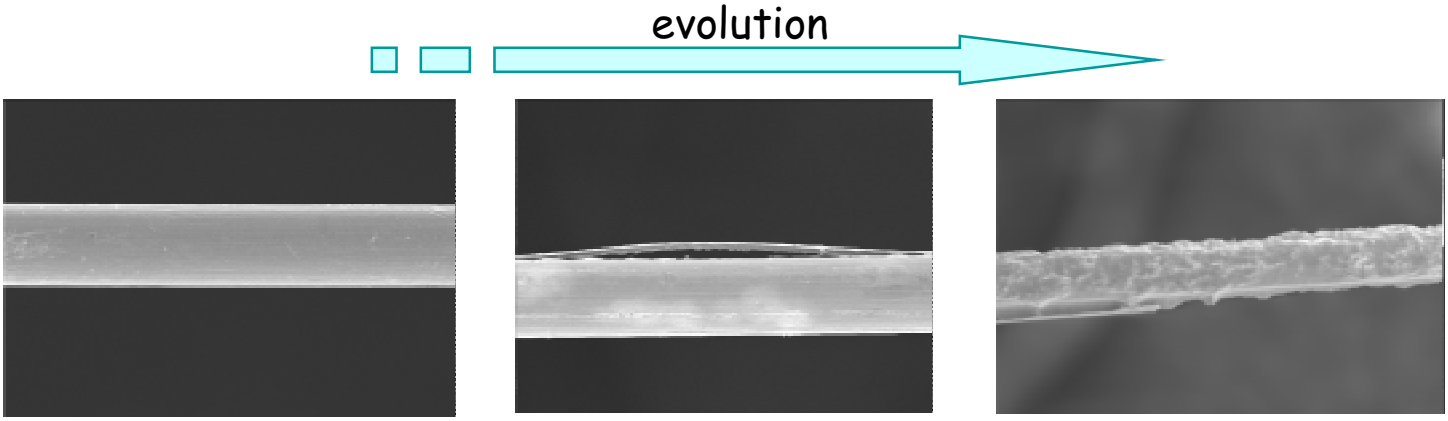
Humidity dependence of anode etching in HERA-B Outer Tracker Chambers with $Ar/CF_4/CO_2$



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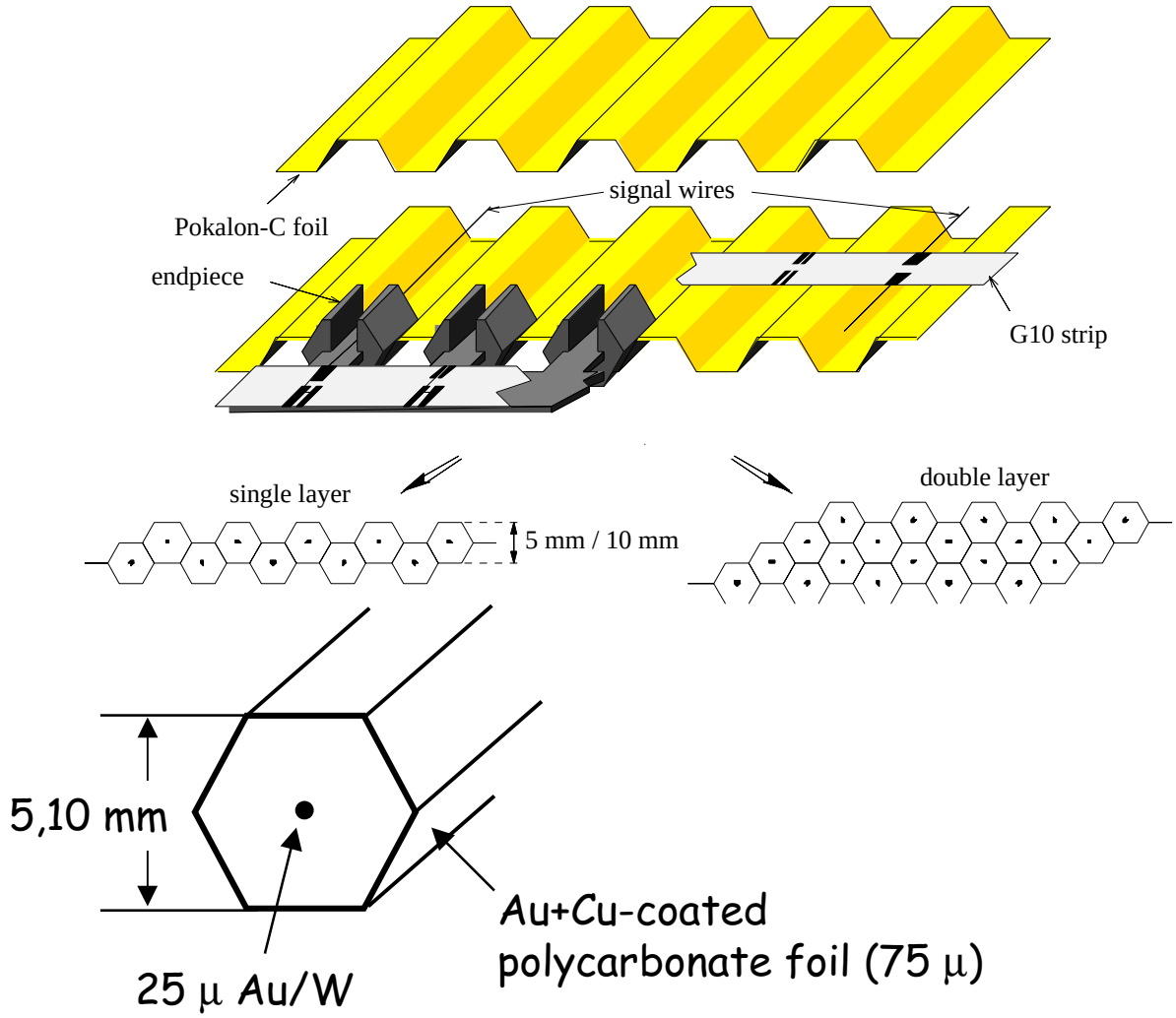
Hamburg 3.10.2001

Contents

- Aging tests with different water contents
  - exp. setup
  - humidity dependence of:
    - wire ruptures
    - transient aging
    - dark currents
- Plasma chemistry in the avalanche
  - production rate of fluorine species
  - lifetimes of radicals
  - concentration profile
  - summary

Chamber construction & parameters

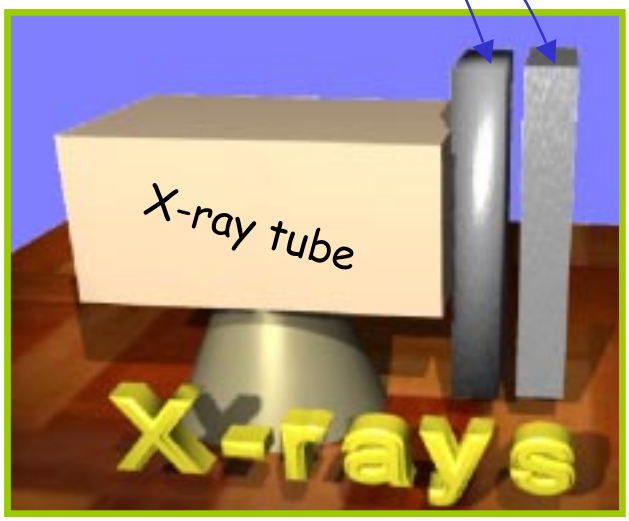


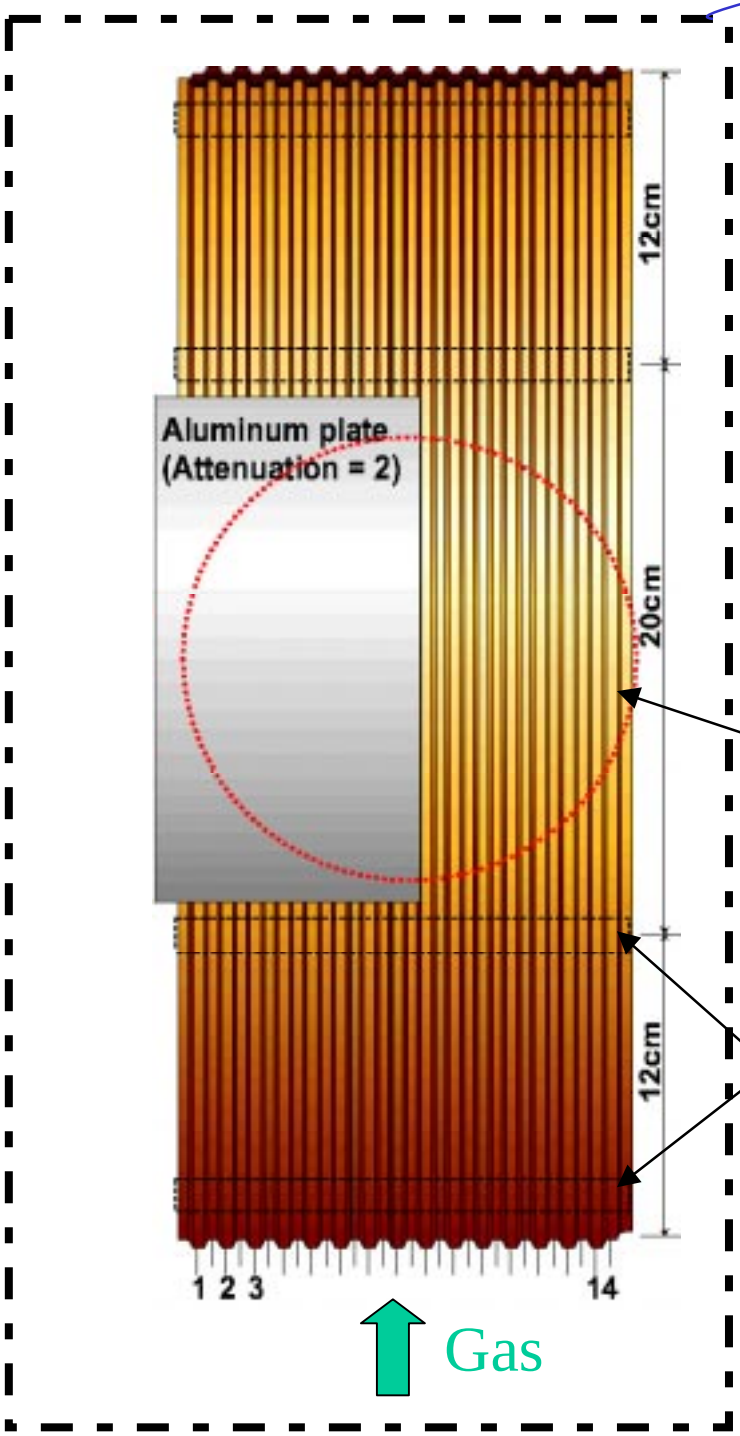
parameter	value in Outer Tracker
HV	1700 V (1900 V for 10 mm)
gain	$3 \cdot 10^4$
gas	$Ar/CF_4/CO_2$ (65:30:5)
current	0.05 µA/cm
flow	1 vol/h

→ X-ray Tests: 0,2-0,8 µA/cm

Setup

boxes with
different humidity





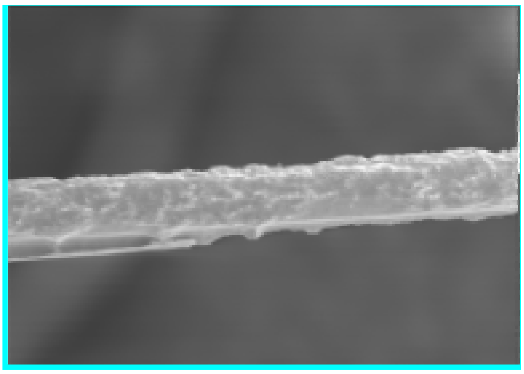
gas box (2.3 l)

irradiated area

G10 (FR4) strips

One mono-layer is equipped with capillaries to convey gas flow through the cells, the other has normal „open" end-pieces.

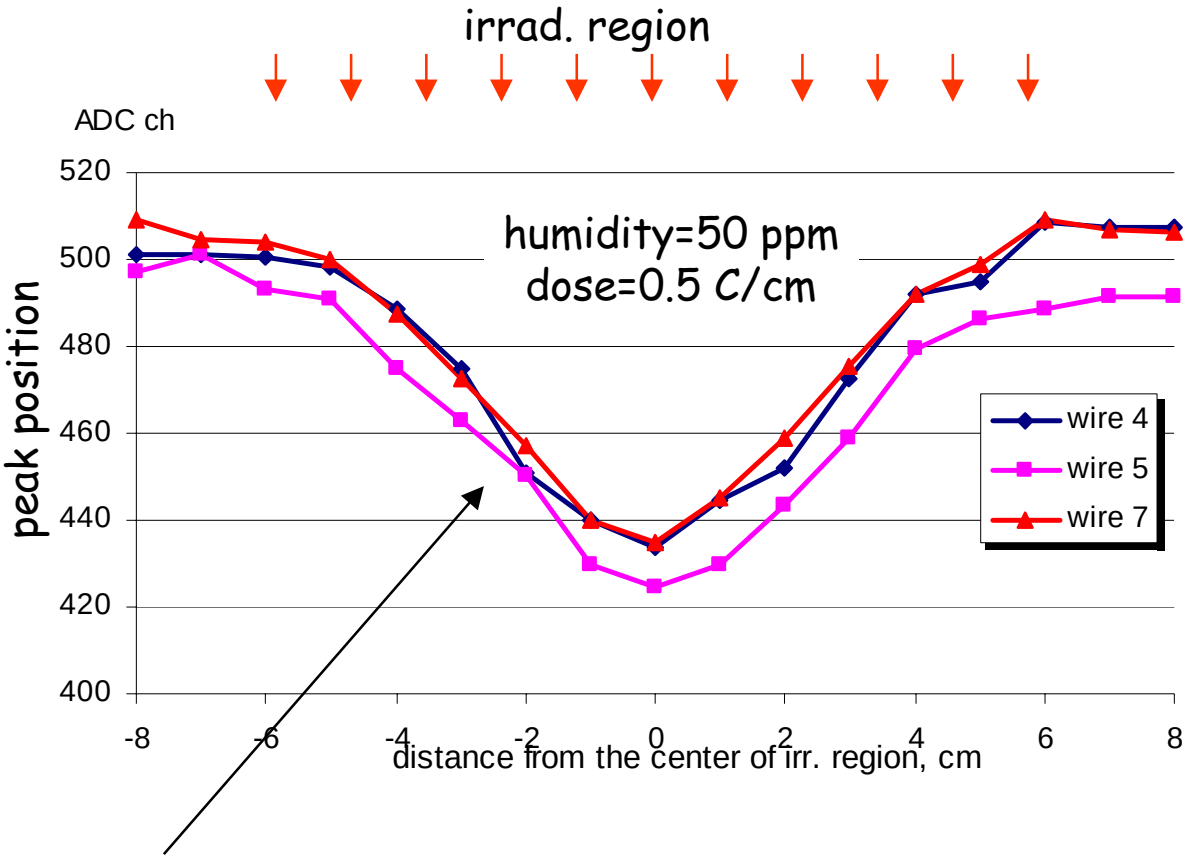
Wire ruptures in X-ray tests with different humidity



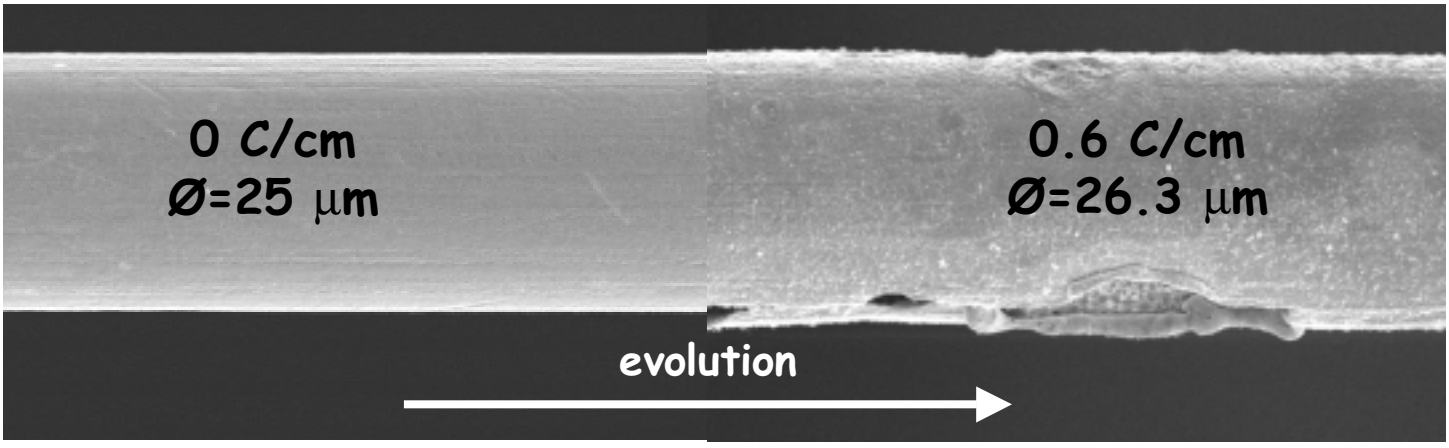
dose C/cm	H_2O (inp/outp) ppm	O_2 (inp/outp) ppm	ruptures
0.55	<10/50	30/200	yes, after 0.3 C/cm
1.2 straws	<10/100	30/200	yes, after 0.6 C/cm
4.5	350/400	30/200	no
3.5	700/750	30/300	no
1.2 used ch.	<10/80	30/250	yes, after 0.28 C/cm
1.2	<10/120	30/250	yes, after 1.2 C/cm

- Wire ruptures after 0.3 C/cm (1/2 years in HERA-B) in dry chambers ($H_2O \lessapprox 100$ ppm)
- No aging effects until 5 C/cm in relatively humid chambers ($H_2O > 300$ ppm)

Longitudinal ^{55}Fe scanning after aging tests

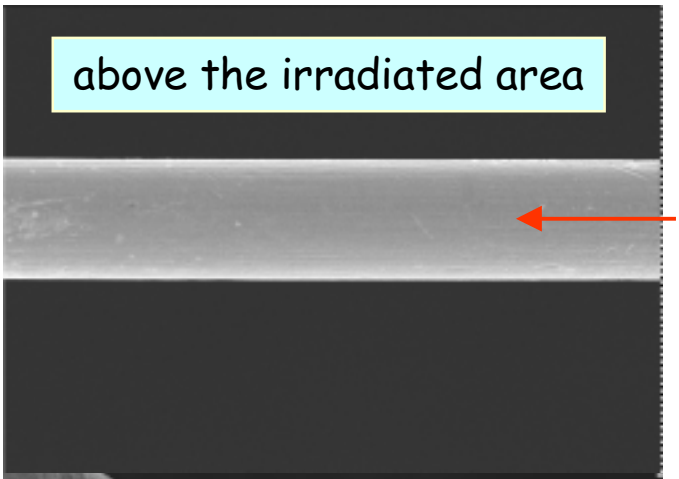


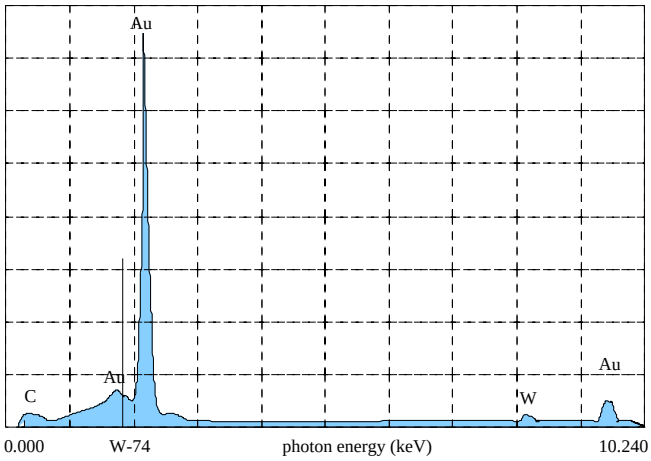
Inspite of the homogeneous irradiation intensity profile,
the gas gain loss increases towards
the center of the irradiated region

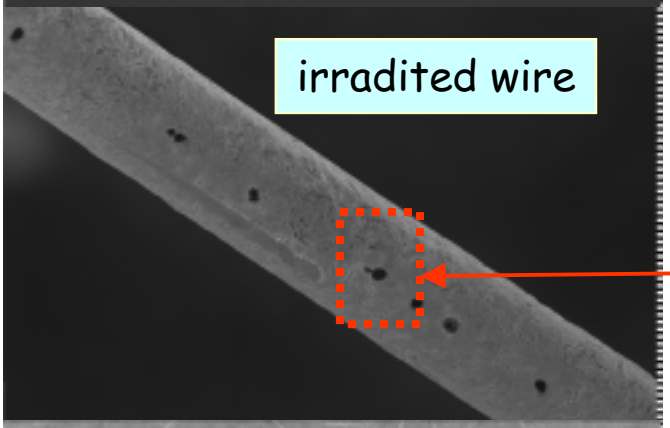


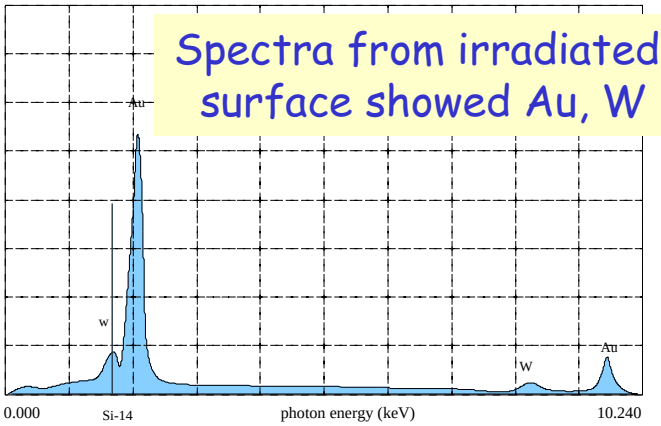
e-microscopy ⇒ gain loss was due to wire swelling

Electron Dispersive X-ray Spectroscopy

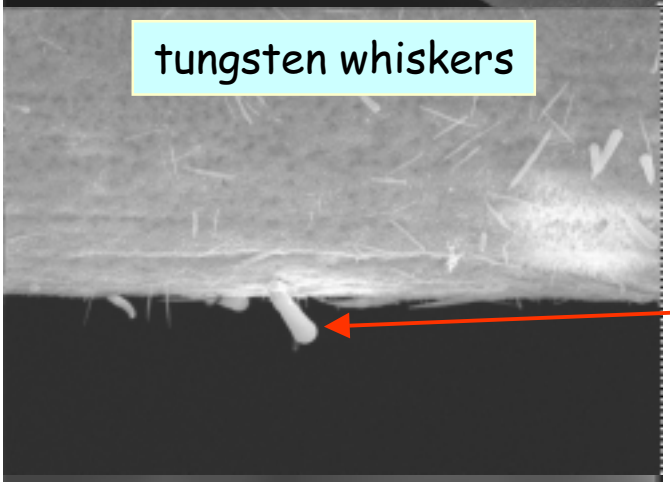


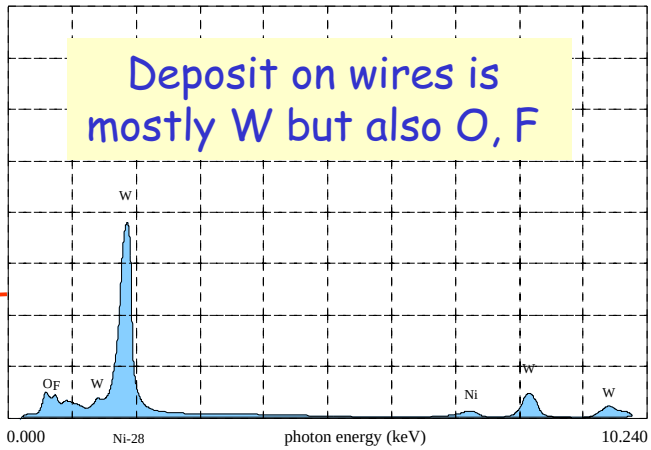




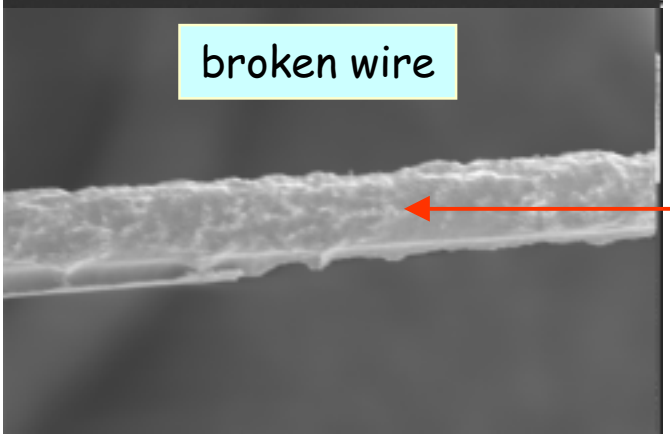


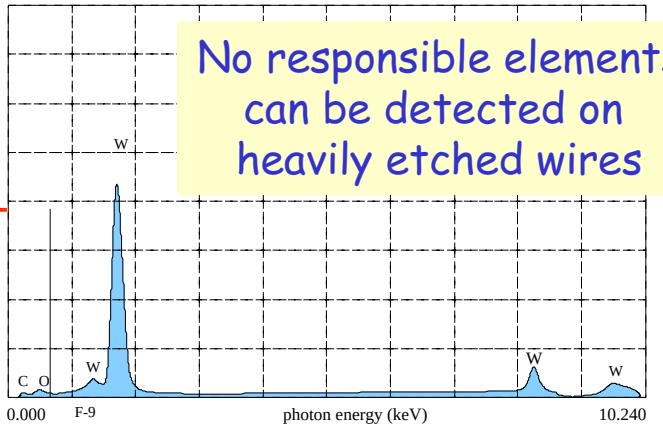
Spectra from irradiated surface showed Au, W





Deposit on wires is mostly W but also O, F

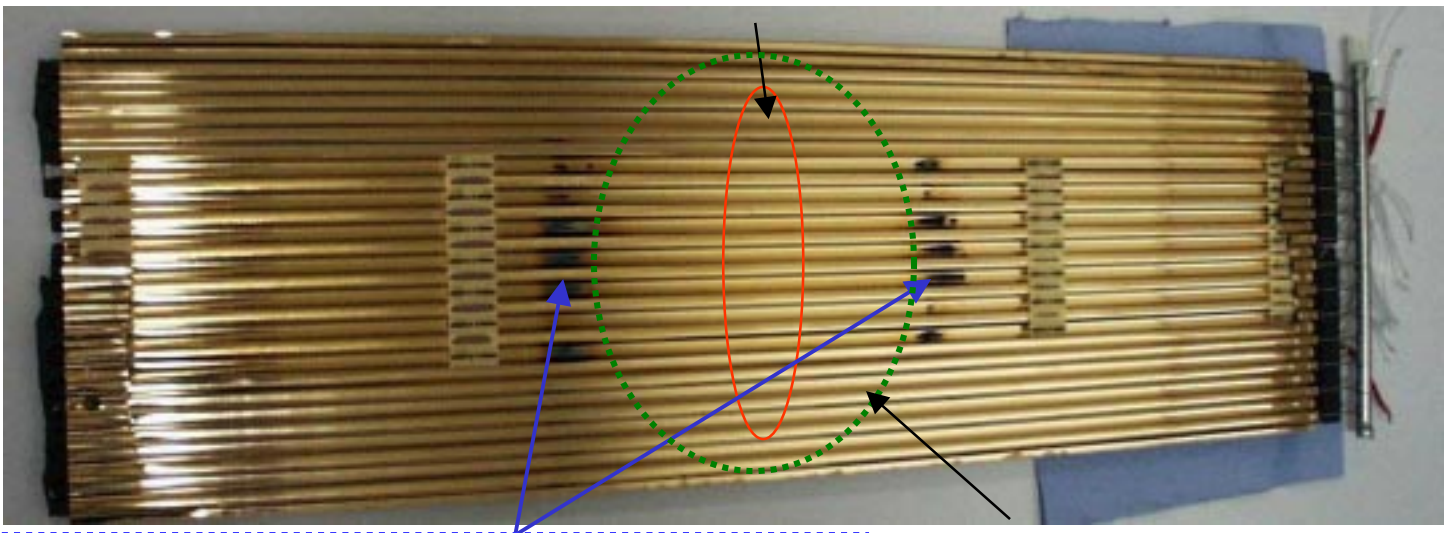




No responsible elements can be detected on heavily etched wires

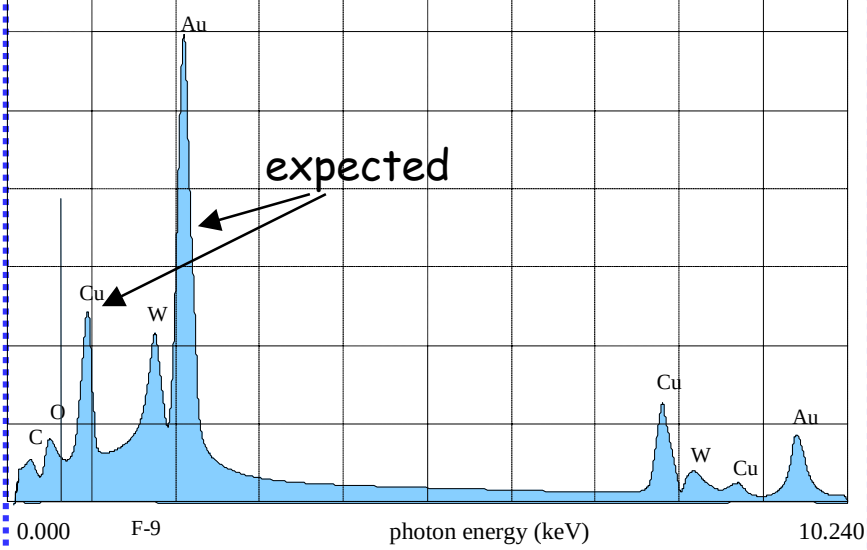
Open dry layer after 0.6 C/cm

area of wire breaking



irradiated region

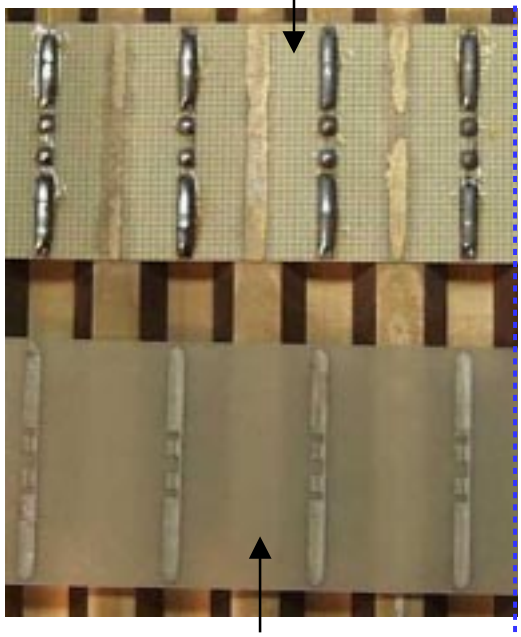
shaded area: deposits of W, O, C



W deposited on cathode was probably etched away in irradiation area

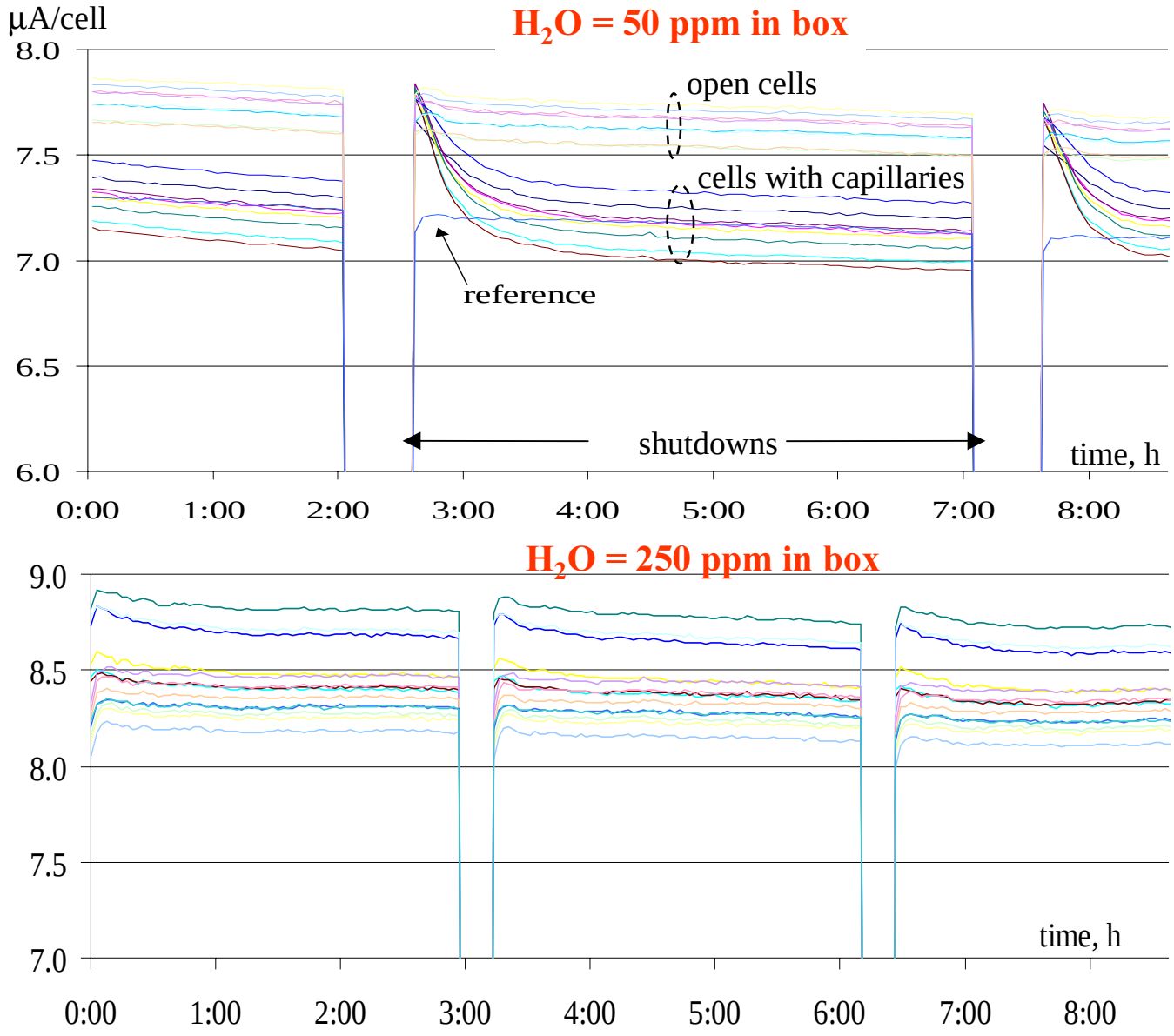
G10 strips

after aging test
(texture became visible)



new

Transient aging - temporary drop of current during high rate irradiation



Transient aging:

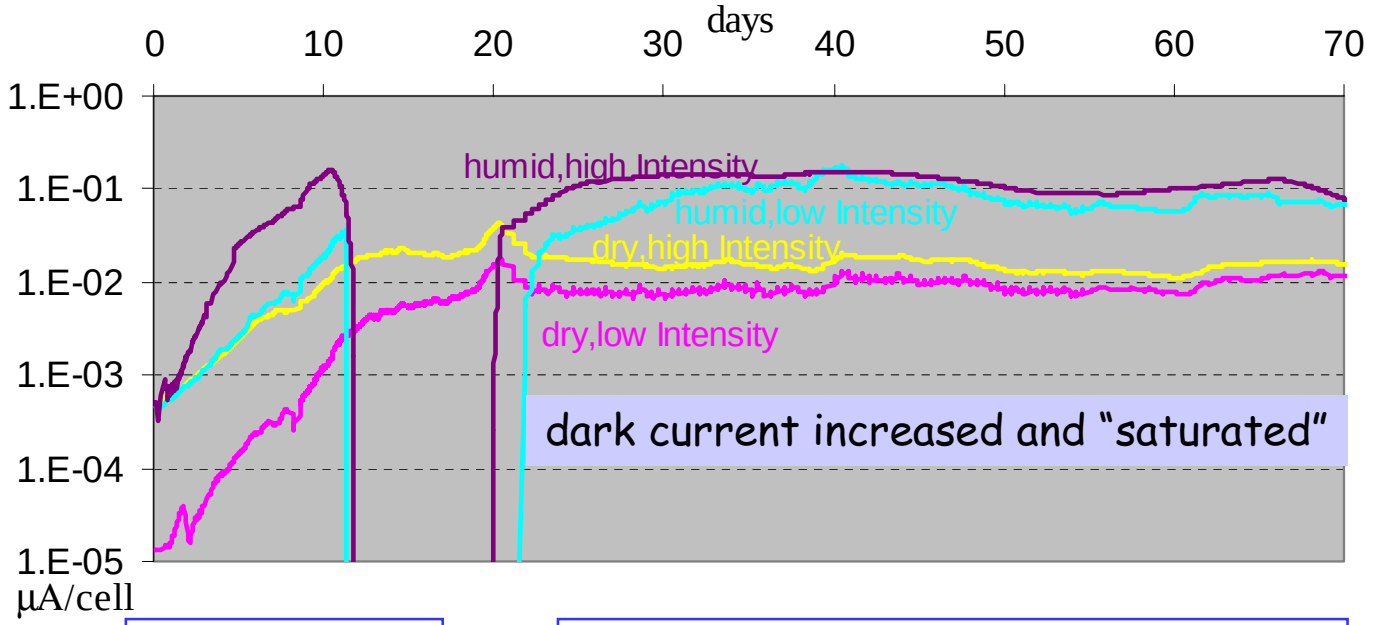
- probably resulted from production of a very electronegative gas in the avalanche.
- was not pronounced in open cells due to higher gas flow (thermal convection)
- was not observed in humid gas

⇓

responsible species are F_2

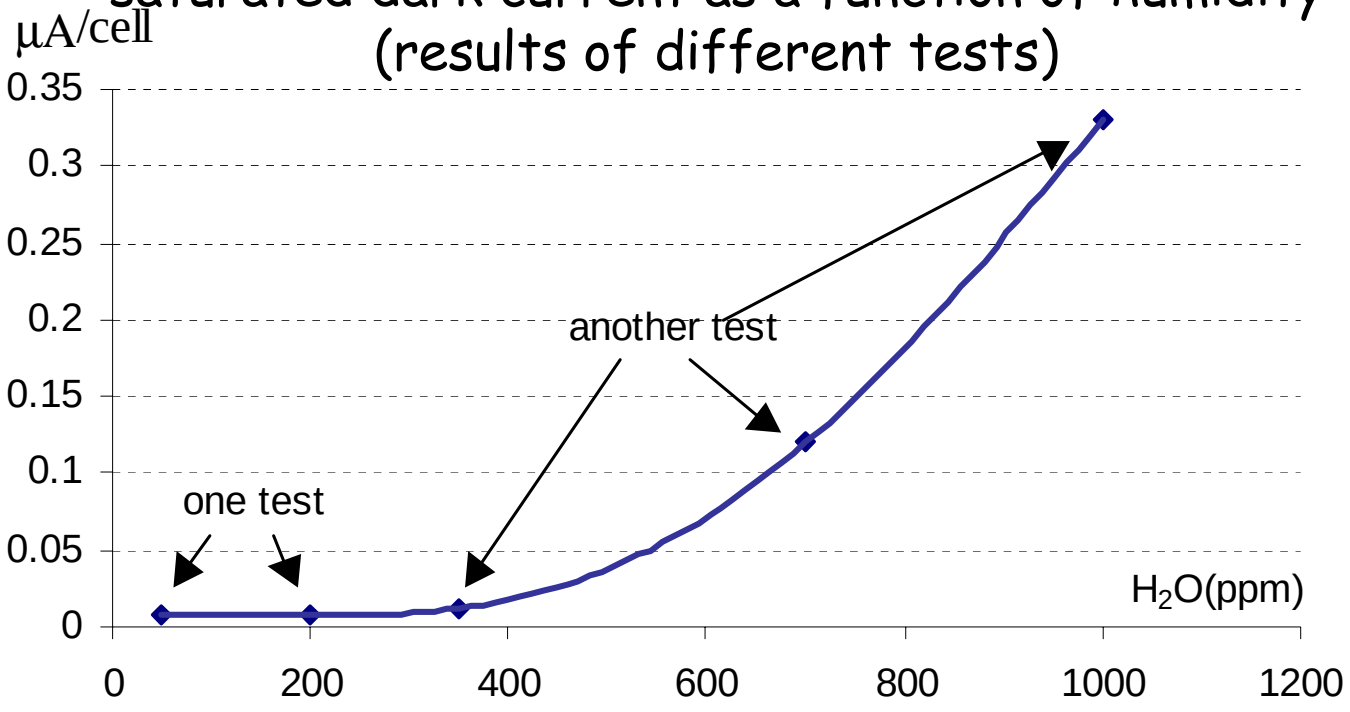
dark currents

high intensity ≈ 2* low intensity



dark currents ⇐ conductivity of wire supporting strips

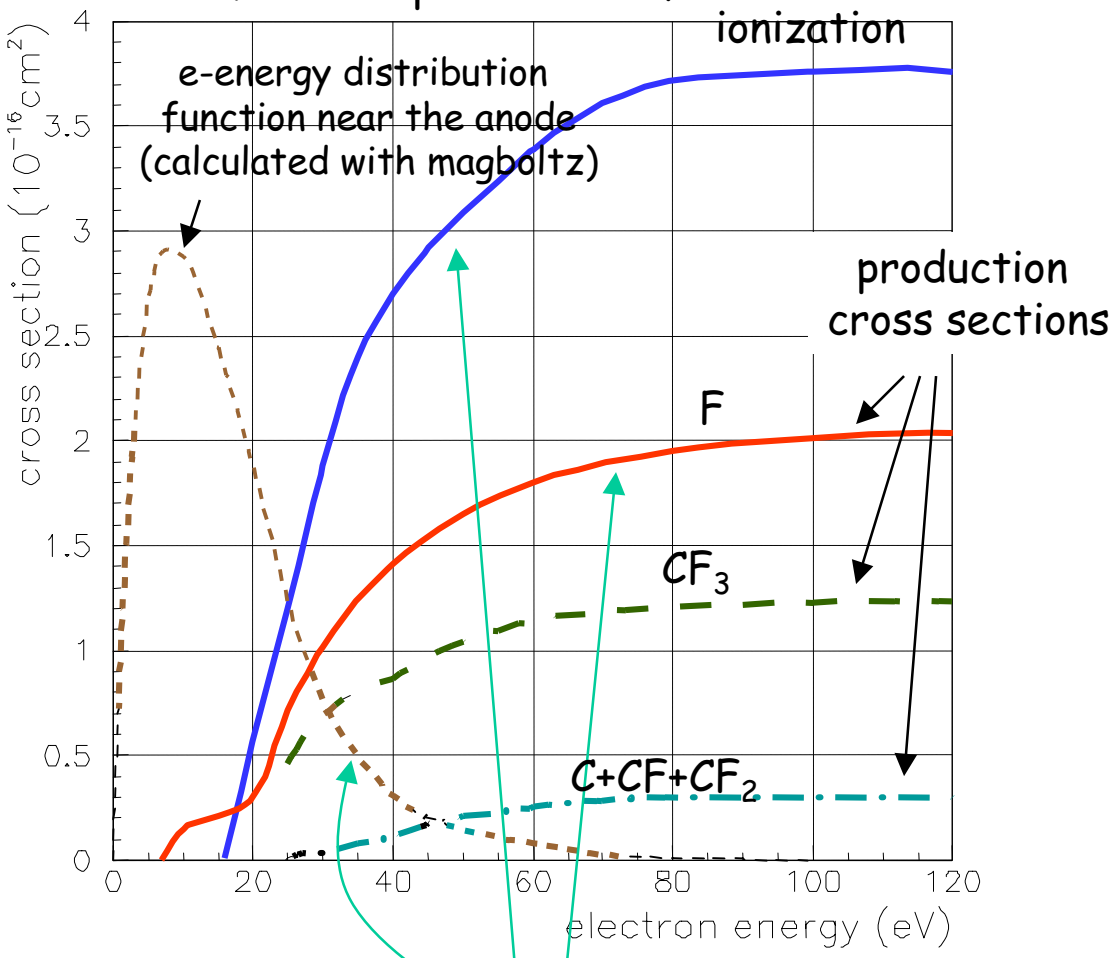
saturated dark current as a function of humidity (results of different tests)



H_2O<400 ppm is save

Molecule-averaged e-impact cross sections for ionization and production of radicals in $Ar/CF_4/CO_2$

e-impact dissociation was considered to dominate in production of radicals



production rate of F

$$\frac{I_F}{I_e} = \frac{\int \sigma_F(\varepsilon) f(\varepsilon) \sqrt{\varepsilon}\, d\varepsilon}{\int \sigma_i(\varepsilon) f(\varepsilon) \sqrt{\varepsilon}\, d\varepsilon} \approx 0.6$$

Lifetimes of radicals

intesity = 0.6 μA/cm

concent

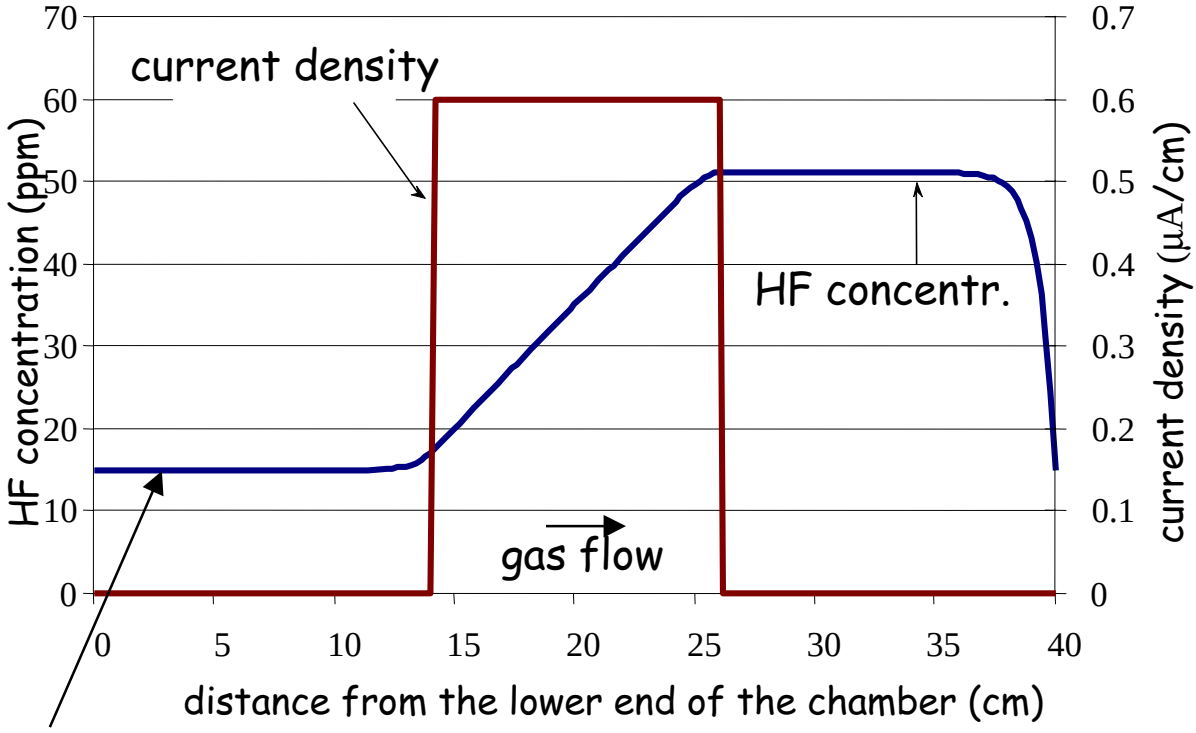
n=100 ppm

n=5%

Reaction	Constant
$CF_3 + F + M \rightarrow CF_4 + M$	0.1 s
$F + F + M \rightarrow F_2 + M$	25 s
$CF_3 + CF_3 + M \rightarrow C_2F_6 + M$	0.046 s
$H_2O + F \rightarrow HF + OH$	2×10^{-5} s
$OH + OH \rightarrow H_2O + O$	0.8 s
$F + OH \rightarrow HF + O$	0.014 s
$F + O_2 + M \rightarrow FO_2 + M$	4 s
$F + CH_4 \rightarrow HF + CH_3$	1.8×10^{-9} s
M≡ collision partner (argon)	

- F rapidly reacts with water ⇒ *probably F is responsible for etching*.
- $I_F \approx I_{HF} \approx 0.6 * I_e$

Longitudinal concentration profile for HF ($\tau \gg 1$ h) in X-ray setup



$\neq 0 \Leftarrow$ accumulation of HF in box

- Concentration of HF is 15 ppm and 50 ppm (maximum) in box and in irr. cells, respectively.
- The concentration profile can be rescaled for other long-lived species.
- Concentration is maximal at the upper parts of chambers.

$\Downarrow$

Species responsible for etching are not long-lived

For more details see:

A. Schreiner, *Aging Studies of drift chambers of the HERA-B Outer Tracker Using CF4-based Gases*,

PHD thesis, Humboldt University

Summary

of results with honeycomb chambers
in $Ar/CF_4/CO_2$ (65:30:5)

✷ **anode etching ⇐ humidity < 100ppm after 0.3 C/cm**

- wires swell (gain drops by O[10%])
- gold coating peels off
- wires rupture approximately

in the centre of irradiated area

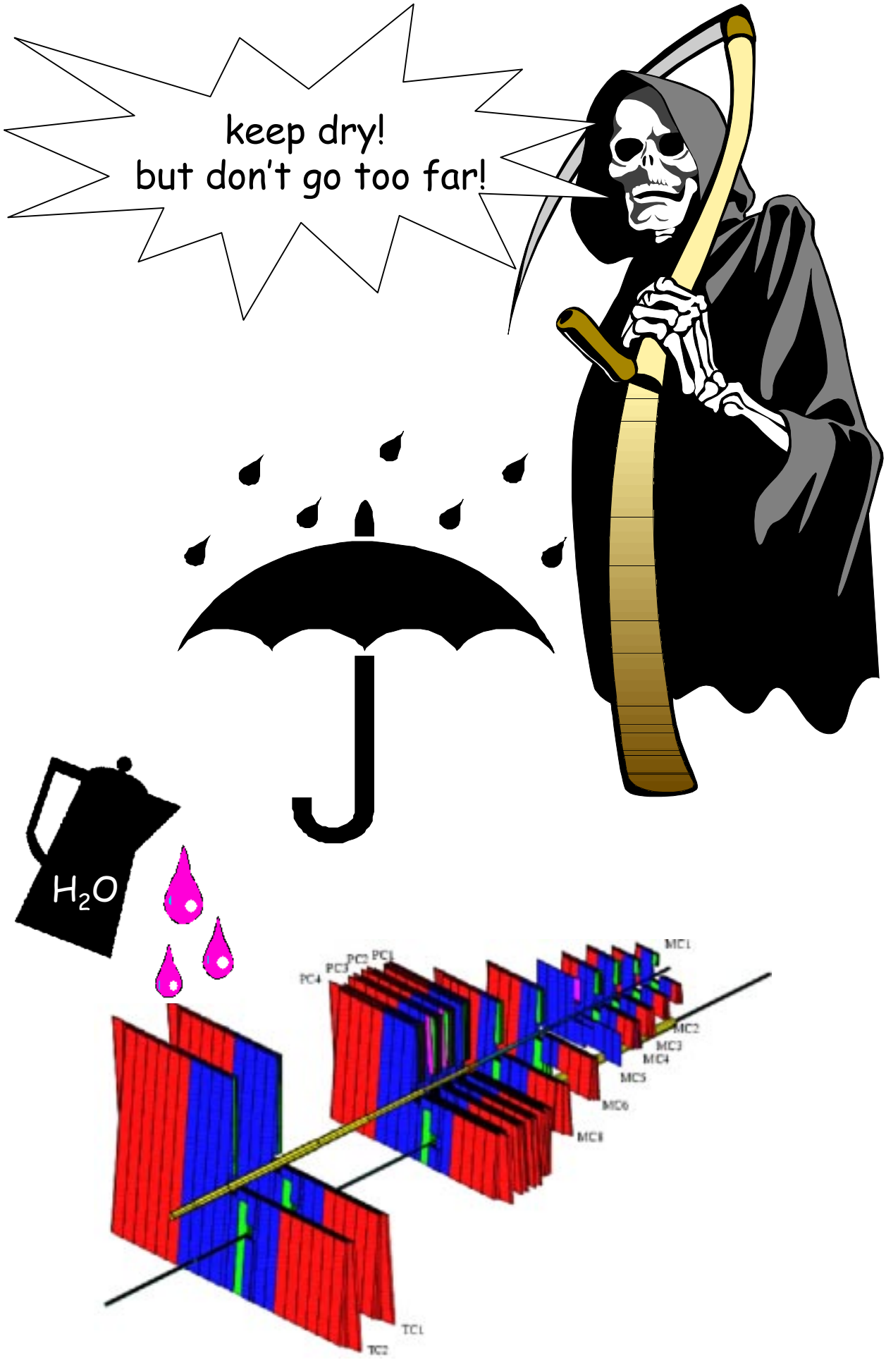
- X-ray spectroscopy of exposed W did not reveal responsible (external) species
- W-deposits contained always O and sometimes C and F
- anode etching correlated with "transient aging"

Because $F_{(2)}$ reacts with H_2O we believe that:

- *anode etching is caused by F and*
- *transient aging by F_2 - very electronegative gas*

✷ **dark currents ⇐ conductivity of G10 strips ⇐ ⇐ humidity > 500ppm**

We assume that conductivity of G10 strips arises due to production of HF forming with water hydrofluoric acid (which is weakly conductive)


keep dry!
but don't go too far!
H_2O
MC1
MC2
MC3
MC4
MC5
MC6
MC8
PC1
PC2
PC3
PC4
TC1
TC2