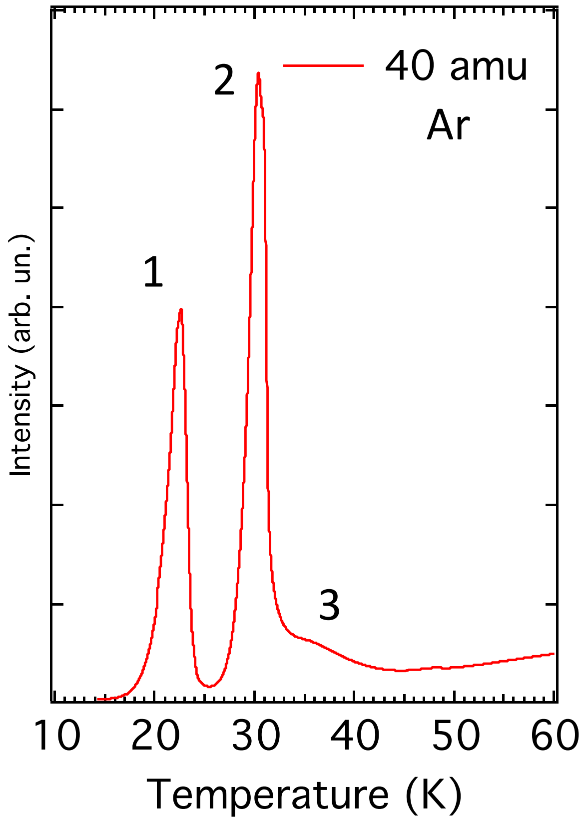
Desorption process heating Cu sample to 100 K




**Same behavior in the opposite direction**

# Argon Desorption (TPD)

Test of Temperature Programmed Desorption (TPD) with Mass Spectrometer




Three different peaks at 22, 30 and 37 K

due to the different desorption of TF from Manipulator (Peak 1 and TF/SL from sample

# Argon Results

## Adsorption Process (LT)

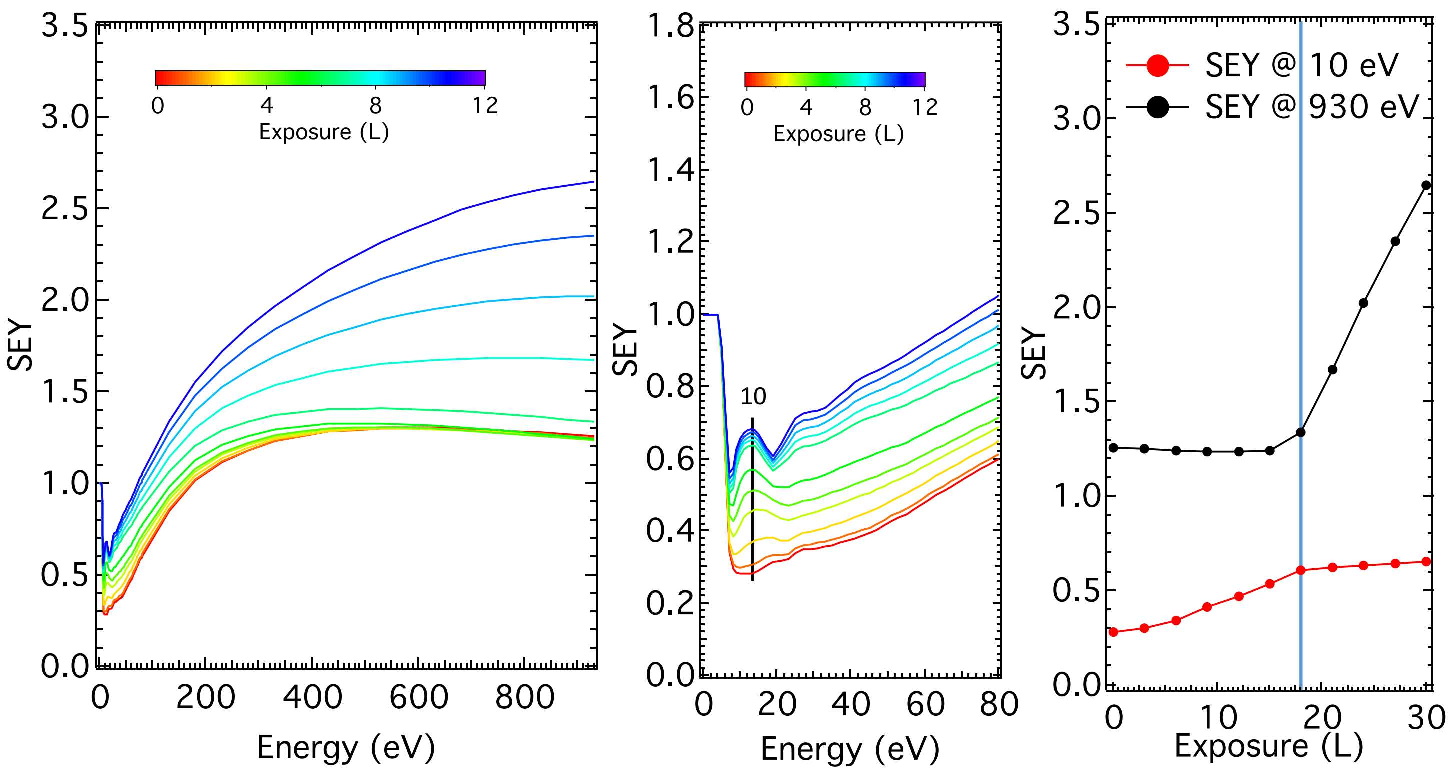
- Formation of a Thick Film (TF) at high coverage (increasing of SEY)
- Formation of a Single Layer (SL) on Cu at LT (characteristic peaks in low energy region)

## Desorption Process (Heating)

- System returns to the original state with slight differences
- Possibility to follow formation of SL from TF
- Possibility to measure desorption temperature with SEY and TPD

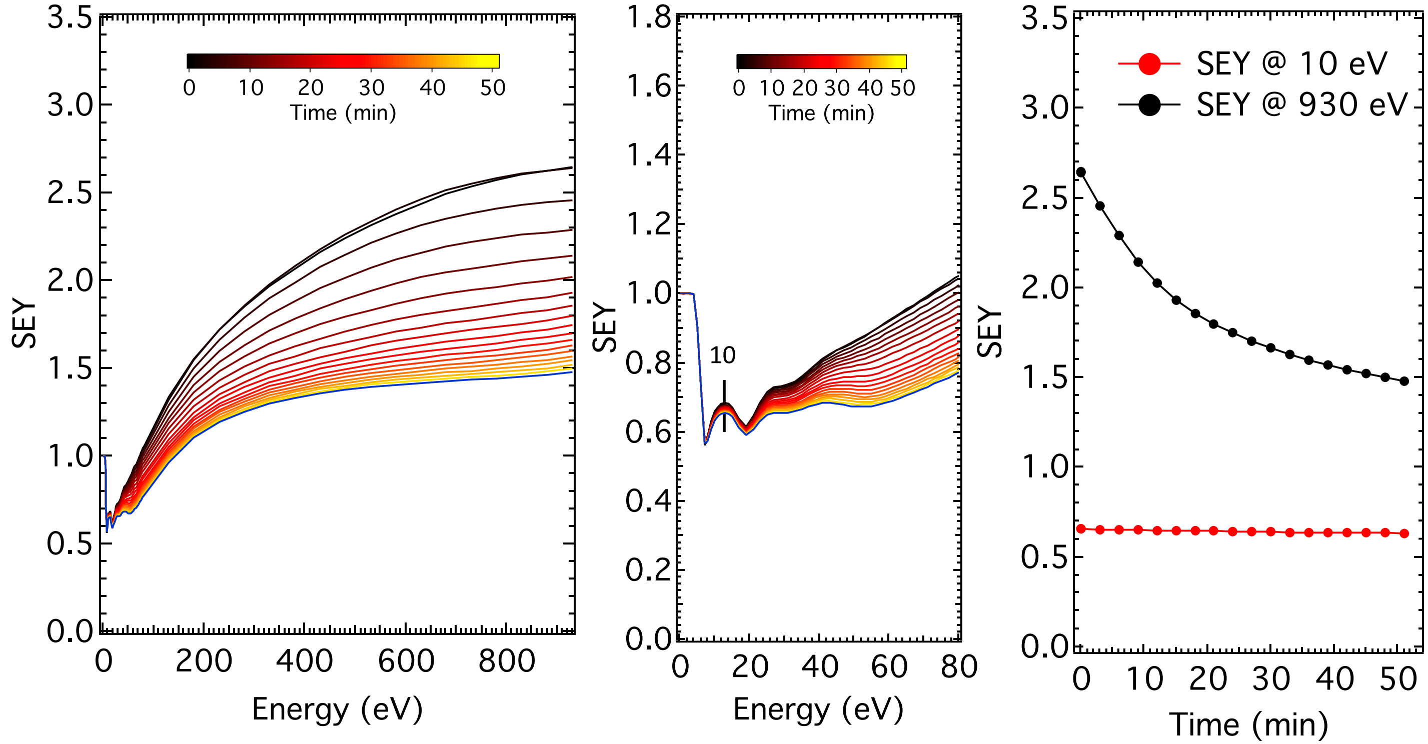
# Argon Adsorption II (SEY)

Second Run of
Adsorption process of Argon on Cu sample at 10 K
Same General behaviour



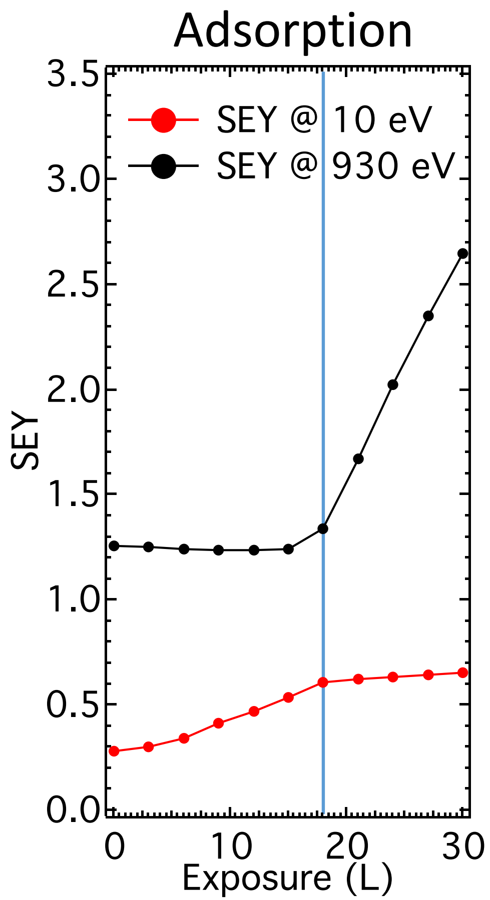
# e⁻-Argon Interaction (SEY)

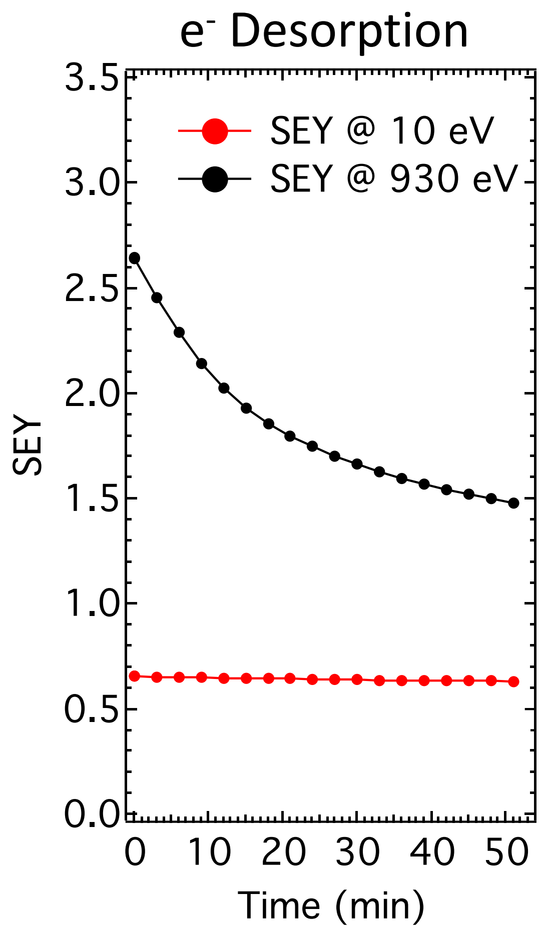
Sample Leaved under continuous scan as function of Time



# e⁻-Argon (SEY)

## SEY under continuous scan



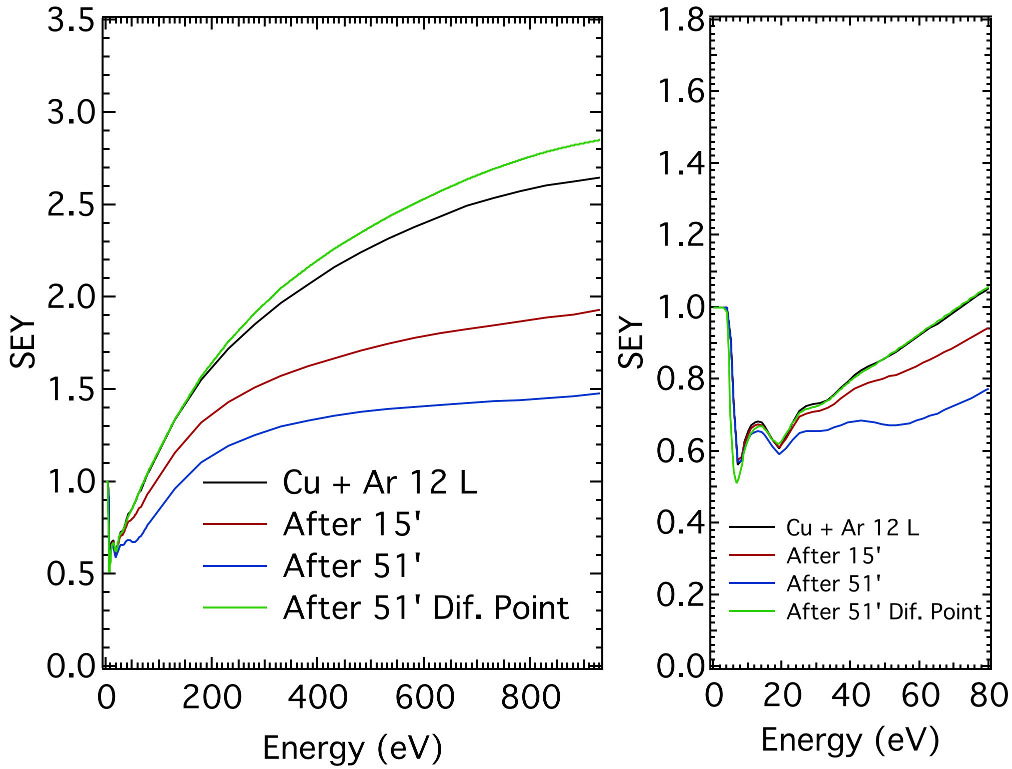




$e^-$ bombardment induced different behaviour

- SEY at 930 decreases as a function of time
- SEY at 10 eV remains constant

# e⁻-Argon (SEY)

SEY measured in different points




New Point presents different SEY spectra
with the same features of SEY with large amount of Ar

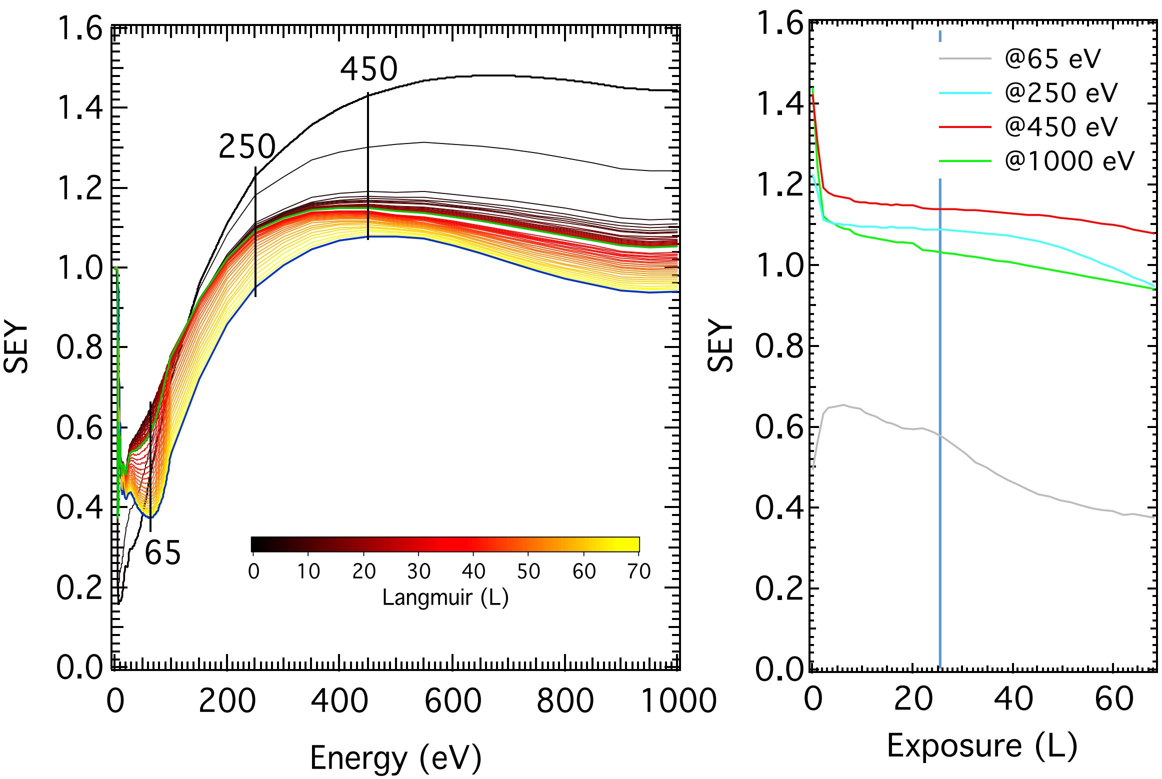
# Argon Results II (SEY)

## Beam-Layer Interaction

Argon Thick film interacts with primary electrons and *desorbs*

# CO Adsorption (SEY)

## Adsorption process of Carbon Monoxide on Cu sample at 10K
## General behaviour



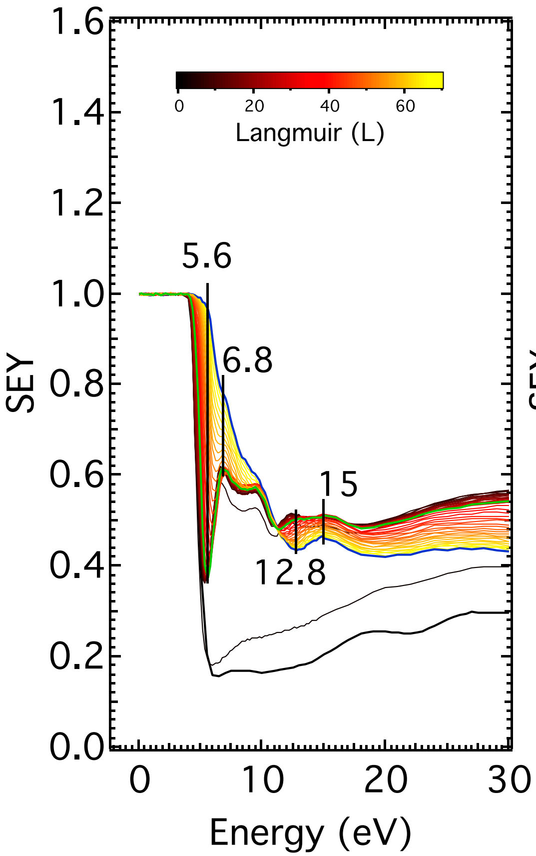

Two different regions

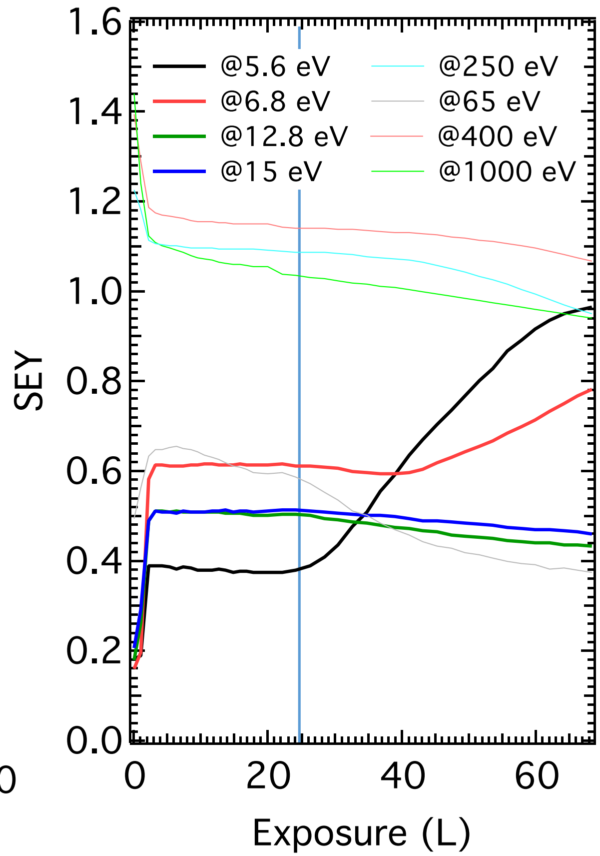
| High Energy (>50 eV) | Low Energy (<50 eV) |
|---|---|

- SEY @ 1000 eV decreases during deposition from 1.4 to 1.1
- Formation of CO Thick Film (TF)
- Characteristic peak of TF at 65 eV

# CO Adsorption (SEY)

Adsorption process of Carbon Monoxide on Cu sample at 10K
Low Energy behaviour




Two different regions

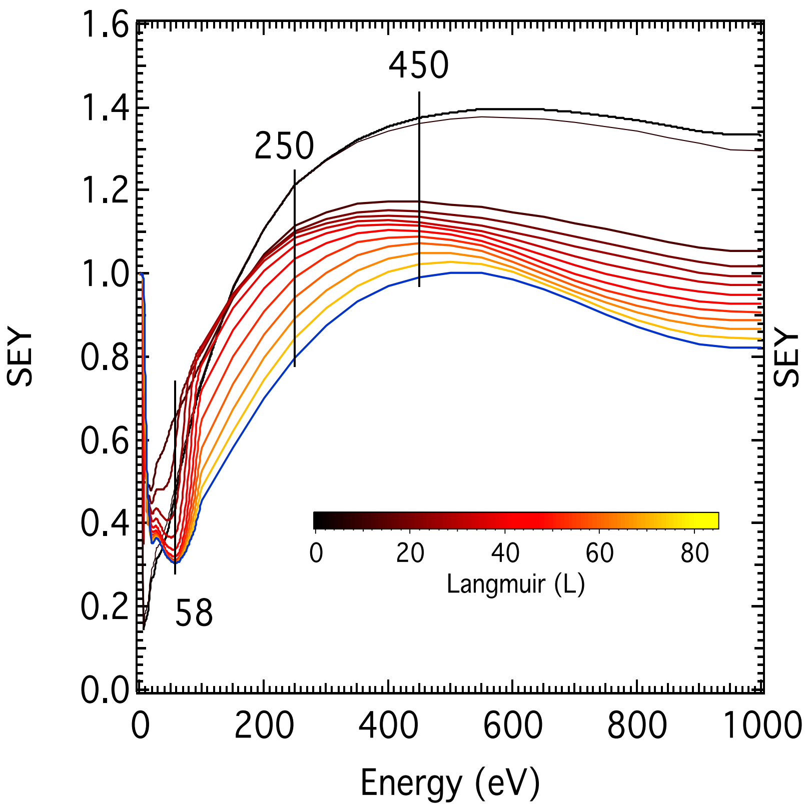
High Energy (>50 eV)

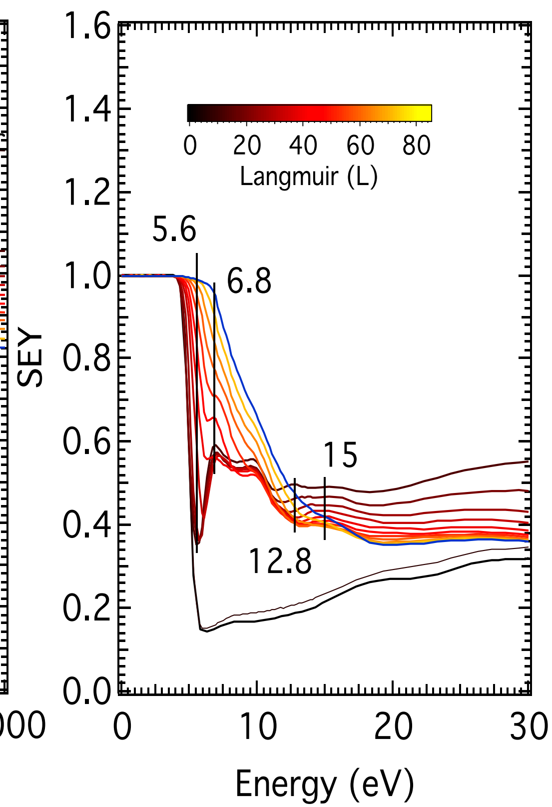
Low Energy (<50 eV)

- Characteristic peaks at different low energies
- Formation of Argon Single Layer (SL)

# CO Adsorption II (SEY)

## Adsorption process of Carbon Monoxide on Cu sample at 10K
## General behaviour

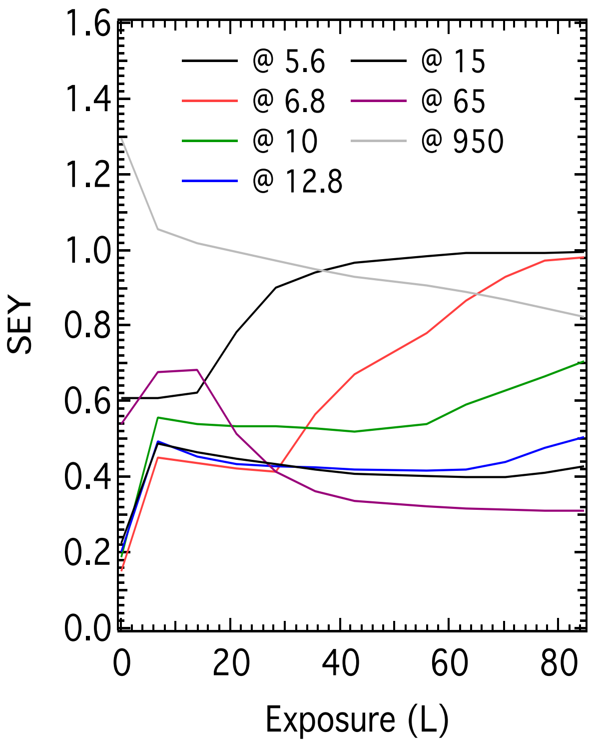


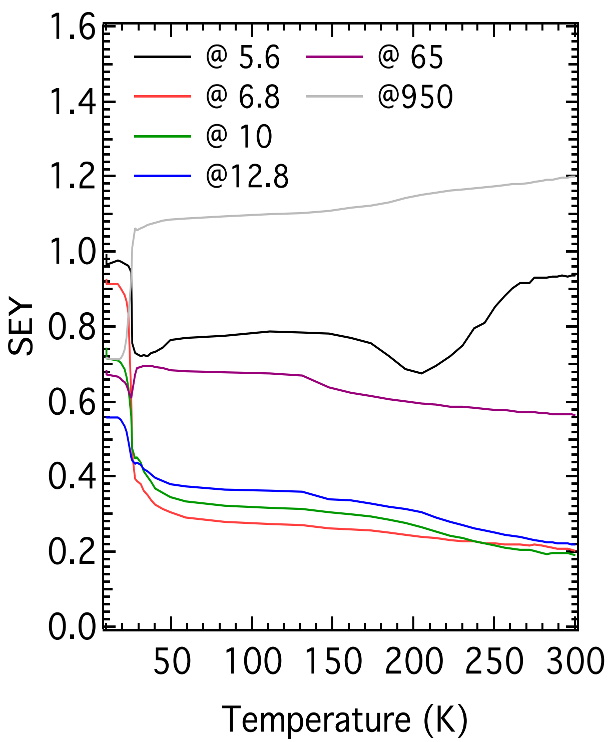




- Higher total Langmuir exposure
- Same characteristic features of TF and SL

# CO Desorption (SEY)

## Desorption process of Carbon Monoxide on Cu sample heated up to 300 K
## General behaviour




- Not Linear behaviour as in Ar
- Two different Desorption process around 30 K and 200 K respectively

# CO Results (SEY)

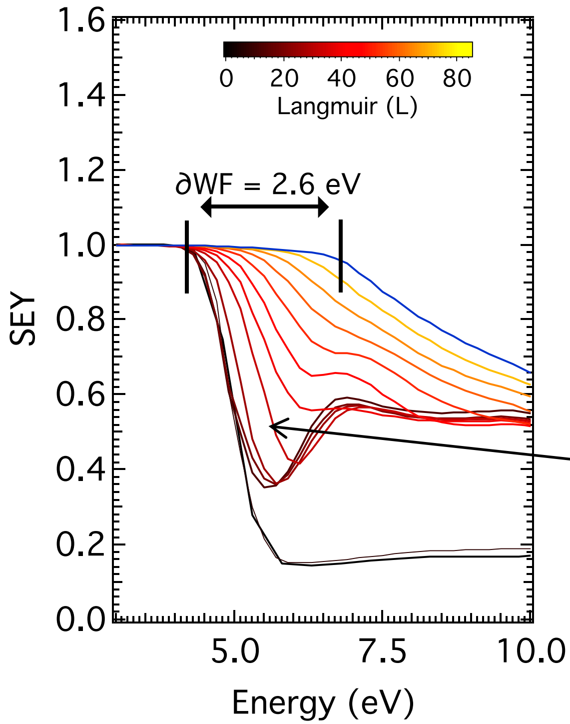
## Adsorption Process (10 K)

- Formation of a TF with Low SEY
- Characteristic peaks for SL in the Low Energy Regions

# Work Function (SEY)

## Work Function variation

CO Adsorption




No changes in the first steps of adsorption

Changes after formation of the multi-layer

# Important Results

- Follow Adsorption process checking the High-Energy SEY (HE-SEY)
- Distinguish Single Layer (SL) formations from Thick Film (TF) by Low-Energy SEY (LE-SEY) behaviour
- Quantify the numbers of adsorbed gas layers on surface
- Measure the desorption temperature of TF and SL with SEY and TPD
- Measure Work Function (WF) variation

# Future Activities

- Different Gases adsorption (CO, $CO_2$, $CH_4$ ...) (pure and mixture)
- Electron desorption
- Thermal Programmed Desorption (TPD)

- Gas-Line Upgrades
- TPD Upgrades

# LNF Lab Upgrades

- Upgrade Gas-line on low temperature system

  Low pressure gas dosing in front of sample (with gas line upgrades)

- Upgrade TPD system

  Measure of temperature, Heating system, relative position in front of mass spectrometer