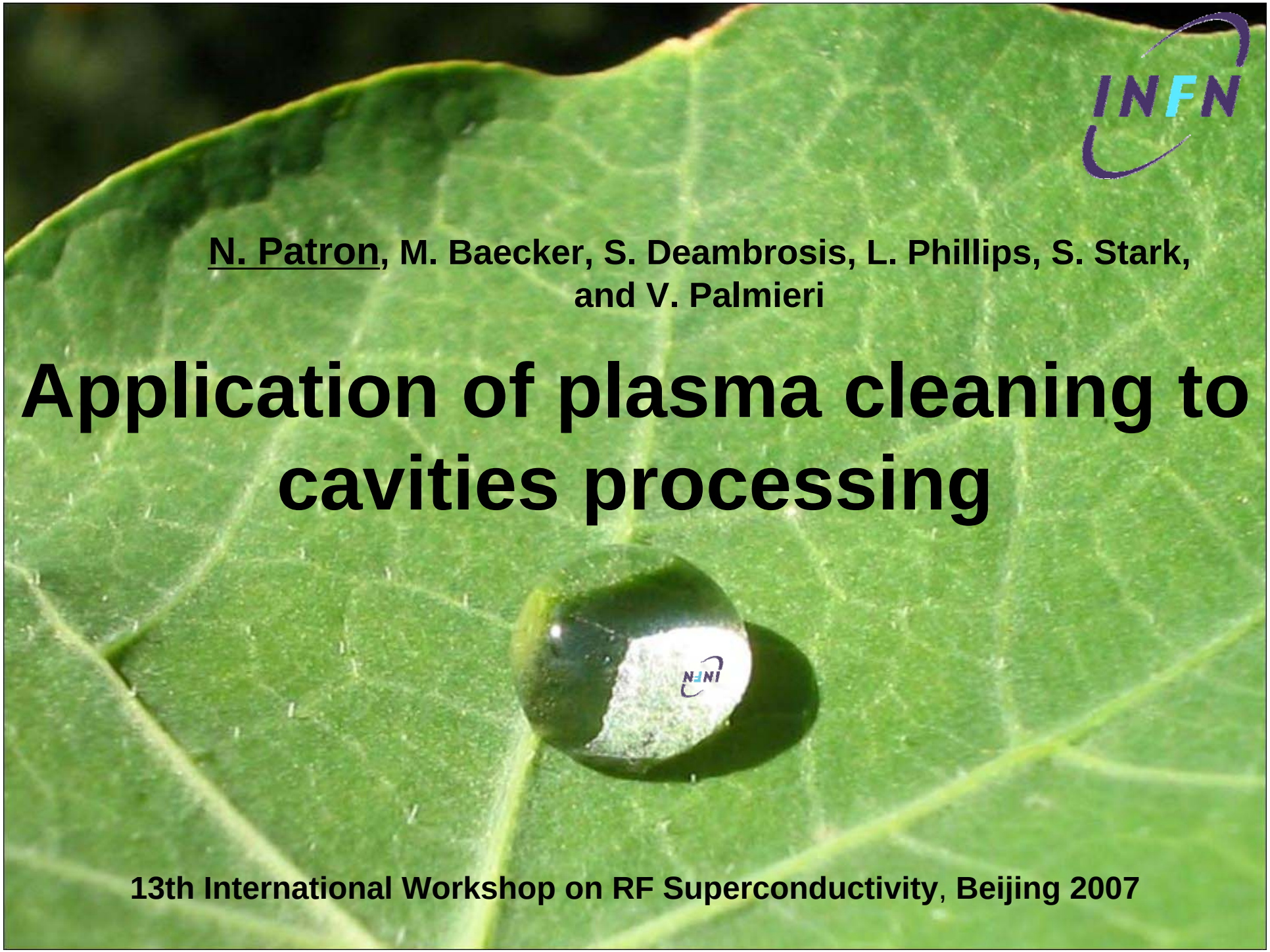
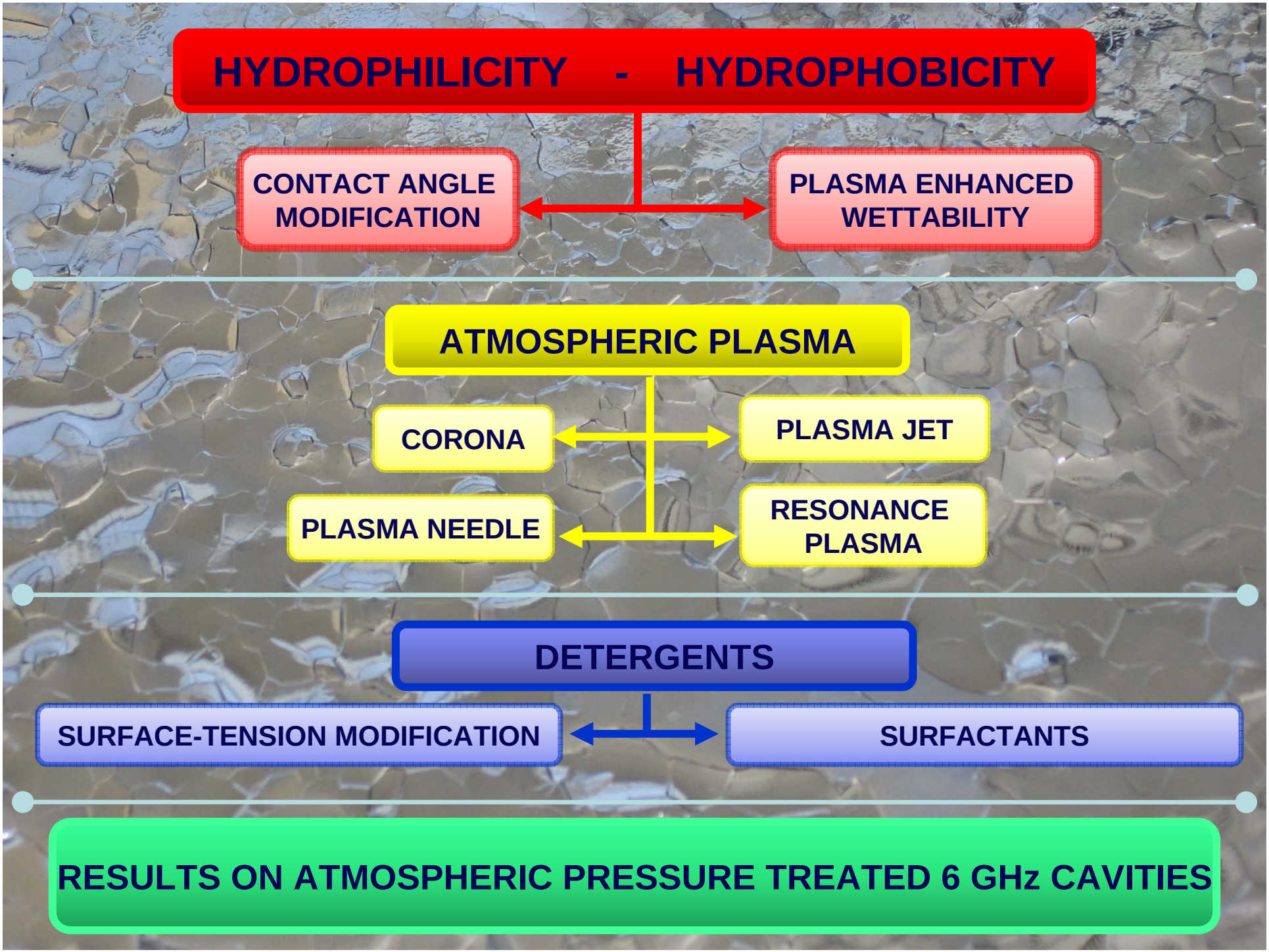


N. Patron, M. Baecker, S. Deambrosis, L. Phillips, S. Stark, and V. Palmieri

Application of plasma cleaning to cavities processing

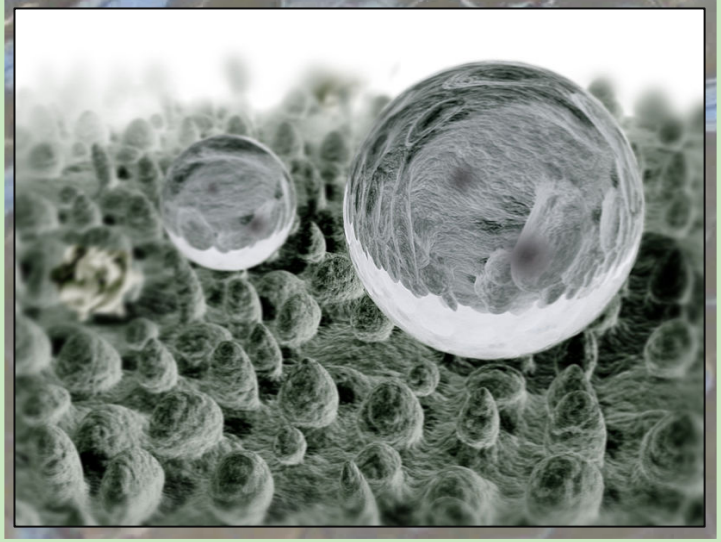
13th International Workshop on RF Superconductivity, Beijing 2007


HYDROPHILICITY - HYDROPHOBICITY
CONTACT ANGLE MODIFICATION
PLASMA ENHANCED WETTABILITY
ATMOSPHERIC PLASMA
CORONA
PLASMA JET
PLASMA NEEDLE
RESONANCE PLASMA
DETERGENTS
SURFACE-TENSION MODIFICATION
SURFACTANTS
RESULTS ON ATMOSPHERIC PRESSURE TREATED 6 GHz CAVITIES

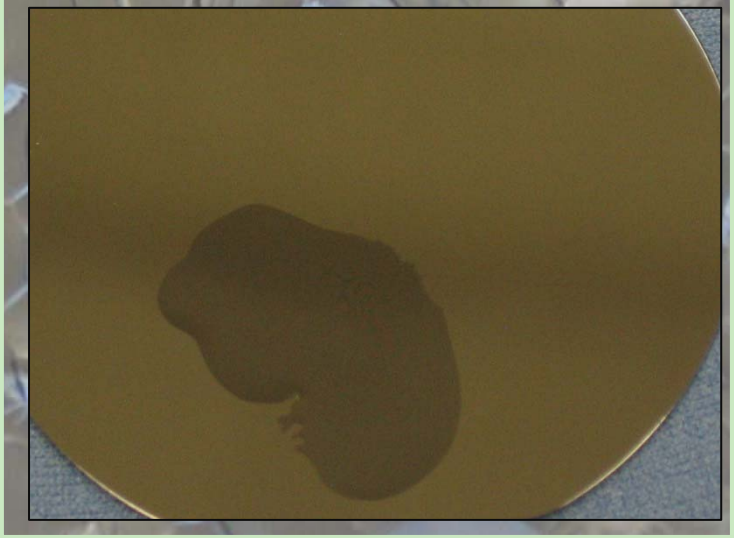
Surface water wettability

HYDROPHOBICITY / HYDROPHILICITY

- Lack of surface- water interaction
- Presence of a dobble ruoghness microstructure



- Chemisorption of water molecules at active surface sites



Niccolò Patron,
INFN-LNL Legnaro

Hydrophobic surface

HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC
PLASMA

CLEANING
MECHANISM

RESULTS ON
6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

Hydrophilic surface

HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC
PLASMA

CLEANING
MECHANISM

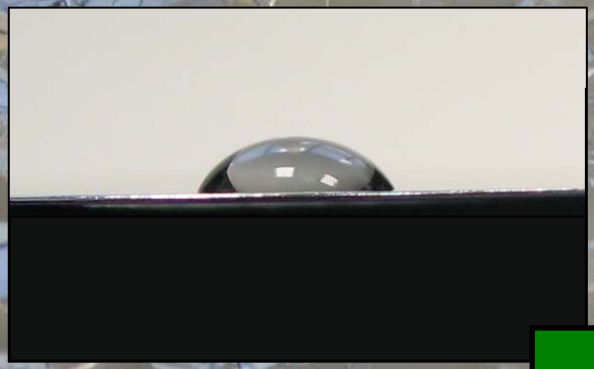
RESULTS ON
6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

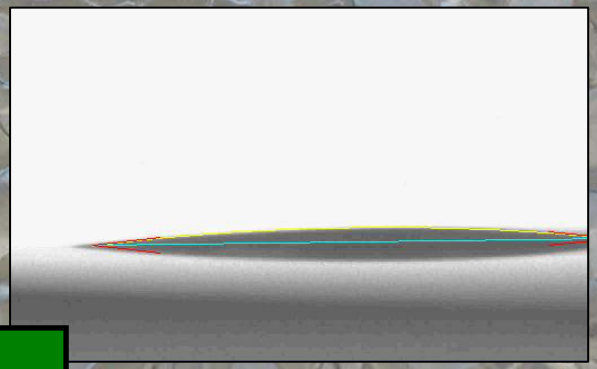
CONTACT ANGLE MODIFICATION

Intermediate regime (untreated)

Super-Hydrophilic regime (treated)



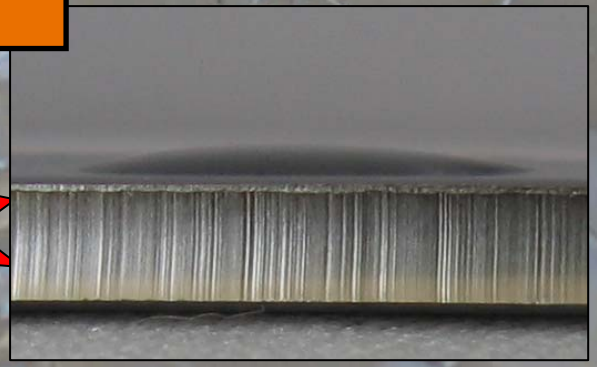
Si



θ = 52°

θ = 6°

Nb



θ = 42°

θ = 9°

HYDROPHILICITY
HYDROPHOBICITY

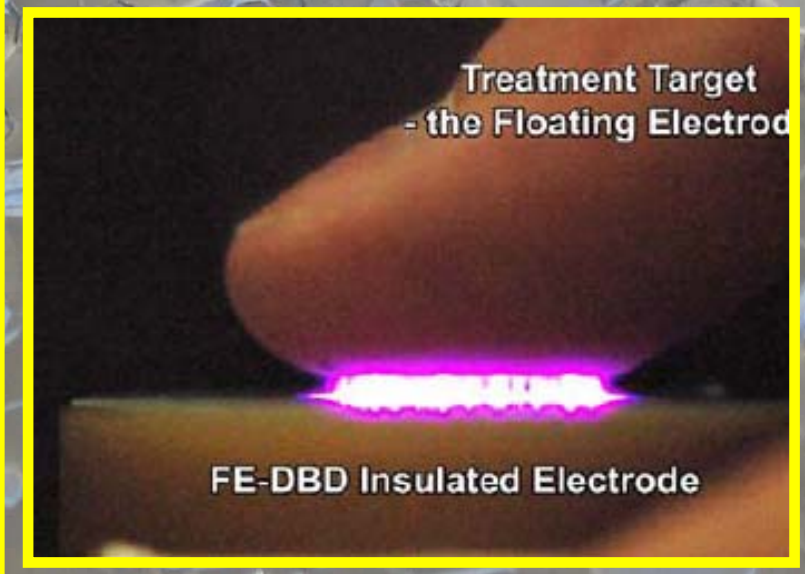
ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

ATMOSPHERIC PLASMA



HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

CORONA PLASMA

•Negative Corona inside a 1,5 GHz cavity

CORONA PLASMA

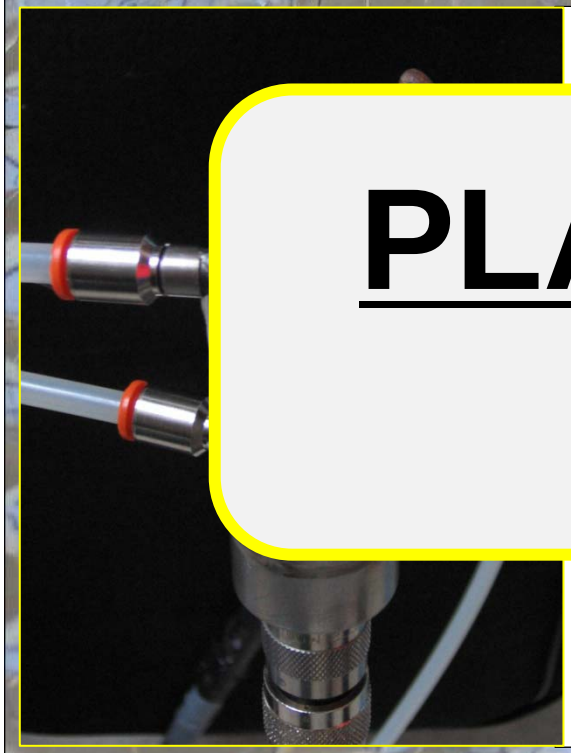
DC

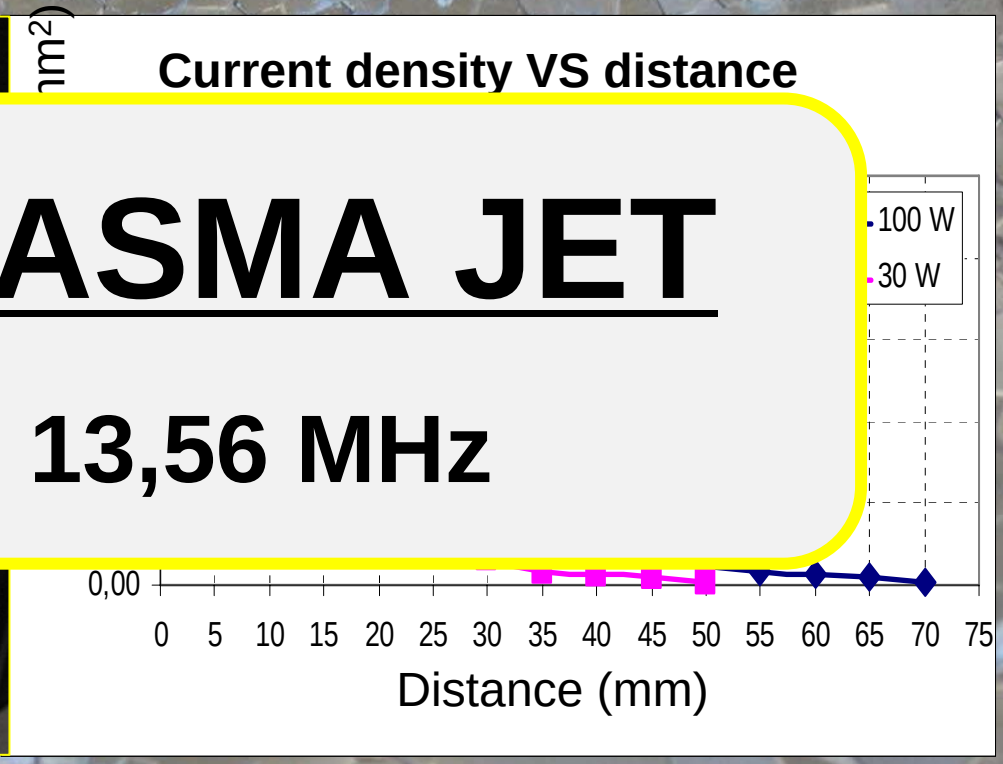
•Strong production of O_3

Niccolò Patron,
INFN-LNL Legnaro

PLASMA JET

Helium fed, RF- excitation at 13.56 MHz





PLASMA JET

13,56 MHz

HYDROPHILICITY HYDROPHOBICITY

ATMOSPHERIC PLASMA

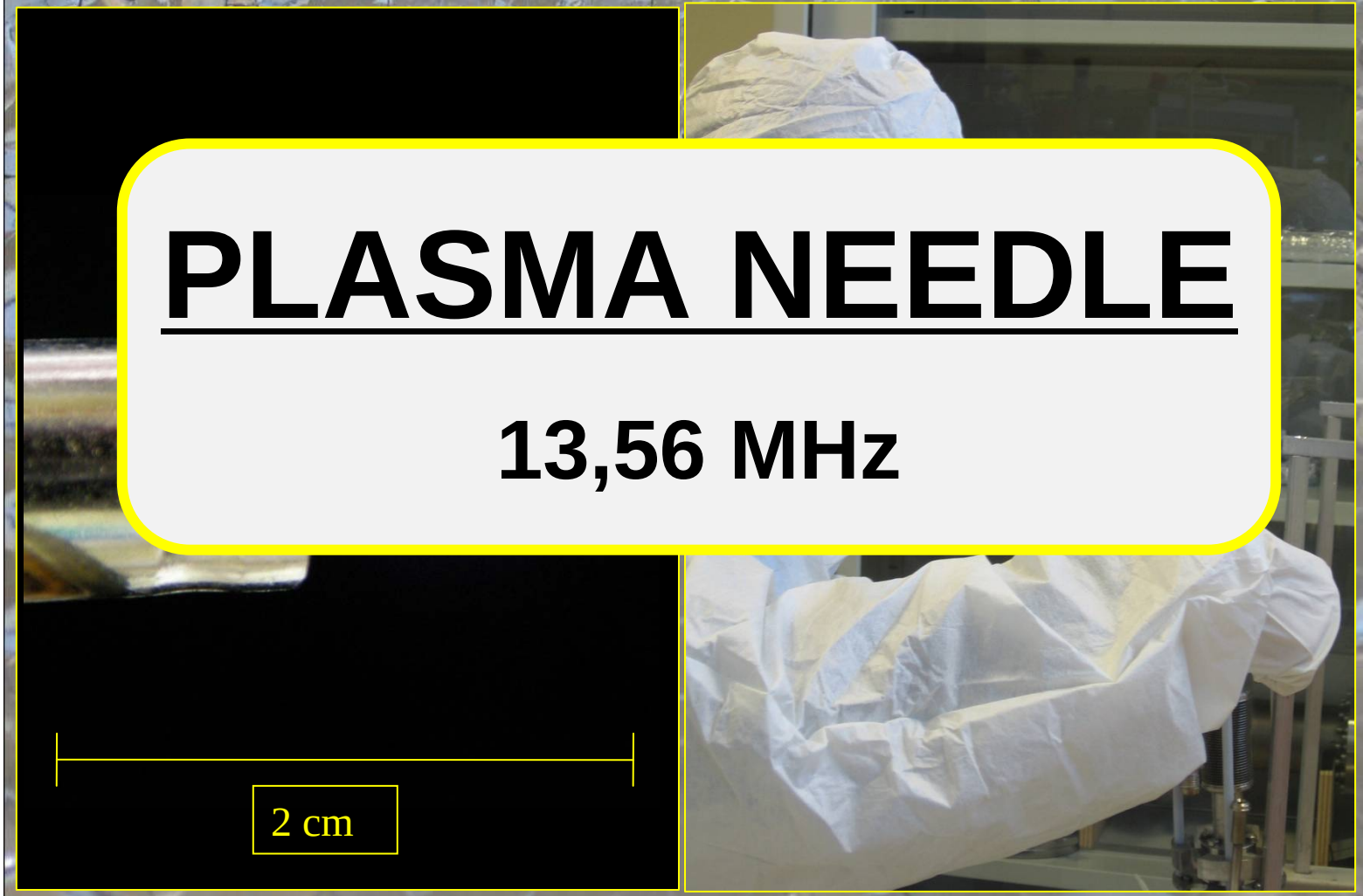
CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

PLASMA NEEDLE

Helium fed, RF- excitation at 13.56 MHz



PLASMA NEEDLE

13,56 MHz

HYDROPHILICITY
HYDROPHOBICITY

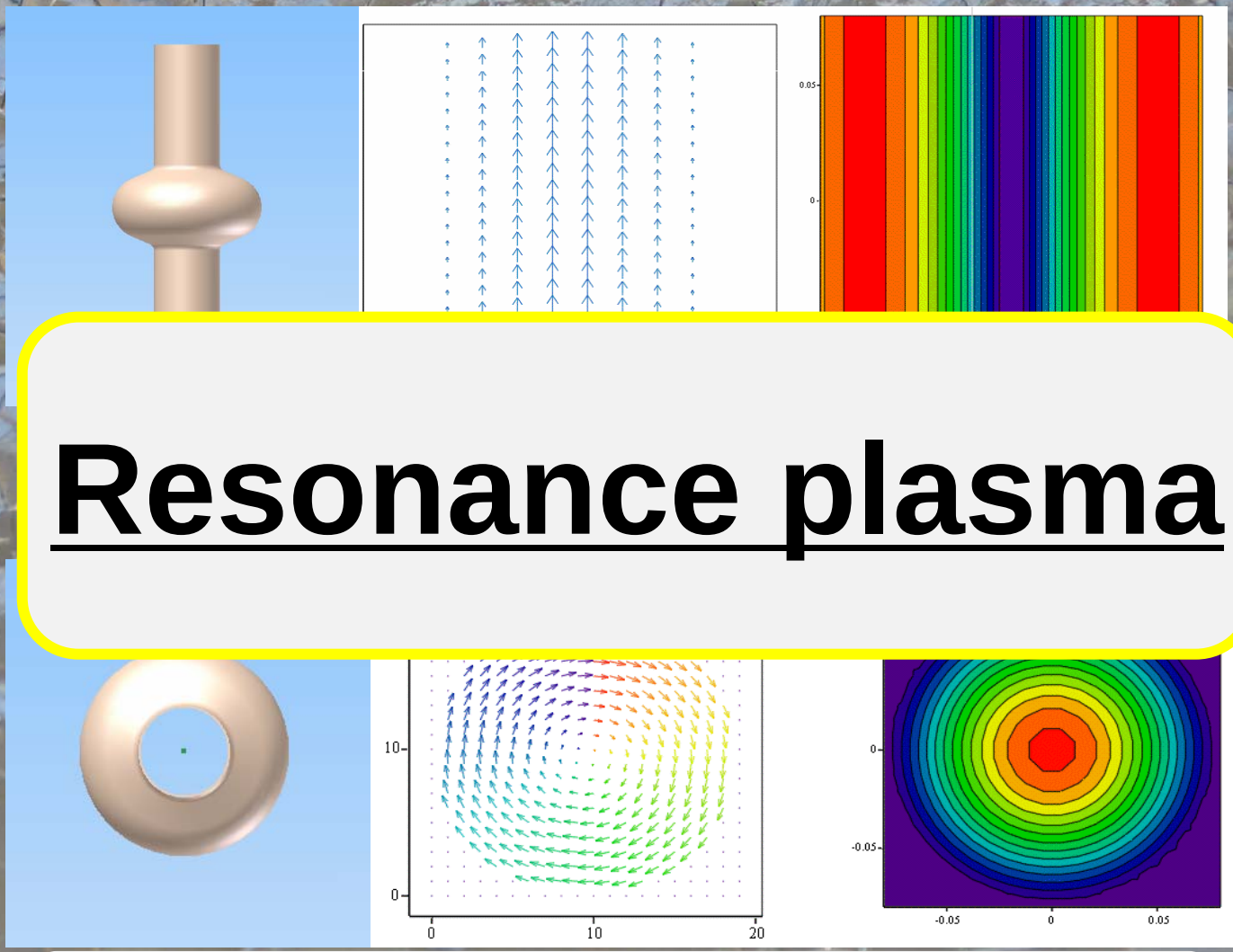
ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

Mode TM010 Resonance Plasma



Resonance plasma

Base view | Magnetic field | Electric field module

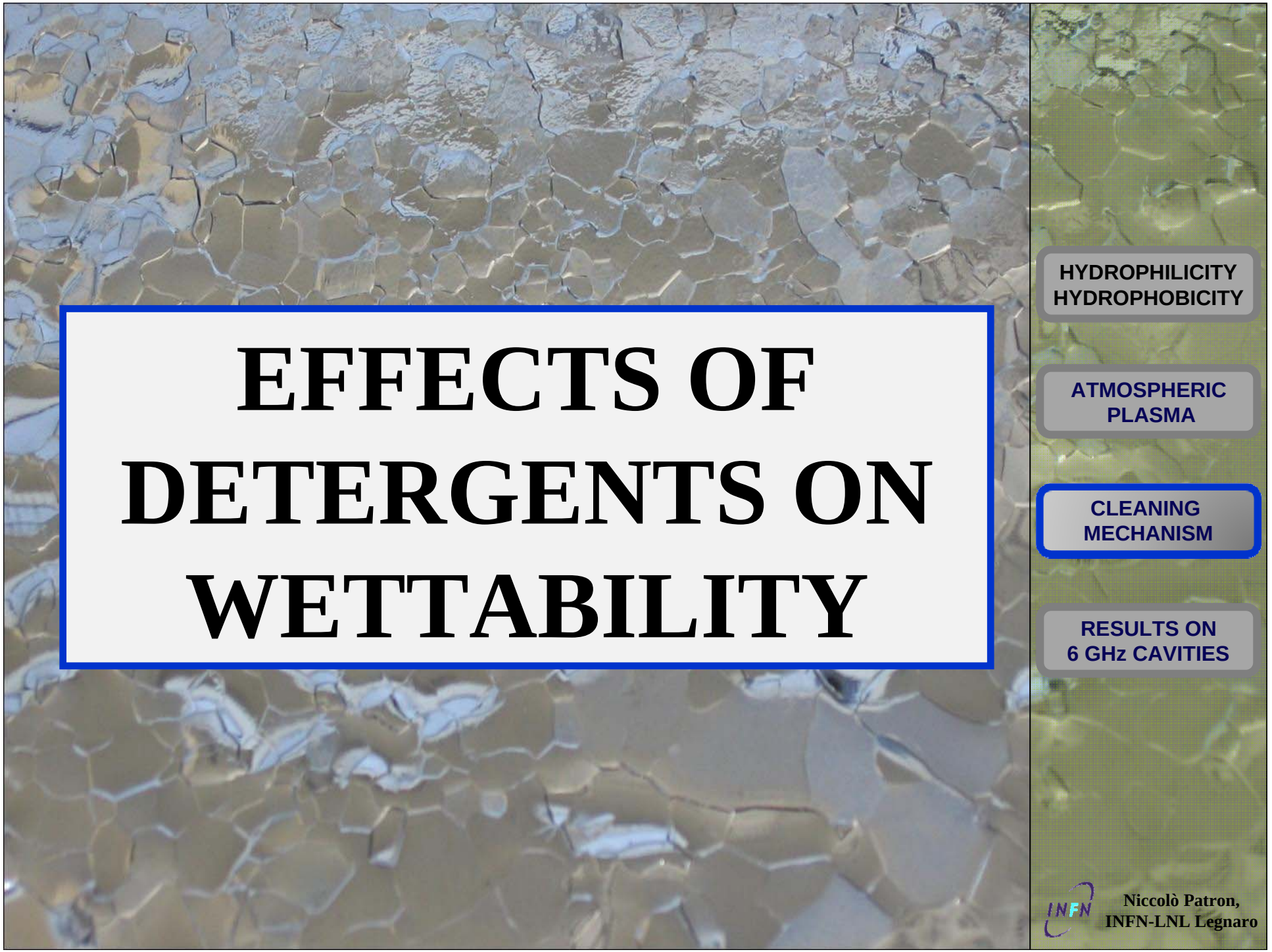
HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro



EFFECTS OF DETERGENTS ON WETTABILITY

HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

SURFACTANTS

Surfactant hydrophobic tails shield water intermolecular interaction

THE SURFACE TENSION DECREASES

HYDROPHILICITY
HYDROPHOBICITY

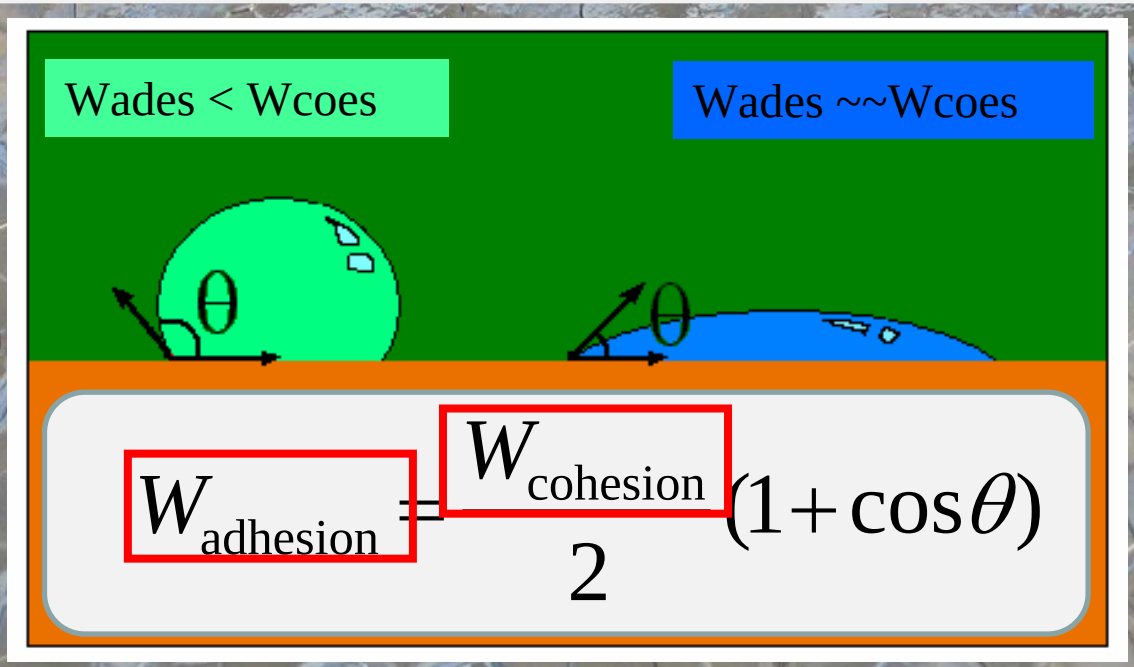
ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

Consequent contact angle modification



$$W_{adhesion} = \frac{W_{cohesion}}{2}(1+\cos\theta)$$

As the surface tension decrease $W_{ades} = W_{coes}$ →

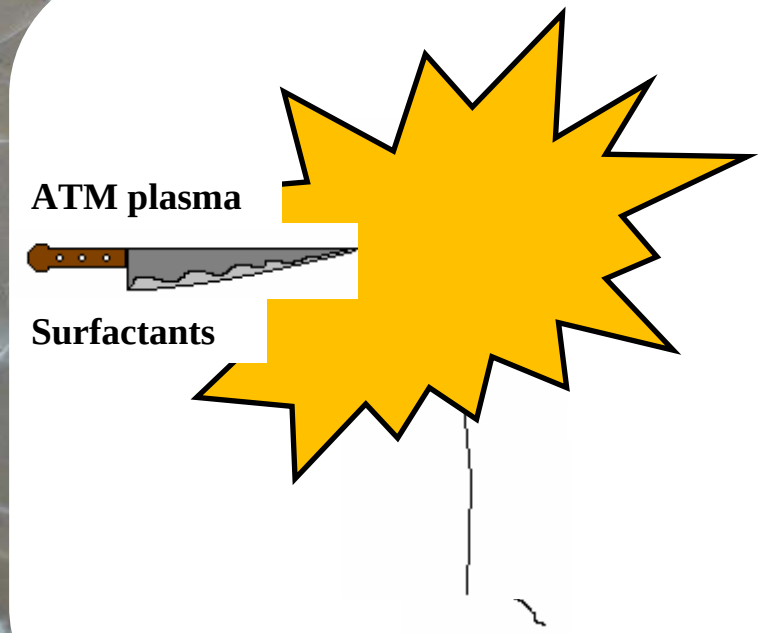
$\theta = 0$

INCREASE THE WETTABILITY

Niccolò Patron, INFN-LNL Legnaro

ATM plasma - surfactants analogy

Surface tension breakdown



HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

Liquid surface tension breakdown

HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC
PLASMA

CLEANING
MECHANISM

RESULTS ON
6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

ATM plasma / surfactants analogy

increase the wettability and break the surface tension

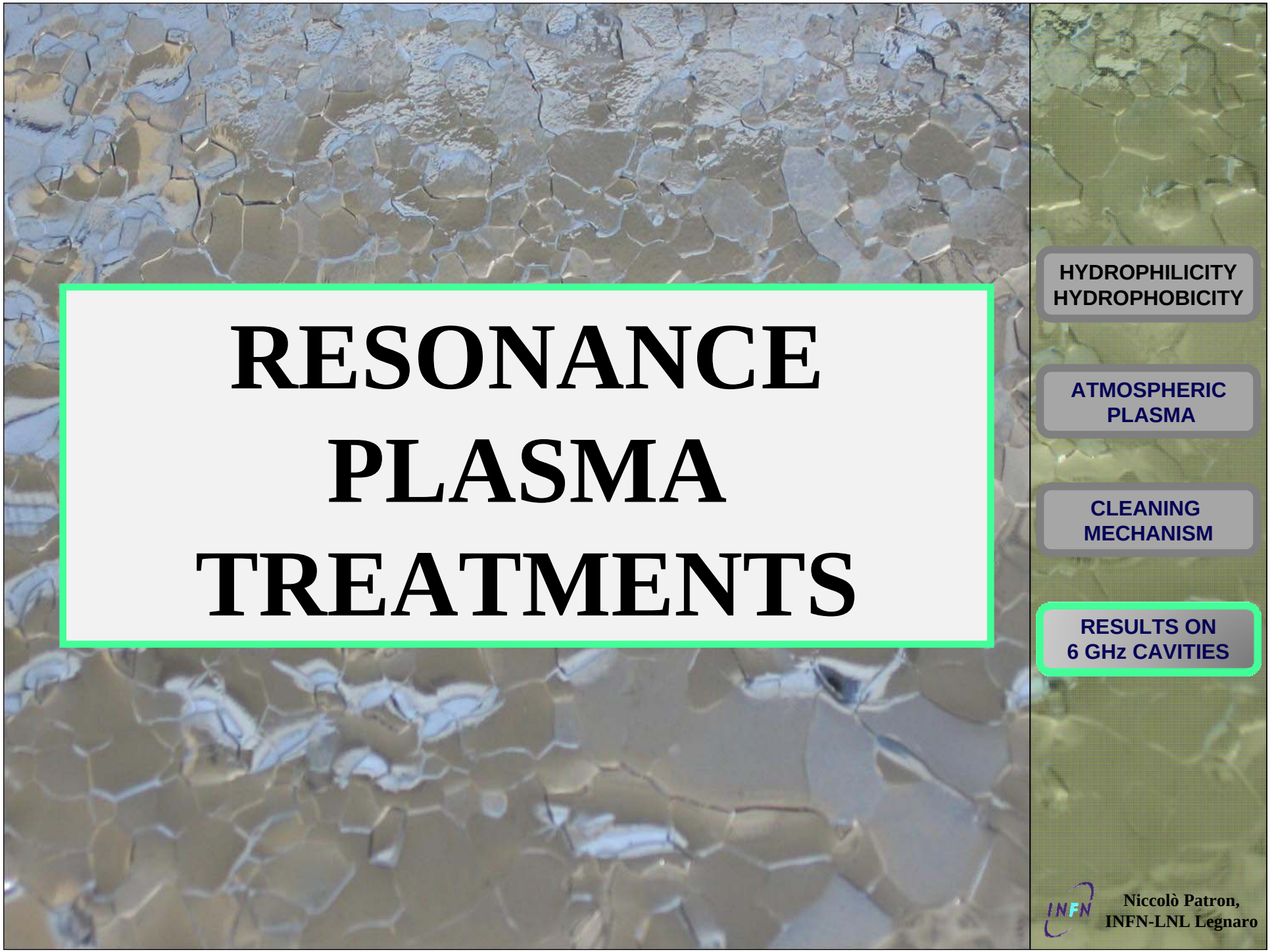
•Surfactants by shielding the H_2O-H_2O molecules interaction

•ATM plasma by increasing the surface energy

BIG ADVANTAGE

ATM plasma doesn't leave surface contamination

Niccolò Patron,
INFN-LNL Legnaro



RESONANCE PLASMA TREATMENTS

HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

TM010 plasma in a 6 GHz Nb cavity

HYDROPHILICITY
HYDROPHOBICITY

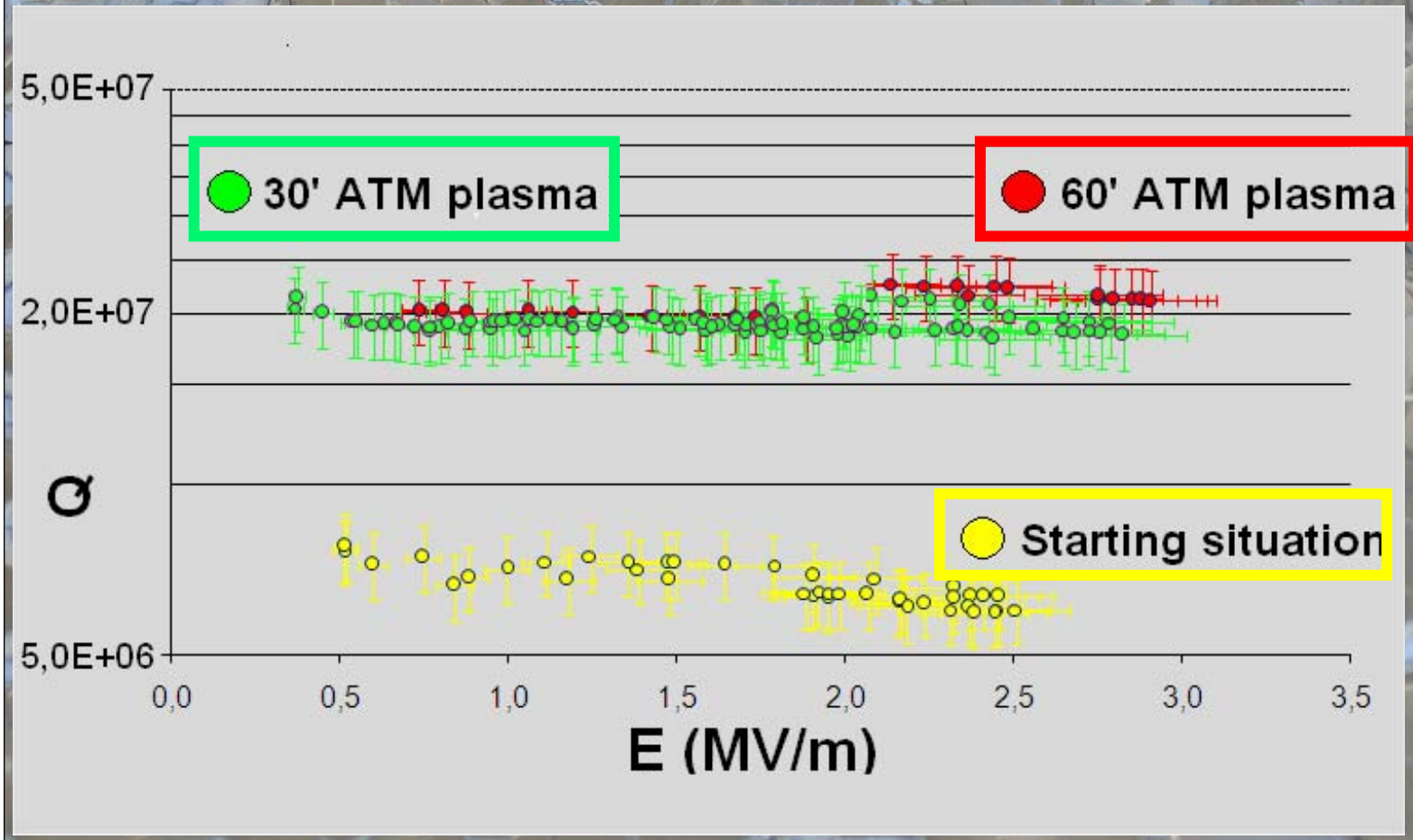
ATMOSPHERIC
PLASMA

CLEANING
MECHANISM

RESULTS ON
6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

Niobium 6 GHz cavity @ 4.2 K



HYDROPHILICITY
HYDROPHOBICITY

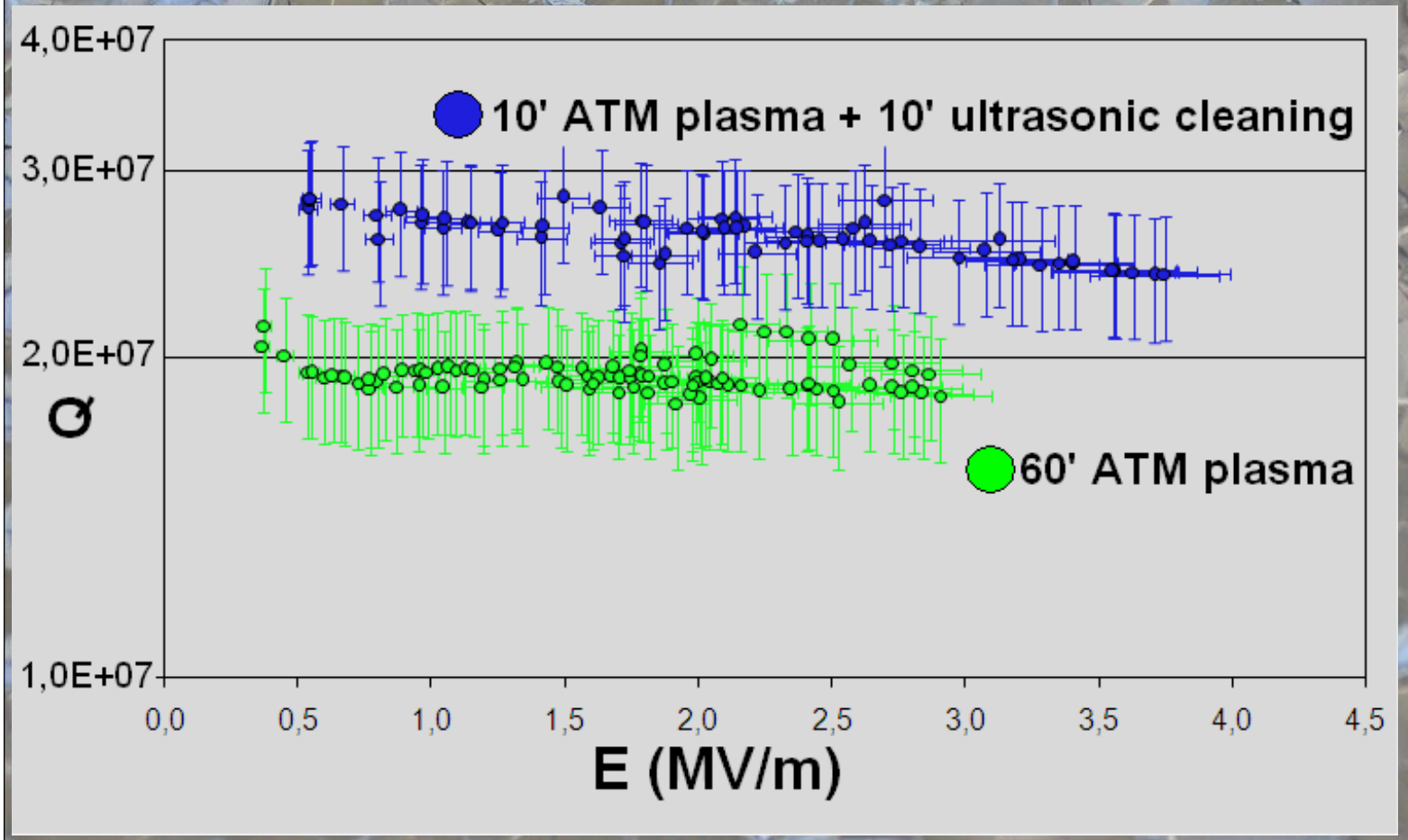
ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

Niobium 6 GHz cavity @ 4.2 K



HYDROPHILICITY
HYDROPHOBICITY

ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

Conclusions

We Just started, why should we conclude?

Better call it: **SUMMARY**

ATMOSPHERIC PLASMA CLEANING:

Three Configurations:

- Corona Discharge
- Plasma Jet
- Resonant Plasma

30 min of Atmospheric Plasma Cleaning is beneficial for Q-value

Atmospheric Plasma make the Nb surface hydrophylic and a following Rinsing become even more beneficial for Q-value

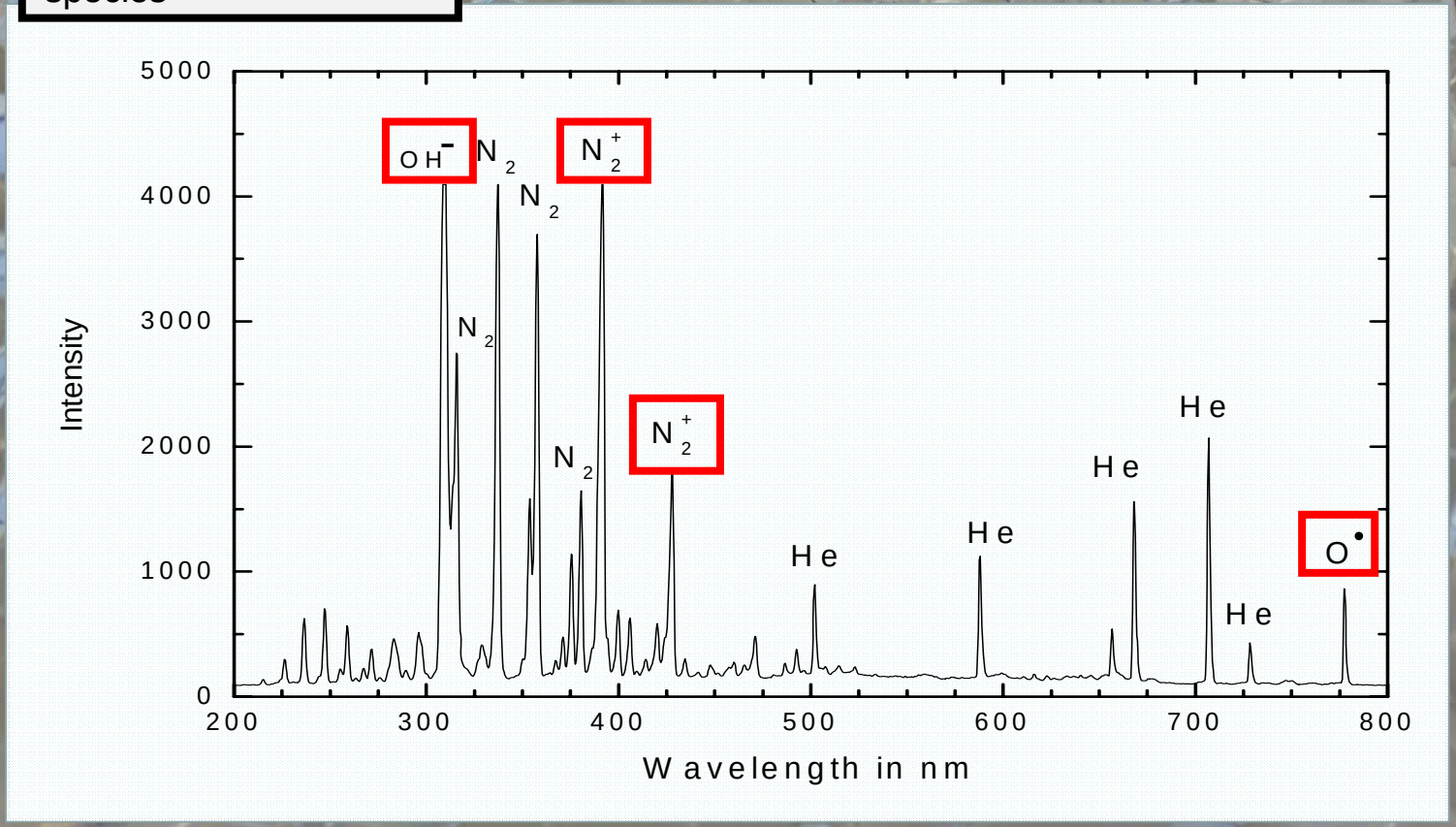
Atmospheric Plasma optical emission

REACTIVE SPECIES (radicals, ozone)

Oxidation of carbon to CO_2 due to the presence of reactive species

POLAR GROUPS (radicals, ions)

Surface energy incrementation and creation of polar sites



HYDROPHILICITY HYDROPHOBICITY

VACUUM PLASMA

ATMOSPHERIC PLASMA

CLEANING MECHANISM

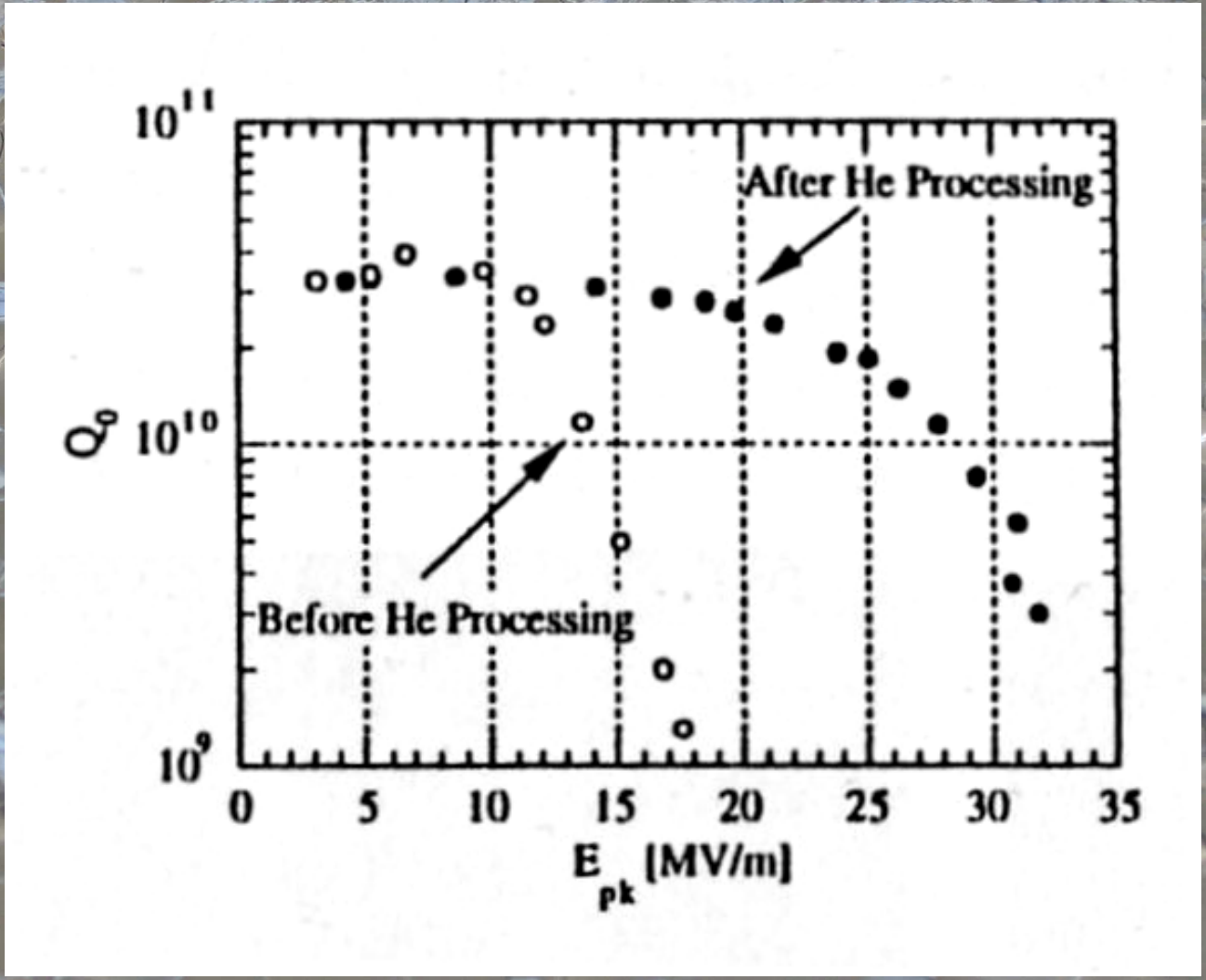
RESULTS ON 6 GHz CAVITIES

Niccolò Patron, INFN-LNL Legnaro

What's exactly happening?

- Desorption of adsorbed gases
- Oxidation of C contamination to CO_2
- Light baking (50° c×10') limited to the cell
- Enhanced ultrasonic cleaning due to the superhydrophilic Nb surface

Helium conditioning



H. Padamsee, J. Knobloch, T. Hays, "RF Superconductivity for accelerators",

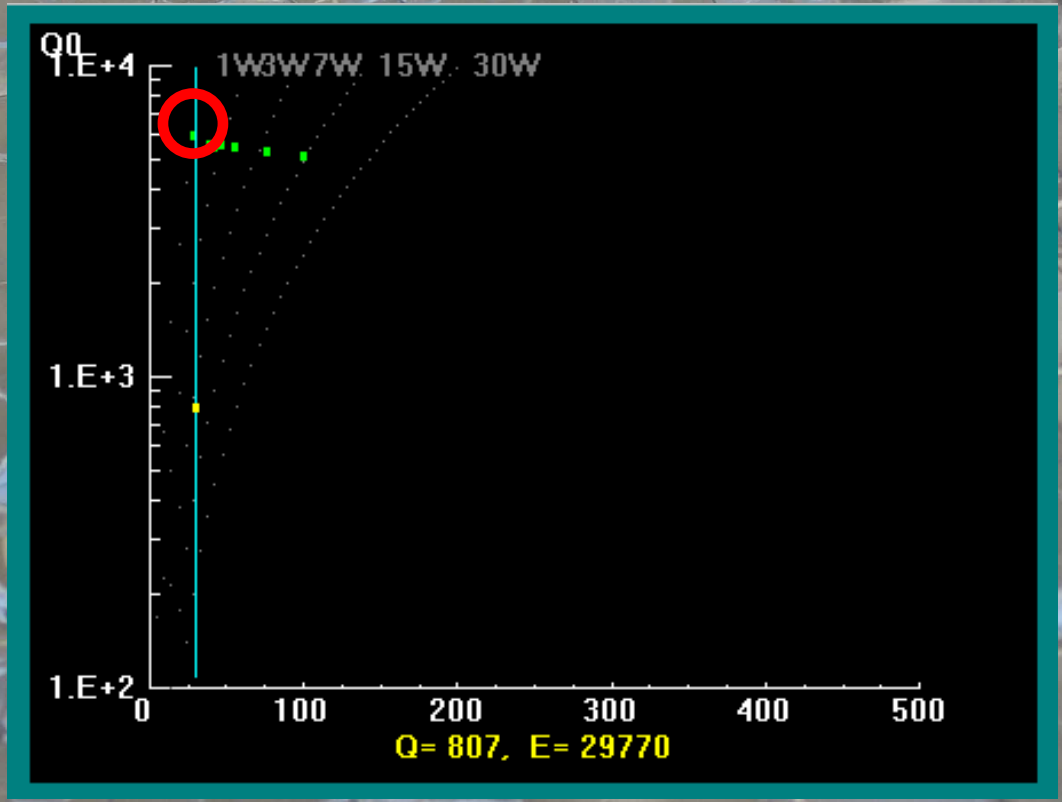
6 GHz Nb cavity plasma treatment

Treatments time:
30 minutes

Plasma power:
8 W

Helium flow:
15 l/min

Cell temperature:
50 ° C



HYDROPHILICITY
HYDROPHOBICITY

VACUUM
PLASMA

ATMOSPHERIC
PLASMA

CLEANING
MECHANISM

RESULTS ON
6 GHz CAVITIES

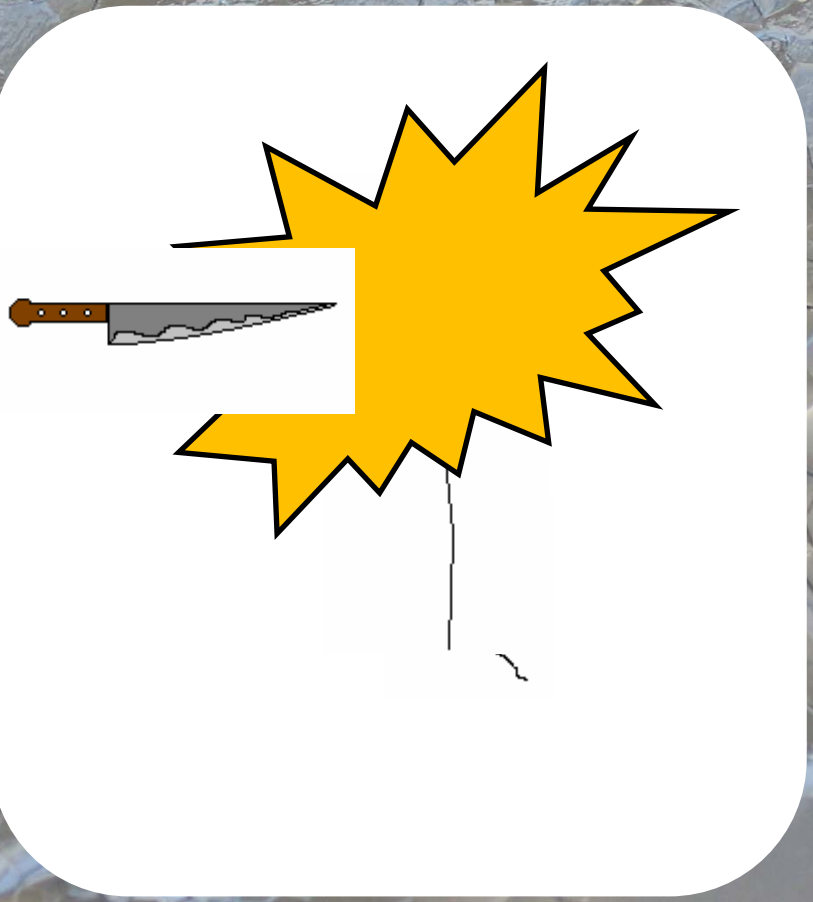
Niccolò Patron,
INFN-LNL Legnaro

PRELIMINARY RESULTS

	30’ ATM plasma	60’ ATM plasma	90’ ATM plasma	10’ ATMplasma+ 10’ UB
Q_0	$7{,}63 \times 10^6$	$2{,}06 \times 10^7$	$2{,}04 \times 10^7$	$2{,}04 \times 10^7$
Power Decay (s)	$1{,}02 \times 10^{-4}$	$2{,}74 \times 10^{-4}$	$2{,}72 \times 10^{-4}$	$3{,}68 \times 10^{-4}$
E_{acc} (MV)	2,5	2,8	2,9	3,7

Niccolò Patron, INFN-LNL Legnaro

ATM plasma / surfactants analogies



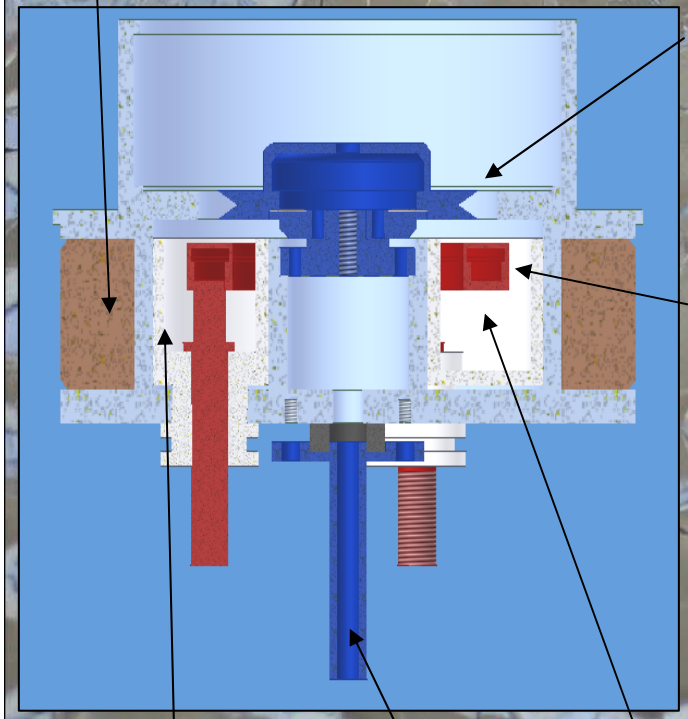
Both increase the wettability:

•Surfactants by breaking the surface tension

•ATM plasma by increasing the surface energy

Niccolò Patron,
INFN-LNL Legnaro

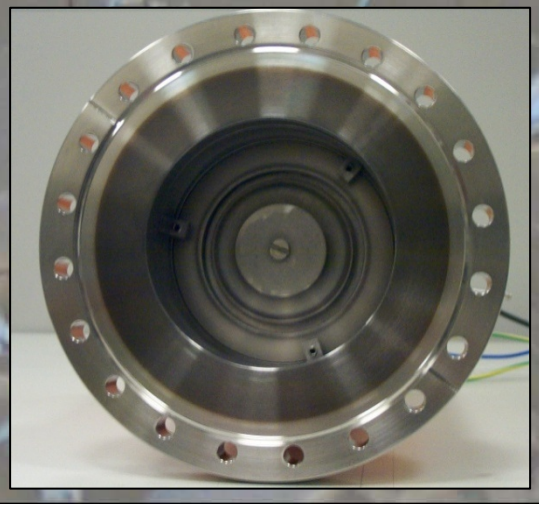
ION GUN SOURCE



The cathode is grounded

The anode is at +2kV

Gas process is Argon



HYDROPHILICITY HYDROPHOBICITY

VACUUM PLASMA

ATMOSPHERIC PLASMA

CLEANING MECHANISM

RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro

ION GUN ETCHING RATES

ION BEAM ETCHING

- Energy: 2 KeV
- Pressure of 4×10^{-2} mbar
- Substrate to source:170 mm

A

2,3 µ m/h

REACTIVE ION ETCHING

- Voltage: 1 kV
- Pressure of 4×10^{-2} mbar
- Diode sputtering with CF_4

CF_4

12,7 µ m/h

HYDROPHILICITY HYDROPHOBICITY
VACUUM PLASMA
ATMOSPHERIC PLASMA
CLEANING MECHANISM
RESULTS ON 6 GHz CAVITIES

Niccolò Patron,
INFN-LNL Legnaro