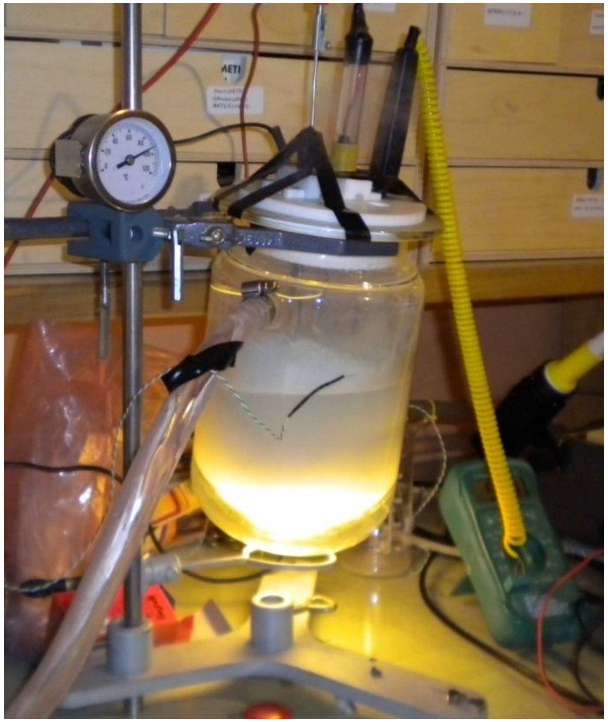
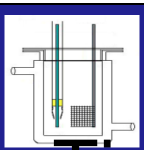
2012 ANS WINTER MEETING NOVEMBER 11-15, 2012
TOWN & COUNTRY RESORT - SAN DIEGO, CA

# SLOW NEUTRON GENERATION BY PLASMA EXCITATION IN ELECTROLYTIC CELL







DOMENICO CIRILLO

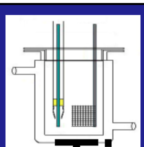
# OUTLINE

- **EXPERIMENTAL EVIDENCE OF NEUTRON FLUX GENERATED BY PLASMA EXCITATION AT THE TUNGSTEN CATHODE OF THE ELECTROLYTIC CELL - BASED ON A CR-39 NUCLEAR TRACK DETECTOR COUPLED TO A BORON CONVERTER**

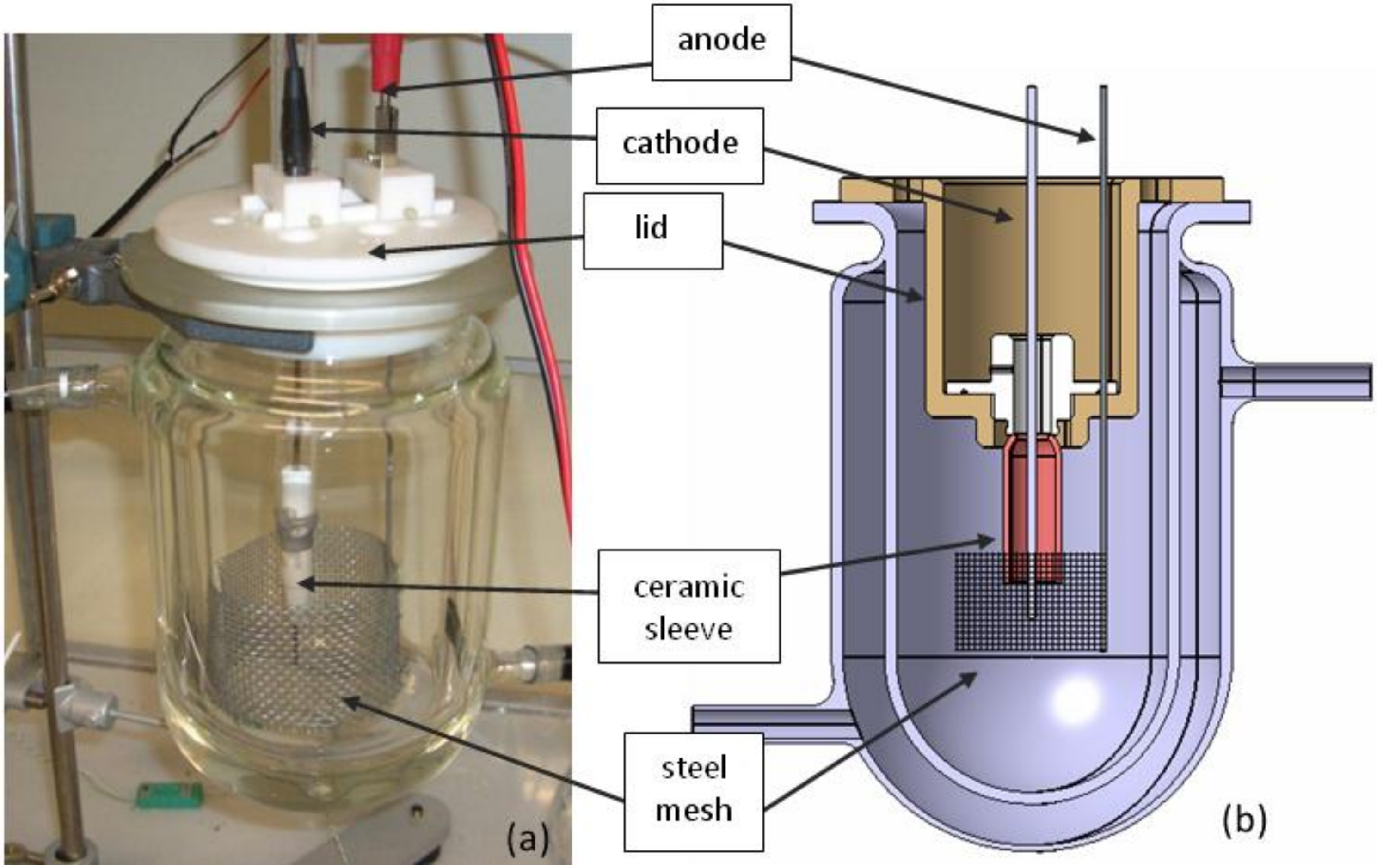
- **BACKGROUND INFORMATION ON UNEXPECTED PHENOMENA OCCURRING IN ELECTROLYTIC PLASMA CELLS WITH ALKALINE WATER SOLUTIONS (NUCLEAR TRANSMUTATIONS)**

- **PLASMA EXCITATION AT THE TUNGSTEN CATHODE OF AN ELECTROLYTIC CELL WITH ALKALINE SOLUTION (OTHER UNEXPECTED PHENOMENA ARE UNDER STUDY)**

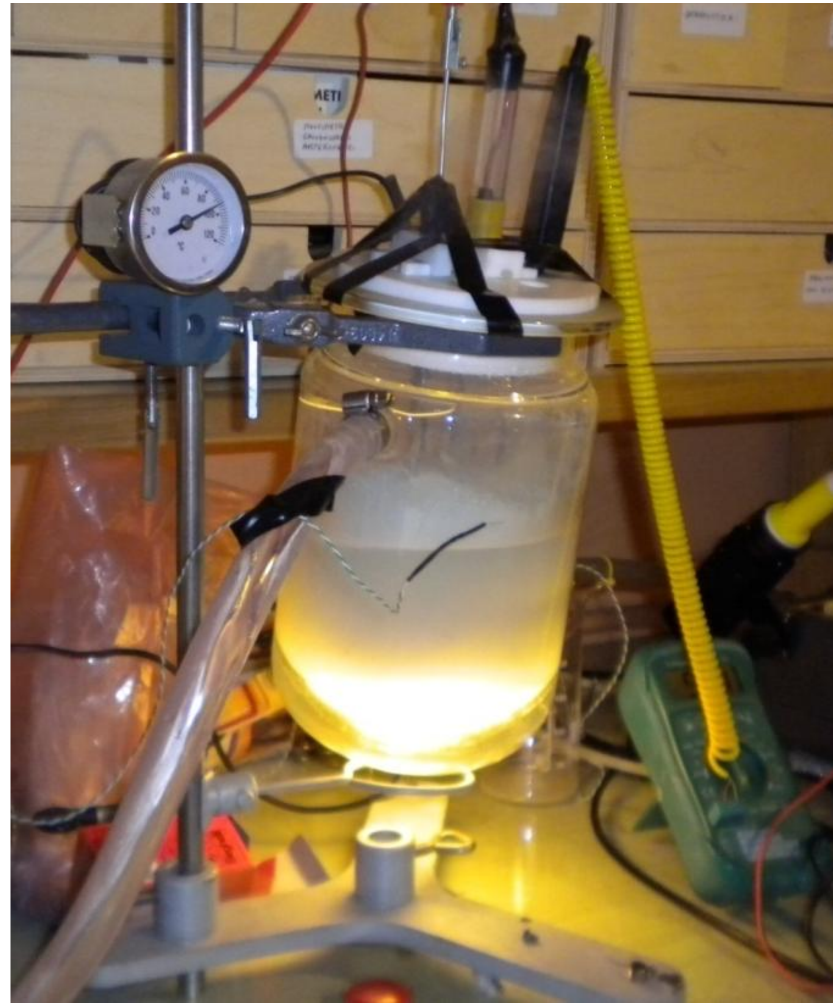




# Cell configuration (new configuration)



# Plasma cell during a run



**Typical aspect during which the breakthrough of electrochemical behaviour is passed and the cell works in plasma mode**

# Steps to reach Plasma mode

conditions depending by cell's parameters

| < 100 V input | 100 – 200 V input | 200 – 240 V input | > 250 V input |
|---|---|---|---|

**Hydrogen generation at cathode**

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

$2H_3O^+ + 2e^- \rightarrow H_2 + 2H_2O$

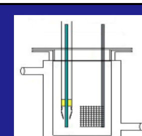
**Discharge (not Faradayan behaviour)**

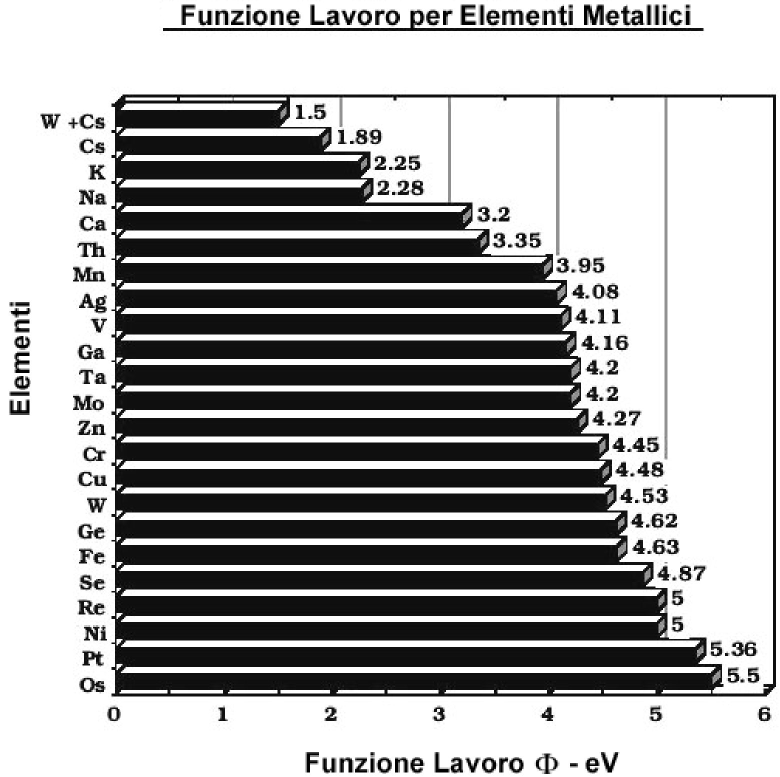
**stable plasma layer**

**active plasma environment**

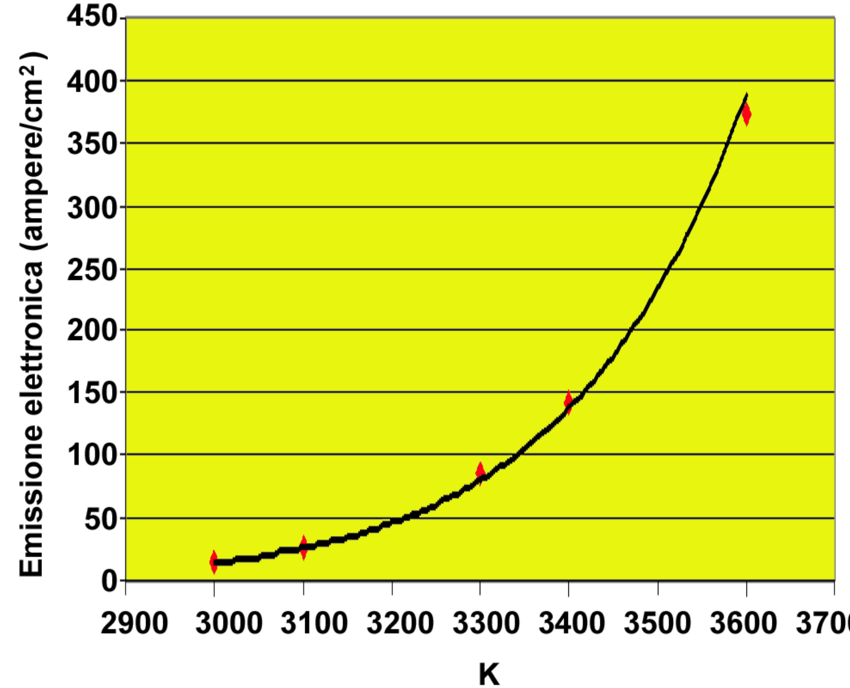
**<u>nuclear activity environment</u>**

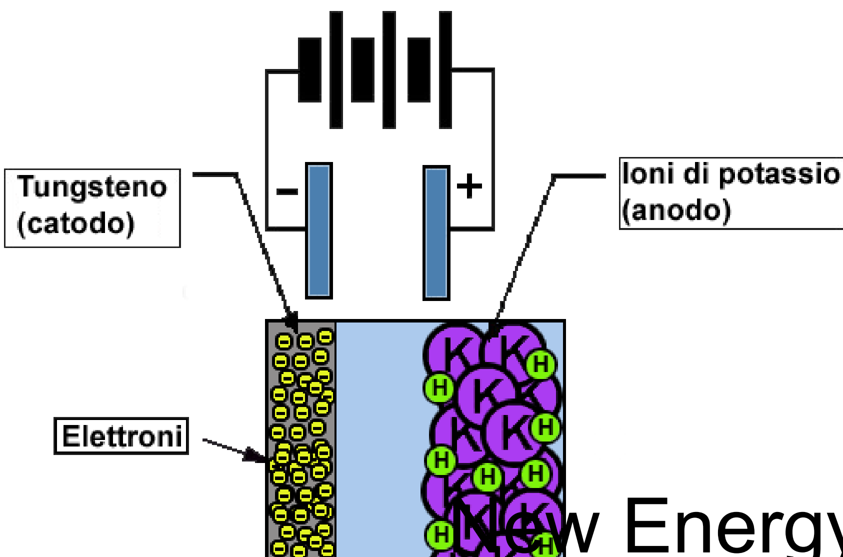







# cathodic conditions

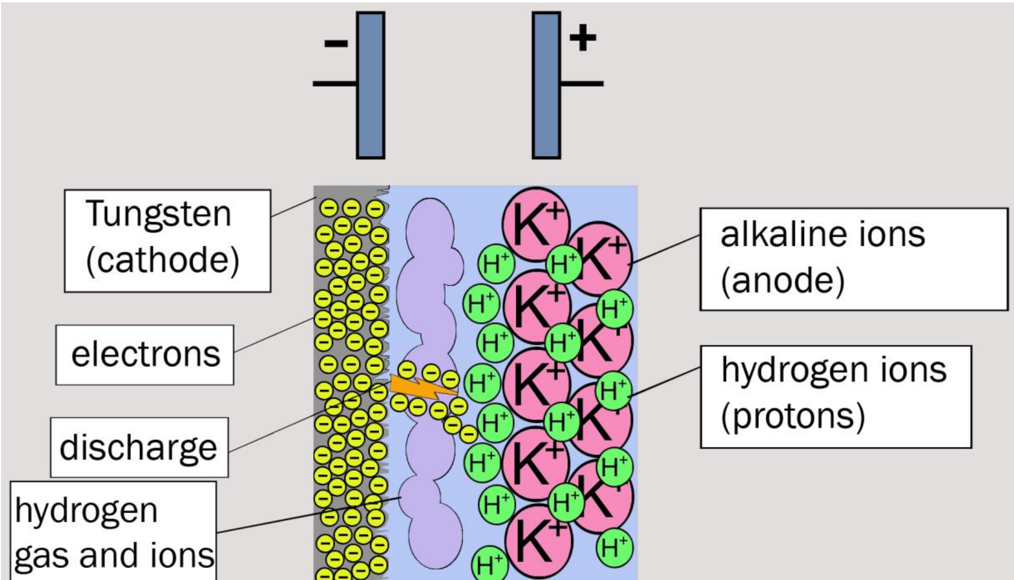



EMISSIONE TERMOELETTRONICA
(Dushman-Richardson)

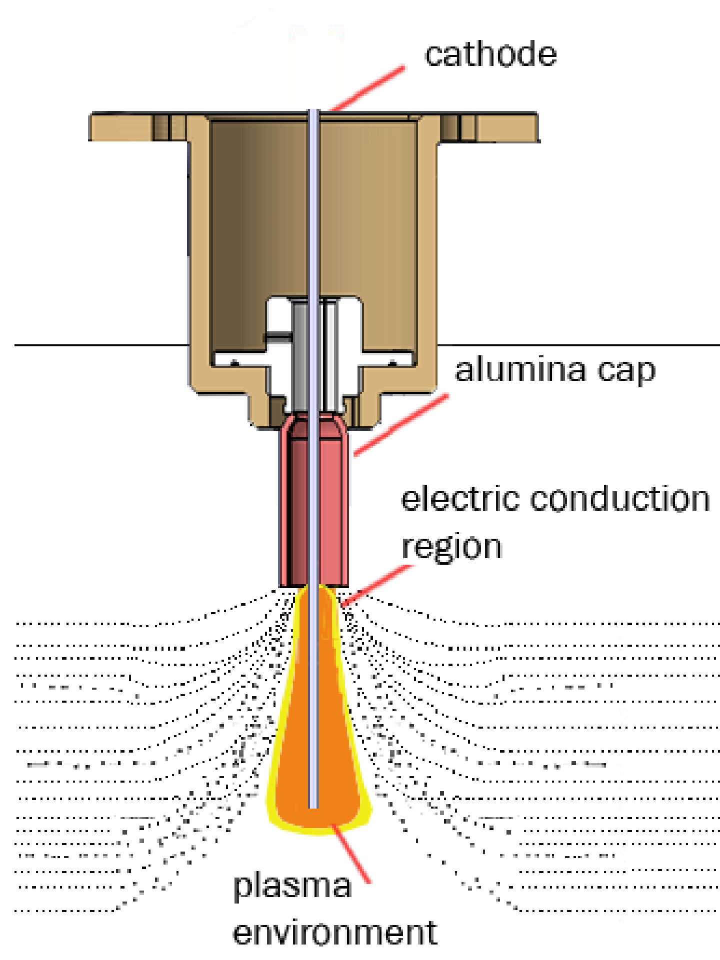
$$I_e = A_0 \cdot S \cdot T^2 \cdot e^{-\frac{b_0}{T}}$$

# Environment’s conditions (>200 V)

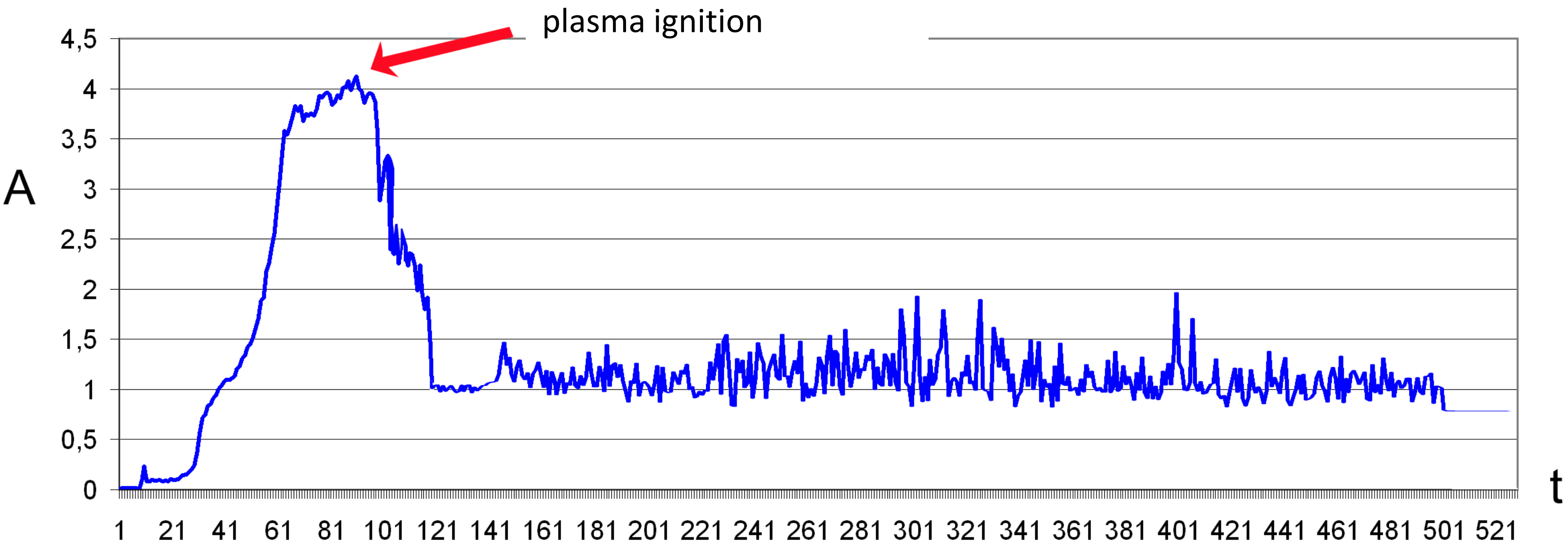



**In proximity of the cathodic surface:**

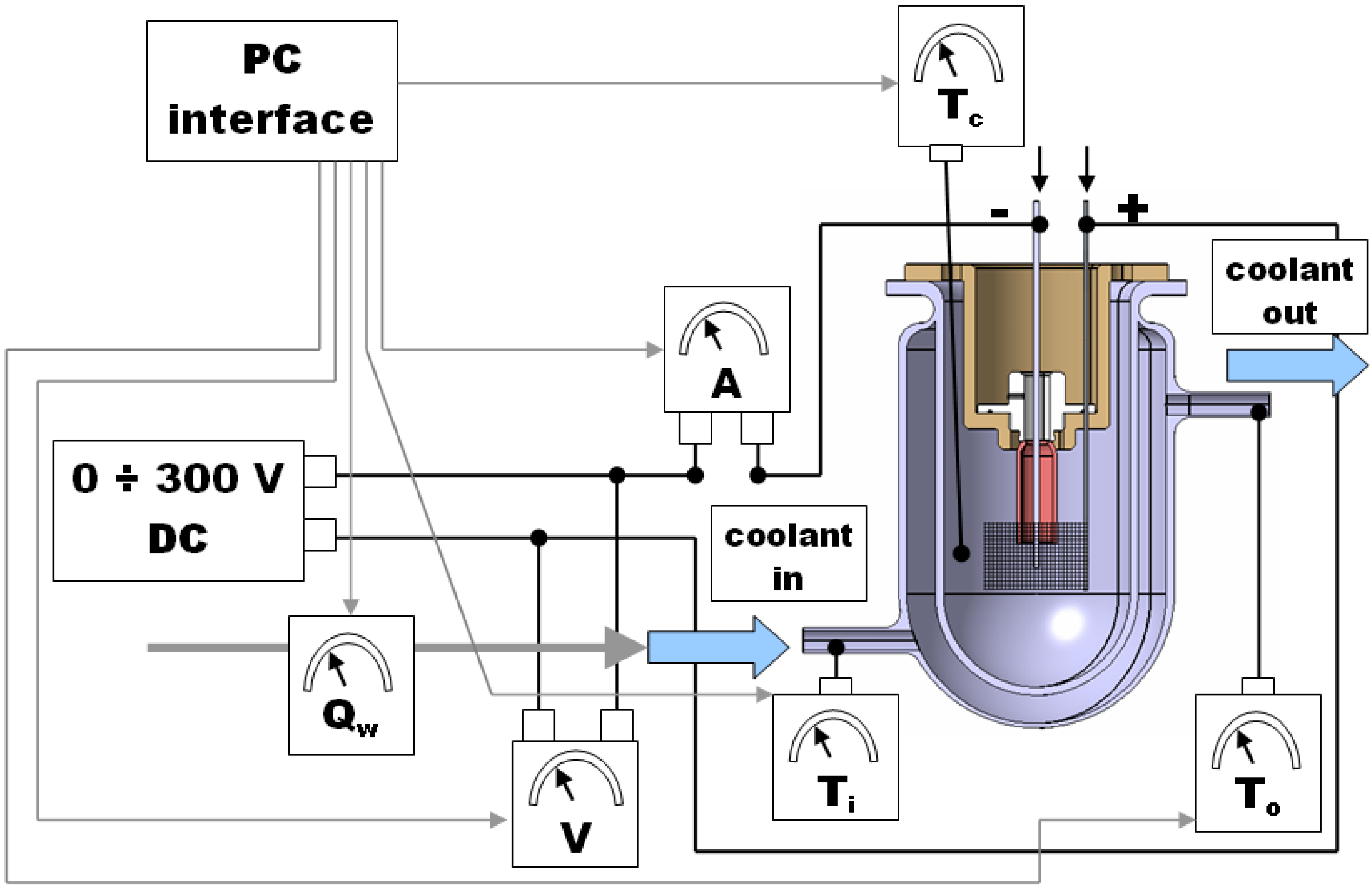
- **cracks on tungsten bulk**
- **hydrogen monoatomic ions**
- **electrons high density**
- **very high electric field**



# Ignition conditions

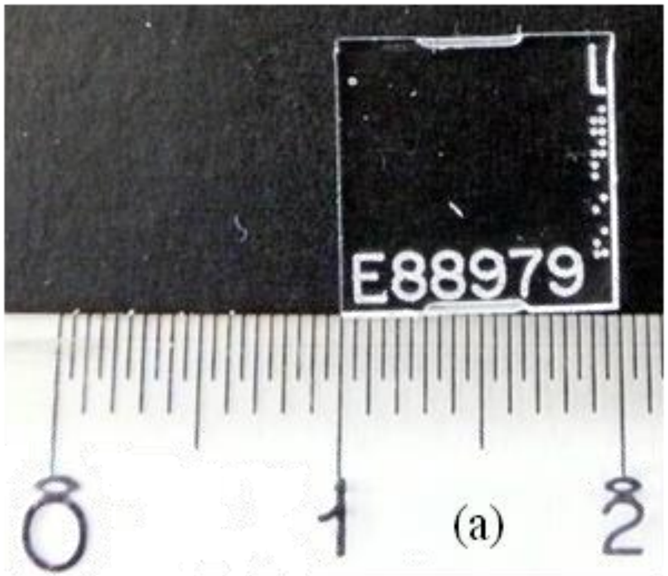


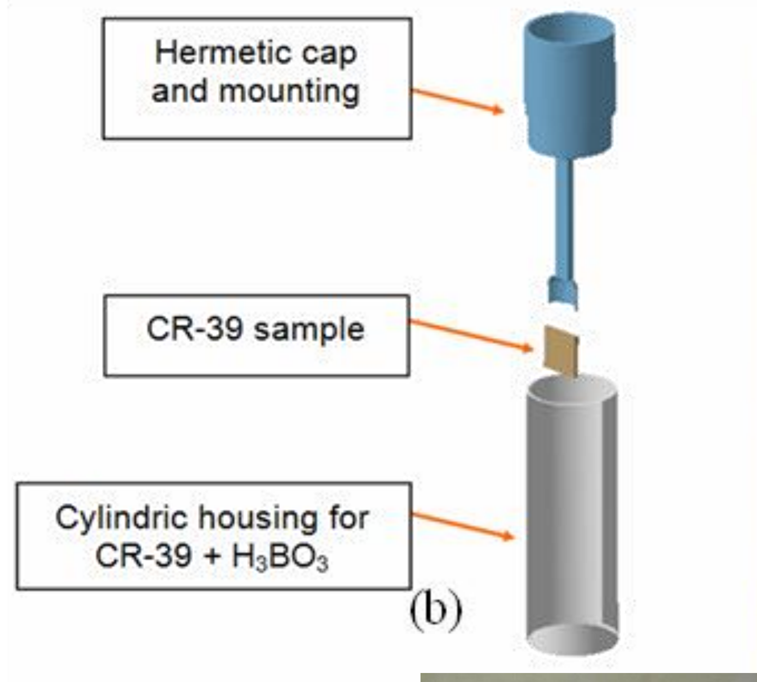
# Data measurement system



# Dosimeter features

CR-39 sample





**In proximity of the cathodic surface:**

- **a) CR39 detector**
- **b) dosimeter's scheme assembling**
- **c) dosimeter**

# Neutron's detection

## CR39 = $C_{12}H_{18}O_7$

$(CH_2\text{=}CH\text{-}CH_2\text{-}O\text{-}CO\text{-}O\text{-}CH_2CH_2\text{-}O\text{-}CH_2CH_2\text{-}O\text{-}CO\text{-}O\text{-}CH_2\text{-}CH\text{=}CH_2)$

<u>polymer sensitive at α (alpha) emission</u>

BORIC ACID= $H_3BO_3$

**the boron contained into the $H_3BO_3$ has got an natural isotopic distribution :**

- **20%** → $^{10}B$ sensitive at thermal neutrons (E @ 0,025 eV)
- **80%** → $^{11}B$

$$^{10}B + n \longrightarrow \alpha\ [1.47\ MeV] + {}^{7}Li + \gamma \qquad (93.6\%)$$

$$^{10}B + n \longrightarrow \alpha\ [2.79\ MeV] + {}^{7}Li \qquad (\ 6.4\%)$$

<u>Energetic range for CR39 vs α (alpha) particle's energy</u>

$\alpha \longrightarrow$ [0.04 MeV; 4 MeV]

# Dosimeters' calibration

**A collection of 20 sample s containing CR39 + $H_3BO_3$ were delivered to the "Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti" "National Institute od Metrology in Ionizing Radiations" (Casaccia ENEA). Such samples were exposed at a calibrated source of thermal neutrons, emitting a flux**

**$1.2\cdot10^2$ $N/mm^2\cdot s$ (0,12 µS/s)**

**The source is composed by six sources based on Am-Be reaction, covered by graphite and polyethilene .**

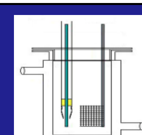
**The exposition was done in '<u>single blind</u>'. We don't know the sample exposed and the exposition time.**

# Dosimeters' calibration

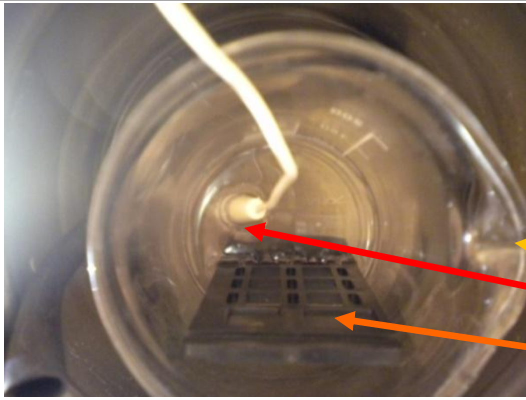
**In order to obtain a calibration and a reference for compare the measurements done through this dosimetric system, the 20 samples were divided into six groups, exposed at thermal neutron flux according:**

1. **group - 1' exposure time**
2. **group - 5' exposure time**
3. **group - 20' exposure time**
4. **group - 40' exposure time**
5. **group - 60' exposure time**
6. **group - NOT exposed (blank)**





# Dosimeters' calibration



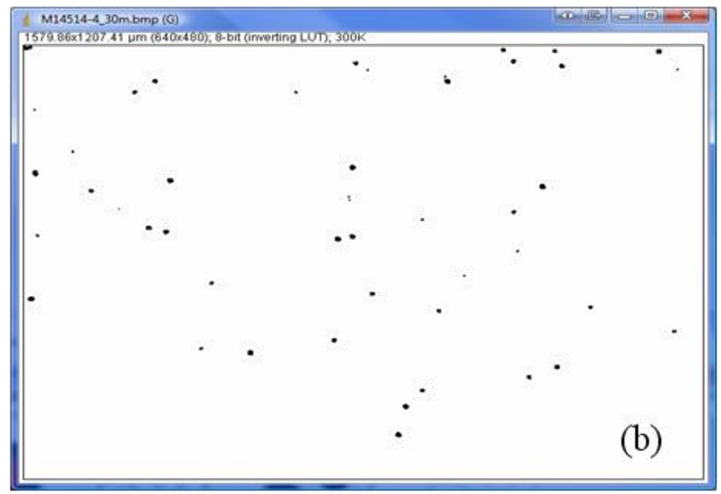
**Etching sample conditions:**

- **Solution 6,2 M NaOH**
- **Temperature process = 65°C**
- **Etching time > 4 h**

**Thermal probe**

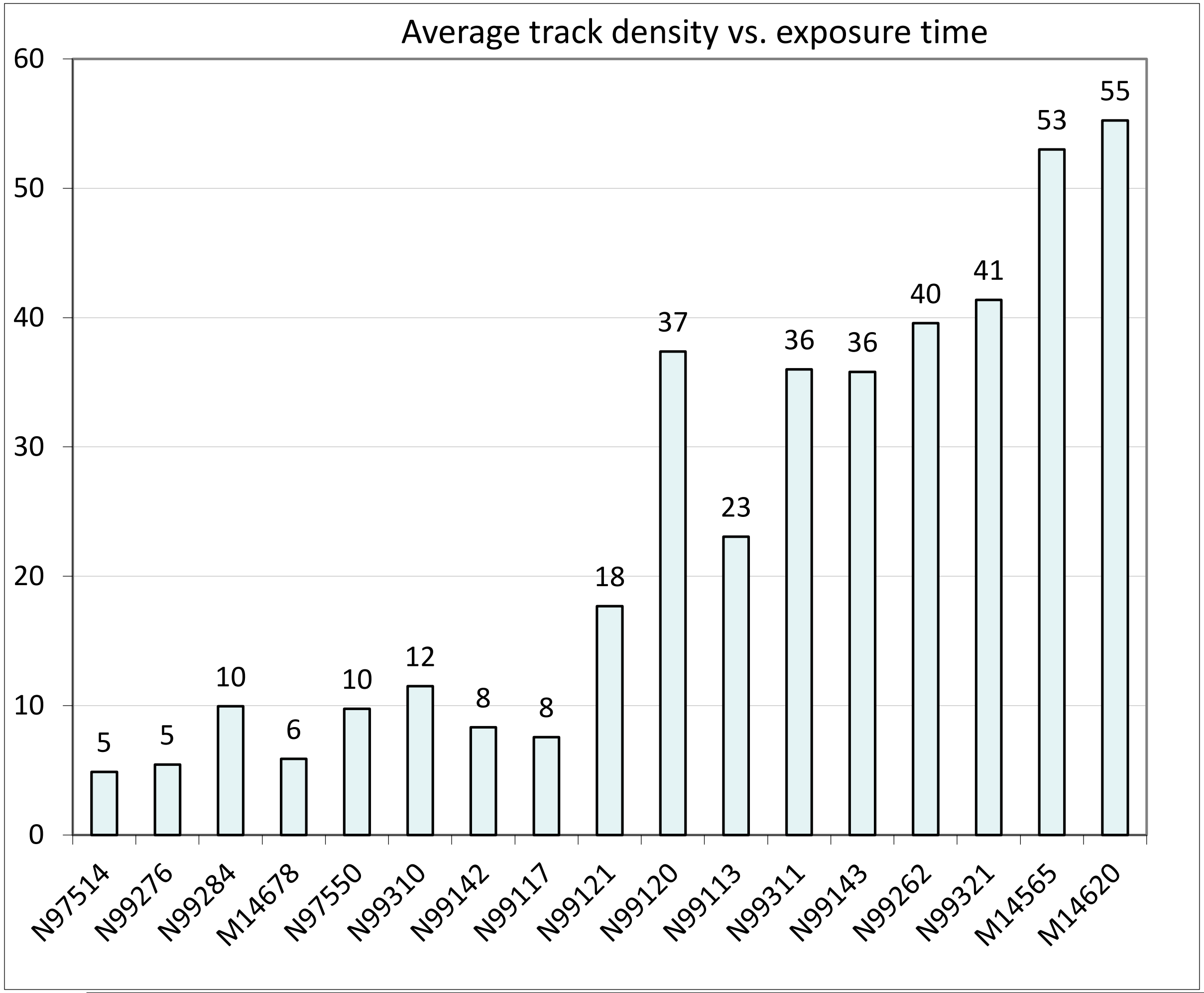
**CR39**

**Thermostatic chamber for CR39 etching process**

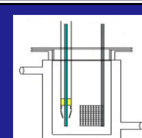

**After etching, the sample is analized through electronic magnifier and a specific software to counts the tracks on CR39 plate after the etching process**

# Dosimeters' calibration (the gauge)

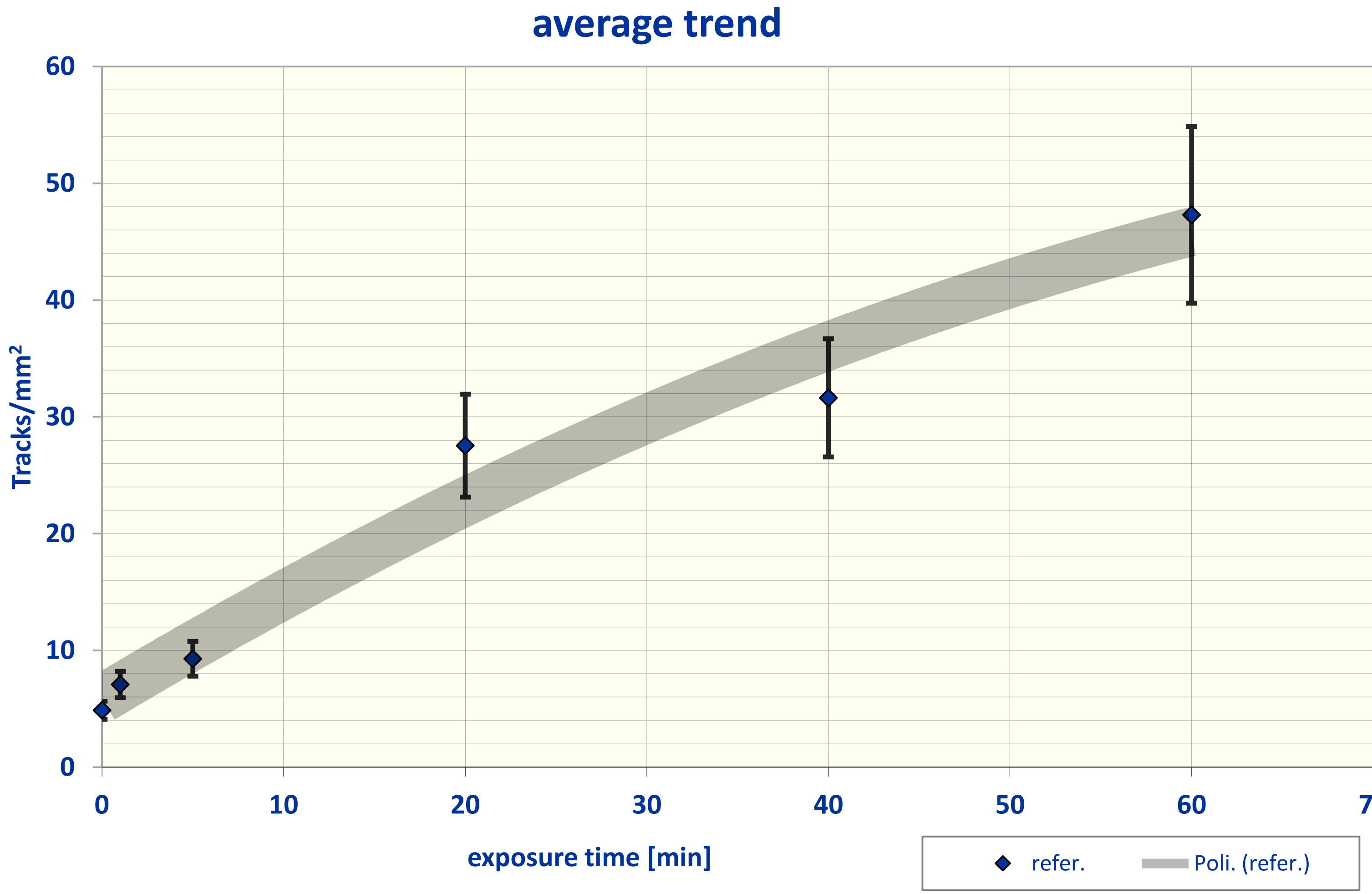



| CR-39 sample code | Exposure time (min.) | Average track density (tracks/mm²) | Group average track density (tracks/ mm²) |
|---|---|---|---|
| N97514 | 0 | 5 | 5 |
| N99276 | 1 | 5 | 7 |
| N99284 | 1 | 10 | |
| M14678 | 1 | 6 | |
| N97550 | 5 | 10 | 9 |
| N99310 | 5 | 12 | |
| N99142 | 5 | 8 | |
| N99117 | 5 | 8 | |
| N99121 | 20 | 18 | 28 |
| N99120 | 20 | 37 | |
| N99113 | 40 | 23 | 32 |
| N99311 | 40 | 36 | |
| N99143 | 40 | 36 | |
| N99262 | 60 | 40 | 47 |
| N99321 | 60 | 41 | |
| M14565 | 60 | 53 | |
| M14620 | 60 | 55 | |

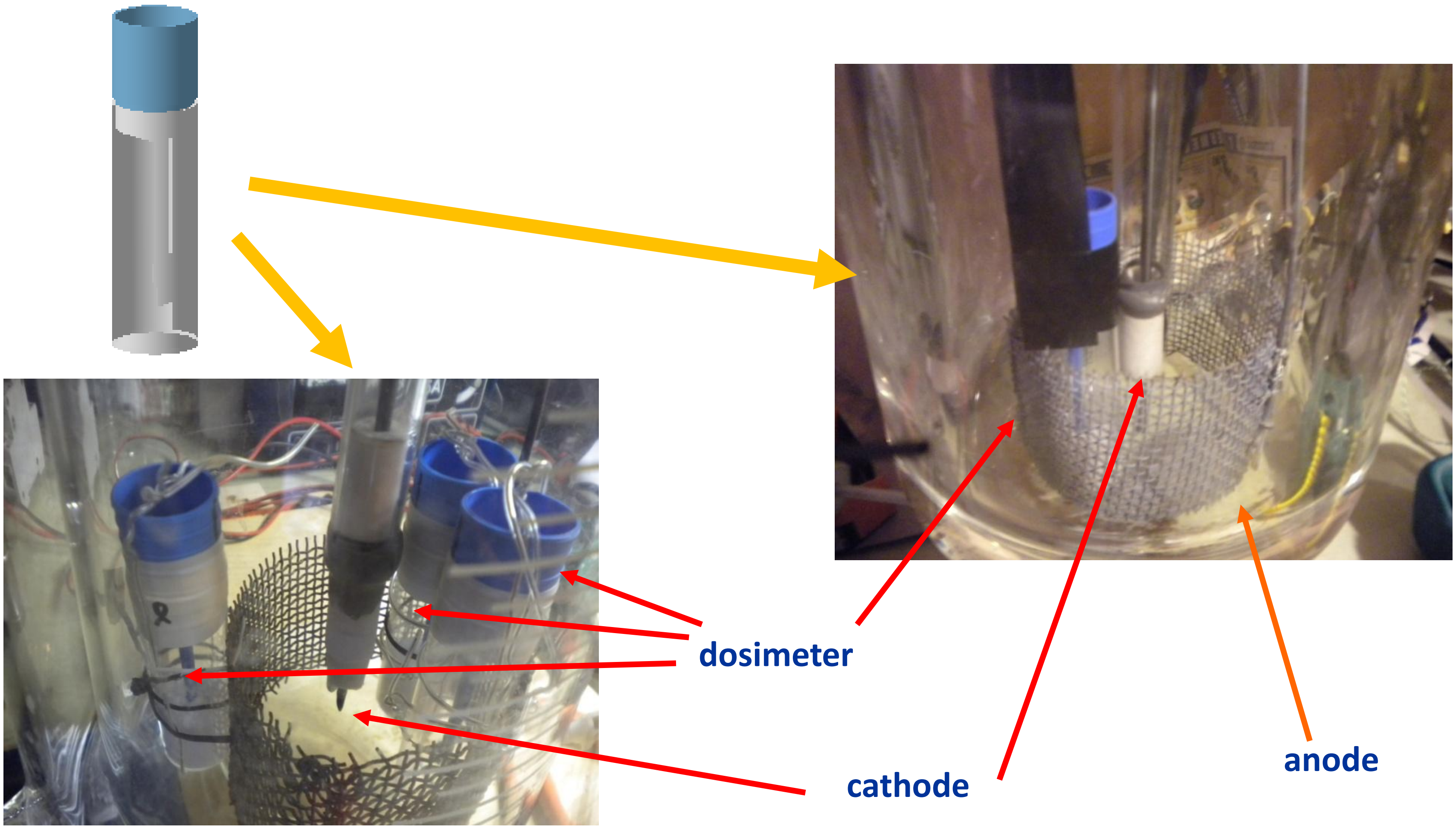




# Dosimeters’ calibration (the gauge)



# Plasma Cell's exposition

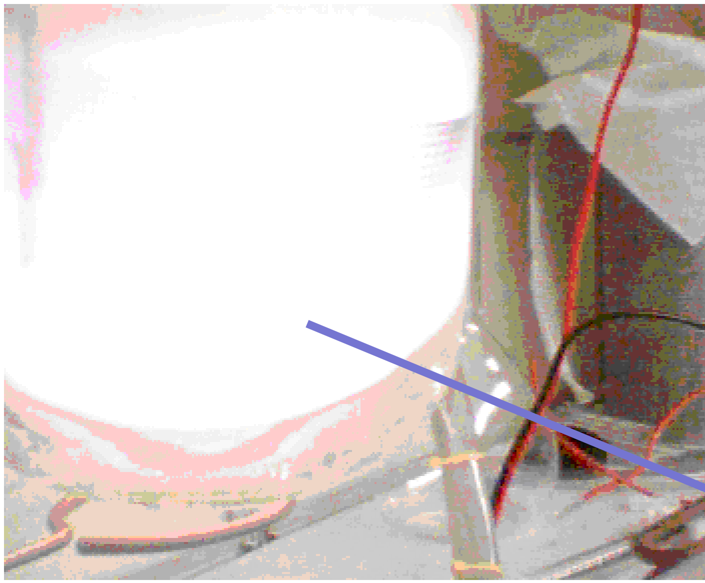




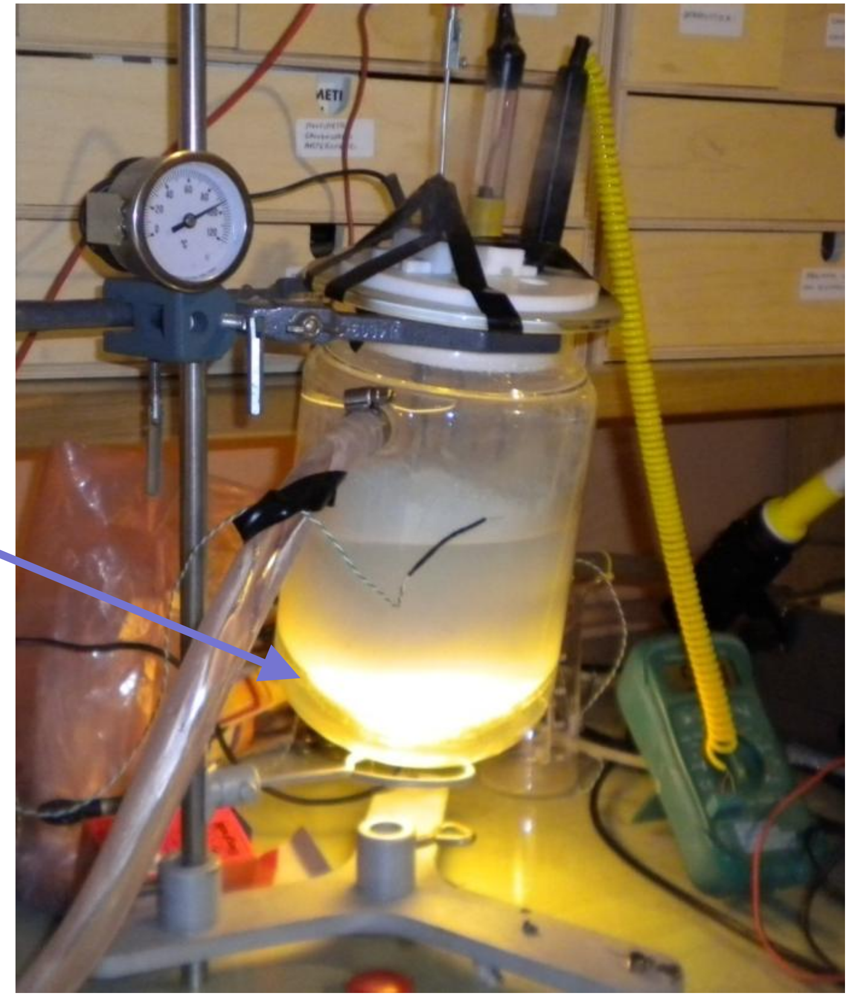



Written D. Cirillo

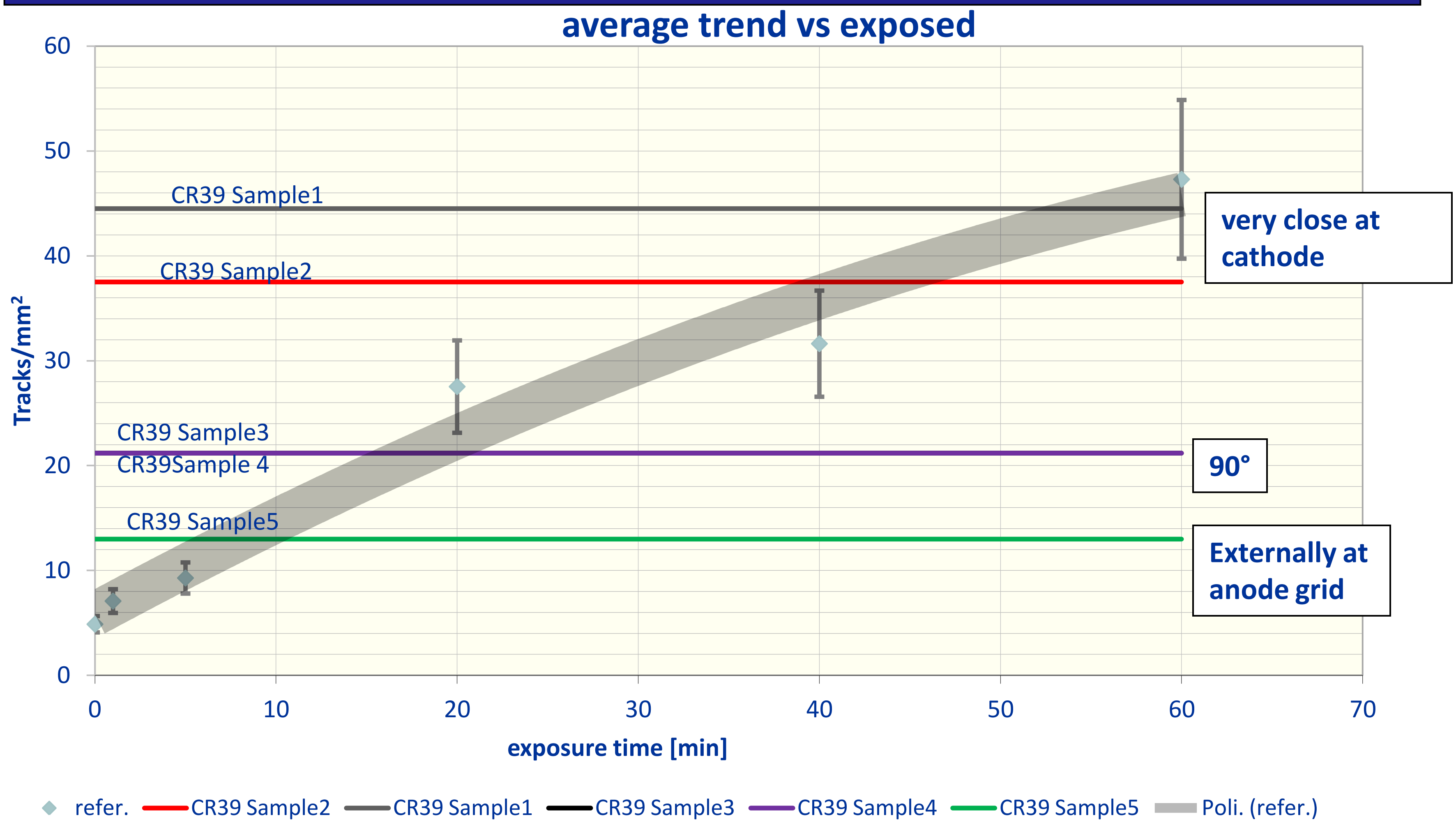
# operative conditions



**Dosimeter after a run very close at cathode**



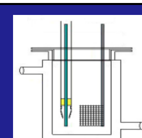
# Tracks comparison (CR39)



# CONCLUSIONS

- The neutron detection method based on CR-39 nuclear track detectors, coupled with a boron converter, has demonstrated neutron generation by plasma discharge in an electrolytic cell with alkaline solution.
- A significant number of tracks were revealed by the CR-39 detector samples positioned in close proximity to the plasma discharge, next to the tungsten cathode of the electrolytic cell.
- the blank detectors show no tracks, if positioned far from electrolytic cell.





# IMPORTANT NOTICE

- **It is important to remember that these thermal neutron flux measurements have a relatively low efficency.**
- **This is because of the sequence of events required to produce a track on the CR-39 detector: the neutrons must be emitted into the detector at a usefule solid angle, then they have to meet a $^{10}B$ nucleus contained in the boric acid grains (18.7 % $^{10}B$ among the total B contained in $H_3BO_3$). Then the α particles must be emitted into the detector at a useful solid angle, reach the detector sample without being absorbed by the converter material and finally they must hit the detector leaving a new track in a sample area free of previous ones.**
- **This dosimeter may be sensitive at α particles and protons, that may be difficult to differentiate from neutrons.**
- **The proposed method provides clear evidence of thermal neutron generation in this low energy system, but the same method requires important deepening.**