REVIEW OF WORKSHOP RESULTS ON THE FUNDAMENTAL UNDERSTANDING OF AGING PROCESSES

Fabio SAULI

CERN

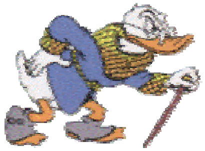
WHAT?
ANOTHER SUMMARY?

International Workshop on Aging Phenomena in Gaseous Detectors
October 2-5, 2001 at DESY, Hamburg

FOREWORD

SUMARIZING 50 AND MORE TALKS AND POSTERS IN 50 MINUTES IS A STRENUOUS TASK. MOREOVER, THERE HAVE BEEN SEVERAL OTHER INTERMEDIATE SUMMARIES AND SUMMARY TABLES ALL ALONG THE WORKSHOP; ONE MORE, 3-DIMENSIONAL SUPER-SUMMARY WOULD BE BORING AND USELESS.

I HAVE TRIED INSTEAD TO SORT OUT FROM THE CONTRIBUTIONS THOSE SUGGESTIVE OF STILL OPEN PROBLEMS OR POSSIBLE INNOVATIVE SOLUTIONS TO THE CENTURY-OLD PROBLEM OF PROPORTIONAL COUNTER AGING. IN DOING THIS SELECTION, I HAD TO NEGLECT SOME VERY GOOD WORKS, PARTICULARLY CONCERNING THE SUCCESSFUL DESIGN AND OPERTATION OF LARGE EXPERIMENTS; I APOLOGIZE IN ADVANCE FOR ALL OMISSIONS. THE READER WILL FIND THESE CONTRIBUTIONS IN THE DETAILED TALKS.



THE BANANA PEEL

DETECTORS AGING

PHYSICS or BIOLOGY ?

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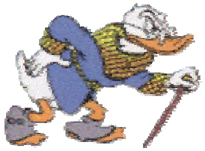
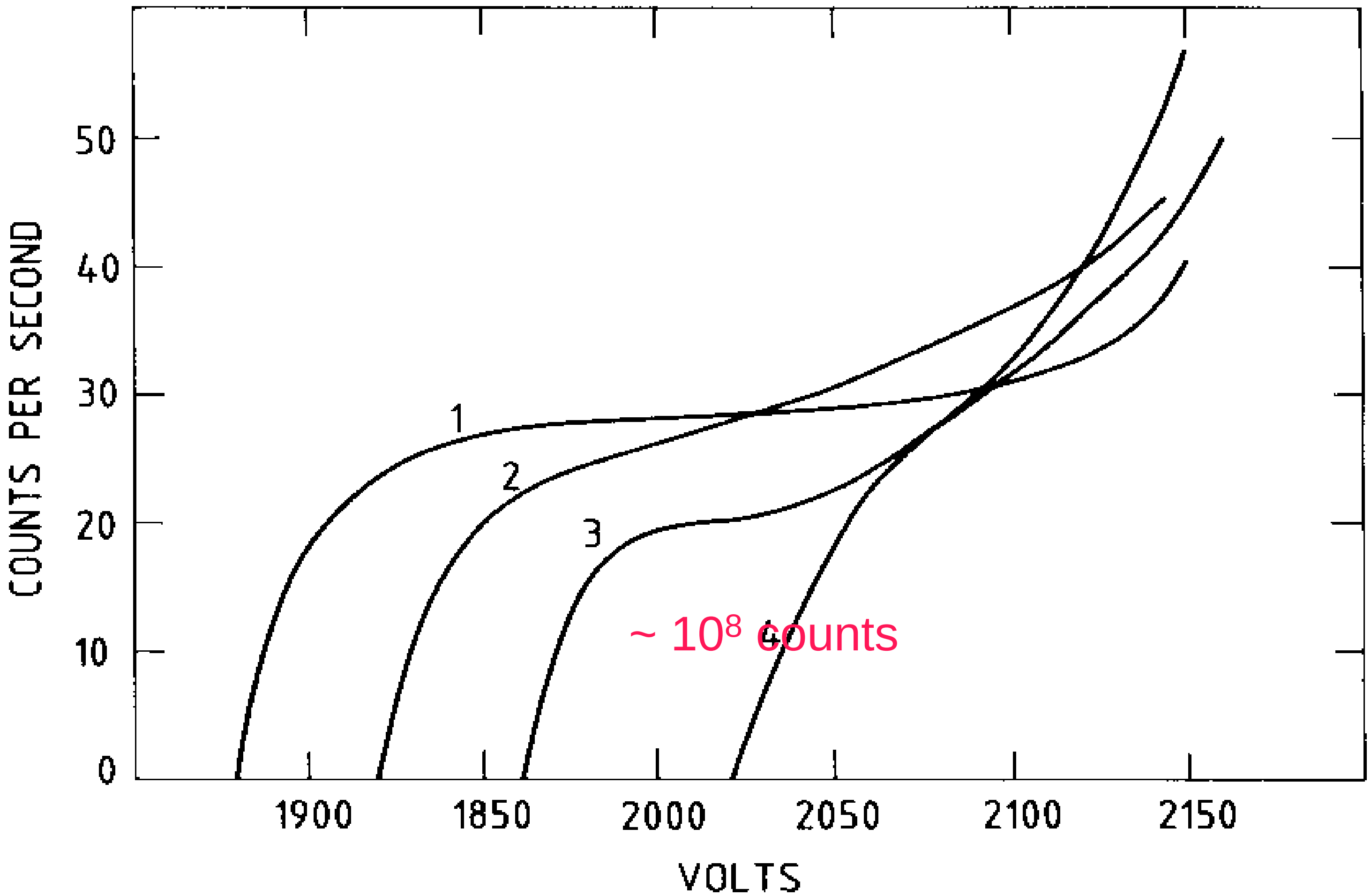


EARLY WARNINGS 1:
DEGENERACY OF GEIGER COUNTERS:



Gas filling: pure CH4

Heavy deposits observed on anodes

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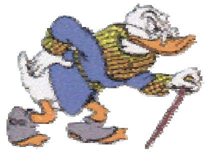
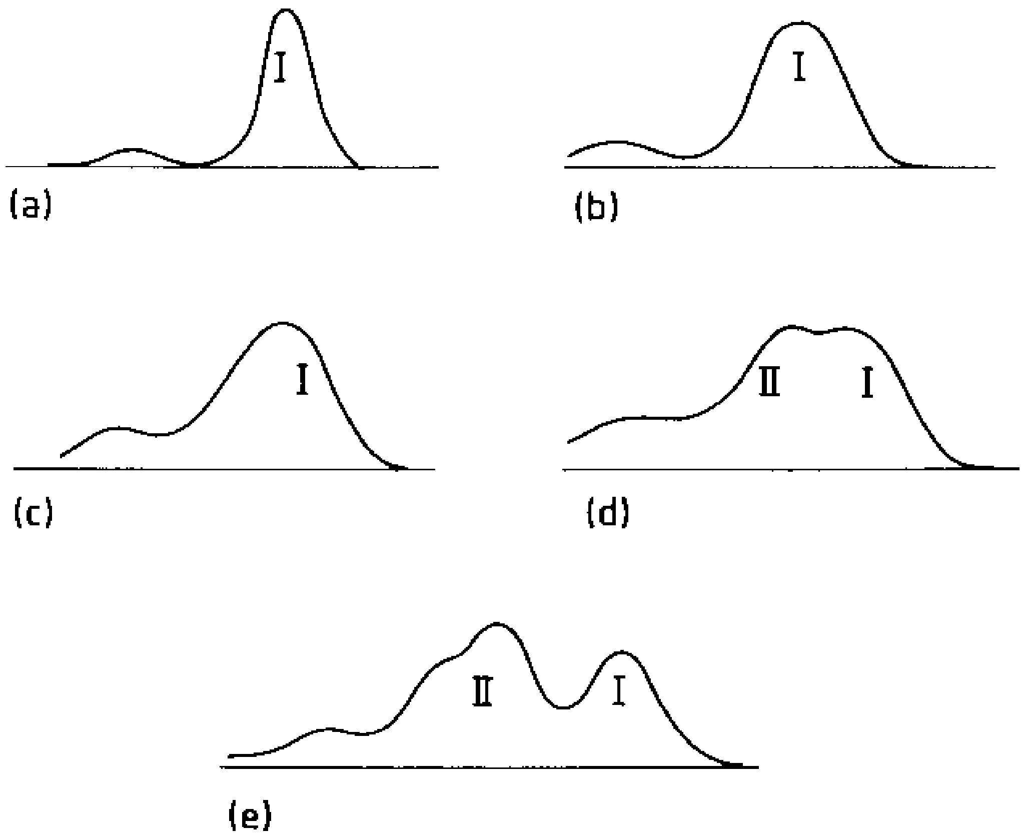


AGING 2001

E. C. Farmer and S. C. Brown, Phys. Rev. 74 (1948) 902

EARLY WARNINGS 2:
DETERIORATION OF PROPORTIONAL COUNTERS WITH IRRADIATION:

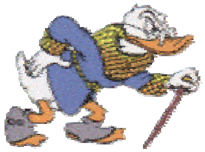


Ar-CH4 90-10
12.µm anode wire Ø

C- rich deposits
CH-chain polymers

Increase of wire diameter for
50% gain reduction: ~ 1 µm

A. Den Boggende et al, J. Scient. Instr. Ser. 2 Vo.l 2 (1999) 701

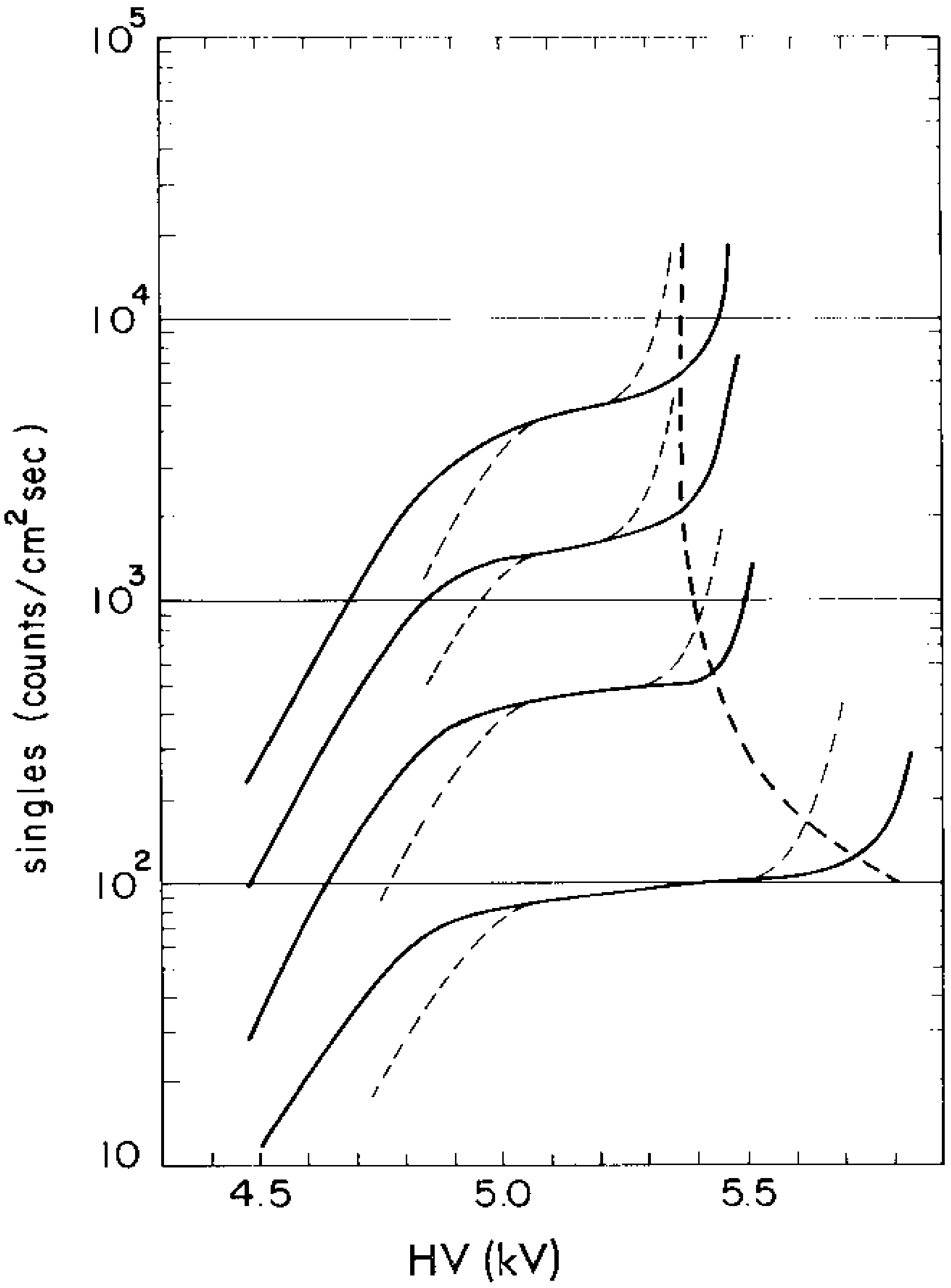


DEGRADATION OF MWPCs (AGING)

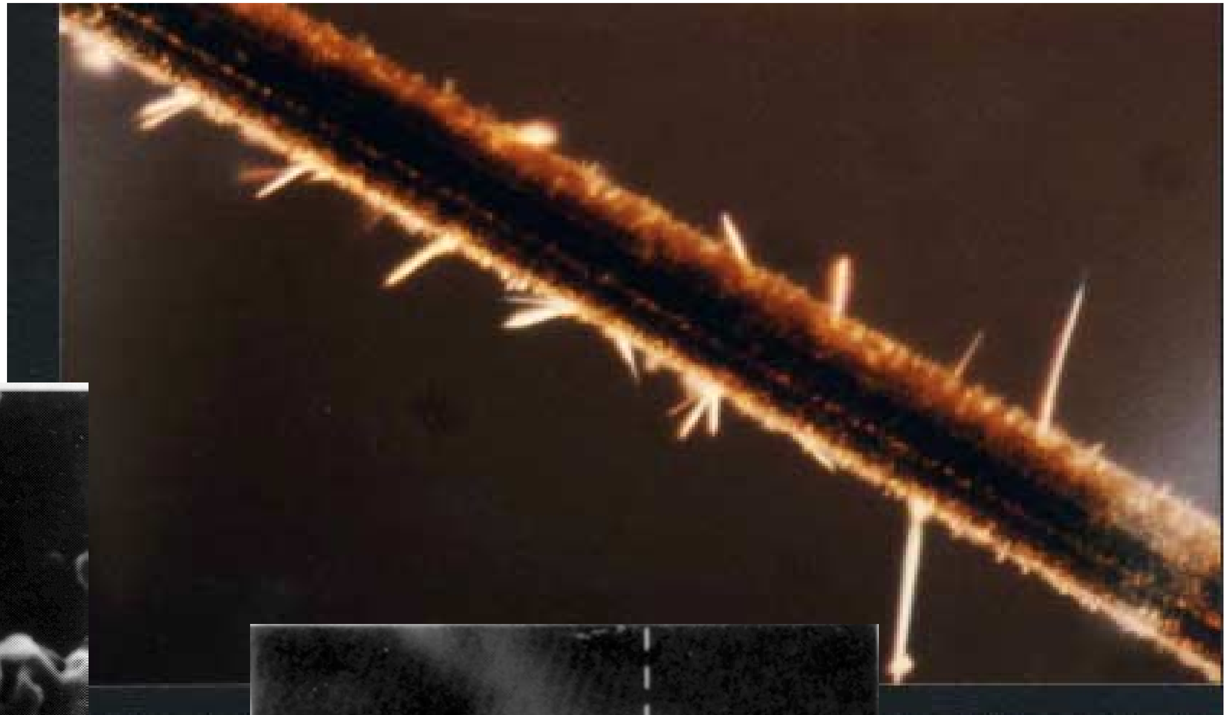
RATE-DEPENDENT SHIFT OF COUNTING RATE AND DISCHARGE VOLTAGE

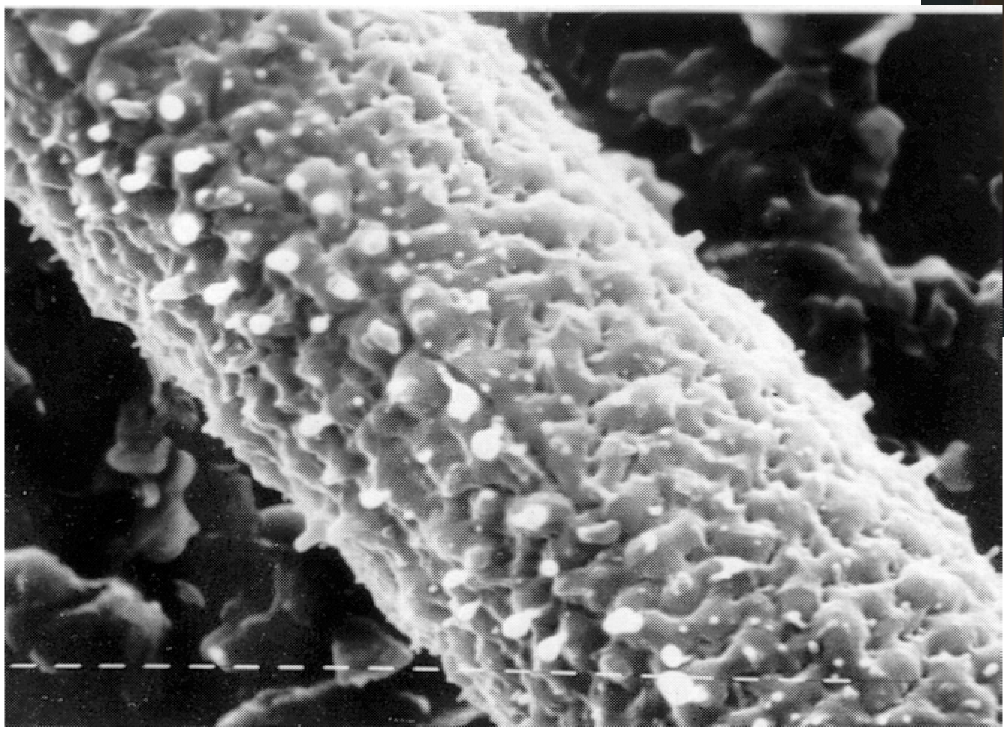
Anode wire deposits:
Lower gain
Cathode deposits:
Electron emission (Malter effect)

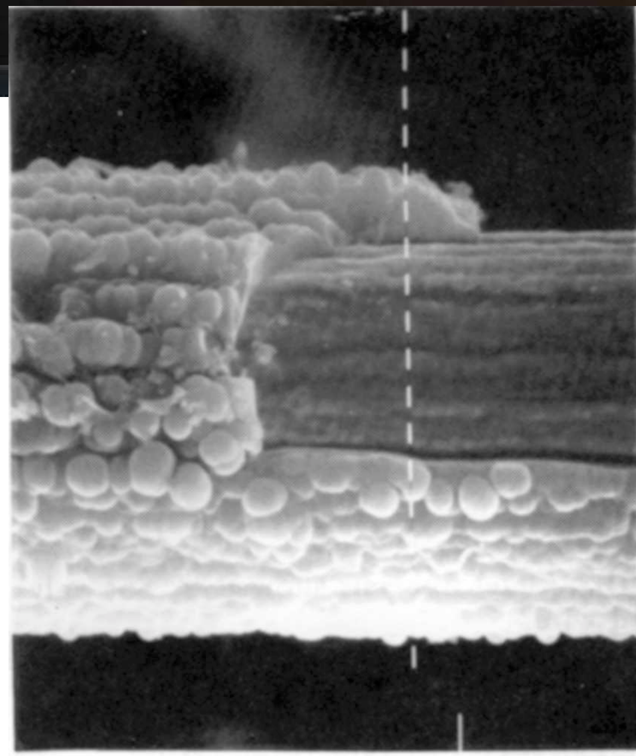
G. Charpak et al,
Nucl. Instrum. Methods 99 (1972) 279

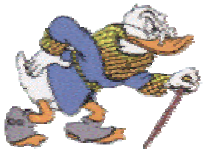


THE ANODE WIRE DEPOSITS SAGA



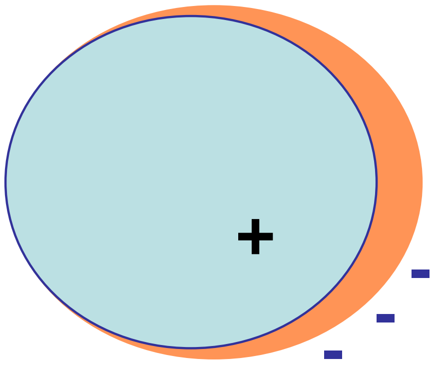






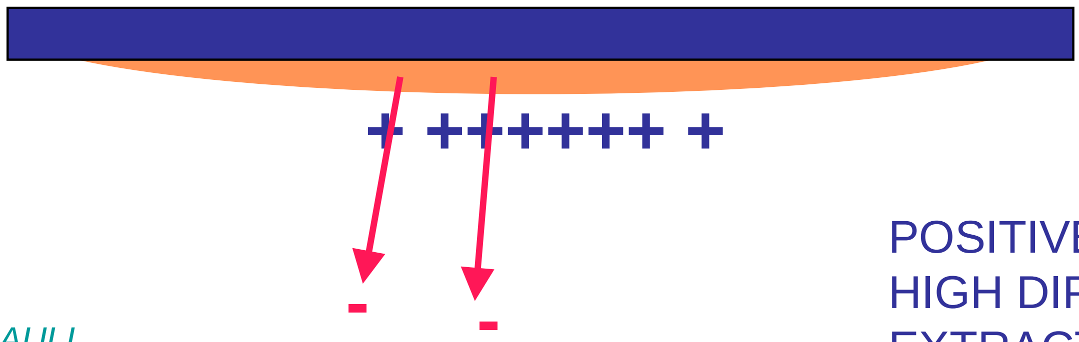
DEPOSITS

ANODE WIRE DEPOSITS DECREASE THE GAIN:

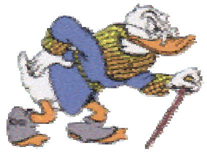


DIRECTLY (CONDUCTING DEPOSIT)
OR INDIRECTLY (DIPOLE CHARGING UP)

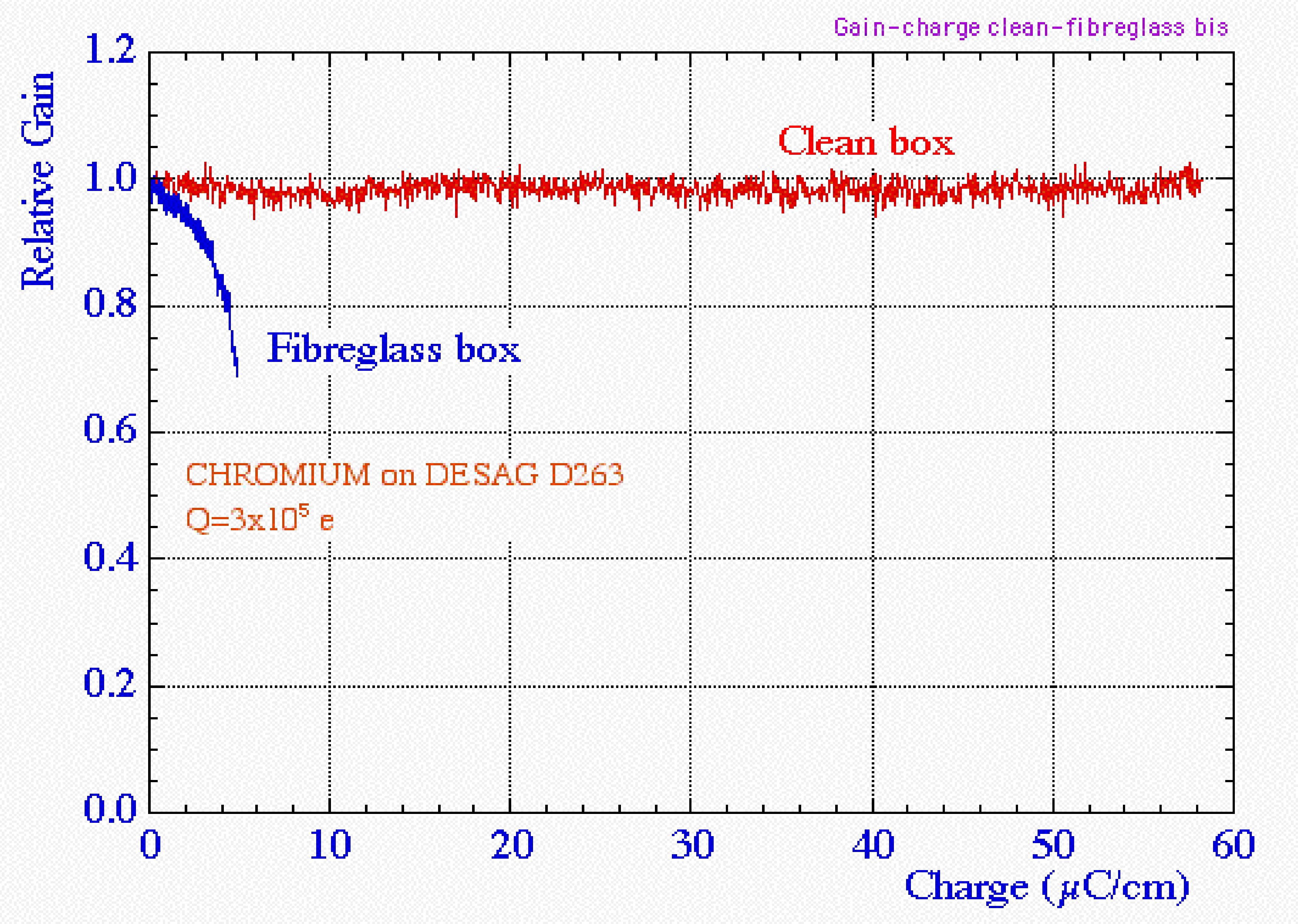
CATHODE DEPOSITS INDUCE DISCHARGES:



POSITIVE IONS ACCUMULATION CREATES HIGH DIPOLE FIELD, INDUCING ELECTRON EXTRACTION (MALTER EFFECT)

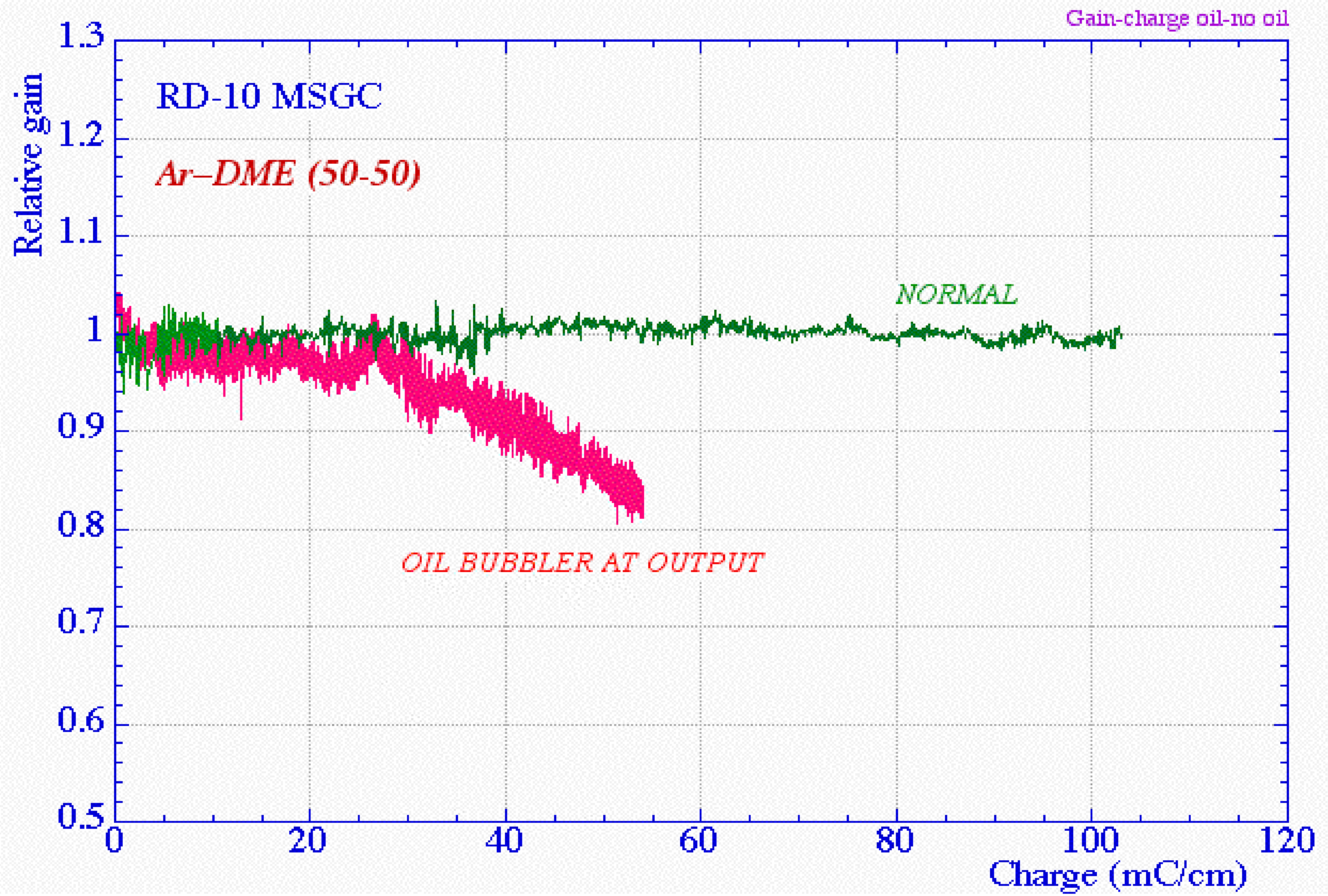


MSGCs: A VERY EFFICIENT POLLUTION DETECTOR!

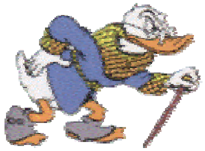


R. Bouclier et al, Nucl. Instrum. Methods A 381 (1996) 289

MSGCs: EFFECT OF OIL BUBBLER

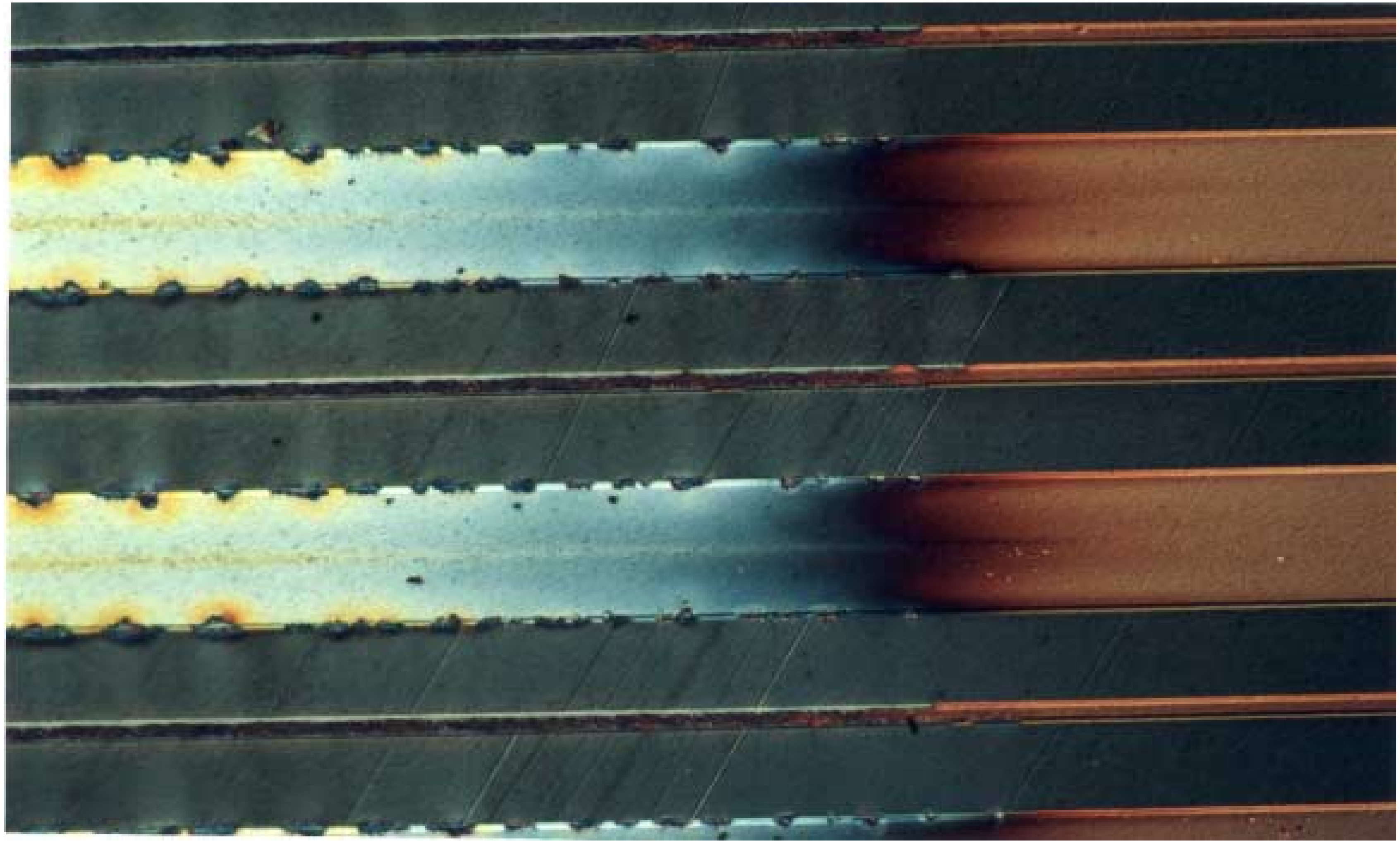


B. Boimska et al, Nucl. Physics B (Proc. Suppl.) 61 B (1998) 498



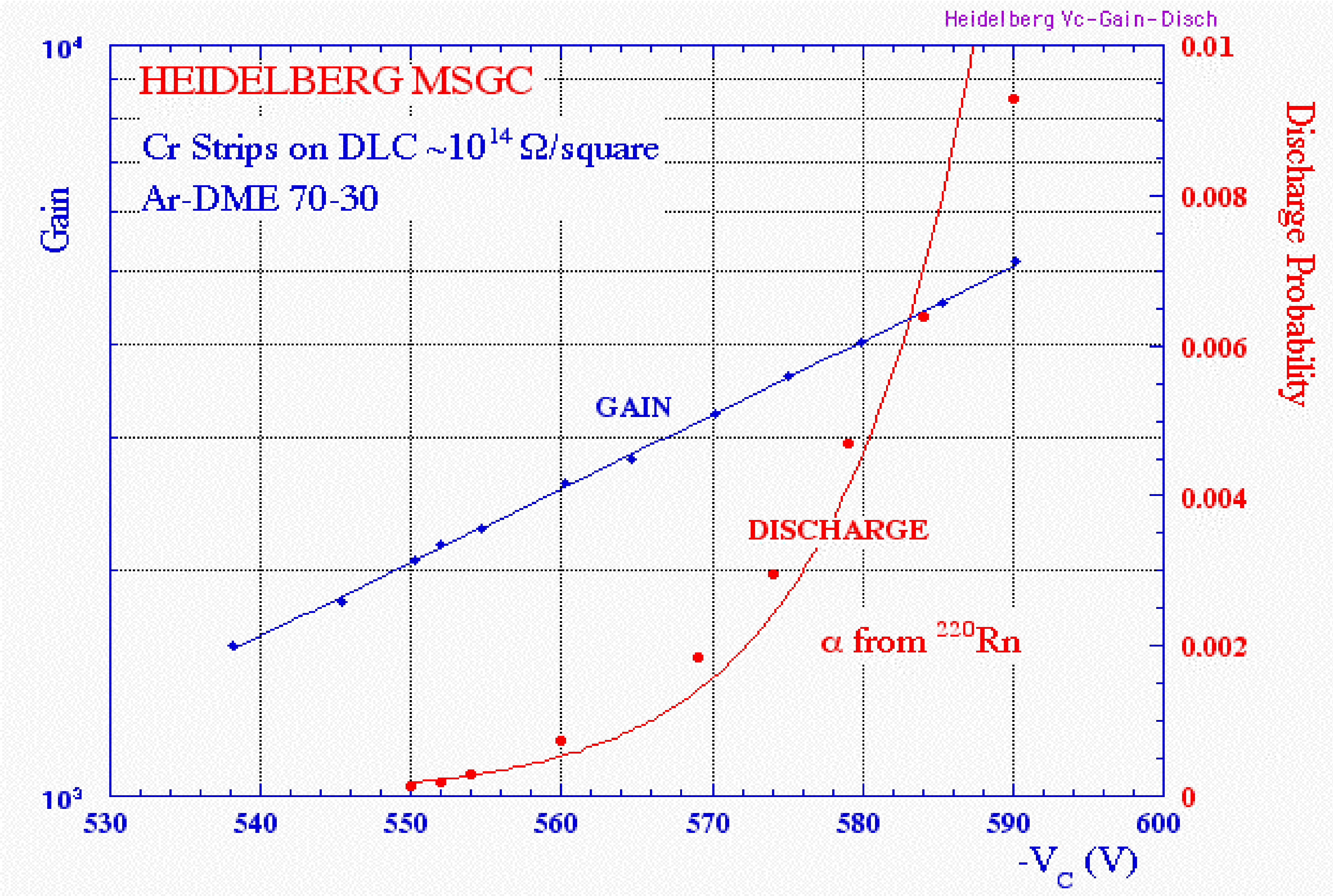
MICRODISCHARGES

AGING OF MSGCs POLYMER COATING, CATHODE EDGE EROSION

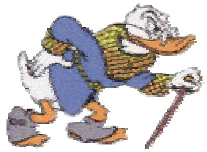


R. Bouclier et al, Nucl. Instrum. Methods A381(1996)289

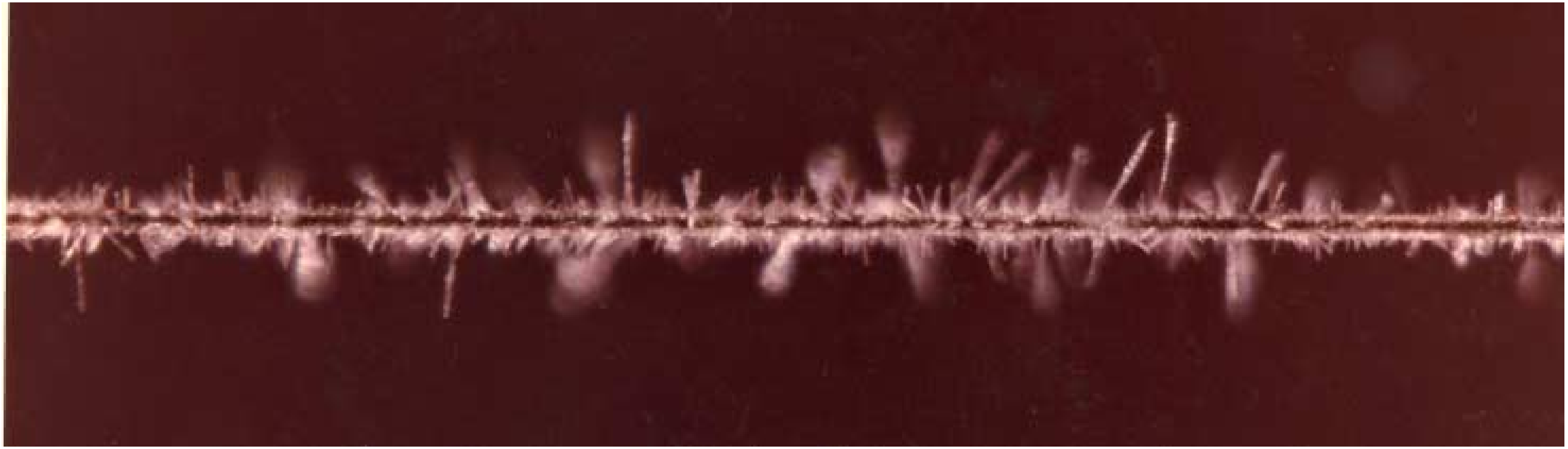
MSGCs: DISCHARGES INDUCED BY HIGHLY IONIZING PARTICLES



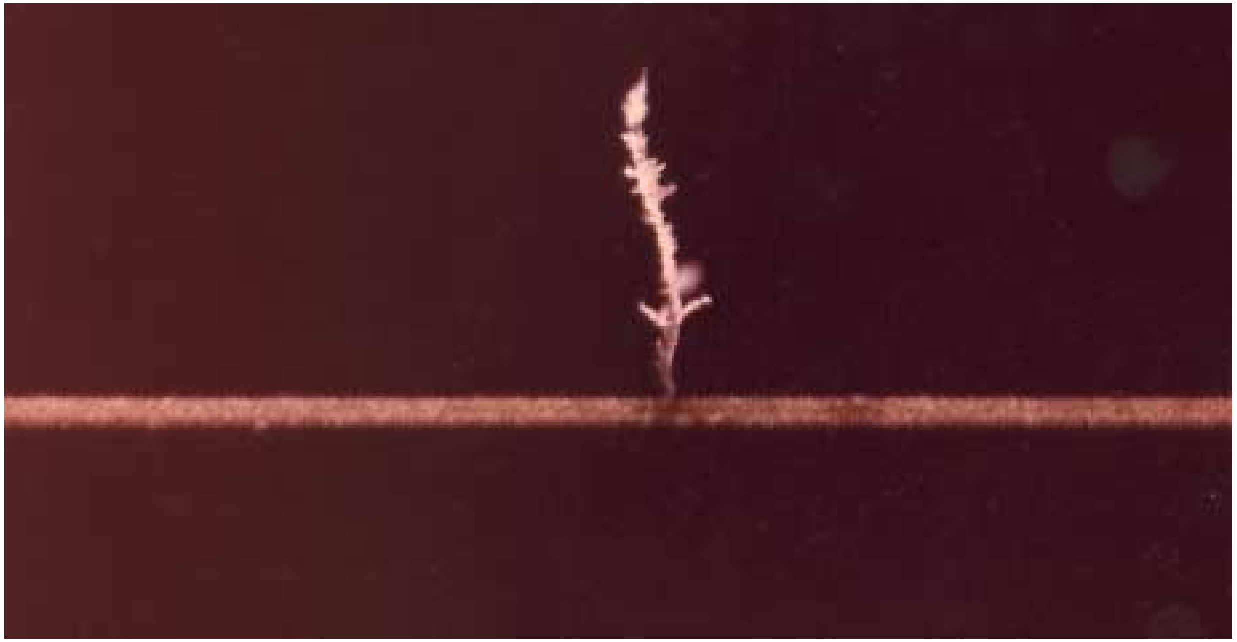
A. Bressan et al, Nucl. Instrum. Methods A424(1999)321



ANODE WIRE "HAIR": EFFECT OF MICRO-DISCHARGES?



TOO HIGH VOLTAGE
DURING IRRADIATION?



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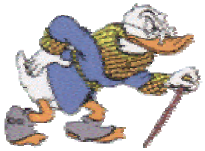

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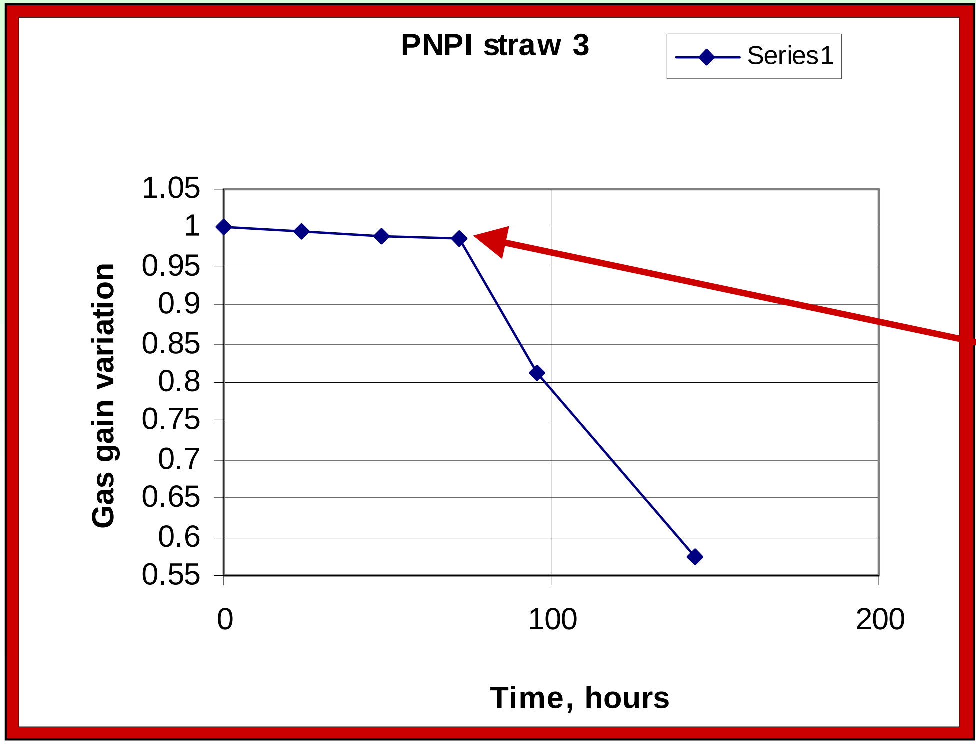
EFFECT OF ONE JOINT!

Flowmeters

- When possible, use electronic mass flowmeters with the adequate O-rings.
- Mechanical flowmeters: Cheap BUT Assembled with lubricants



ATLAS/TRT
CERN

VOEGTLIN Flowmeter
Type V100 (CERN std.)
Inserted in gas stream

M. Capeáns

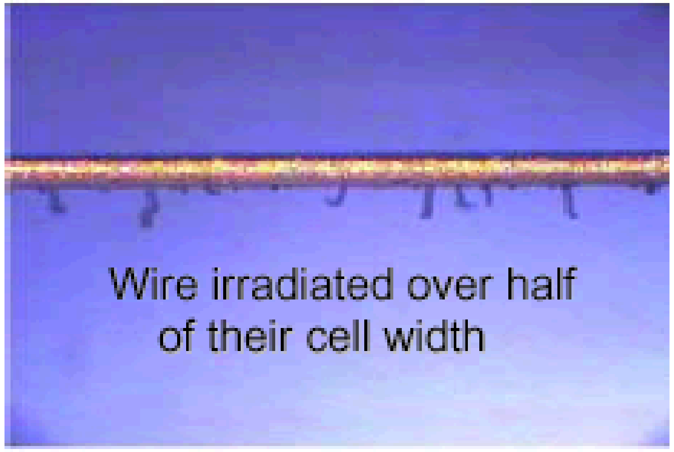
WHISKERS

Aging Studies in a 100 MeV alpha-beam
Ar/CF4/CH4(74:20:6)

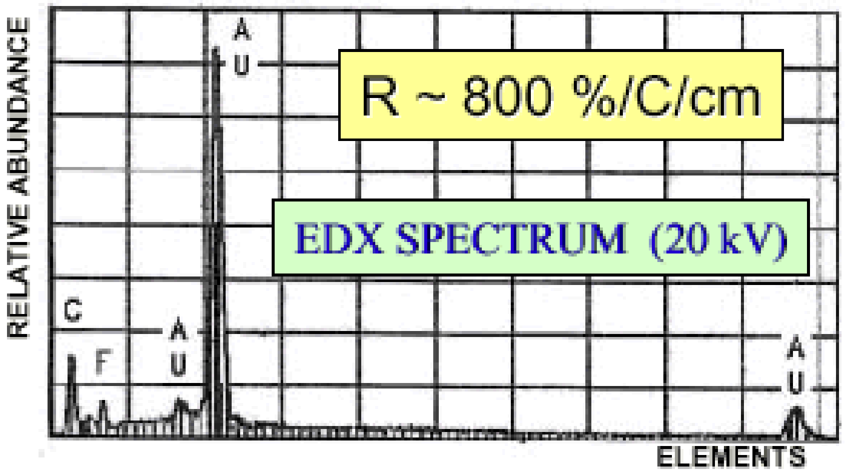
Operating conditions:

- α-beam area 8 * 8 cm^2
(Irradiation of 4 wires fully, 2 wires exposed over half of their cell width)
- HV=2.35 kV, gas gain ~4 *10^4
- current density ~ 250 - 750nA/cm
- Gas flow ~5 l/h

Total collected charge ~280 mC/cm:

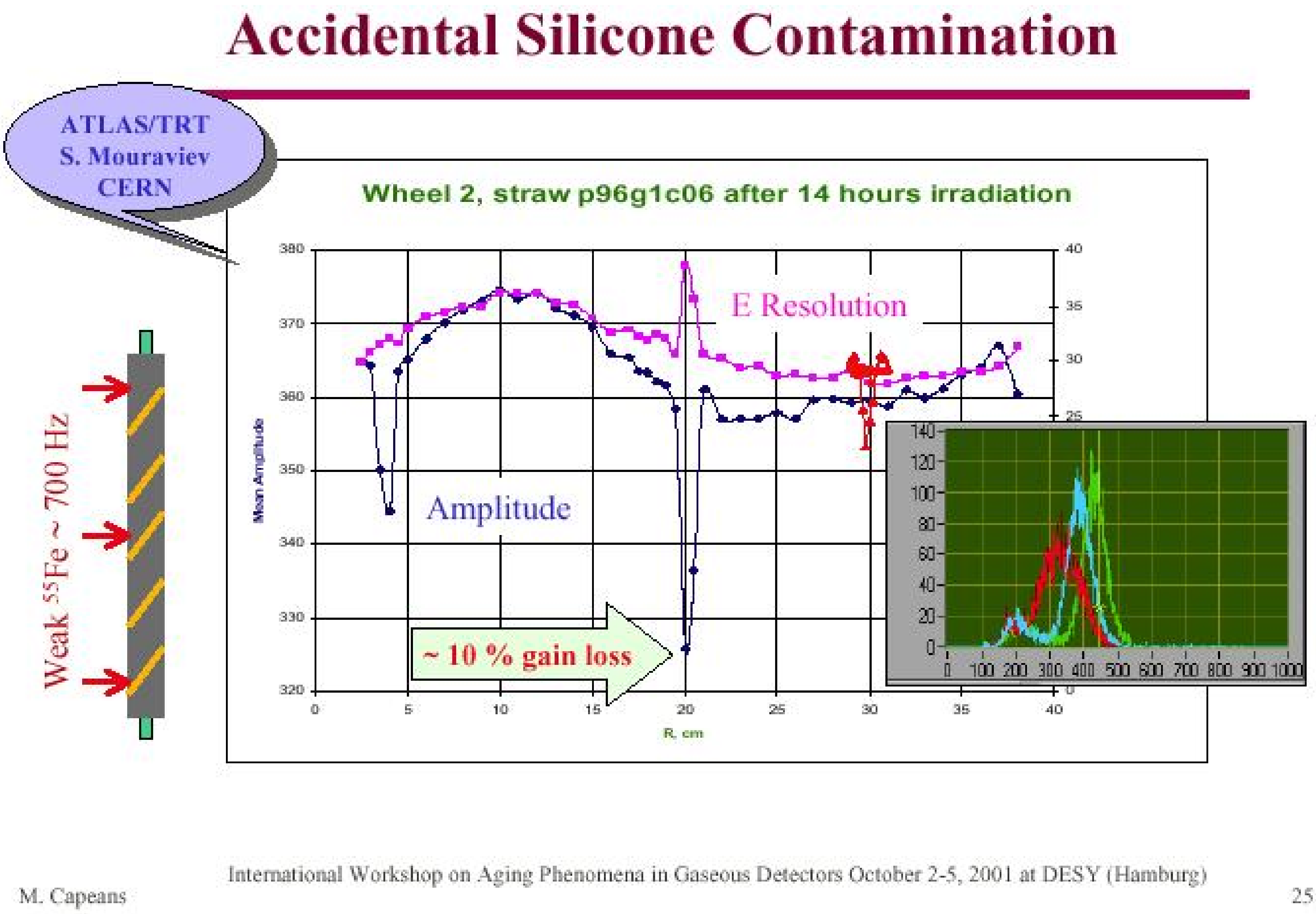


Gain reduction was observed after ~60 mC/cm

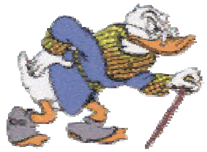


Fe^{55} source R ~ 8 %	? →	HERA-B environment	← ?	100 MeV α's R ~ 800 %

M. Titov



Accidental Silicone Contamination
ATLAS/TRT
S. Mouraviev
CERN
Wheel 2, straw p96g1c06 after 14 hours irradiation
Weak 55Fe ~ 700 Hz
E Resolution
Amplitude
~ 10 % gain loss
Mean Amplitude
R, cm
M. Capeans
International Workshop on Aging Phenomena in Gaseous Detectors October 2-5, 2001 at DESY (Hamburg)
25



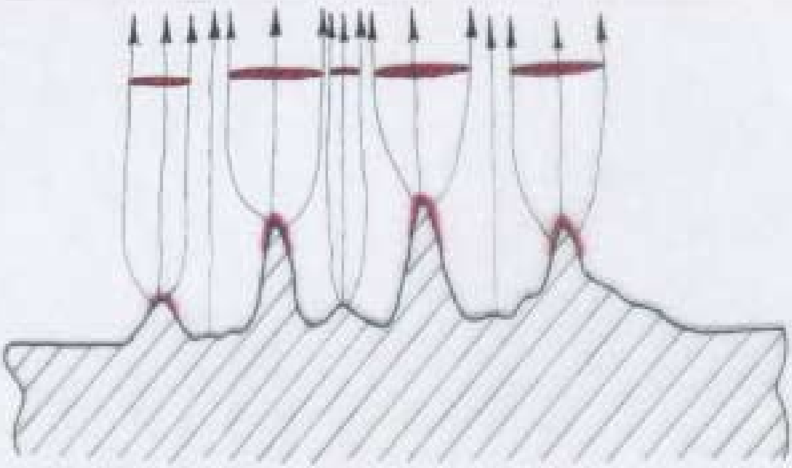
SILICA FIBRES

M. Binkley

Unprocessed gas from the new vendor: 1400 ppm ethylene, 1100 ppm propylene, 600 ppm propane. Wire aged to 30% gain loss (about 0.13 coulomb/cm).

WHISKERS GROWTH

Model of film creation and growth



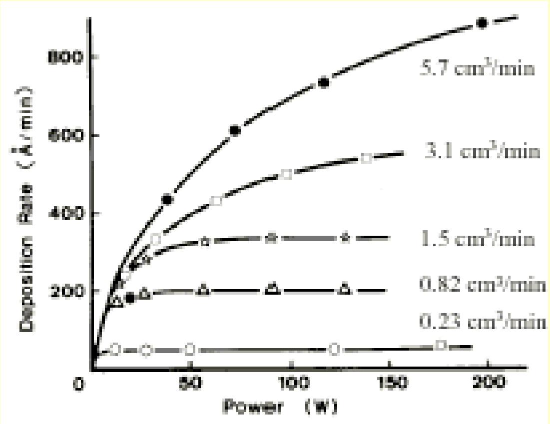
1. The main part of electrons and negatively charged polymers from avalanche reach sense wire surface on peaks and process of polymer film formation start on the surface of peaks in the regions with highest electric field strength. $(S_{eff} << S_{wire})$

Polymers fibers on early stage of growth

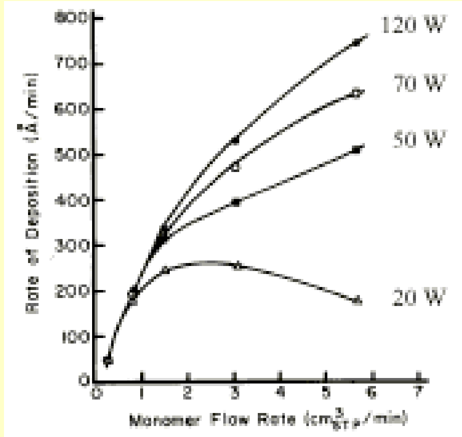
V. Blinov

DEPENDENCE OF PLASMA POLYMERIZATION 1

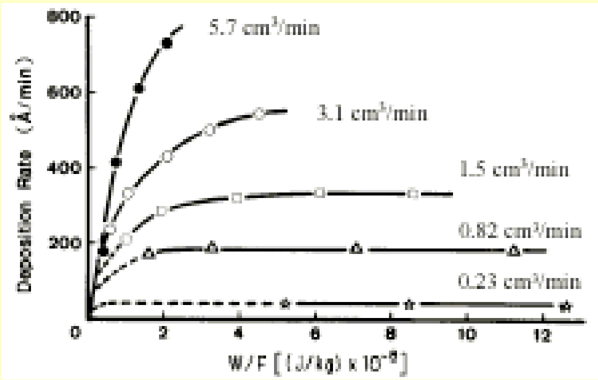
Dependence of deposition rate on operational parameters and domains of plasma polymerization



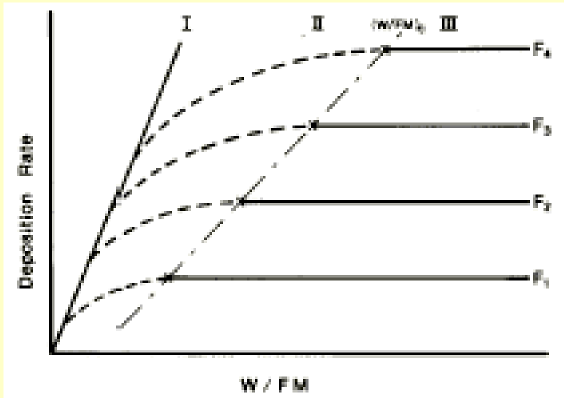
Dependence of deposition rate of plasma polymer of tetramethyldisiloxane on discharge wattage at the flowing monomer flow rates (cm³/min).



Dependence of deposition rate of the plasma polymer of tetramethyldisiloxane on discharge power at a fixed flow rate



Dependence of deposition rate of the plasma polymer of tetramethyldisiloxane on W/FM at different flow rates

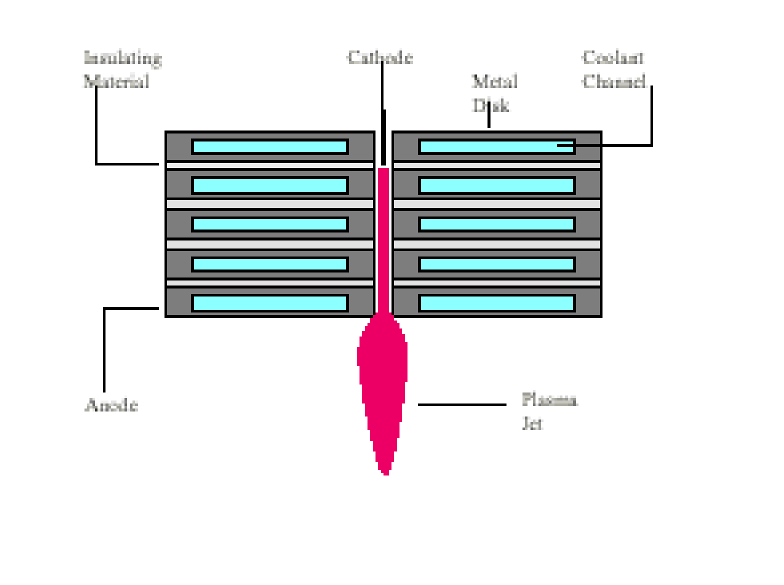


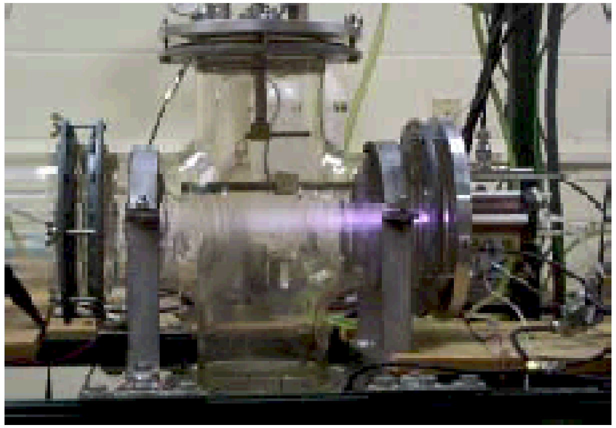
Dependence of plasma polymerization domains on deposition rate and W/FM at various flow rates.

H. Yasuda

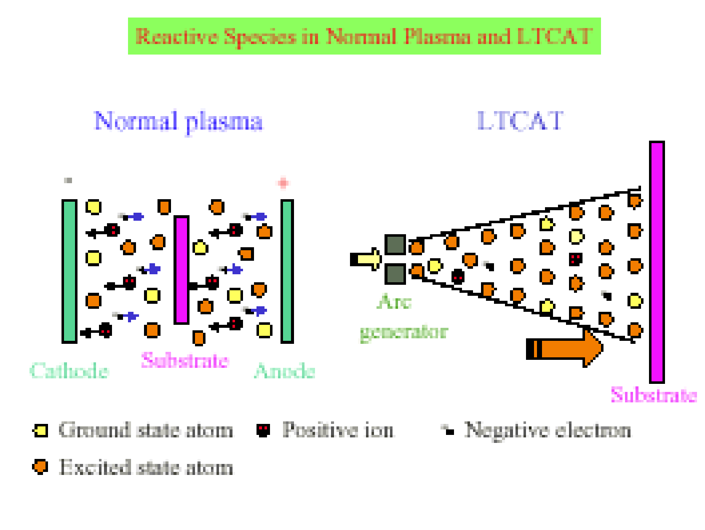
DEPENDENCE OF PLASMA POLYMERIZATION 2

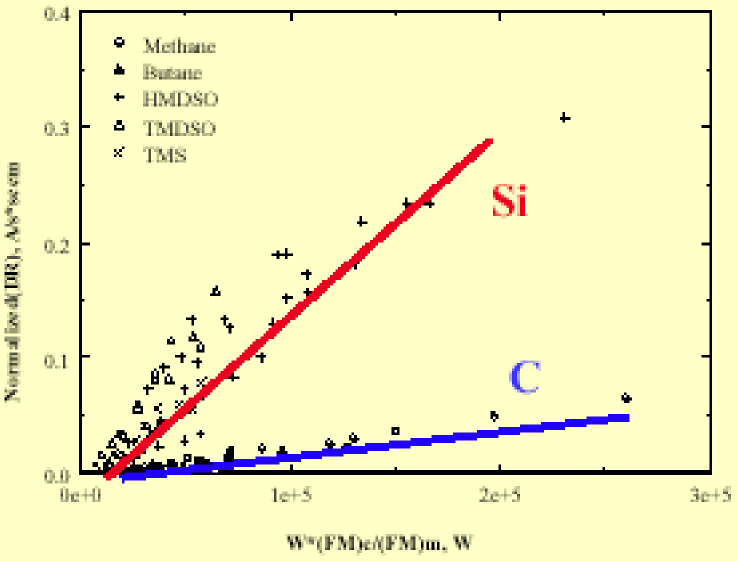
Each Element Has Its Own Characteristic Polymerization Rate





Cascade Arc Reactor



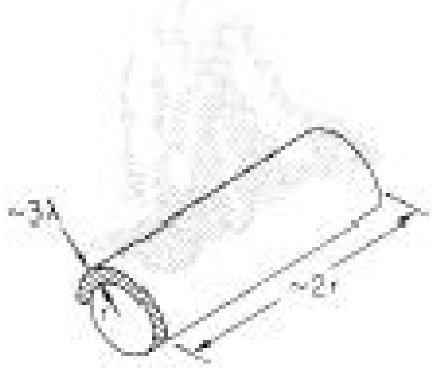


H. Yasuda

WIRE CHAMBERS VS PLASMA CHEMISTRY

J. Va'vra, DESY workshop, October 2, 2001

Wire Chambers vs. Plasma Chemistry



λ - Mean free path between the electron collisions (~1μm)

τ - Mean free time between collisions (~1ps)

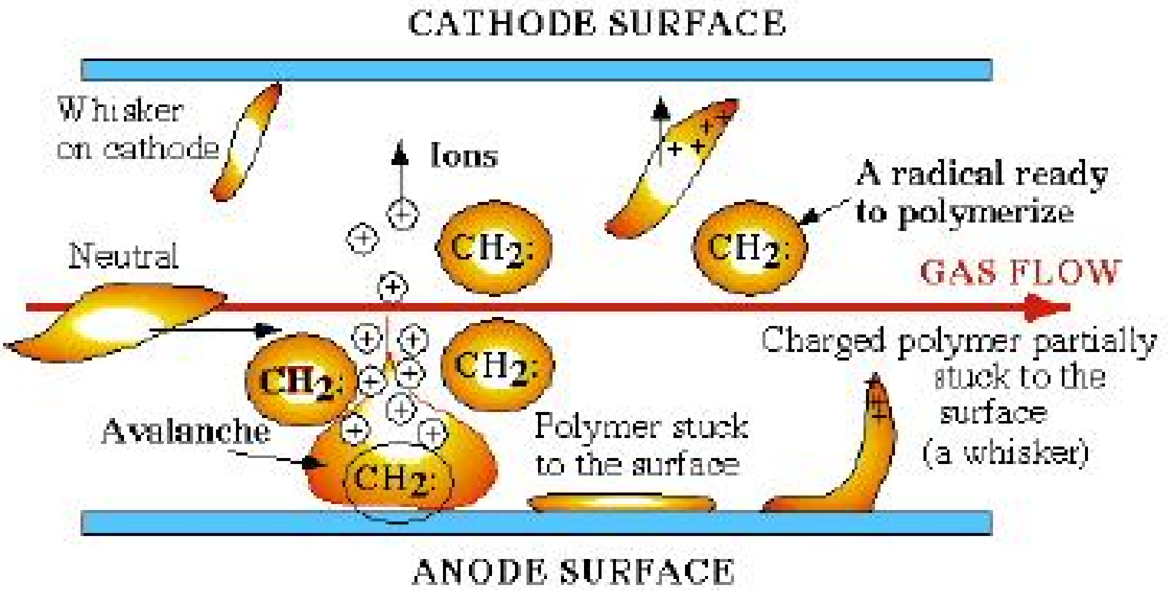
Parameter	Plasma Chemistry [1]	Wire Chambers
Average Electron Energy	1 – 10 eV	5 – 10 eV (Ar)
Effective Volume	100 – 1000 cm^3	10^{-10} – 10^{-8} cm^3
Typical Electron Density	10^7 – 10^{12} e/cm^3	10^{14} – 10^{17} e/cm^3/avalanche
Typical Power Density	0.01 – 10 $watts/cm^3$	10^8 – 10^{12} $watts/cm^3$/avalanche
Gas Pressure	0.01 – 10 Torr	$\geq$ 760 Torr
E/p	10 – 50 V/cm-Torr	100 – 400 V/cm-Torr (on the surface of the anode)
Type of Electric Field	RF	DC
Typical Gas Flow	~ 1 Gas Volume/1-10 minutes	~ 1 Gas Volume/1-8 hours

(J.Va'vra, NIM A252(1986)547)

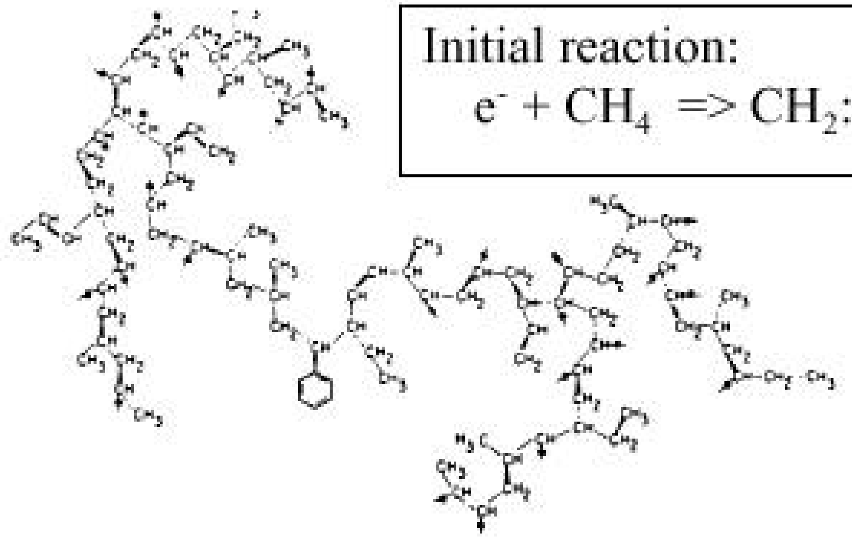
- Parameters are vastly different in the two fields.
- Yet, in retrospect, some conclusions from the Plasma Chemistry proved to be directly applicable to our field. (For example, a role of H_2O, O_2 or oxygen-based additives)

POLYMERIZATION PROCESS

- Polymerization of molecules



Example of polymerization of ethylene:



Initial reaction:

$e^- + CH_4 \Rightarrow CH_2: + H_2 + e^-$

Necessary condition for polymerization:

a) e^- or γ => "Brake a covalent bond" => "Radicals"

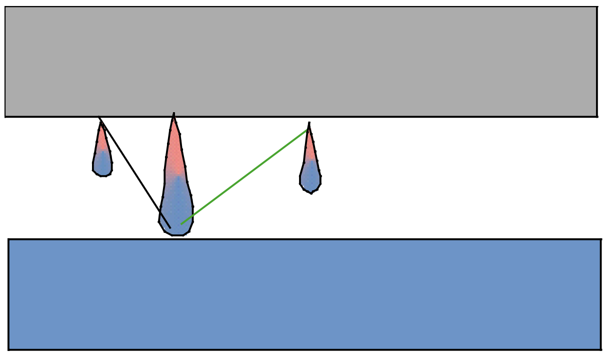
b) "Radicals" may have large dipole moments – they stick to electrodes.

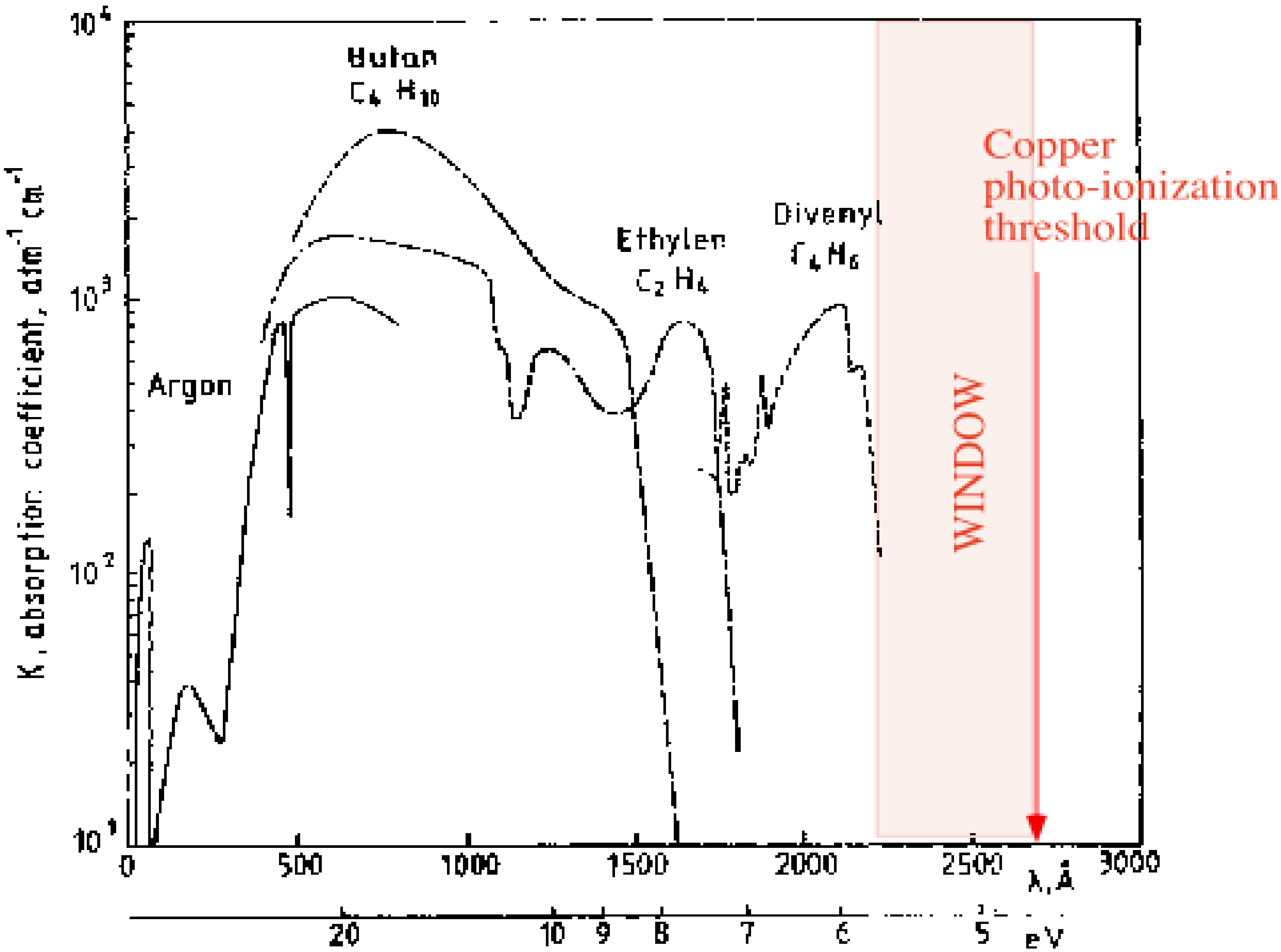
c) "Radicals" are chemically very reactive.

(A typical polymer precursor is radical of ethylene CH_2:).

PESTOV COUNTERS

SECONDARY AVALANCHE PROPAGATION (DELOCALIZATION)

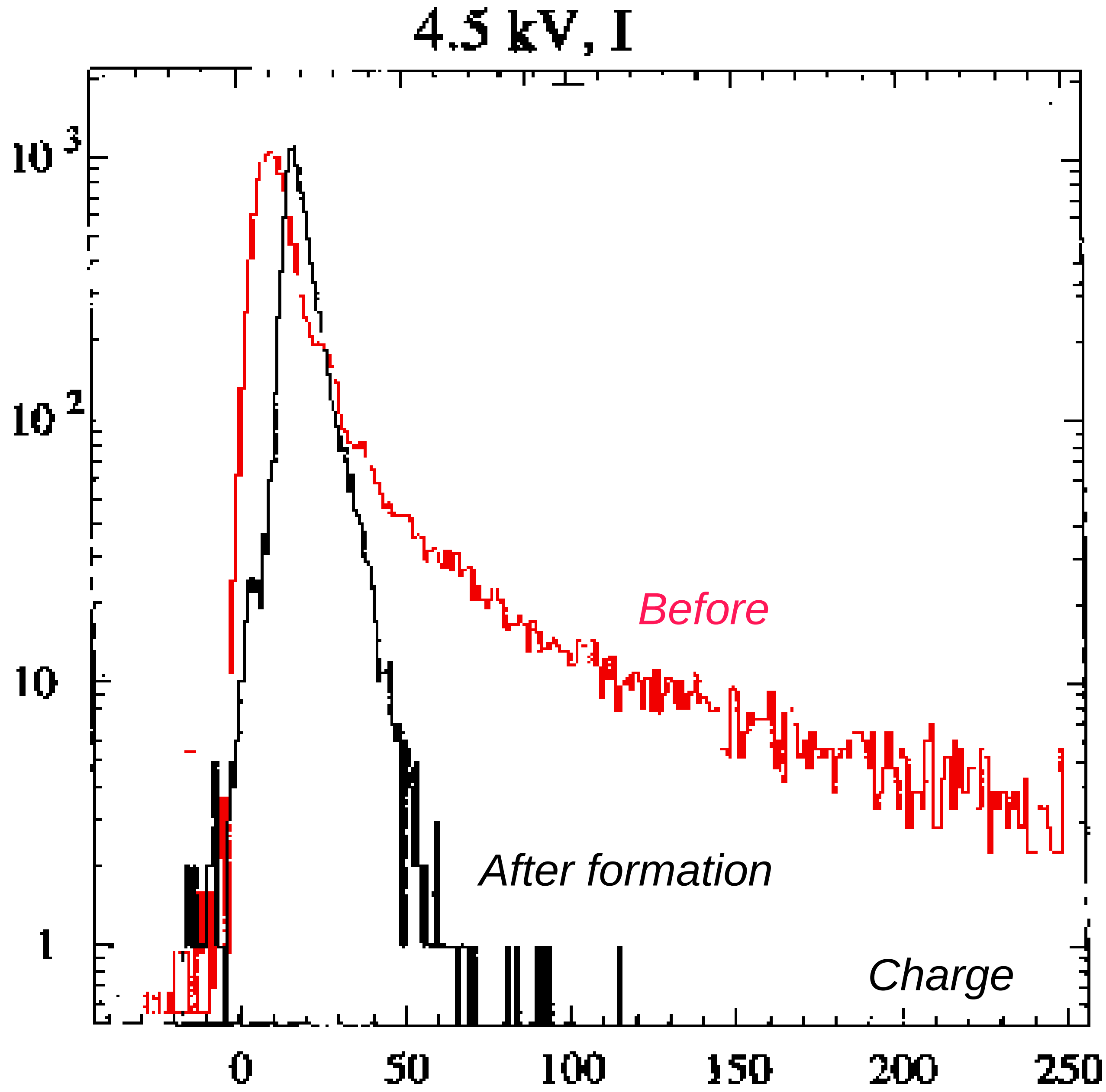




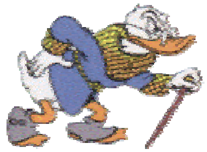
Yu. Pestov, Nucl. Instrum. Methods 196 (1982) 45
H. R. Schmidt, Nucl. Physics B (Proc. Suppl.) 78 (1999) 372

PESTOV COUNTERS: A CASE OF BENEFICAL POLYMER FORMATION

CHARGE SPECTRA
BEFORE AND AFTER
LONG-TERM
SUSTAINED
DISCHARGES
(FORMATION)



H. R. Schmidt, Nucl. Physics B (Proc. Suppl.) 78 (1999) 372



FUNDAMENTS OF AGING STUDIES

AGING DEPENDS ON TOTAL COLLECTED CHARGE Q:

$$Q = M \; R \, T \; ne$$ *(GAIN x RATE x TIME x PRIMARIES)*

Coulombs/cm of wire or strip (MWPC, MSGC)

Coulombs/ mm^2 or $/cm^2$ (PPAC, RPC, µM, GEM…)

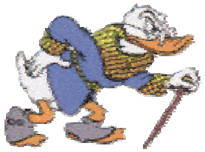
“INVARIANT” AGING PARAMETER:

$$R = -\frac{1}{Q}\frac{\Delta A}{A}$$ (J. Kadyk, ~1985)

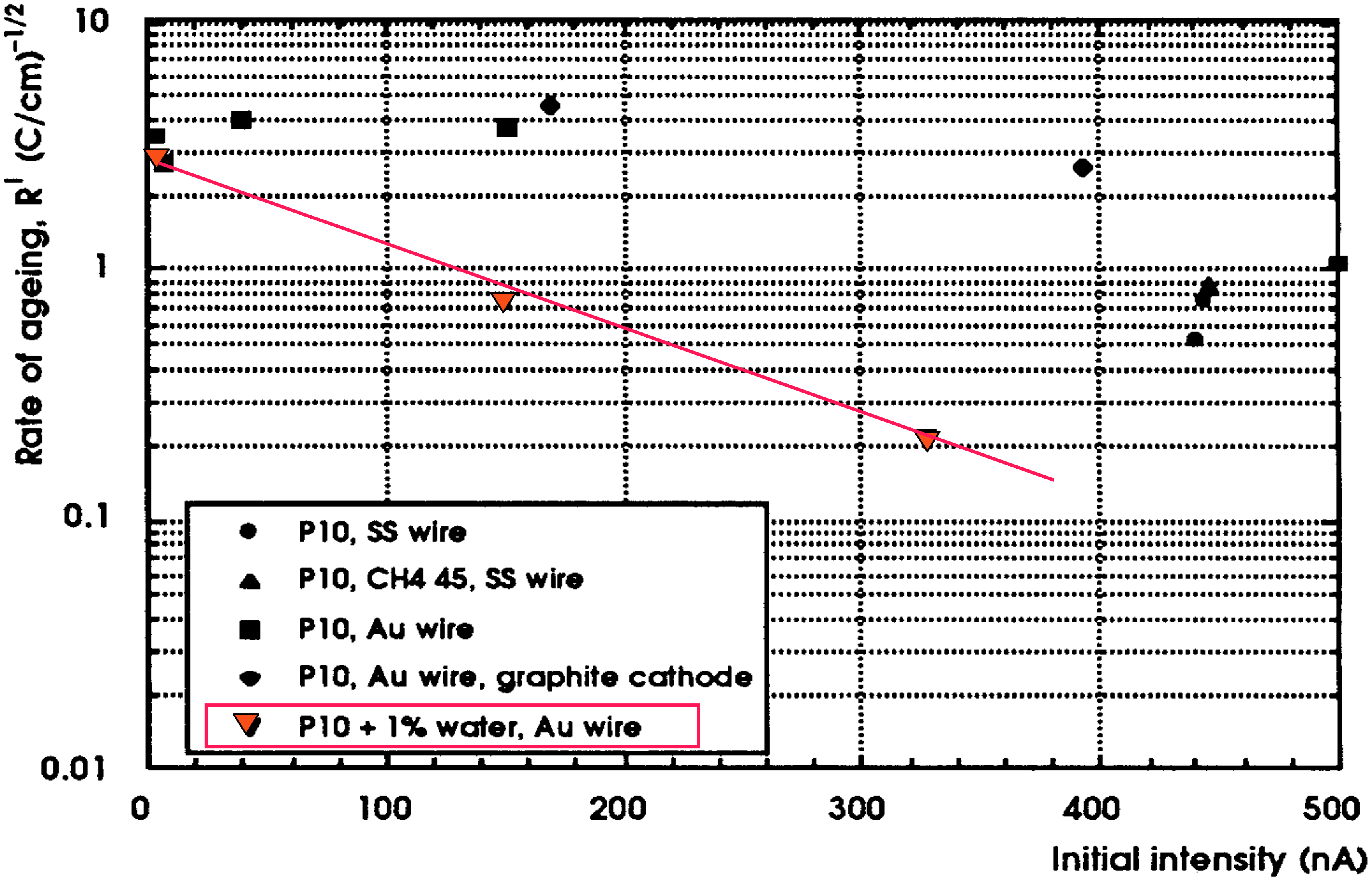
IMPLICIT ASSUMPTION:

AGING RATE DOES NOT DEPEND ON

- GAIN
- ELECTRIC FIELD STRENGTH
- DOSE RATE
- IONIZATION DENSITY
- TYPE OF PARTICLE
- GAS FLOW…



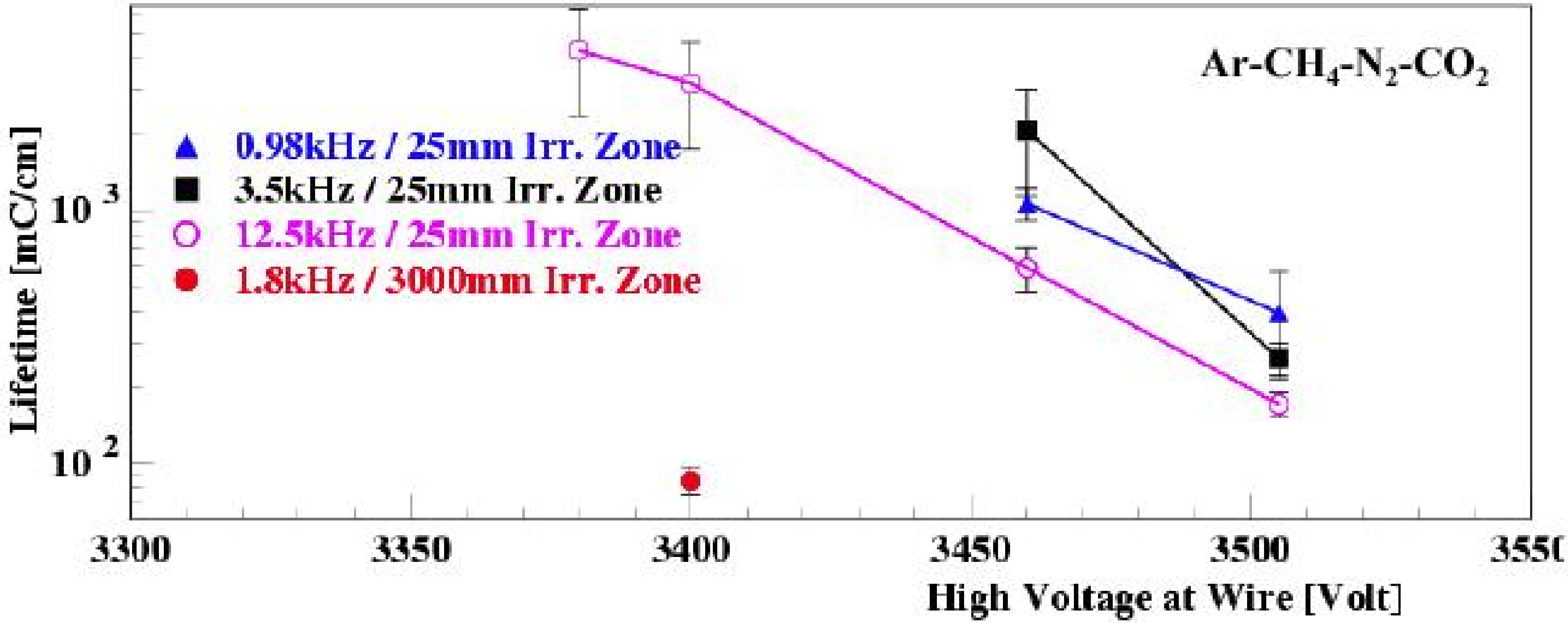
DOSE RATE DEPENDENCE



R. Bouclier et al, Nucl. Instrum. Methods A346(1994)114

AGING DEPENDENCE ON HIGH VOLTAGE

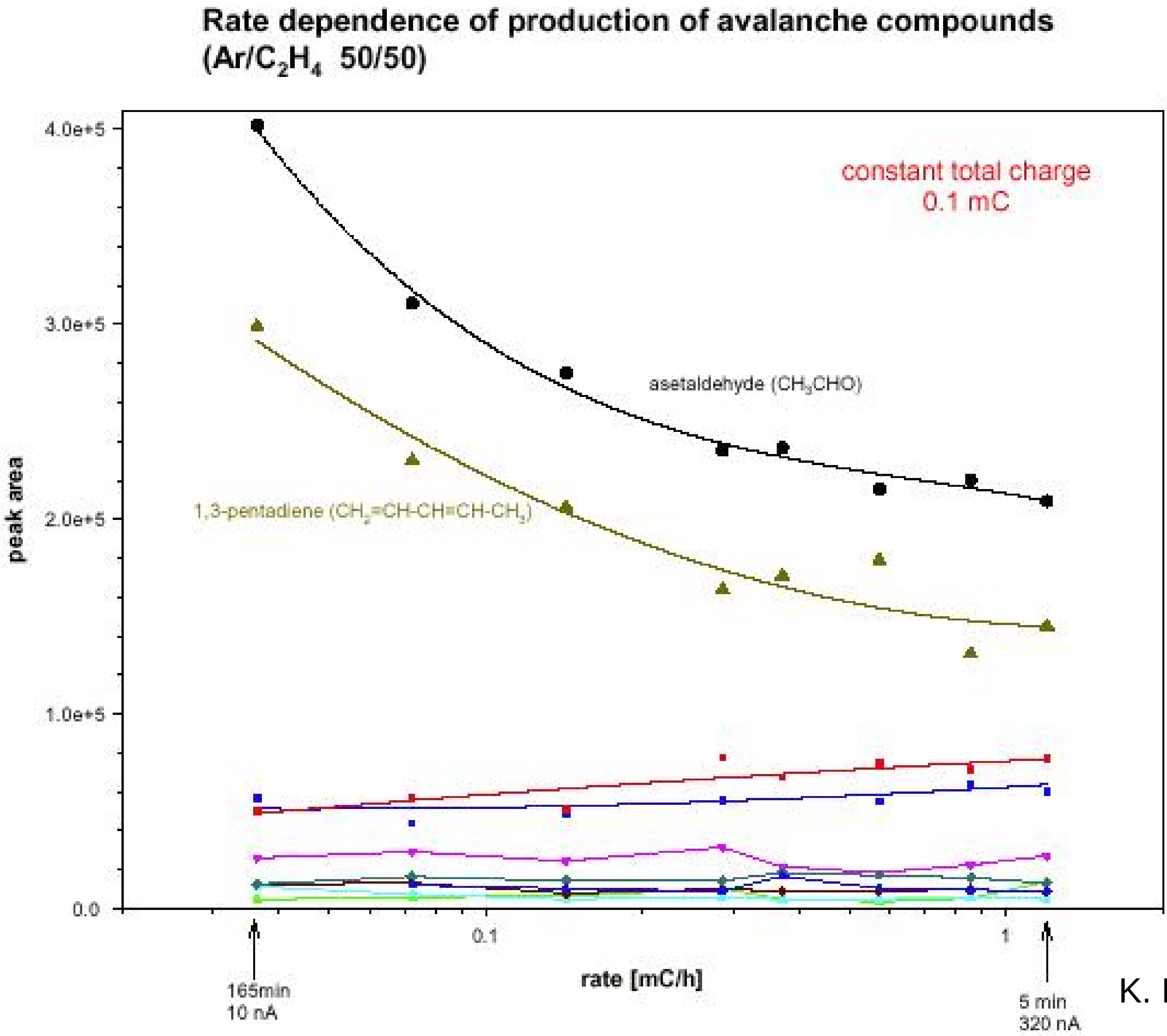
Ageing dependence on High Voltage



Lifetime = Total Charge/Length up to 70%-Level of pulse height
Equal Colors = identical parameters **except Voltage**

→ **Strong HV-Dependence** of Lifetime

POLYMERS PRODUCTION RATE

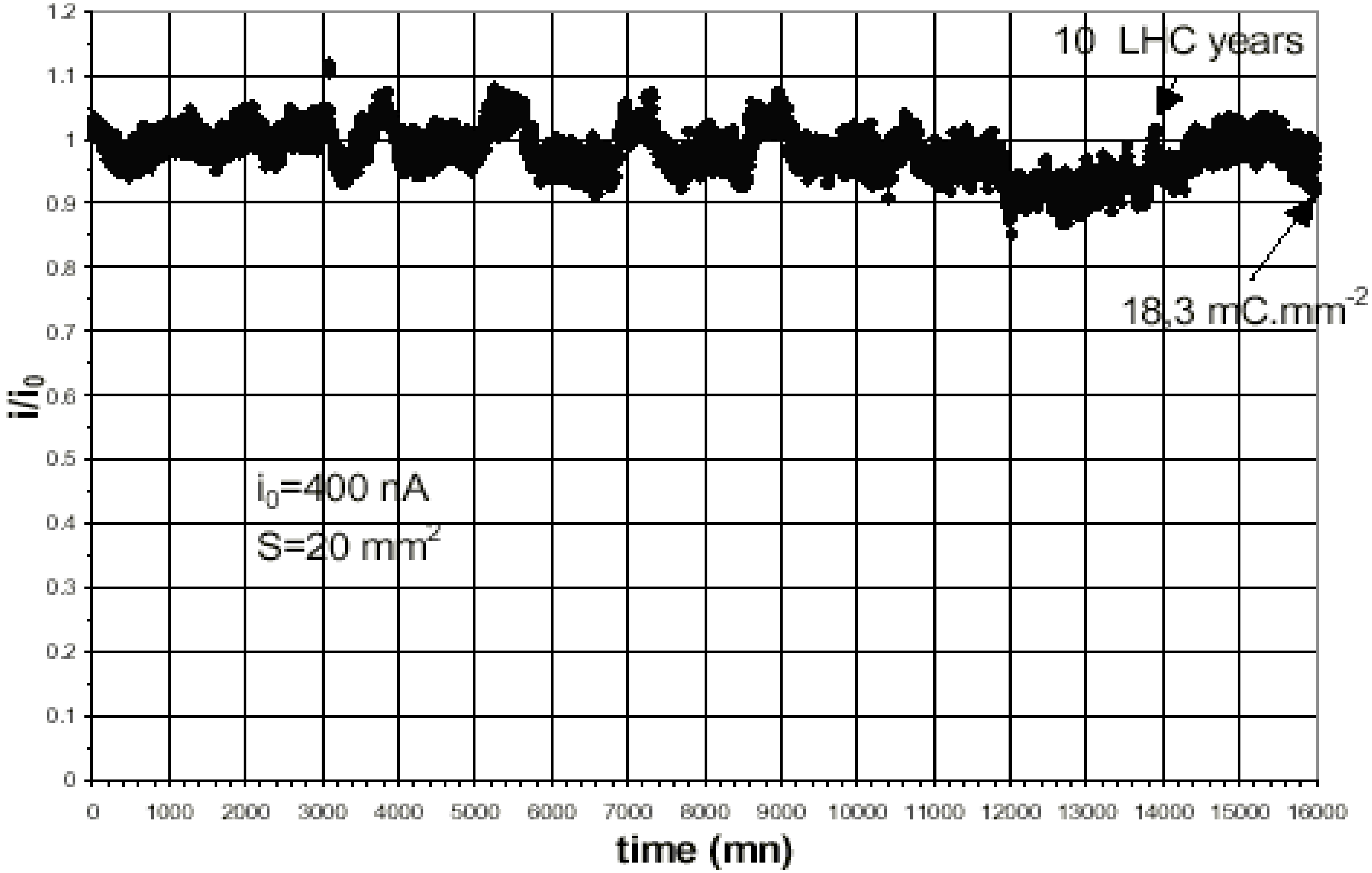


K. Kurvinen

DOSE RATES: TOO HIGH?

MICROMEGAS CURRENT DENSITY 20 nA mm^{-2}

10 LHC years in 10 days:



G. Puill et al, IEEE NS-46(1999)594

EFFECT OF IONIZATION DENSITY

CHAMBERS AGE TWO ORDERS OF MAGNITUDE FASTER WHEN IRRADIATED WITH α PARTICLES AS COMPRED TO X-RAYS (AT GAIN ADJUSTED FOR EQUAL AVALANCHE SIZE)

M. Danilov et al, ITEP 43-00

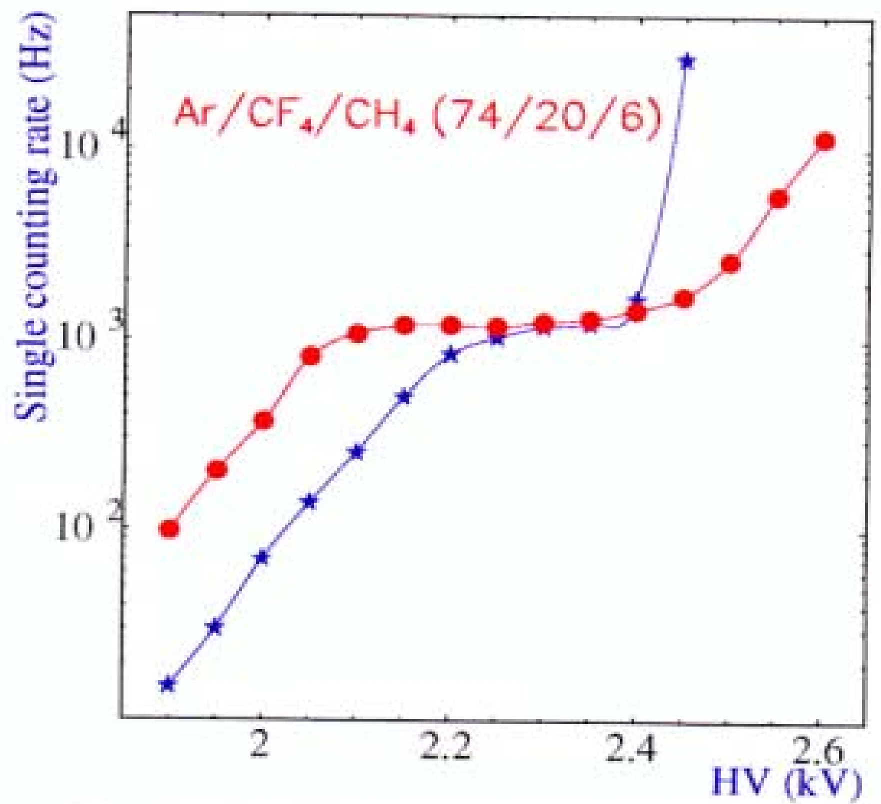
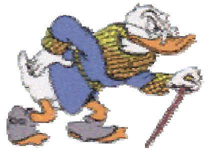


Figure 9: Singles rate curves for the 'reference wire' in the irradiated region (stars), after exposure to 60 $\frac{mC}{cm\ wire}$, and outside of it (circles).

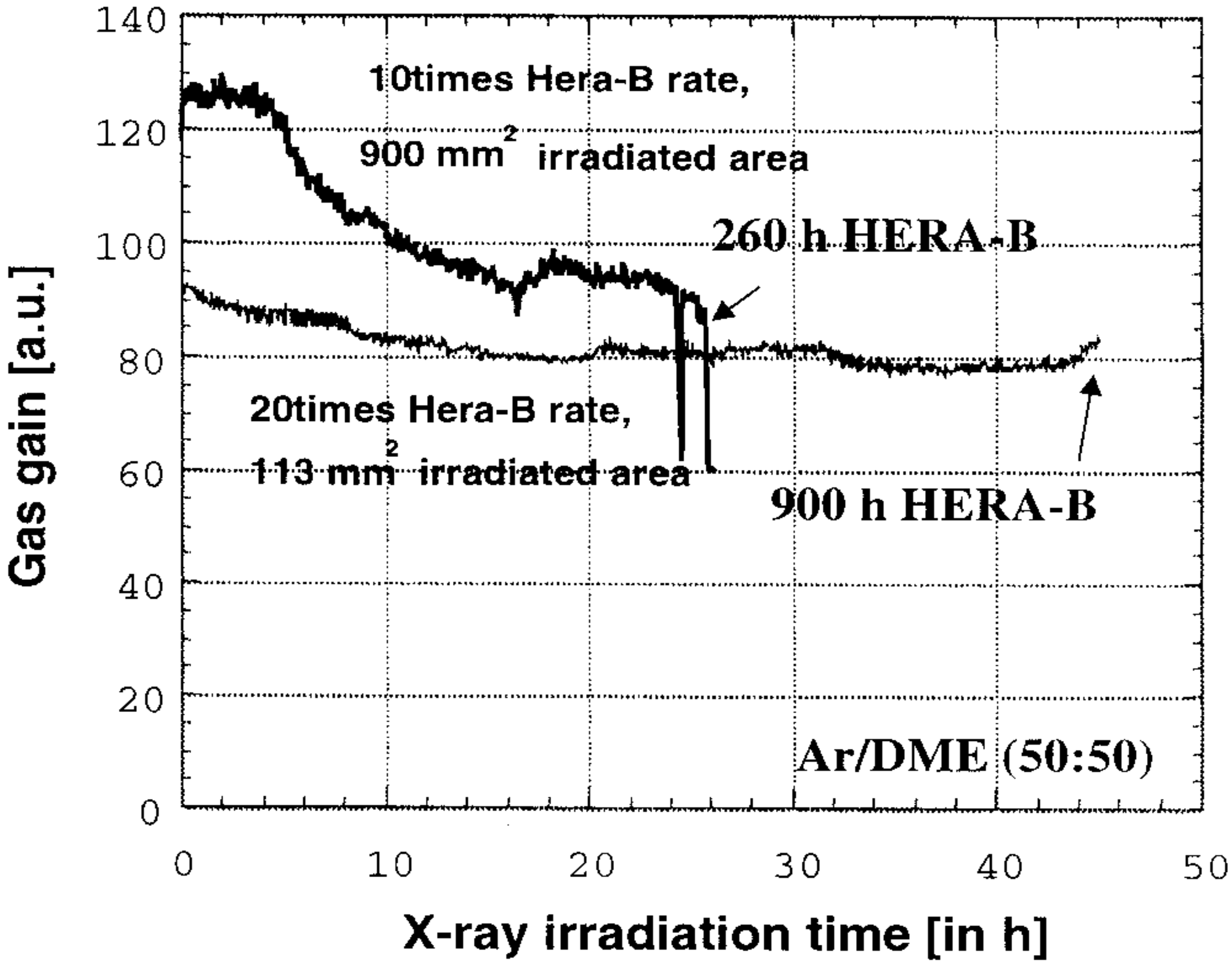


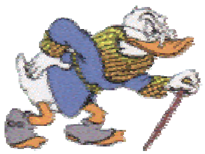
DEPENDENCE FROM IRRADIATED SURFACE

HERA-B MSGC+GEM

C. Richter
Heidelberg PhD

MPGD Workshop
Orsay 1999





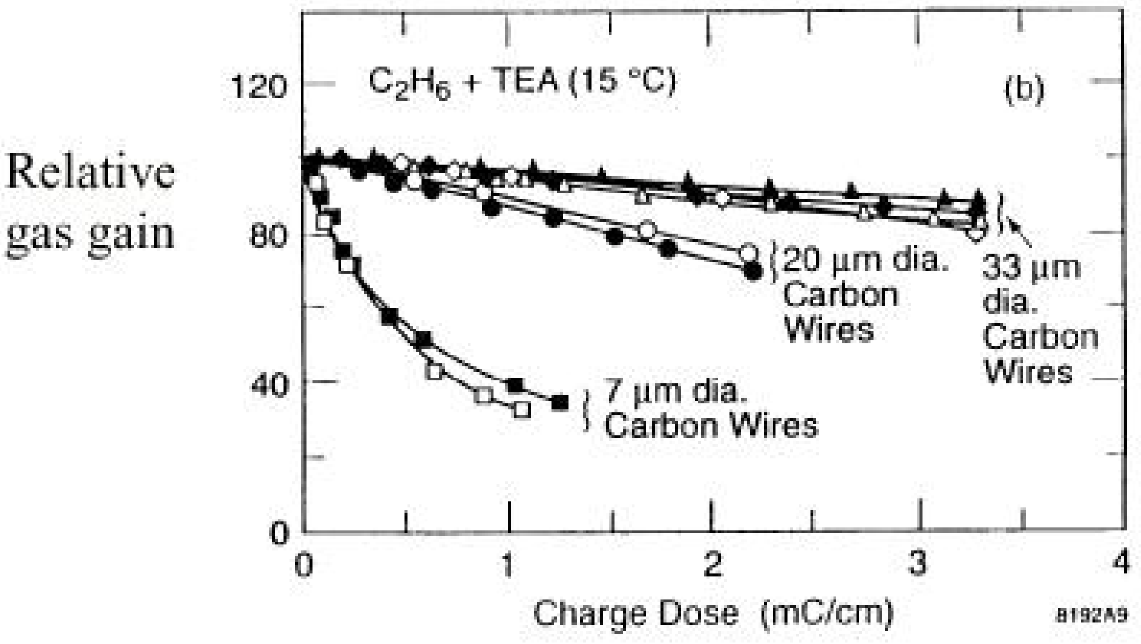
DEPENDENCE ON WIRE DIAMETER (SURFACE FIELD?)

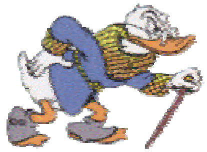
J. Va'vra, October 2, 2001

- Aging rate as a function of wire diameter

(J. Va'vra, NIM A387(1997)183)

- To be able to measure a finite result, choose molecules where the aging is reasonably fast.
- Both of these molecules leave a smooth film on the surface





F. SAULI

AGING 2001

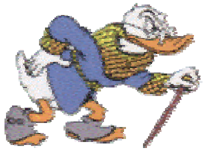
Possible Beams: Hadronic Sources

Facility Radiation Type	Radiation Density	Radiation Density	Irradiation area	Gas Mixture	Effect seen?
Rossendorf Protons 13 MeV/c	5 mC/cm	0.3 µA/cm	~9x9 cm^2	$Ar/CF_4/CH_4$	NO
Rossendorf α-part, 28 MeV/c	3 mC/cm	0.6 µA/cm	~1x3 cm^2	$Ar/CF_4/CH_4$	NO
PSI p 70 MeV/c	~ mC/cm	0.2 µA/cm	~0.5x0.5 cm^2	$Ar/CF_4/CH_4$	NO YES*
PSI π/p 350 MeV/c	~ mC/cm	0.02 µA/cm	~12x22 cm^2	CF_4/CH_4	YES
Karlsruhe α-part, 100 MeV/c	~ mC/cm	0.02 µA/cm	~7x7 cm^2	$Ar/CF_4/CH_4$	YES
HERA-B P(920 GeV)-N	~ mC/cm	0.03 µA/cm	100x30 cm^2	All gas mixures	YES

* Effect could be ignited increasing the irradiation area

A chamber in which the cathode was coated with carbon spray did not show Malter effect

F. SAULI



GEM AGING 1

The Gas Electron Multiplier
as a Charge Amplification Stage

The GEM Principle:

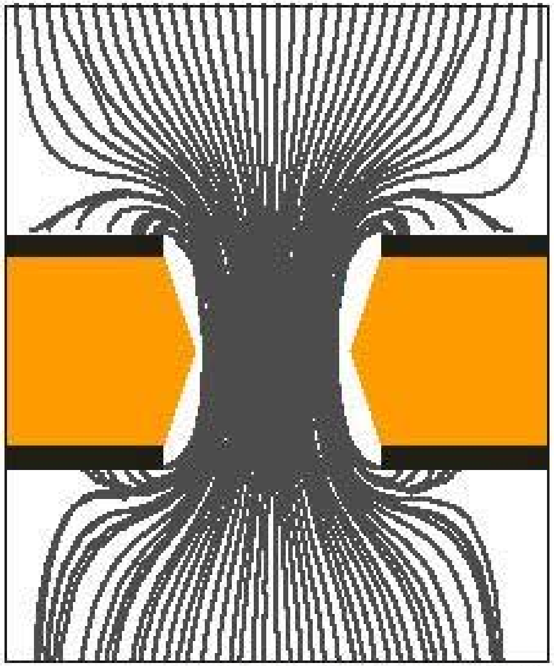
+ High voltage on electrodes (0.3-0.5kV)

+ Fieldlines from the volume above the GEM are strongly compressed into the holes:

  -> High fields inside the holes
  -> ***Proportional Gas Amplification***

+ A big part of the fieldlines are decompressed into the volume below the GEM,

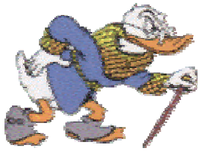
  -> High electric transparency
  -> Effective gains up to 10^3



Electron drift lines through a GEM

Steffen Kappler et al.
GDD, CERN, Geneva (Switzerland)

IEKP, Karlsruhe University (Germany)



Previous Aging Measurements
with a Double-GEM Detector

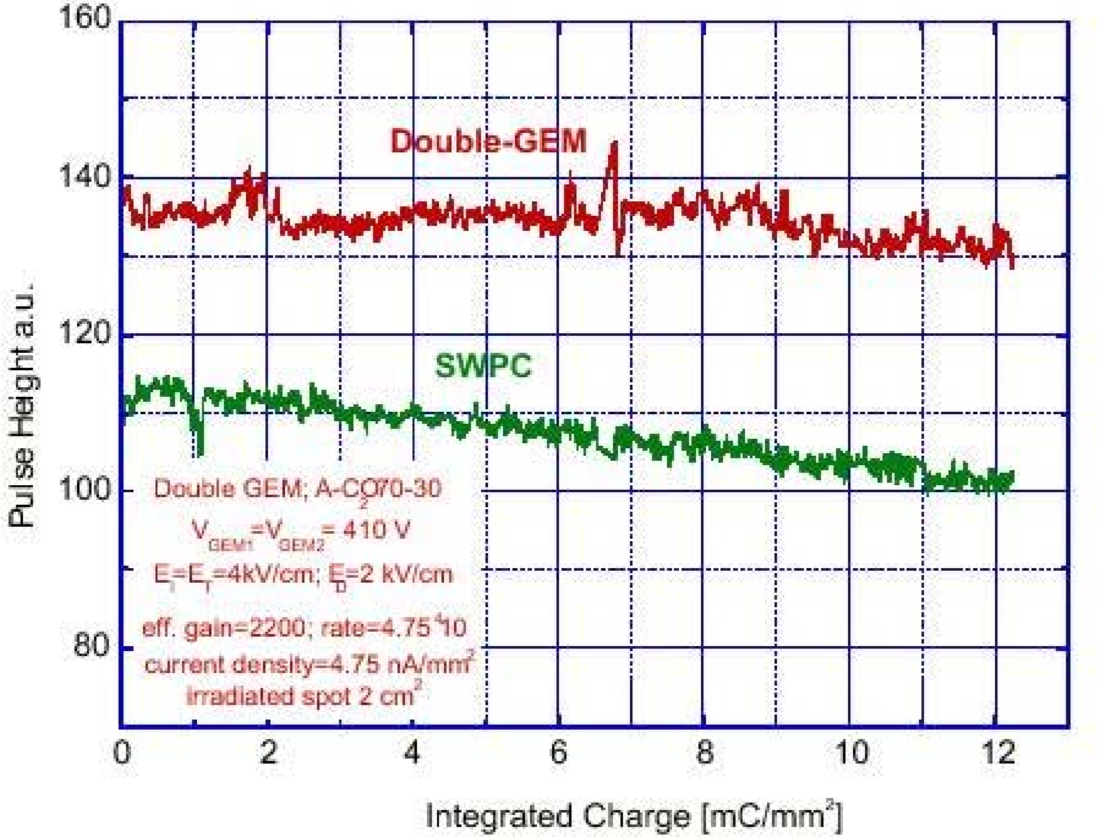
Former Studies:

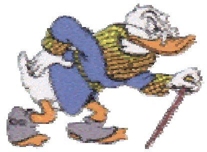
+ Double-GEM detector, standard GEMs & PCB readout

+ Detector operated with
  - Ar:CO_2 (70:30)
  - Effective gain $G = (2.2\underline{+}0.4) \cdot 10^3$
    - $E_D = 2.0kV/cm$,
    - $E_T = E_I = 4kV/cm$
    - GEM voltage: $410/410V$

+ $6keV$ X-ray tube, $2cm^2$ irradiated

+ SWPC for reference, installed in the same gas line

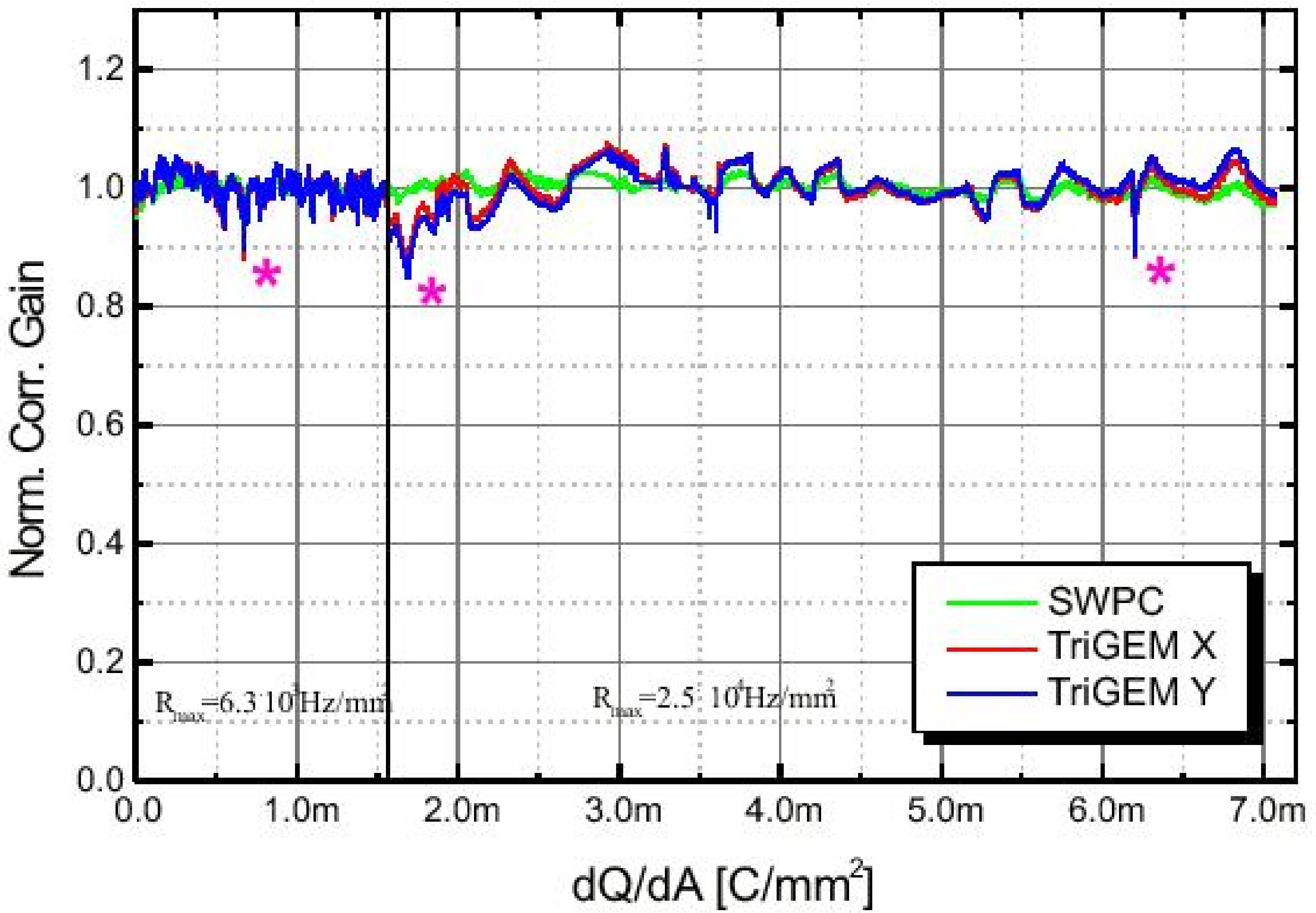




Steffen Kappler et al.
GDD, CERN, Geneva (Switzerland)
IEKP, Karlsruhe University (Germany)

GEM AGING 3

Results
Corrected Gain

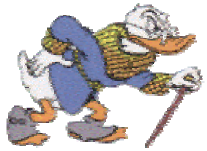


Convention:

We give the quantity dQ/dA as the charge accumulated in the region of the 1 -line of the beam profile.

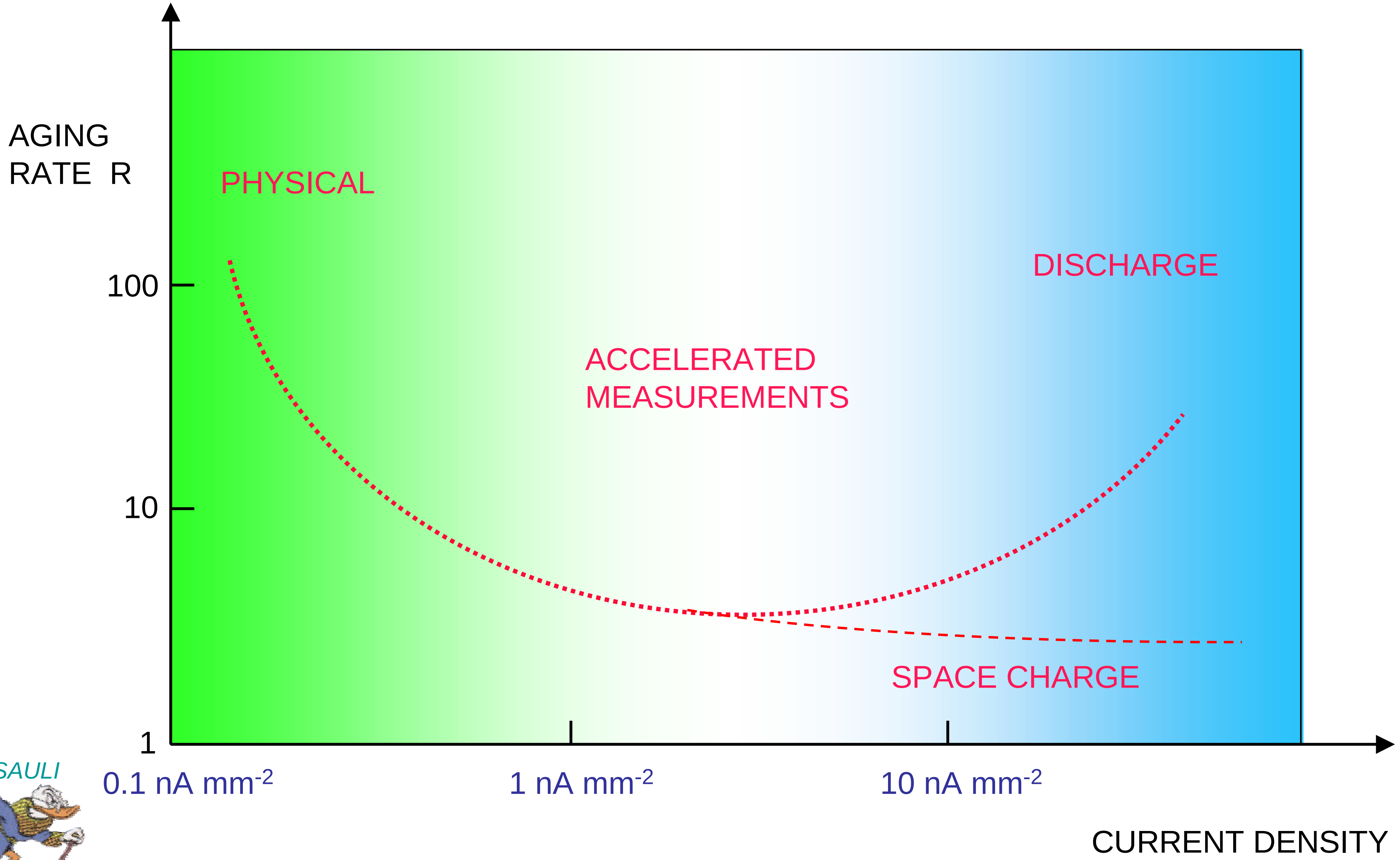
*** = gas bottle exchanged**

F. SAULI

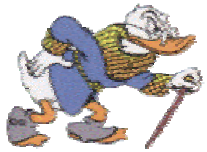


AGING 2001

DOSE RATE SPACE (A GUESS):

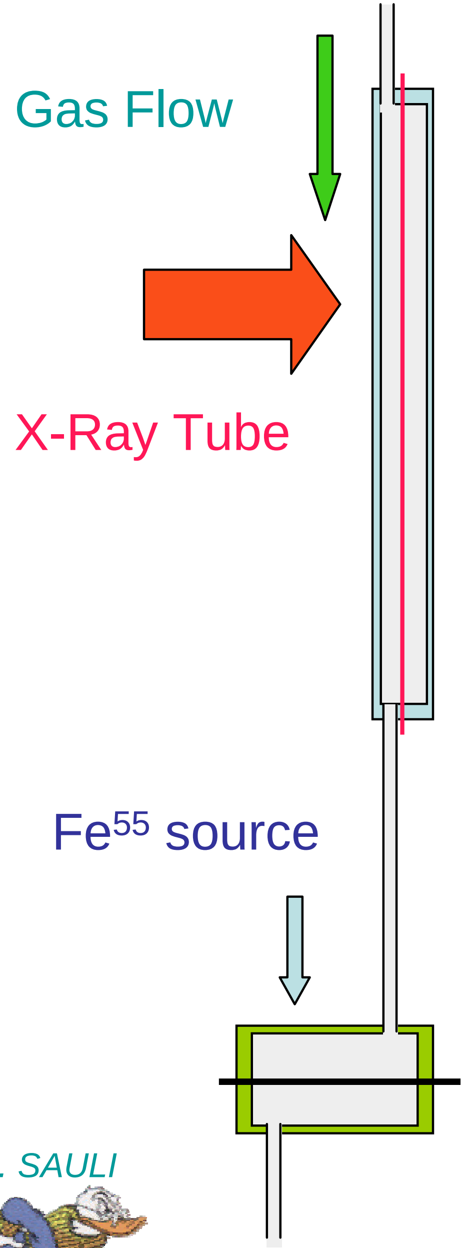


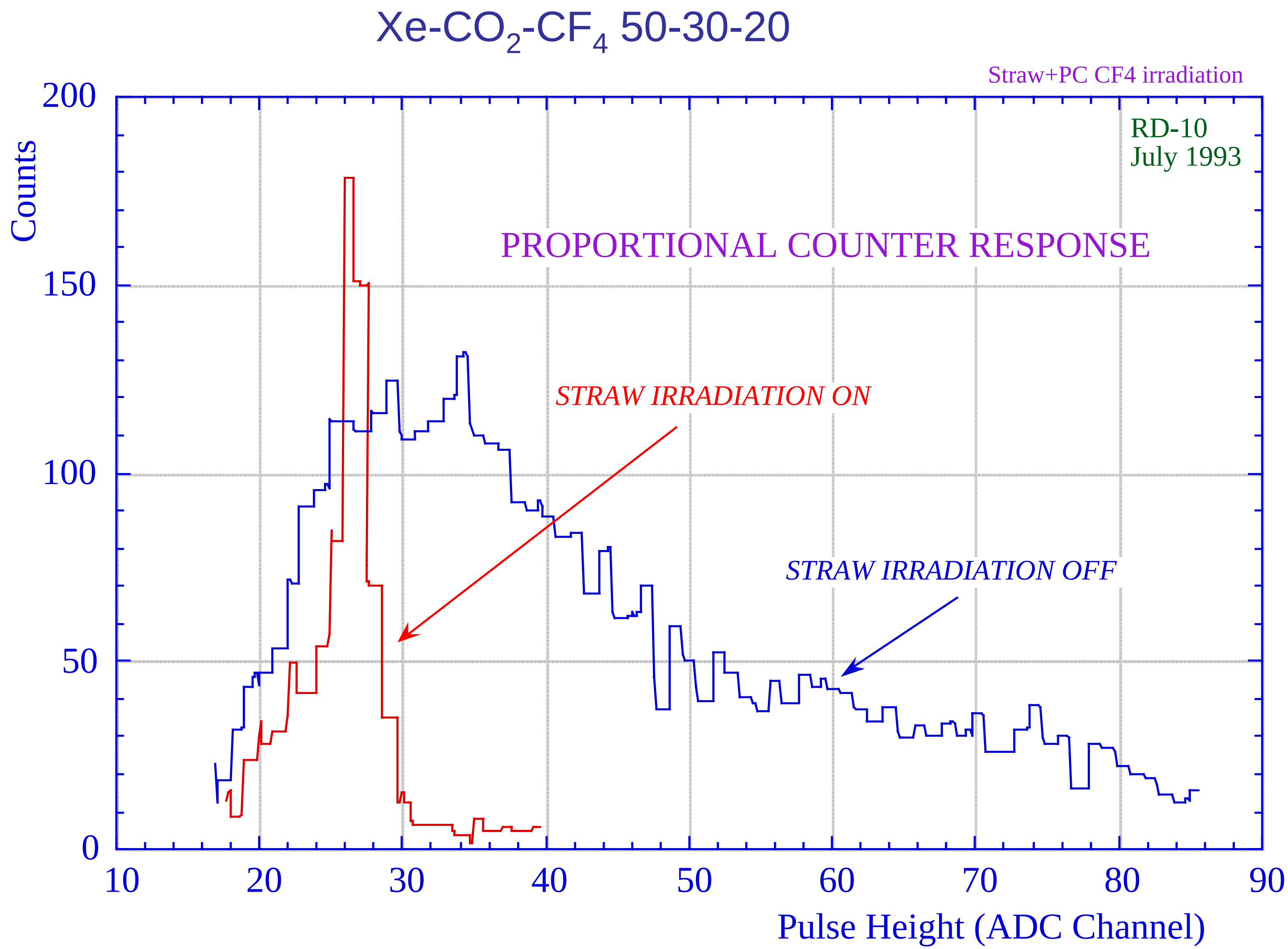
F. SAULI



AGING 2001

EFFECT OF GAS FLOW - IRRADIATING CF4





M. Capeáns et al, Nucl. Instrum. Methods A 337(1993)122

F. SAULI
AGING 2001

LIFETIME OF RADICALS

Lifetimes of radicals

intesity = 0.6 $\mu A/cm$

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
$\underline{H_2O + F \rightarrow HF + OH}$	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
$M \equiv$ collision partner (argon)	

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

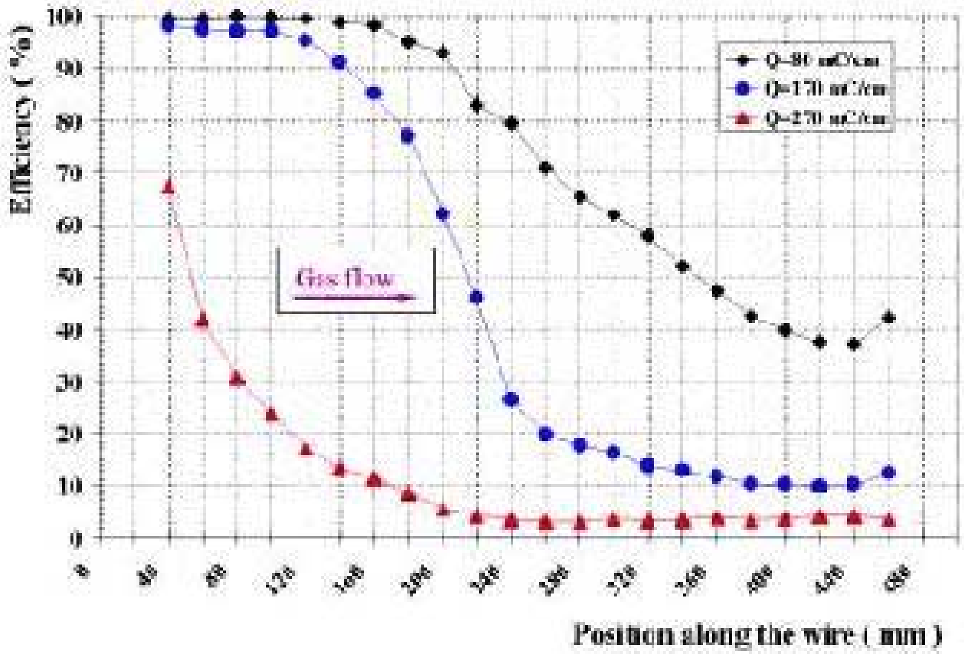
A. Schreiner

EFFECT OF GAS FLOW 1

Ar/CF4/CH4(67:30:3) + 500 ppm H2O

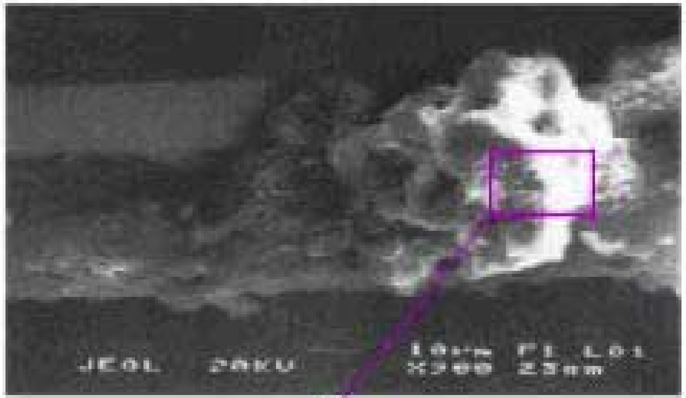
Wires irradiated at 2.65 kV (2.6 kV, gain ~10^5) started to show gain reduction and dark currents above a collected charge of 25 mC/cm (80 mC/cm):

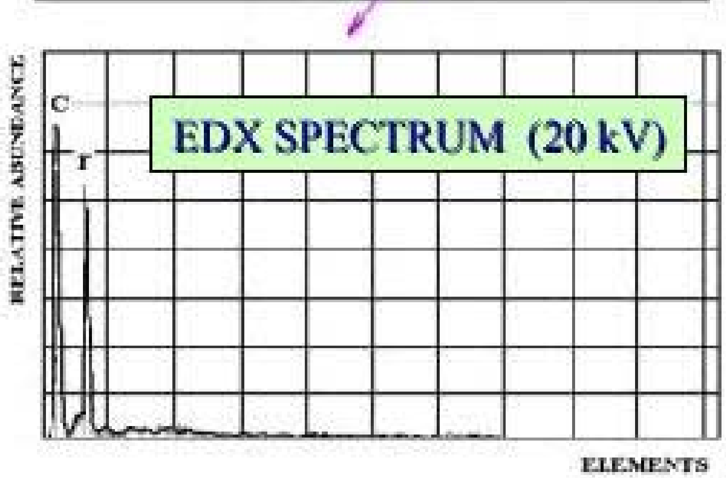
Wire irradiated at 2.6 kV:



- Efficiency decreases in the direction of the serial gas flow
- Wire deposits, containing only C and F elements (H is not observable)

Total collected charge ~400 mC/cm:





M. Titov

EFFECT OF GAS FLOW 2

KAPTON STRAWS Ar-CO_2-$C_2H_2F_4$ 40-40-20

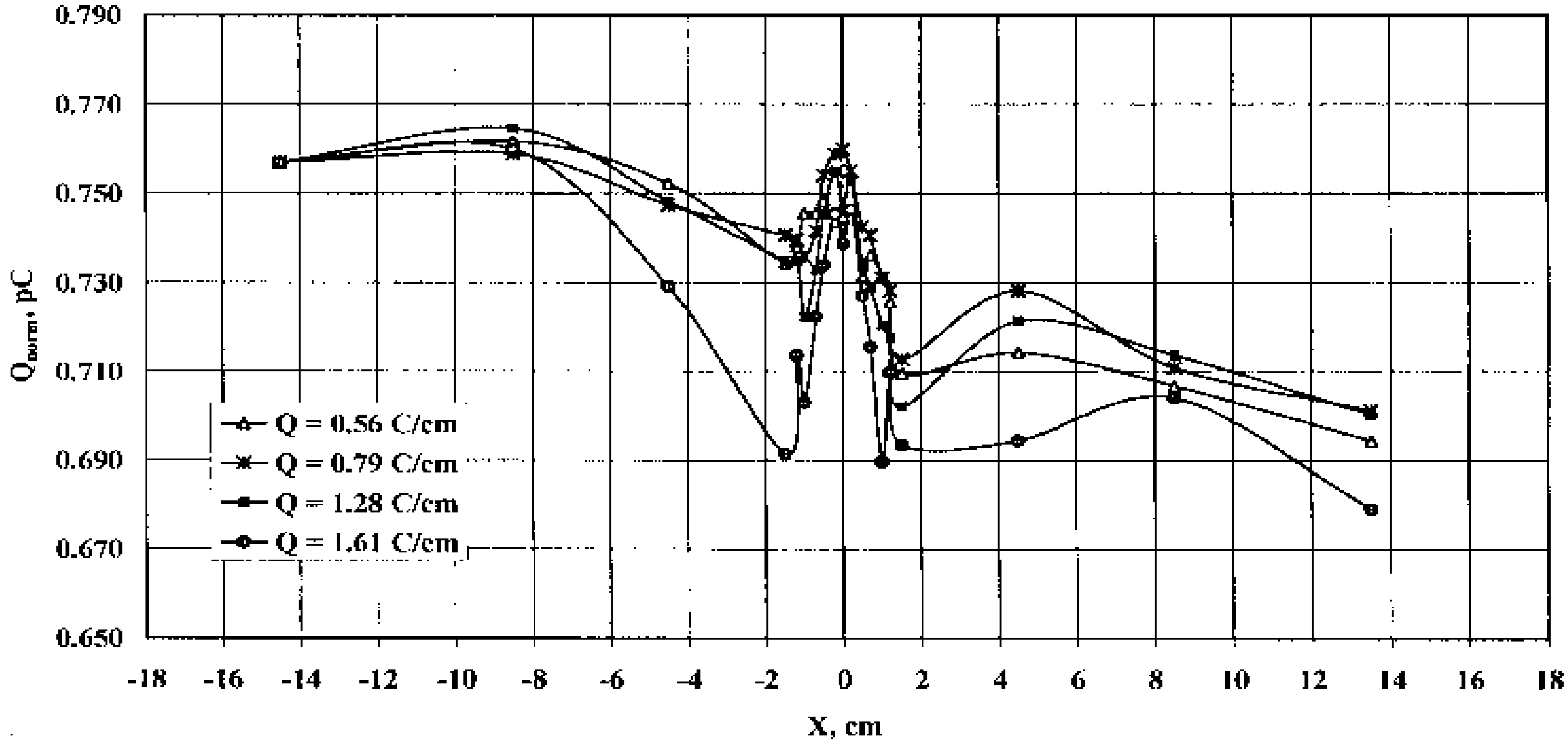


Figure 5. Gas gain distribution along the straw for different accumulated doses. The gas gain was estimated as a ^{55}Fe source pulse spectrum peak position in units of the charge integrated for $\tau = 1$ μsec and measured in the test points presented in Fig.2.

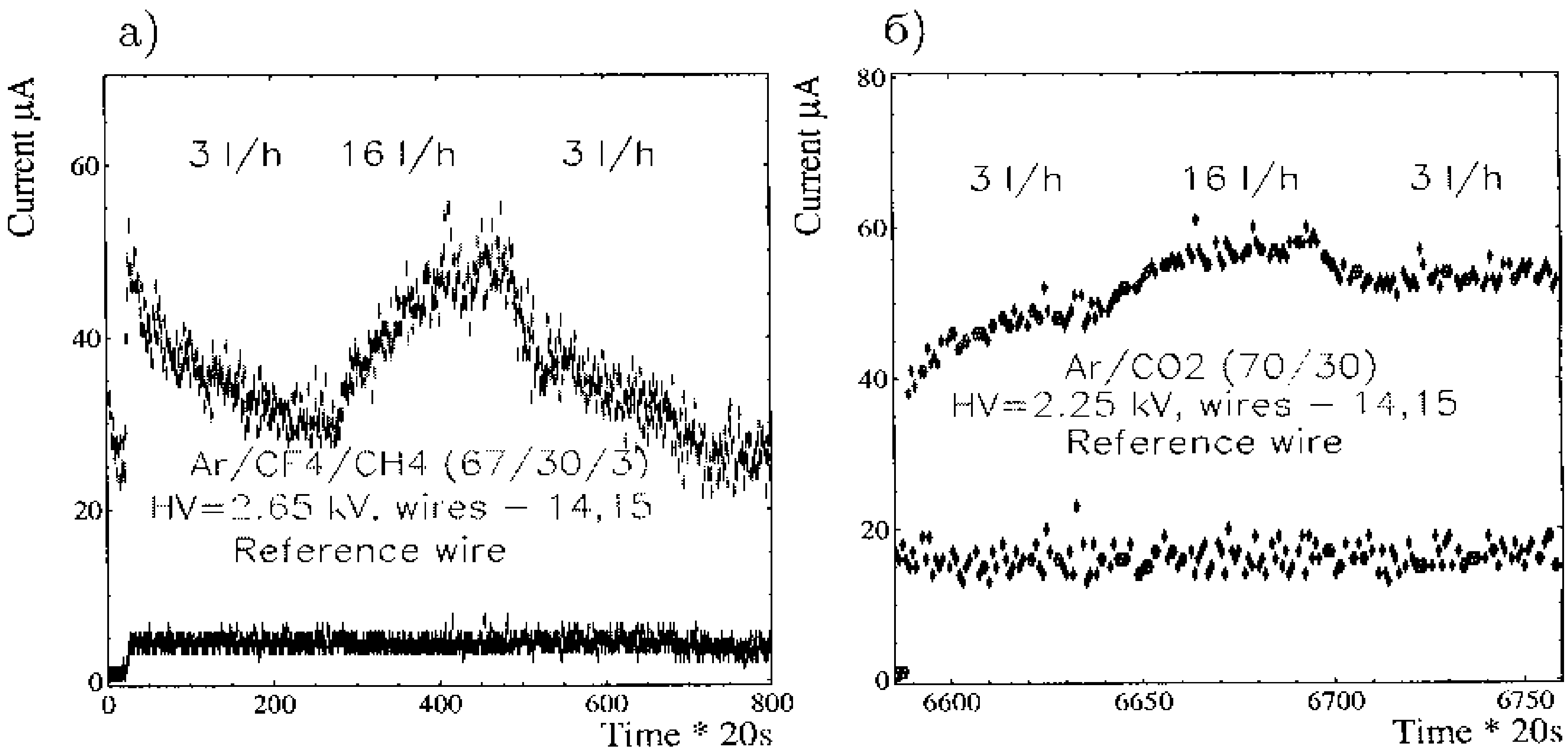
F. SAULI

AGING 2001

G. Gavrilov et al

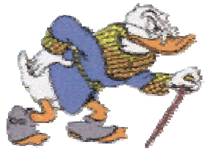
EFFECT OF GAS FLOW 3

GAS-FLOW DEPENDENCE OF GAIN DURING IRRADIATION IN CF4 MIXTURES



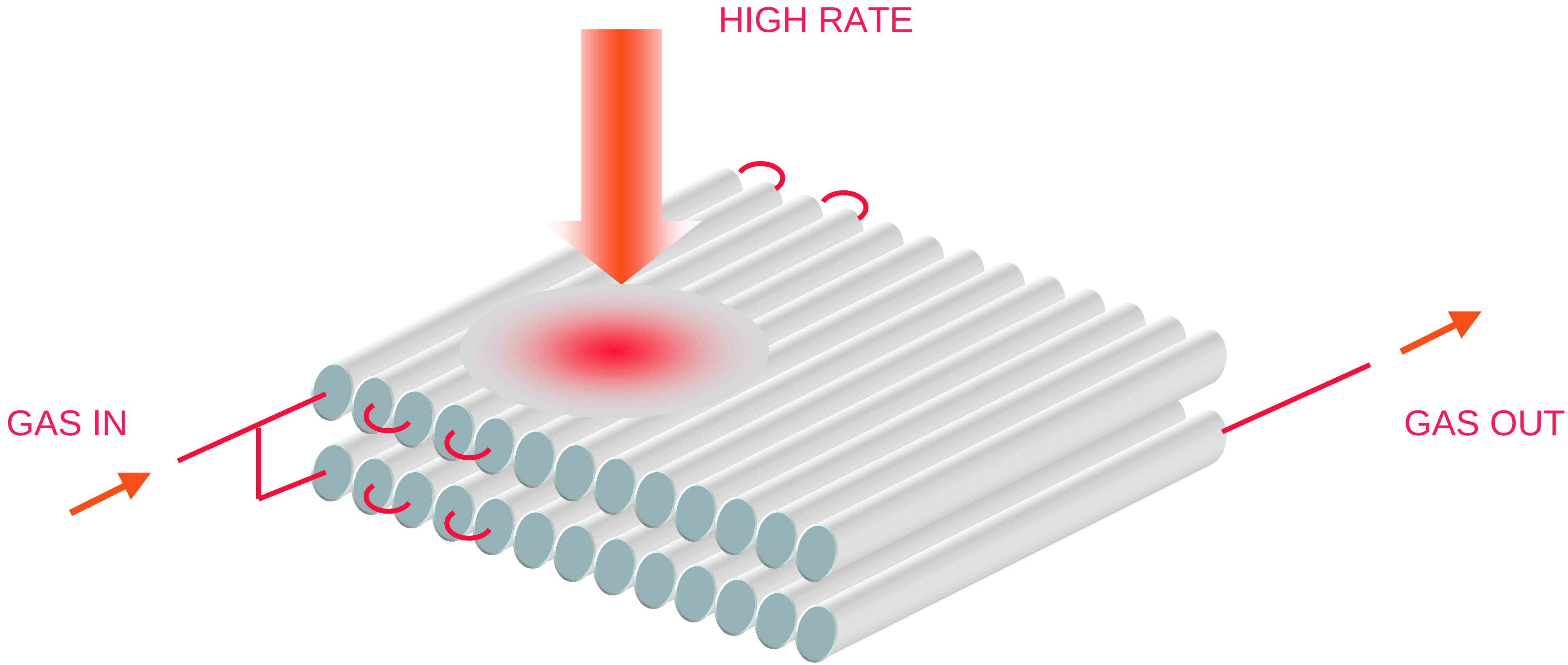
M. Titov
Muon Detector HERA-B

F. SAULI



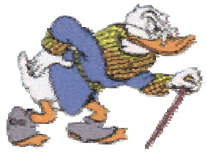
AGING 2001

WILL LARGE SYSTEMS WORK?



PROGRESSIVE DETERIORATION OF PERFORMANCES
ALONG THE GAS FLOW ?

F. SAULI



MATERIALS

STUFF WE NEED:

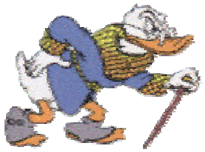
FRAMES: GLASS, FIBREGLASS, KAPTON….
ELECTRODES: WIRES, METAL FOILS, GRAPHITE…
GLUES: EPOXIES, SEALANTS
GAS FILLING: RARE GASES, CH_4, C_2H_6, C_4H_{10}….CO_2….CF_4….
ADDITIVES: METHILAL, ALCOHOLS, WATER…..

STUFF WE DON'T NEED:

POLLUTANTS IN THE MAIN GASES
SILICON, SILICON OILS
PLASTICIZERS
EPOXY OUTGASSING
WATER, ……..

THE WATER CASE:

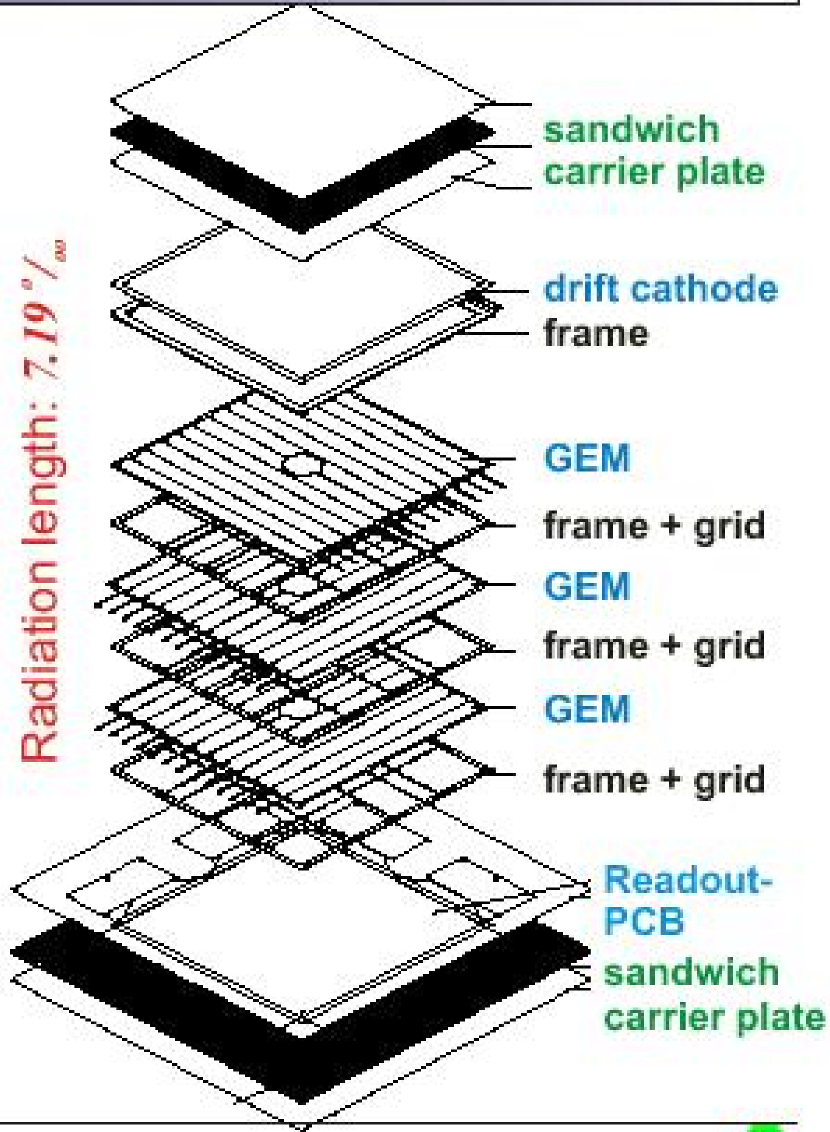
SOMETIMES GOOD, SOMETIMES BAD….



COMPASS TGEM MATERIALS

Detector Components
Overview of the Materials used

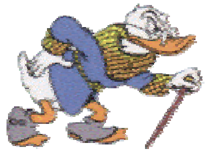
Material	Details	Supplied or manufactured by
Assembly Glue	ARALDIT AY103 + HD991 (ratio 10:4)	CERN store
Frame & grid spacer conditioning	Polyurethane (2 component)	Nuvovern LW Walter Mader AG CH-8956 Killwangen
Sandwich structure (external)	Sandwich Stesalit (125μm)- Honeycomb Nomex (3mm)- Stesalit (125μm)	Nomex: Socol 24 Rue du Lac, CH-1020 Renens Stesalit: Stesalit AG, CH-4234 ZULLWIL SO
Shielding	Aluminium (10μm)	GDD
GEM foils (50μm)	50μm thick Kapton, 5μm Cu, 70μm hole diam., 140μm pitch	CERN/EST
Drift	5μm Cu on 50μm Kapton	CERN/EST
Frame	3mm thick Stesalit	CERN/EP/TA1
Spacers	Vetronite grids 2mm thick	CERN/EST
Gas pipes	PP tube (3mm diam.)	Angst-Pfister Thurgauer Str. 66 CH-8052 Zürich
Gas outlet	F-glass + fitting	CERN/EP/TA1
PCB	Active area 30.7 x 30.7 cm^2, 2-dim. 2x 768 strips, 400μm pitch	CERN/EST
HV boards	Custom made	CERN/EST



Steffen Kappler et al.
GDD, CERN, Geneva (Switzerland)

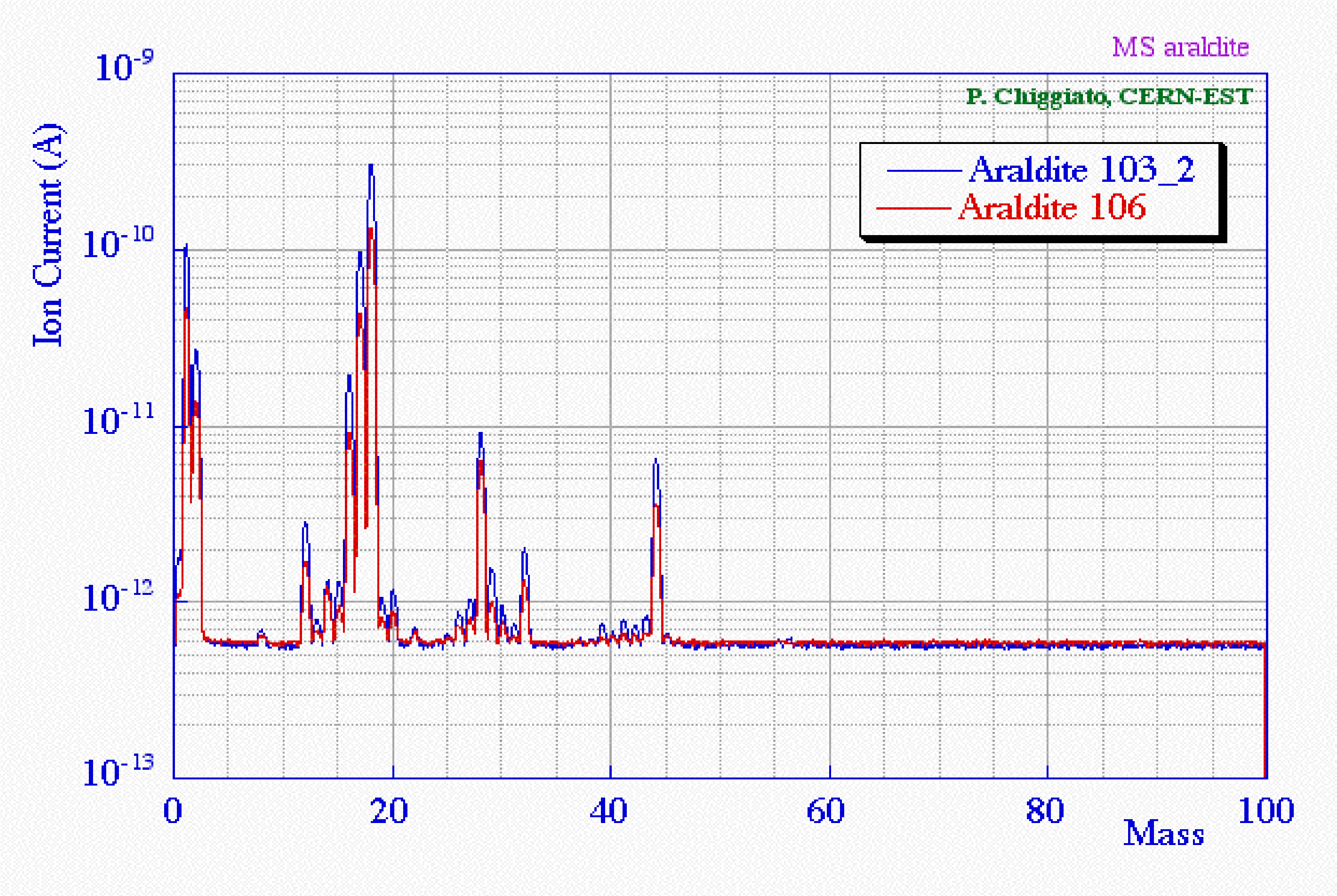
IEKP, Karlsruhe University (Germany)

F. SAULI

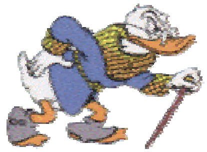


AGING 2001

EPOXY OUTGASSING

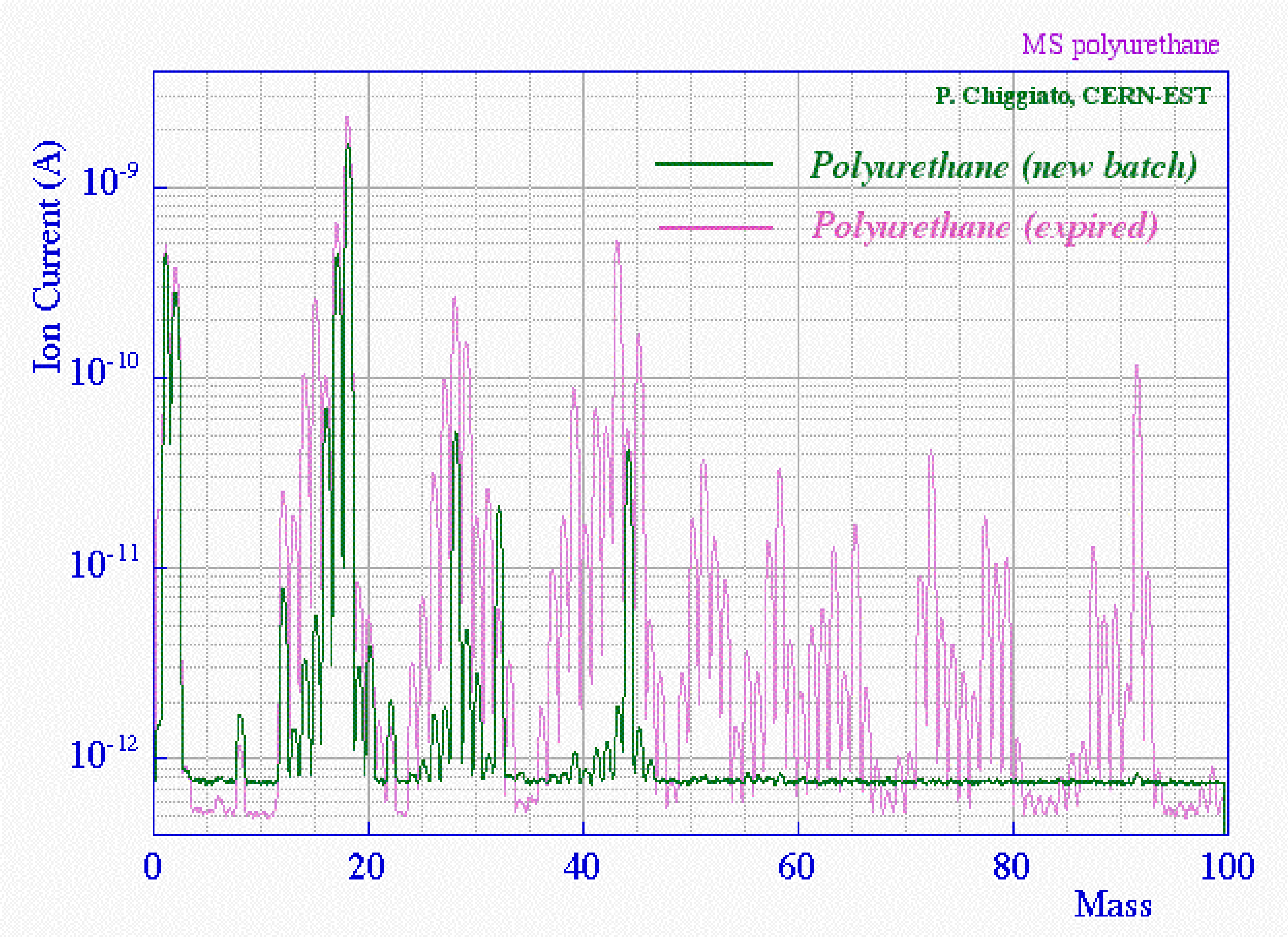


P. Chiggiato, CERN-EST (August 2001)

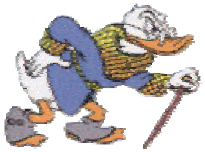


NEW VS EXPIRED

NUVOVERN LW - HARDNER PUR LW (Mäder Lacke AG)

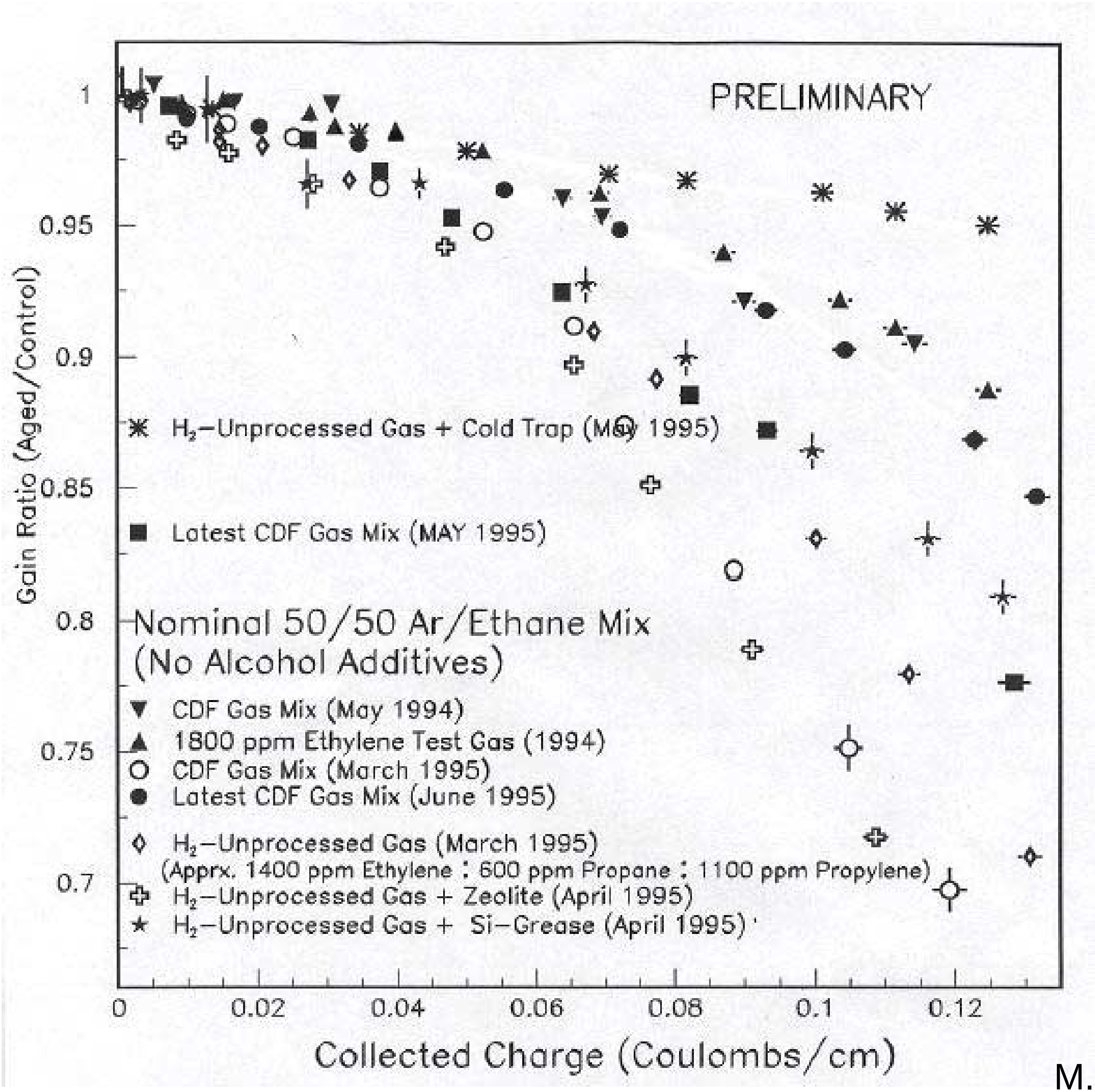


F. SAULI



AGING 2001

BEST SOLUTION: A COLD TRAP?

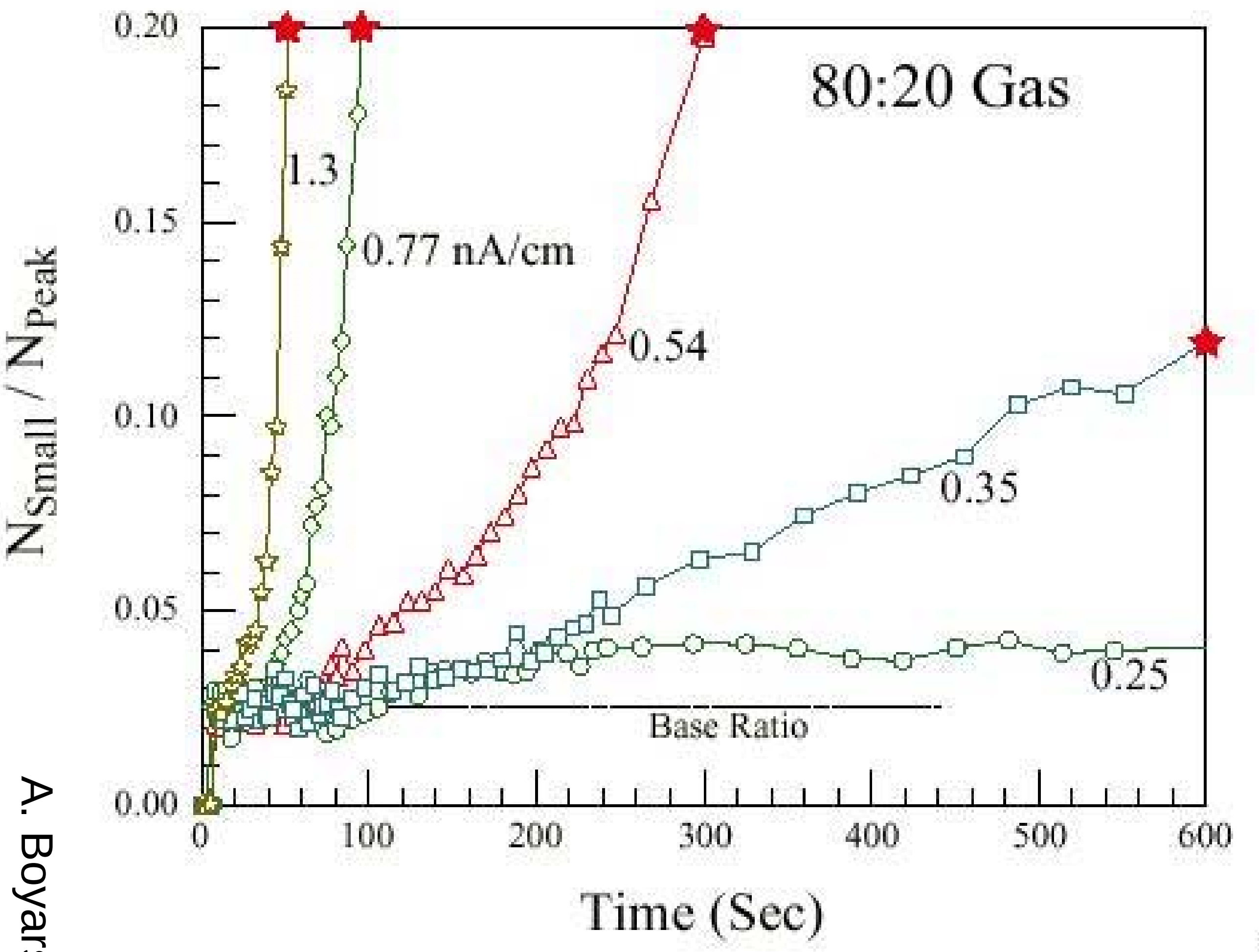


M. Binkley

MALTER - NO ADDITIVES

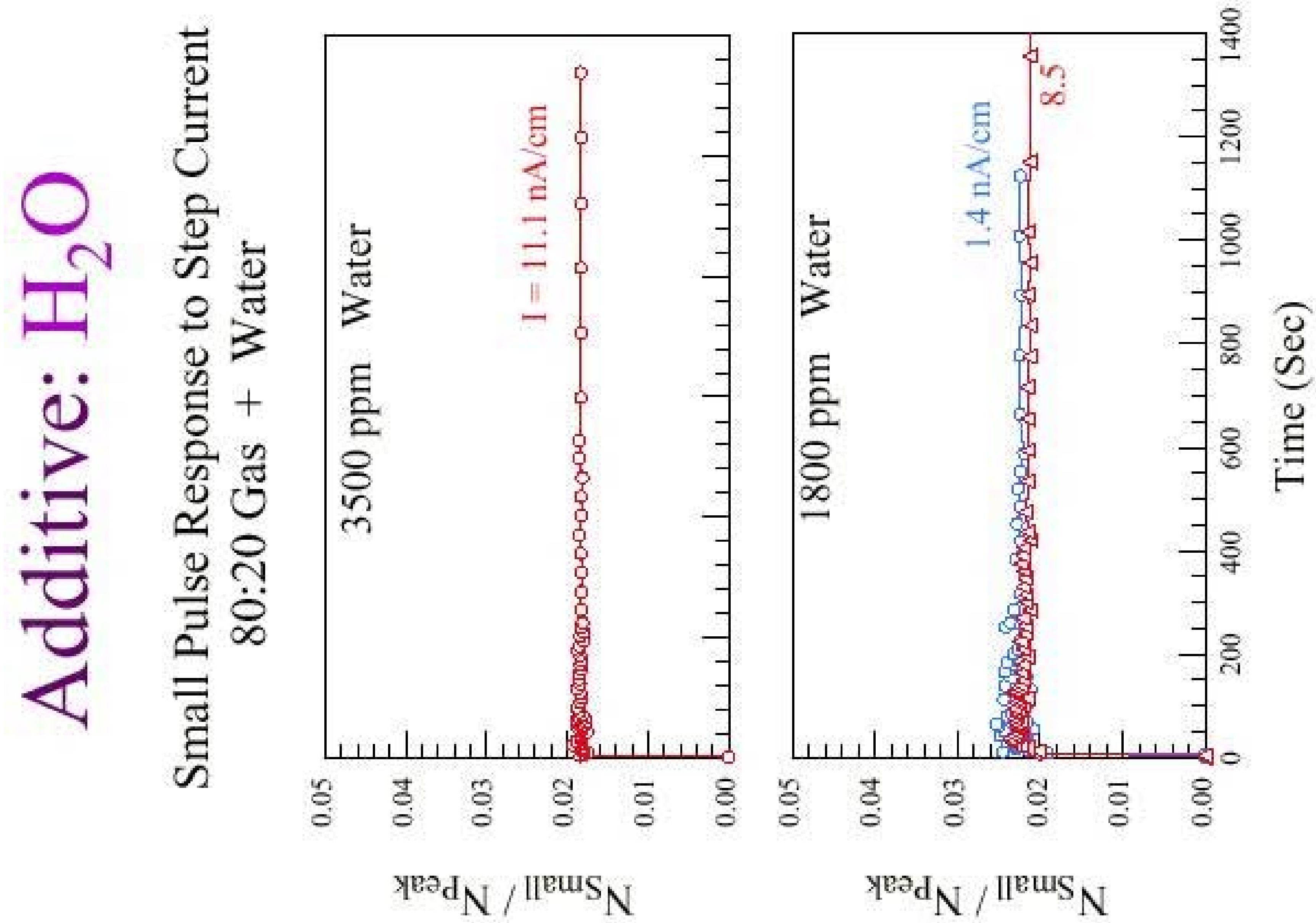
Additive: None.

The small pulse response to a step current in an aged chamber is shown for several anode currents. The ratio starts at a .025 base level, and then increases rapidly at higher anode currents to Malter breakdown, as indicated by the star symbol on boundary. An anode current of ≤0.3 nA/cm is stable.



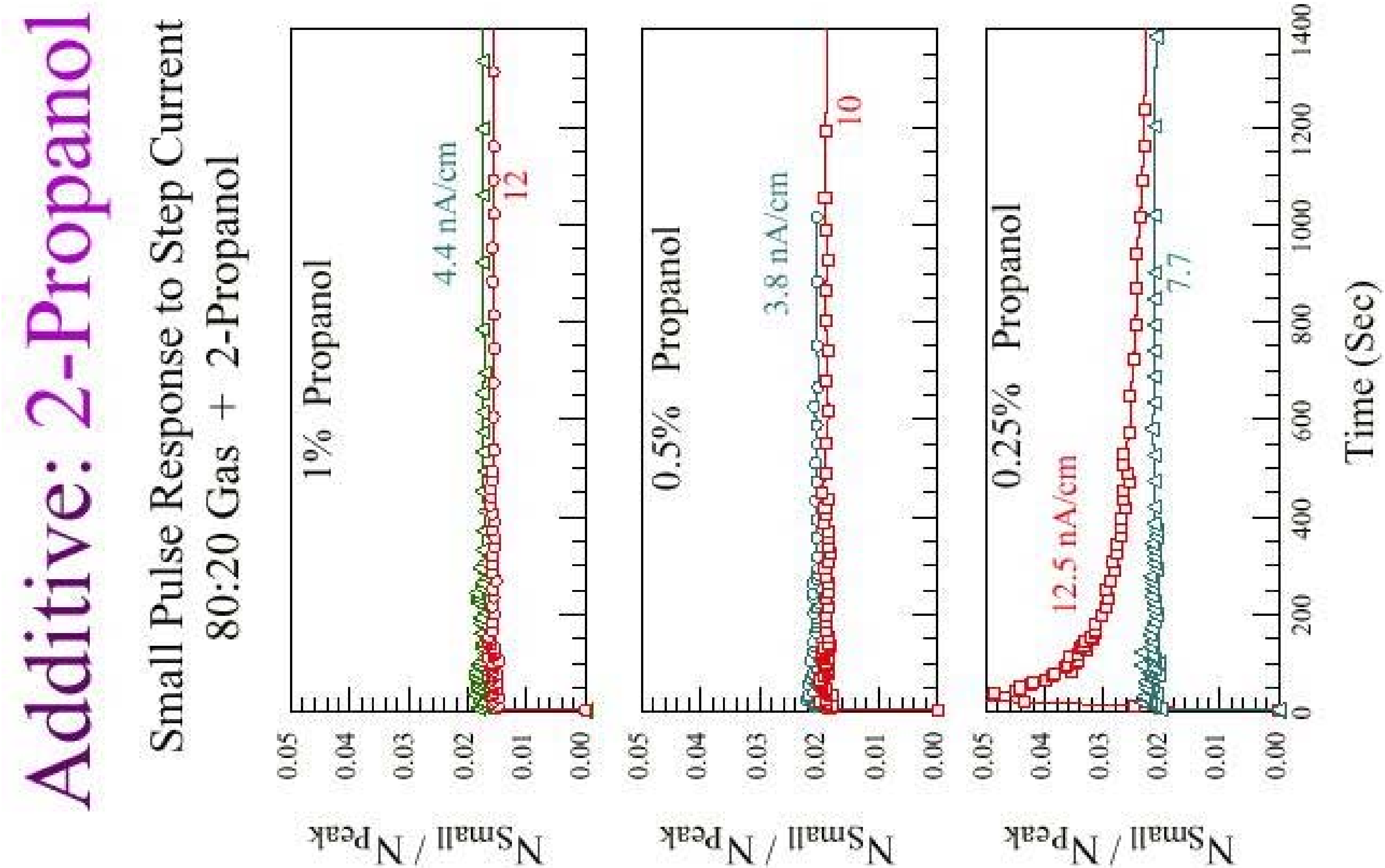
A. Boyarski

WATER ADDED



A. Boyarski

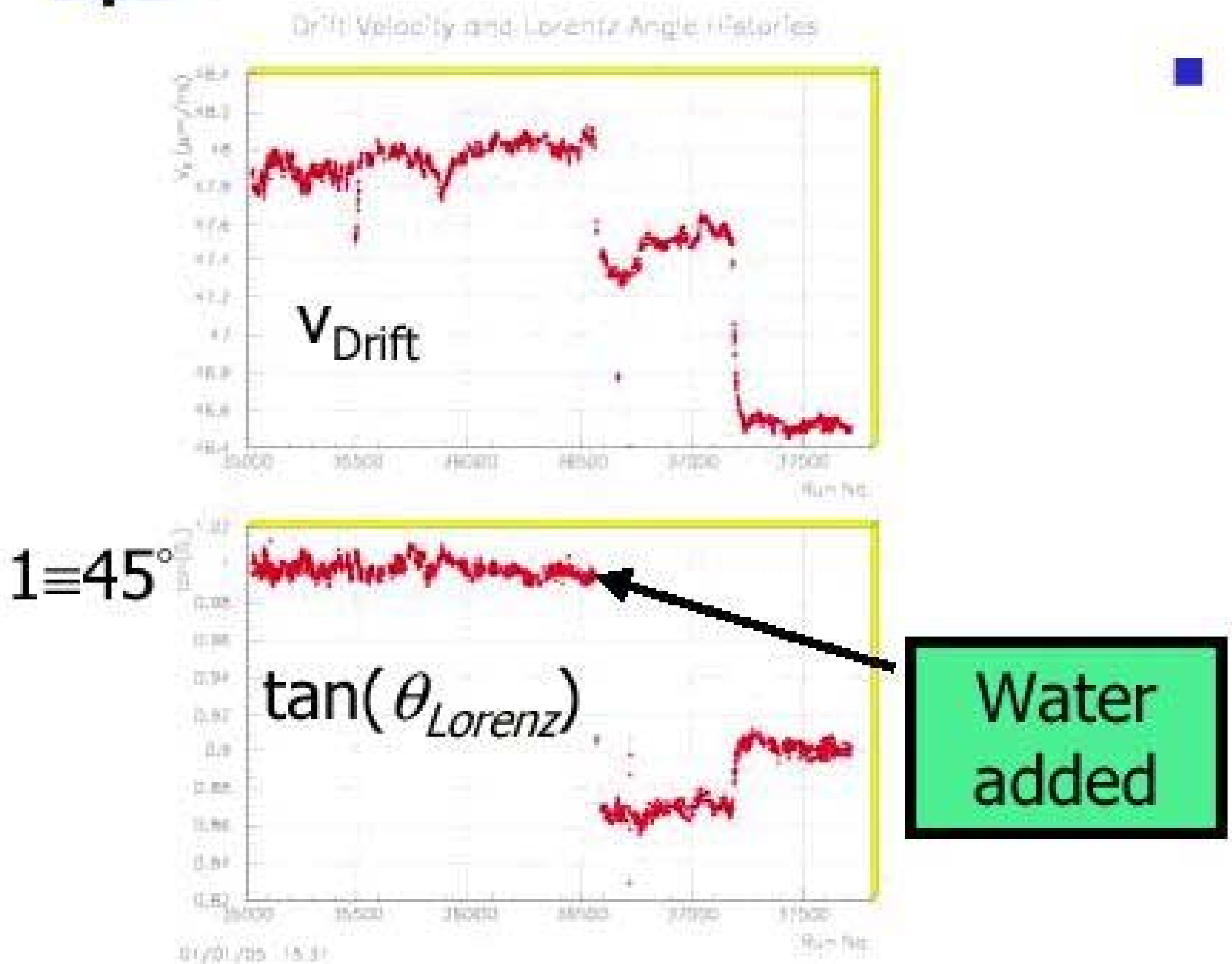
PROPANOL ADDED



A. Boyarski

WATER ADDED 2

Solution and Effects

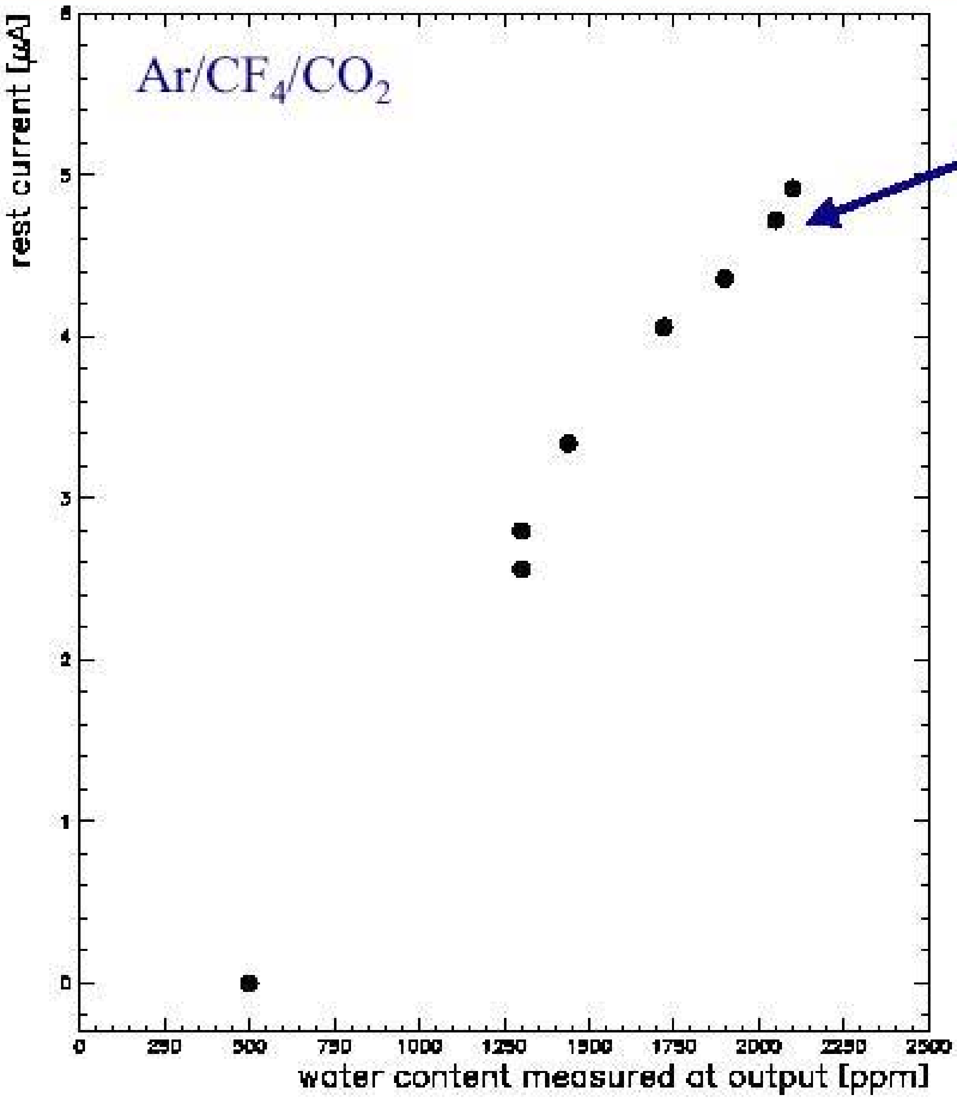


- Added water to the gas mix
  - Tripping seems cured
    - Ongoing test really
  - Operating parameters shifted and required adjustment

D. Bailey

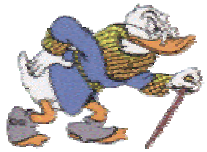
CONDUCTIVITY VS WATER

Implications for the Gas System



Clear dependence with the water content in the gas

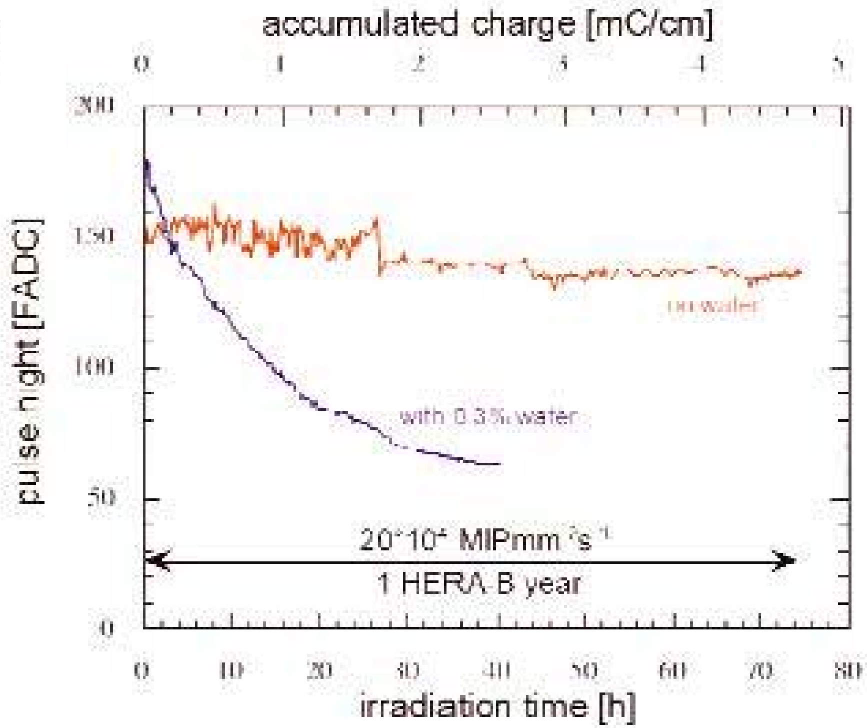
Surface conductivity in the supporting bridges strips can be avoided by carefully controlling the gas water content (< 500 ppm)



Water Admixture (0.3%)

"super clean" GEM-MSGC

MSGC structure:	gold
frame material:	glass
drift electrode:	glass, gold
filling gas:	Ar/DME (50/50) pre-mixed DESY ± 0.3% H_2O
particle flux:	$20 \cdot 10^3\ \gamma/mm^2 s$



- experience in long term measurements:
  increased running stability, but massive anode ageing …

Influence of H_2O Content on Discharge Probability

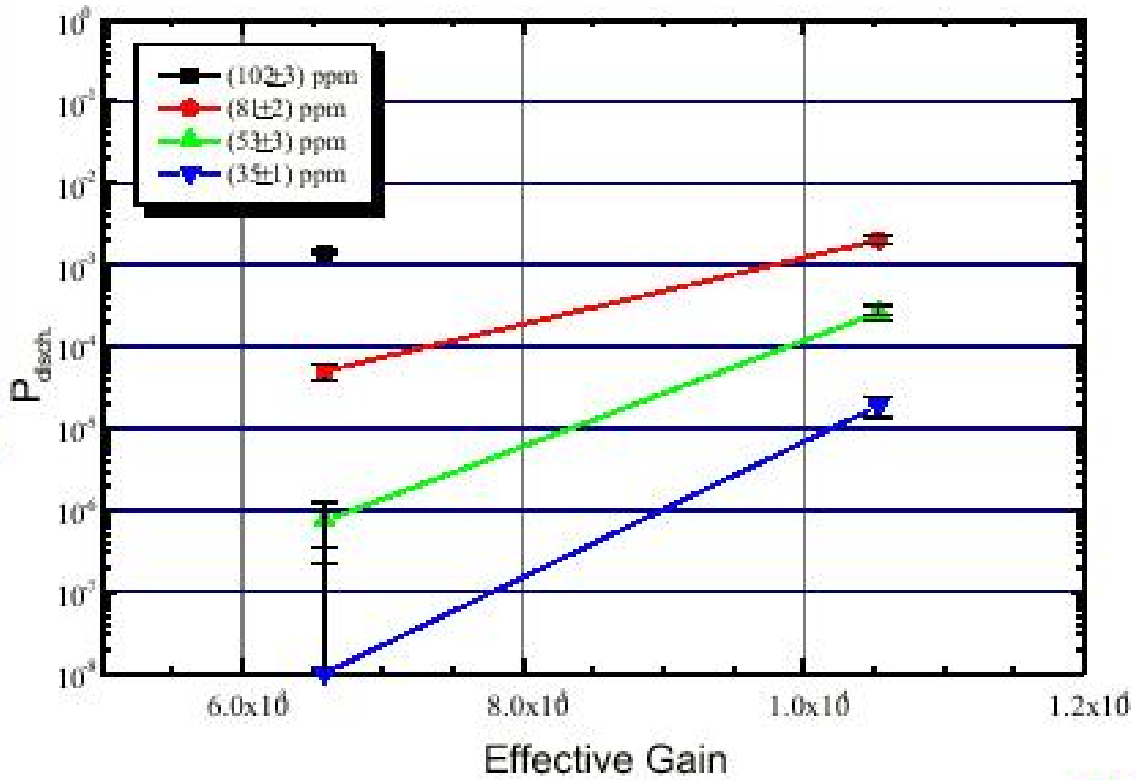
Laboratory Studies

Measurement:

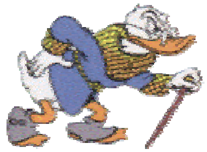
+ Discharge prob. in presence of heavily ionizing -radiation

+ Double-GEM detector

+ Detector operated with
  - $Ar:CO_2$ (70:30)
    - $E_D = 3.0 kV/cm$,
    - $E_T = E_I = 3.5 kV/cm$



F. SAULI



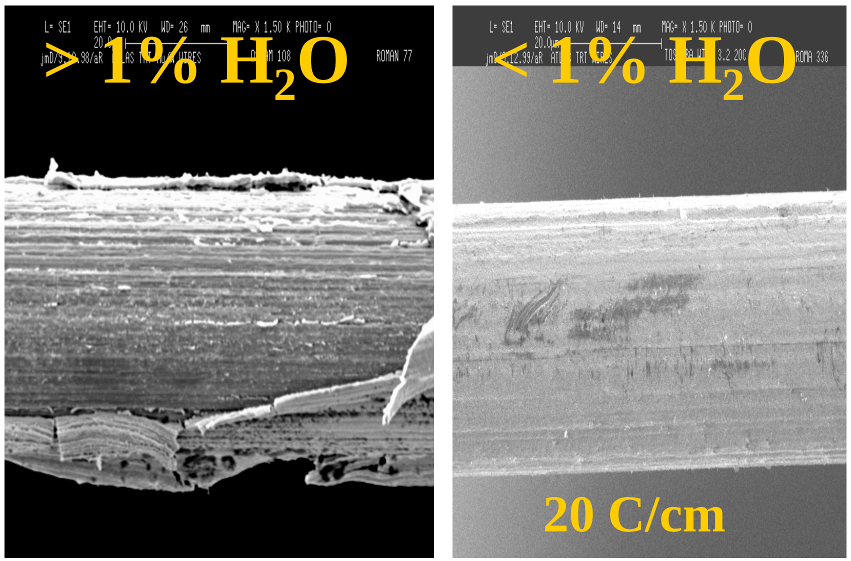
CF4: ETCHING/DEPOSITION 1

Plasma processing: CF_4-based gases are used for both etching and deposition processes.

Chemistry is shifted to:

Etching	Deposition
if oxygenated species are added	in hydrogenated atmospheres

Au/W wire



Strict Control of Pollutants

M. Capeáns

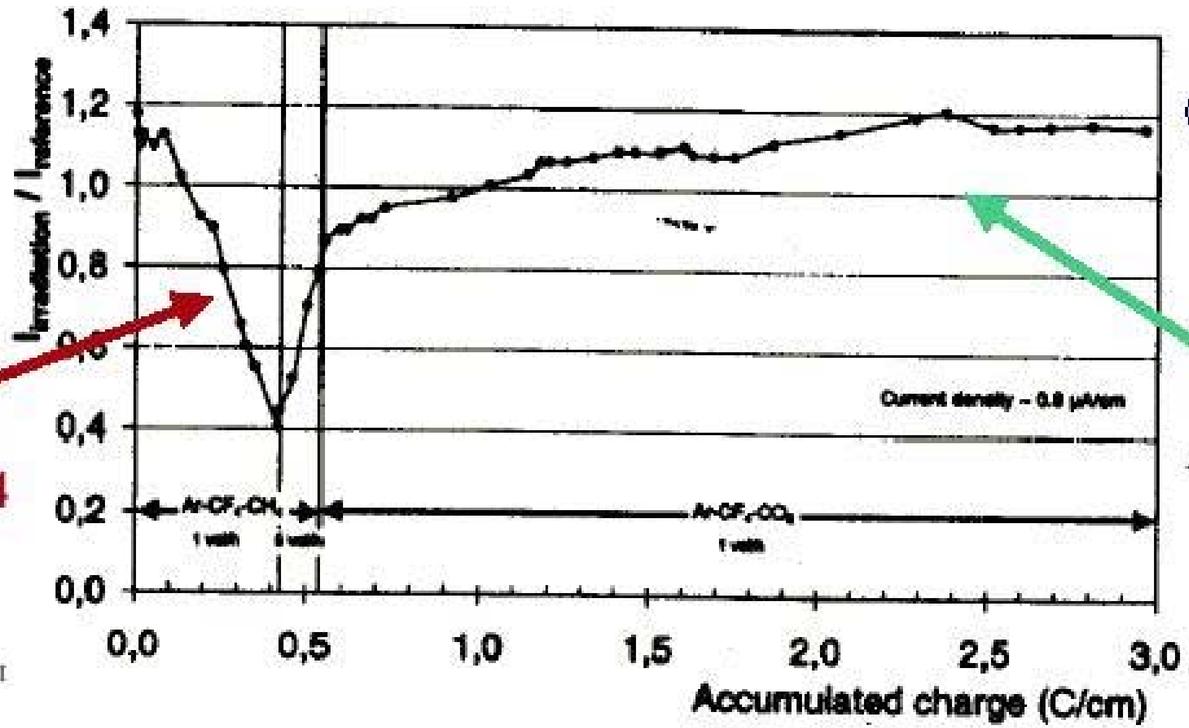
CF_4: Etching/Deposition balance

Plasma processing: CF_4-based gases are used for both etching and deposition processes.

Chemistry is shifted to:

Deposition	Etching
in hydrogenated atmospheres	if oxygenated species are added

Ar-CF_4-CH_4



Ar-CF_4-CO_2

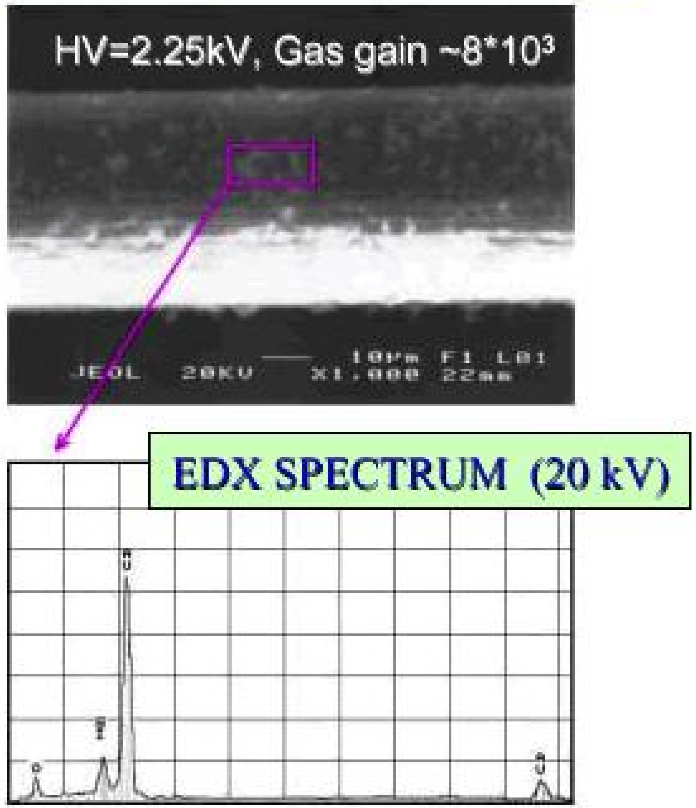
Hera-B/OTR
DESY

CF_4 AGING

Ar/CF4/CH4(67:30:3)

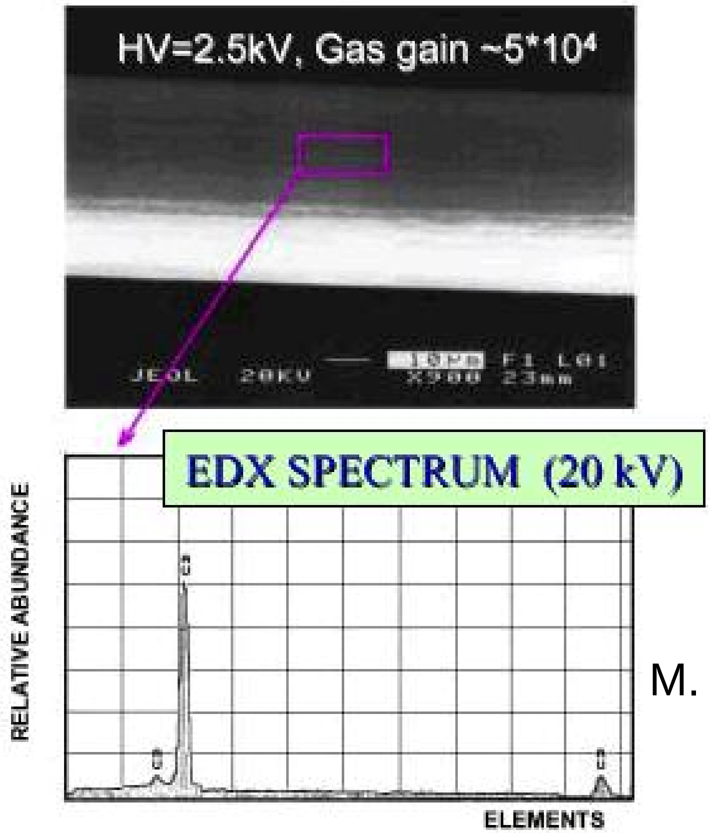
Two wires irradiated at 2.25 kV up to:
100 mC/cm Ar/CF4/CH4+500 ppm H2O
100 mC/cm Ar/CF4/CH4+1400 ppm H2O

No gain reduction for one wire, Si-based deposits on the other **(maximum gain reduction is in the region of lowest radiation intensity)**



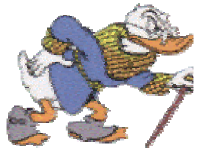
Four wires irradiated at 2.5 kV,2.55 kV up to:
400 mC/cm Ar/CF4/CH4+500 ppm H2O
400 mC/cm Ar/CF4/CH4+1400 ppm H2O

No gain reduction for all wires after 800 mC/cm, several distinct spots on the wires with gas gain loss after 400 mC/cm, which afterwards vanished



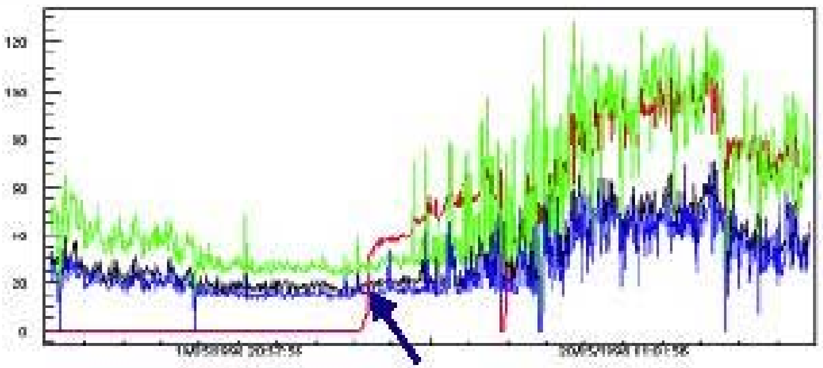
M. Titov

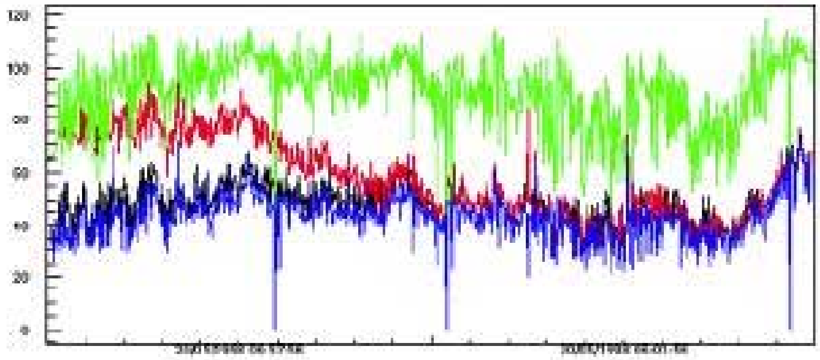
F. SAULI



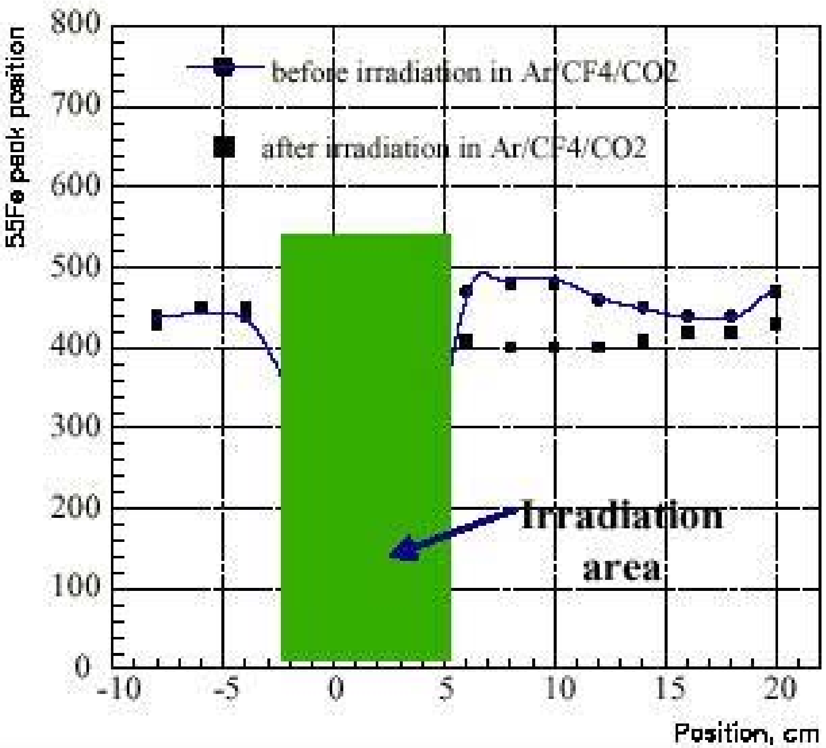
AGING 2001

Recovery: Exchange CH_4 – CO_2





Start irradiation after gas exchange

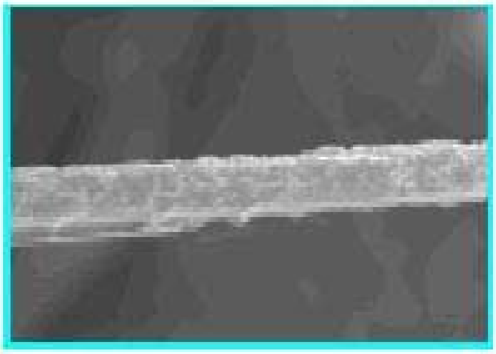


A chamber previously irradiated with $Ar/CF_4/CH_4$ that showed fast anode aging and Malter effect was completely recovered after several hours of irradiation with $Ar/CF_4/CO_2$

(CF_4 wire and cathode etching??)

NO WATER-WIRE BREAKS

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

A. Schreiner

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

TUNGSTEN WIRE SWELLING 1

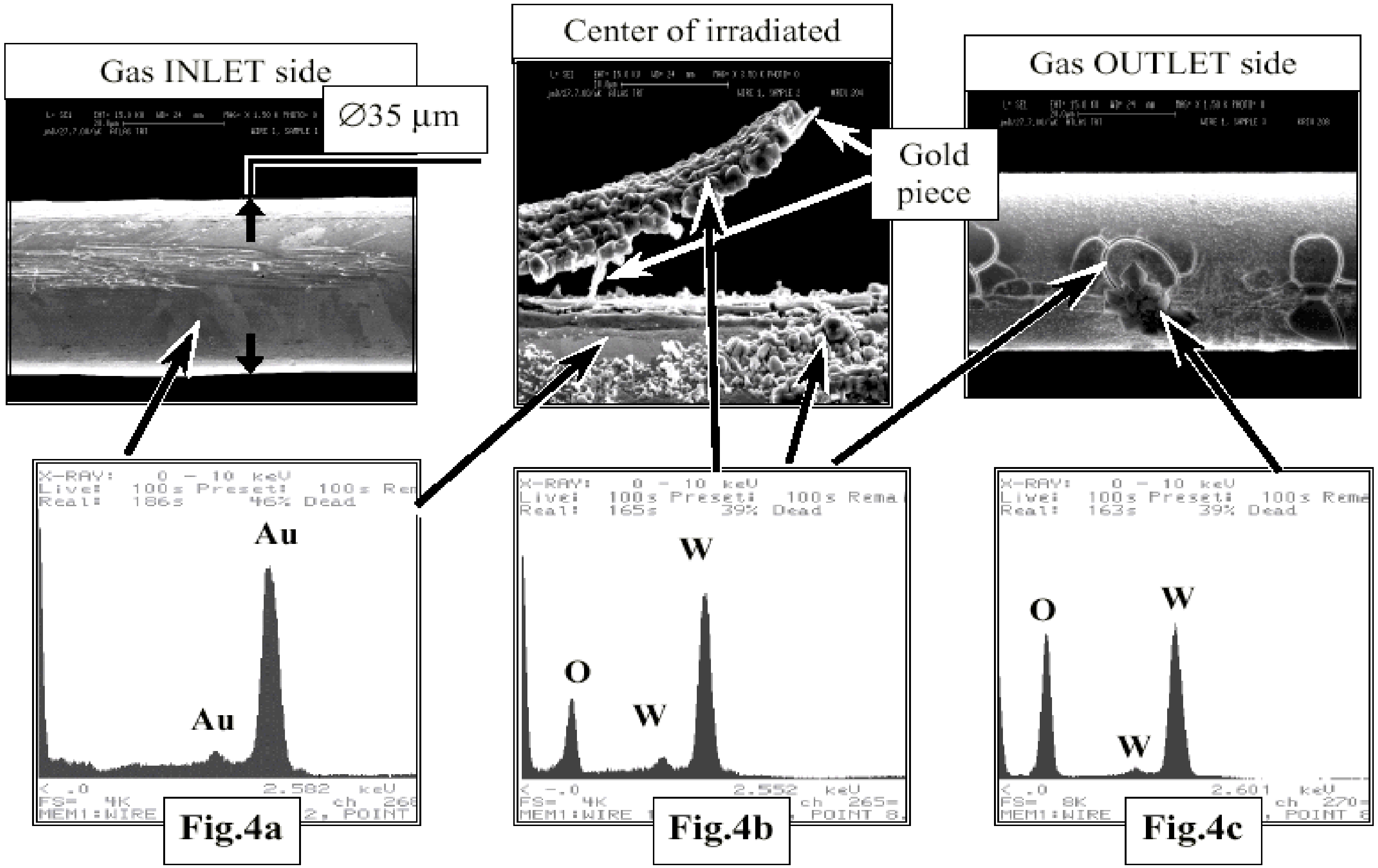
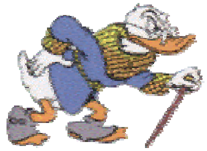
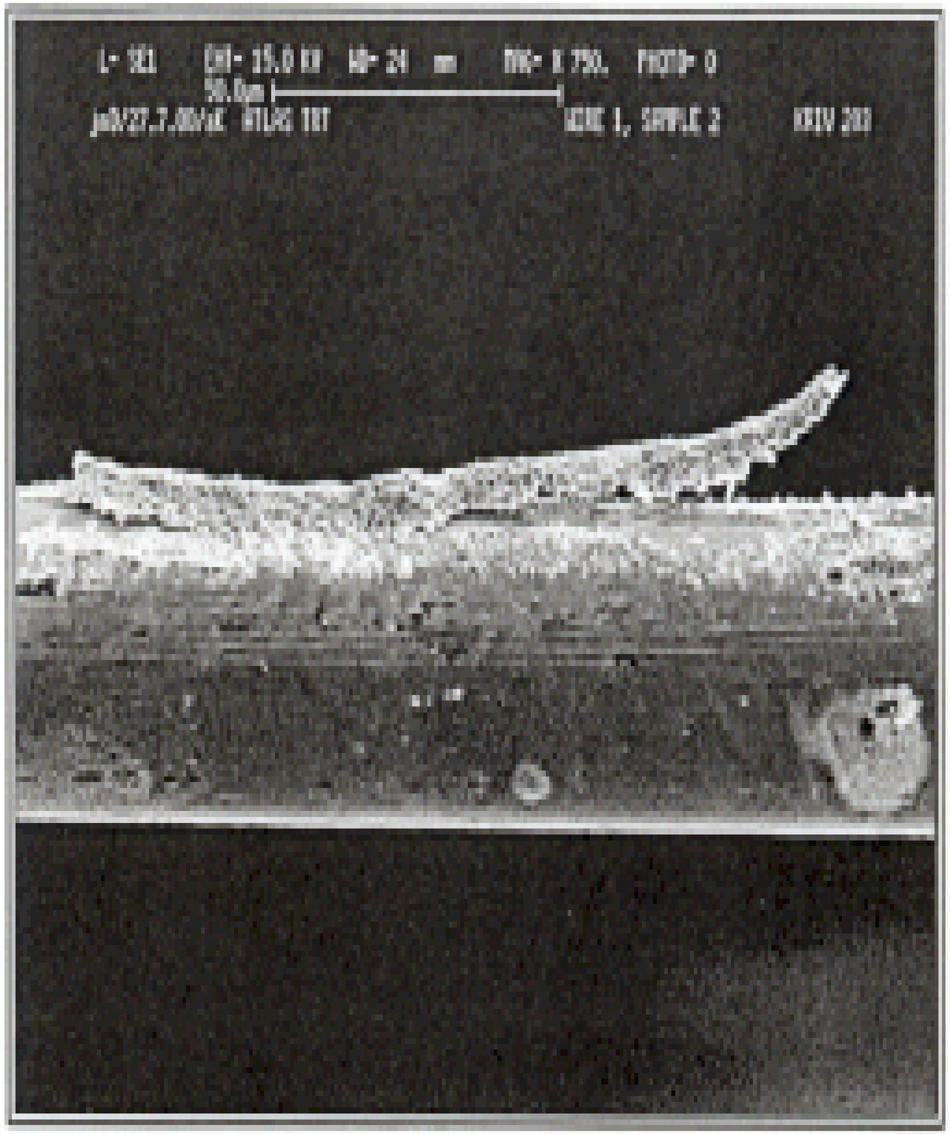


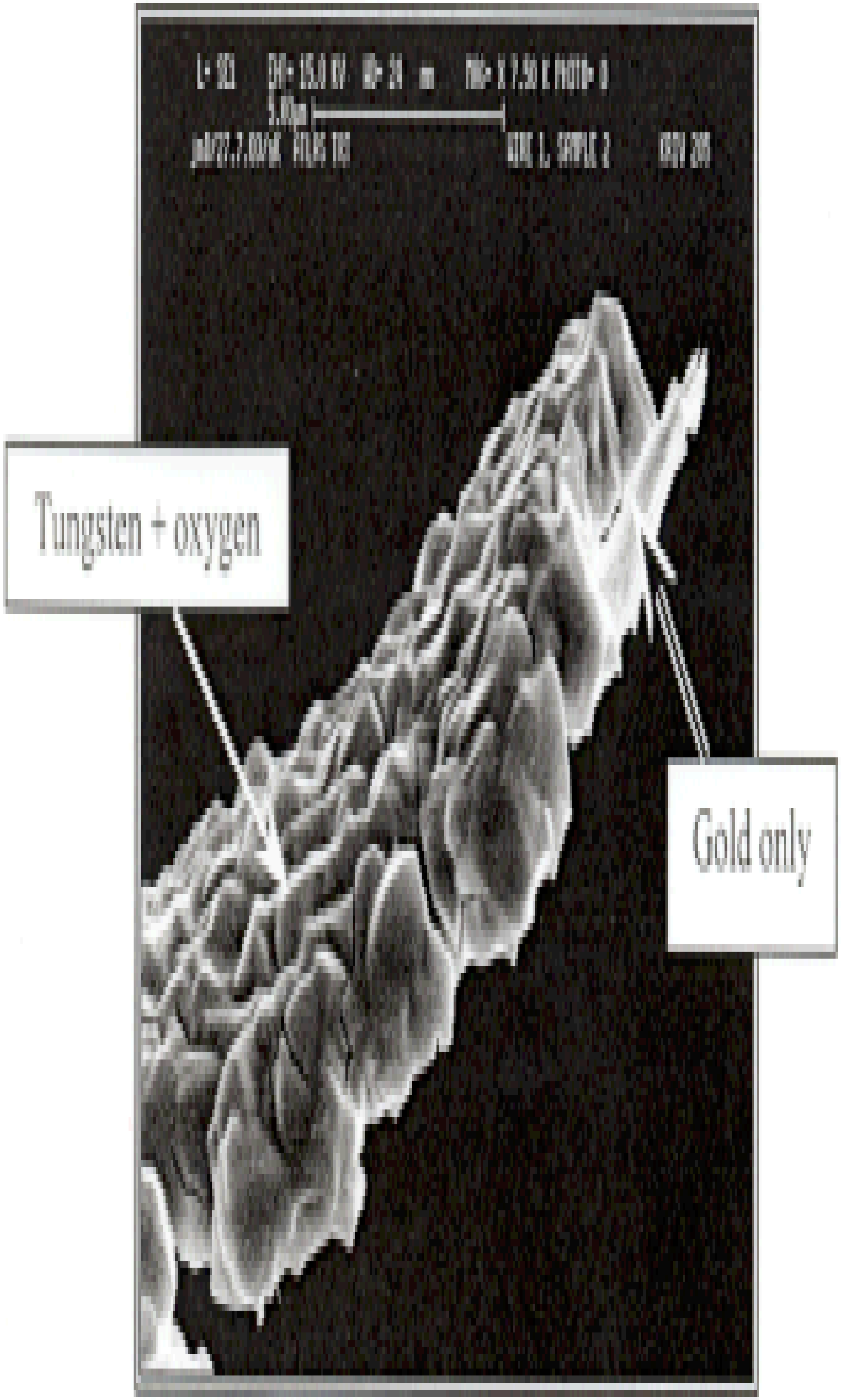
Figure 4: *The results of SEM/XEM examination of the wire surface along the wire. Reference part of the wire surface is smooth and undamaged (Fig.4a). XEM analysis of the wire surface, presenter in Fig.4b and 4d, shows that deposits containt a large amount of oxygen and tungsten.*

G. Gavrilov et al



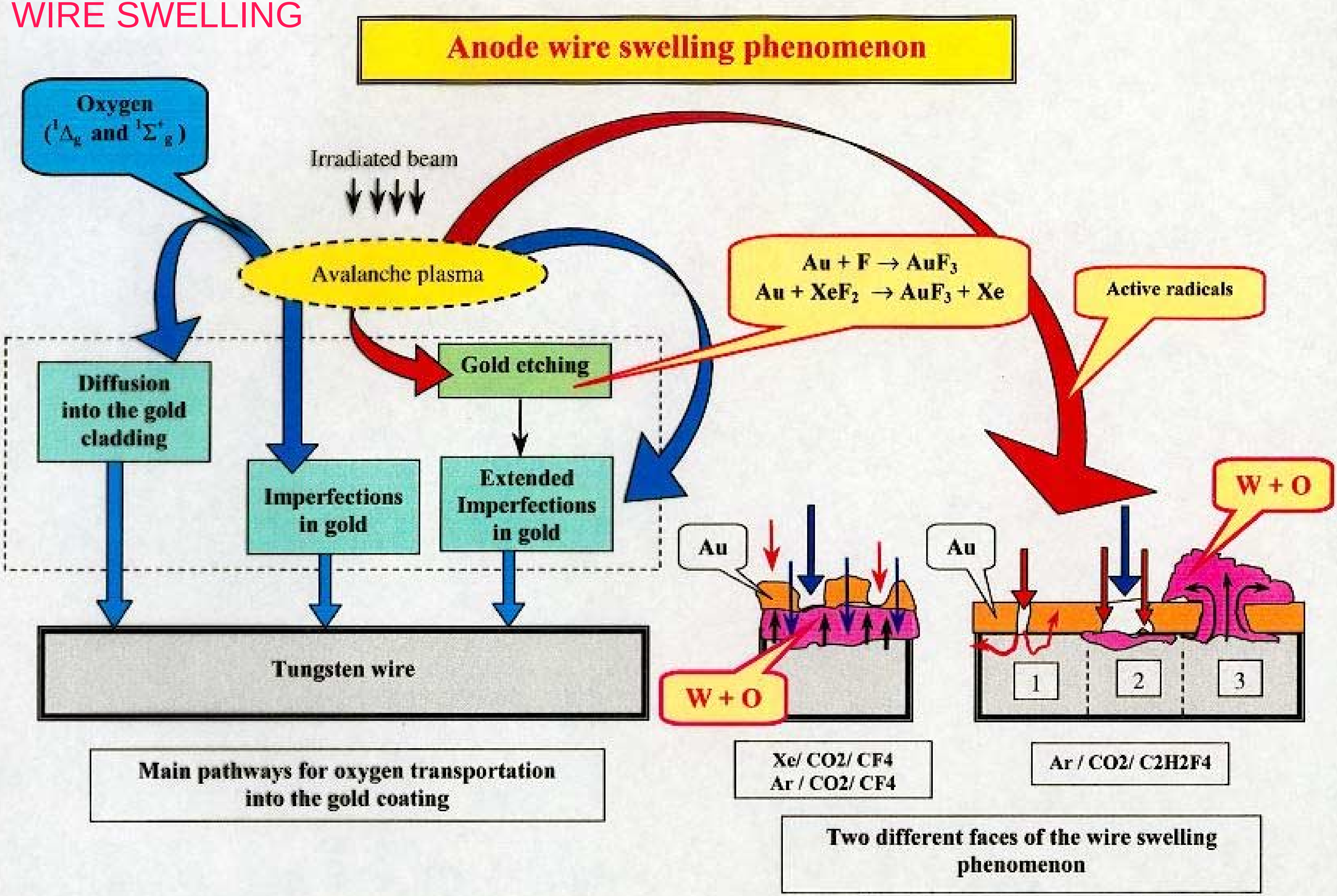
TUNGSTEN WIRE SWELLING 2





T. Ferguson, G. Gavrilov et al

WIRE SWELLING



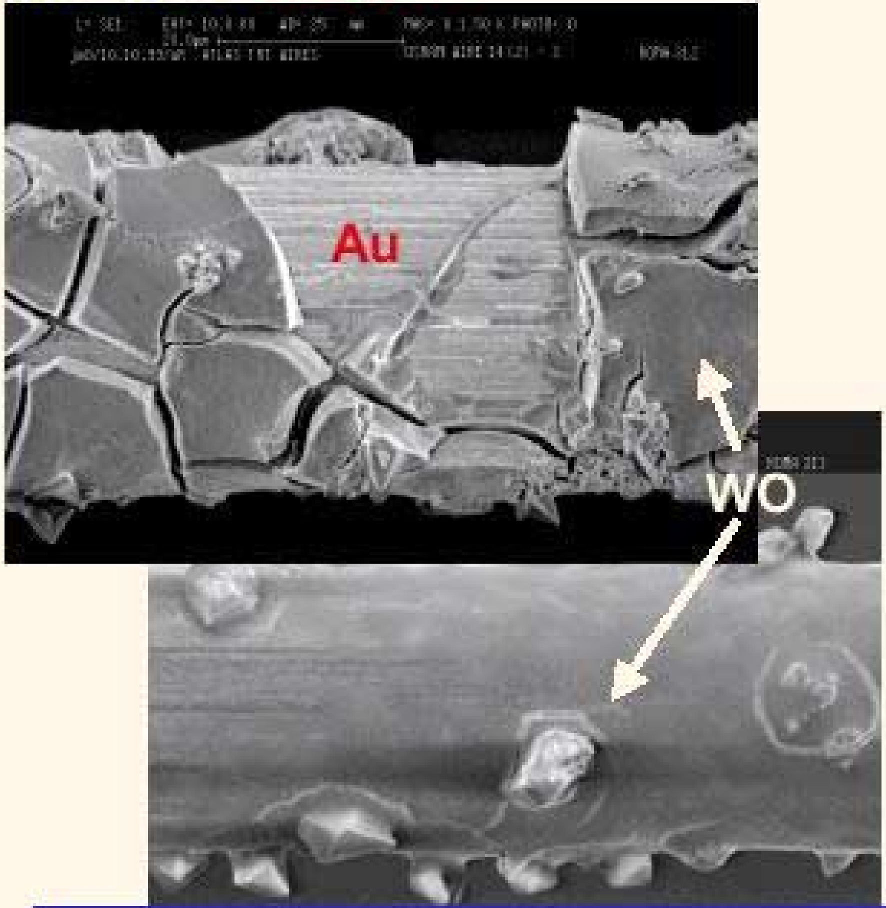
GOLD DAMAGE 1

Gold-damage effects: Reason

OSRAM wire, 3 % Au

Standard mixture +1.2% H_20 and 1.5%O_2

Total dose: *0.5 C/cm*

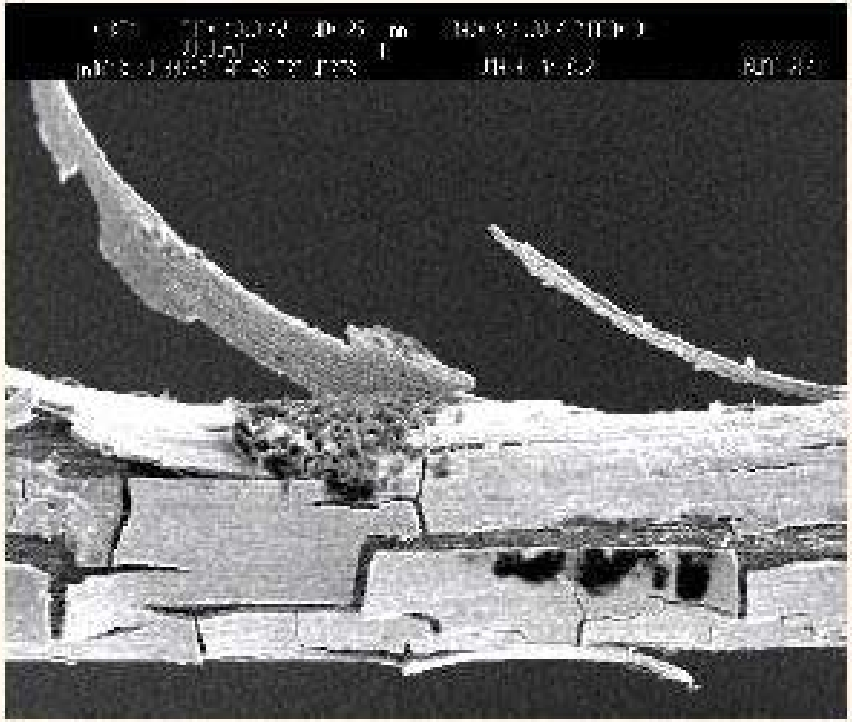


Luma wire, 5 % Au,

Ni-substrate

Standard mixture +1.2% H_20 and 1.5%O_2

Total dose: ~3 C/cm



Presence of molecular Oxygen makes processes more complicated!

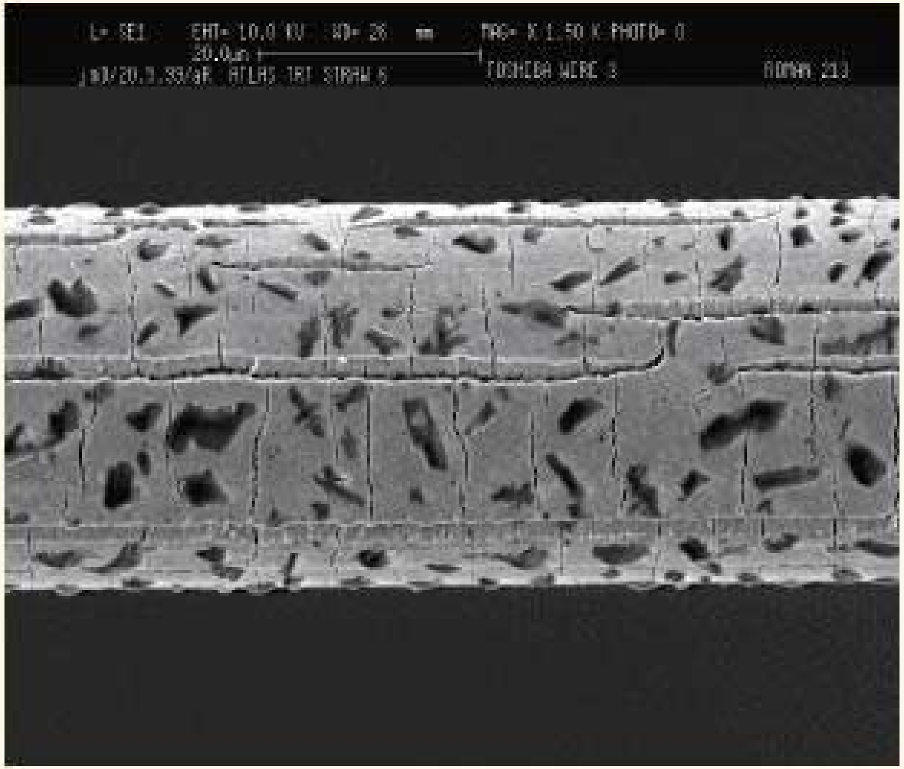
GOLD DAMAGE 2

Gold-damage effects: Reason

Toshiba W wire (1 μm Au)

Standard mixture +1.2% H_2O

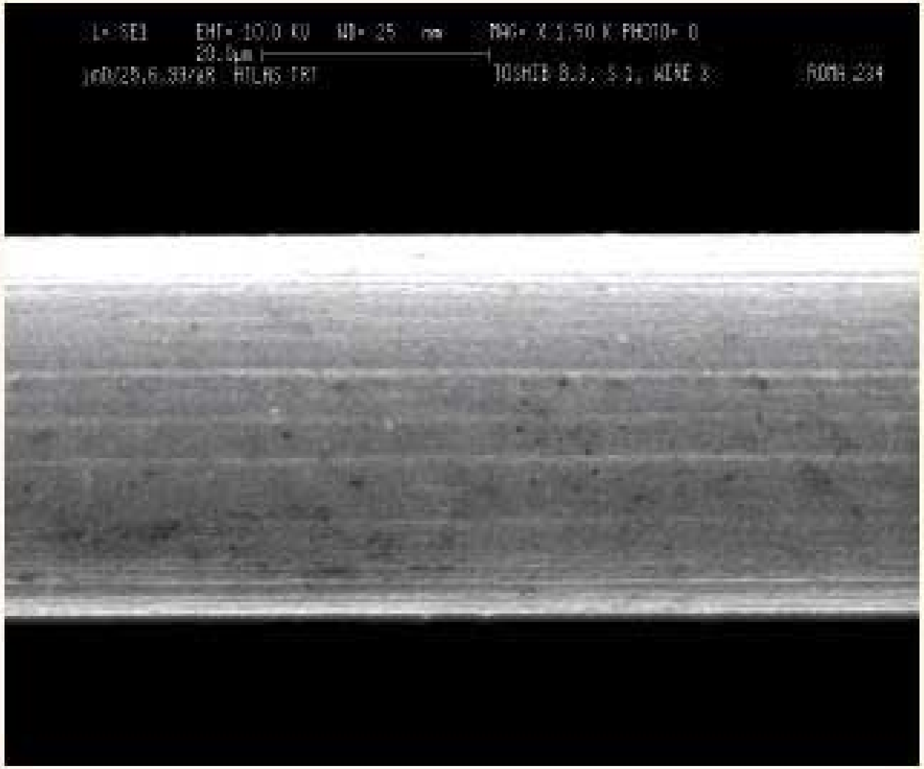
6.5 C/cm



Toshba W wire (1 μm Au)

Standard mixture +1.5% O_2 (NO H_20)

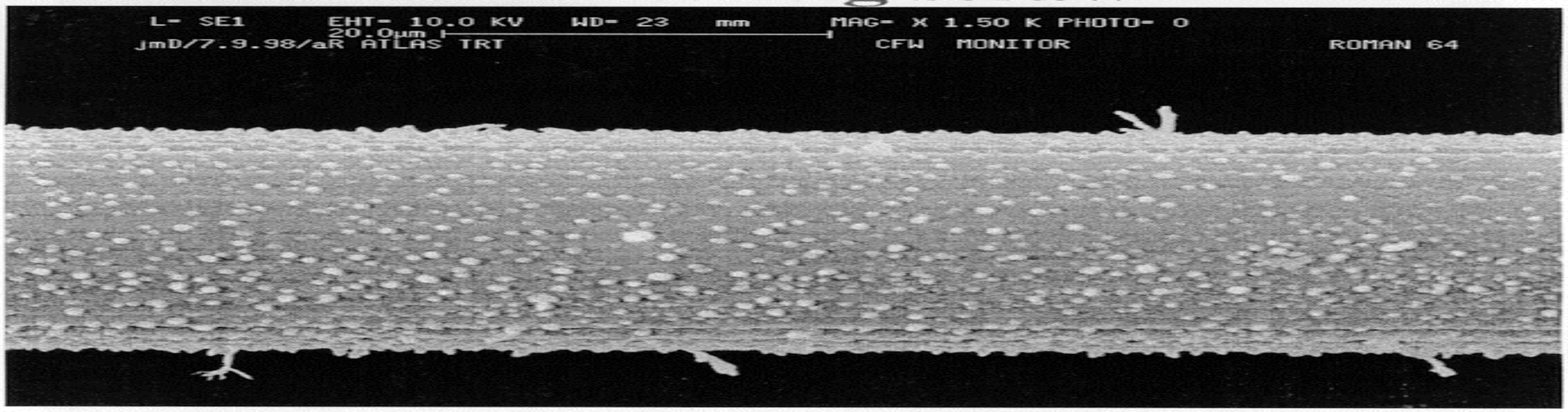
6.5 C/cm



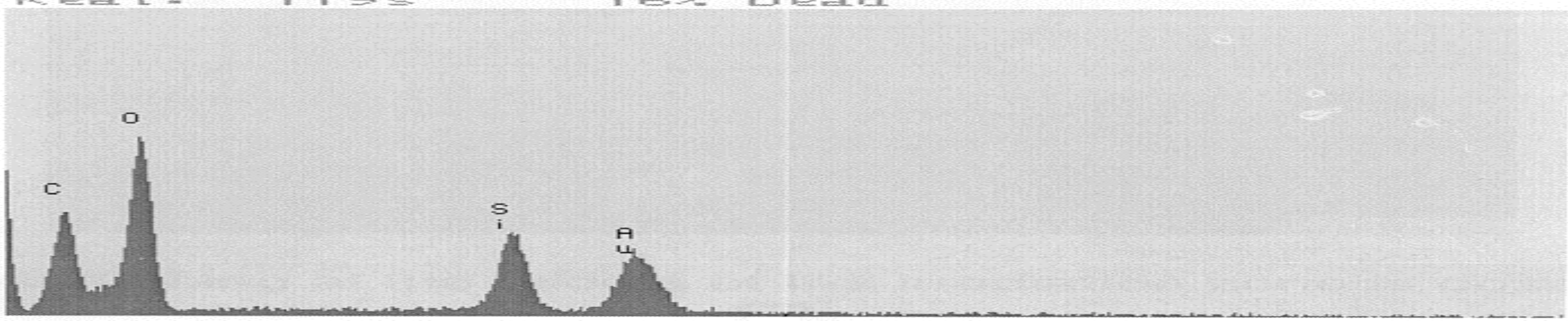
TRT STRAWS 3

Effect of Si-based lubricant initially used for the straw production

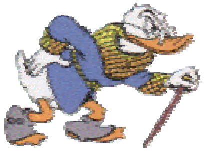
Monitoring straw



Counting rate ~5 kHz/cm:~ 20 times less than at LHC)



F. SAULI



AGING 2001

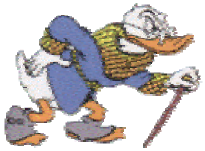
A. Romaniouk

DOES ANODE METAL MATTER?

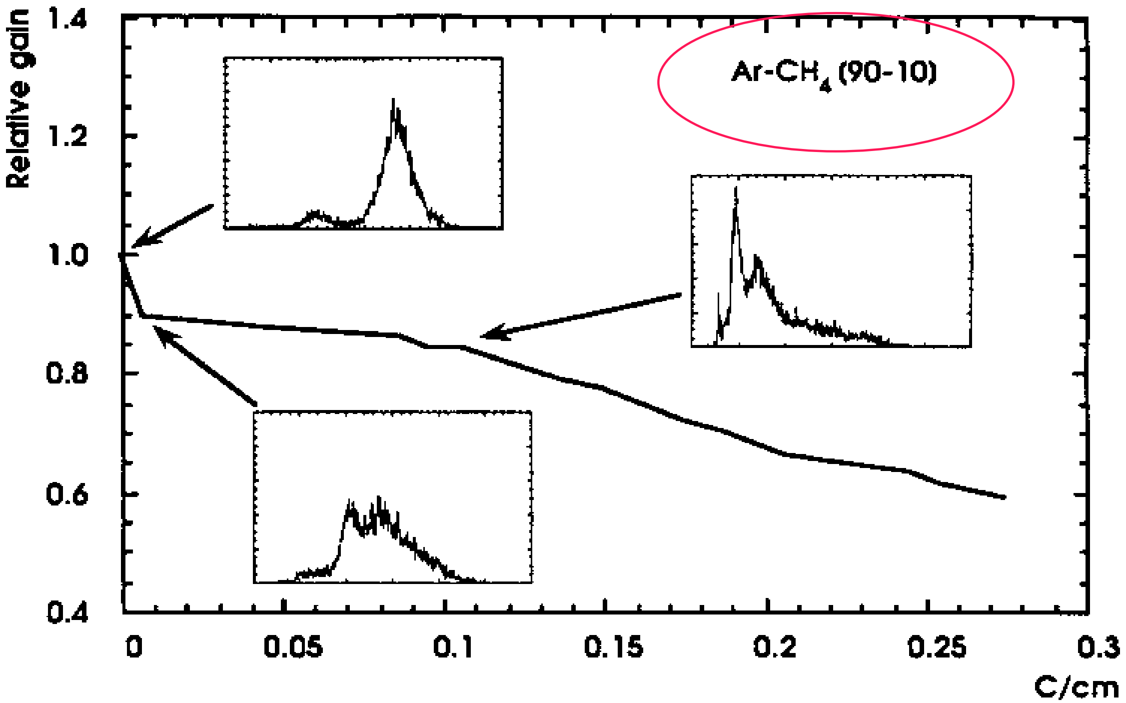
J. Kadyk reported worse aging in some gases for Stableohm wire as compared to Au-plated tungsten (LBL Workshop 1986)

Ar-C_2H_6-Ethanol	Au/W :	R=1.3%/C cm
	Stableohm:	R= 800%/C cm

ANY OTHER EVIDENCE?

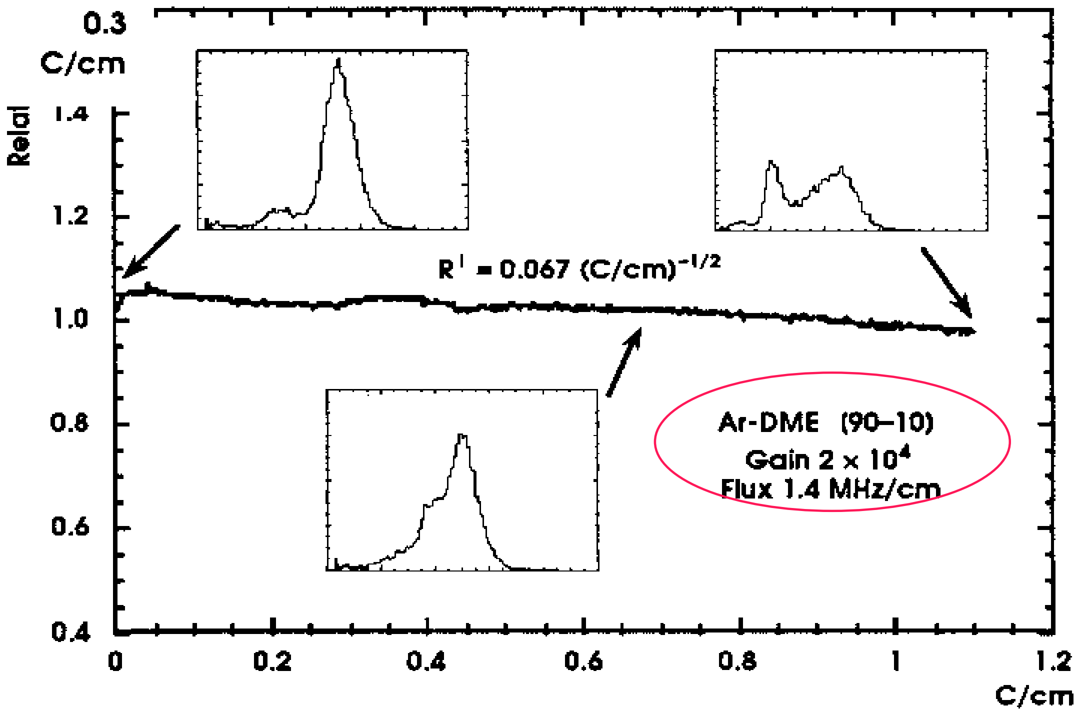


DOES ANODE METAL MATTER (3) ?

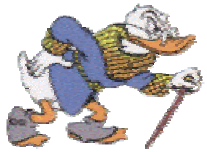


SINGLE WIRE COUNTER
STAINLESS STEEL WIRE

BAD IN $Ar\text{-}CH_4$
GOOD in DME



R. Bouclier et al, Nucl. Instrum. Methods
A346(1994)114



RECOVERING AGING CHAMBERS: HEAT TREATMENT

HERA-B RICH   CH4-TMAE

WIRE HEATED (WITH CURRENT)

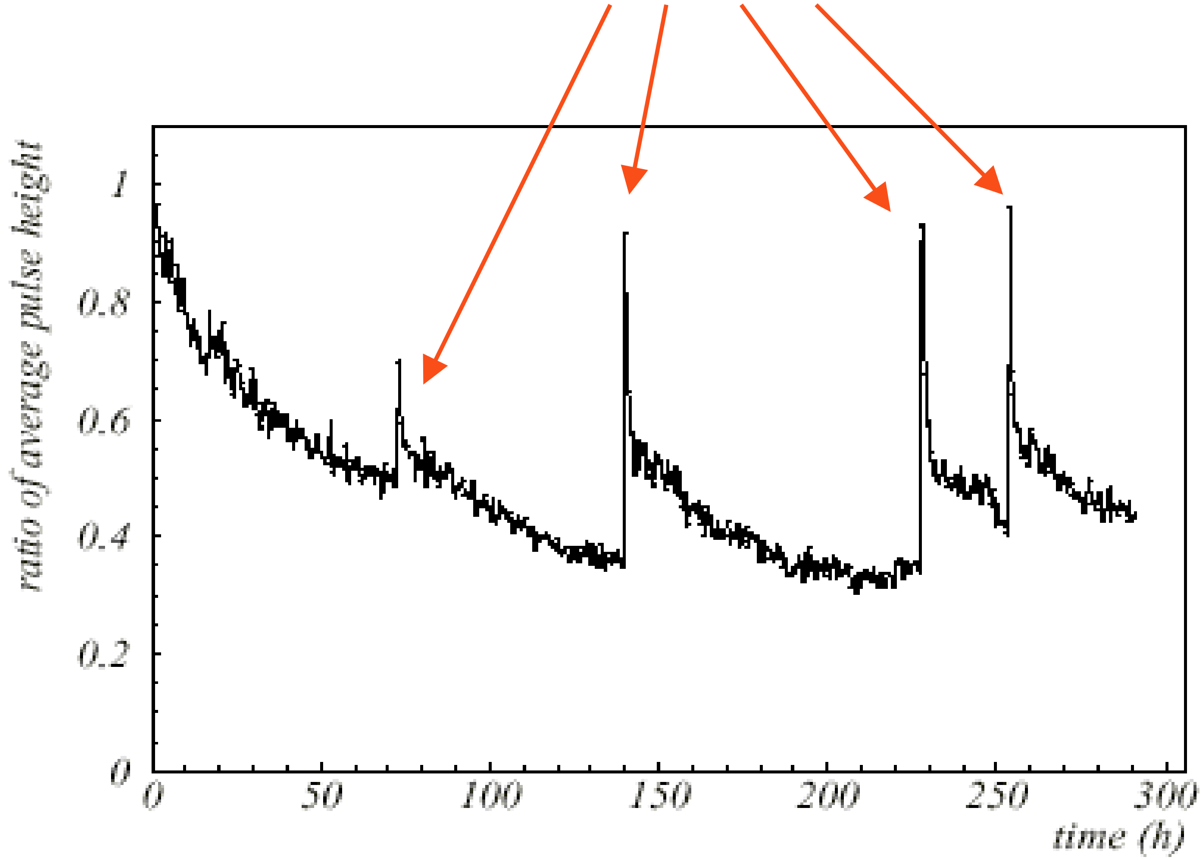
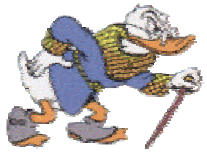


Figure 10: Time dependence of the ratio of average pulse heights between illuminated to non-illuminated cells which have been heated.

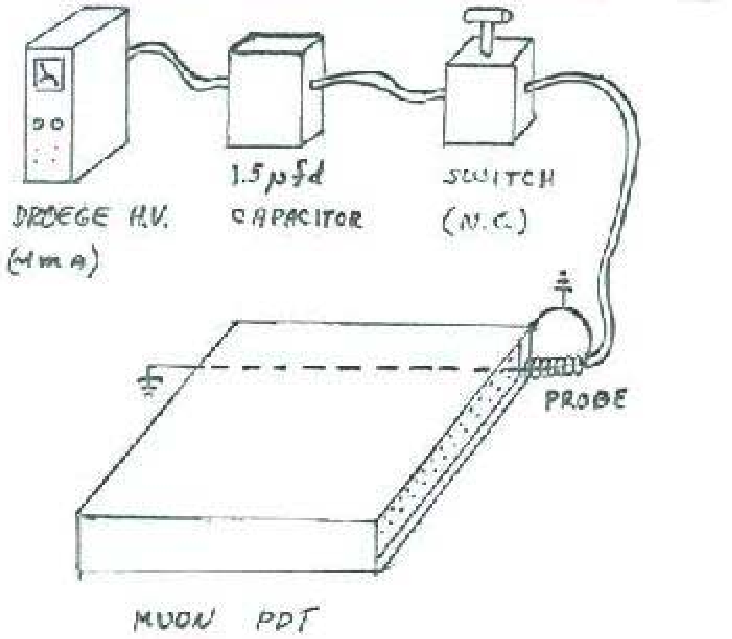
F. SAULI



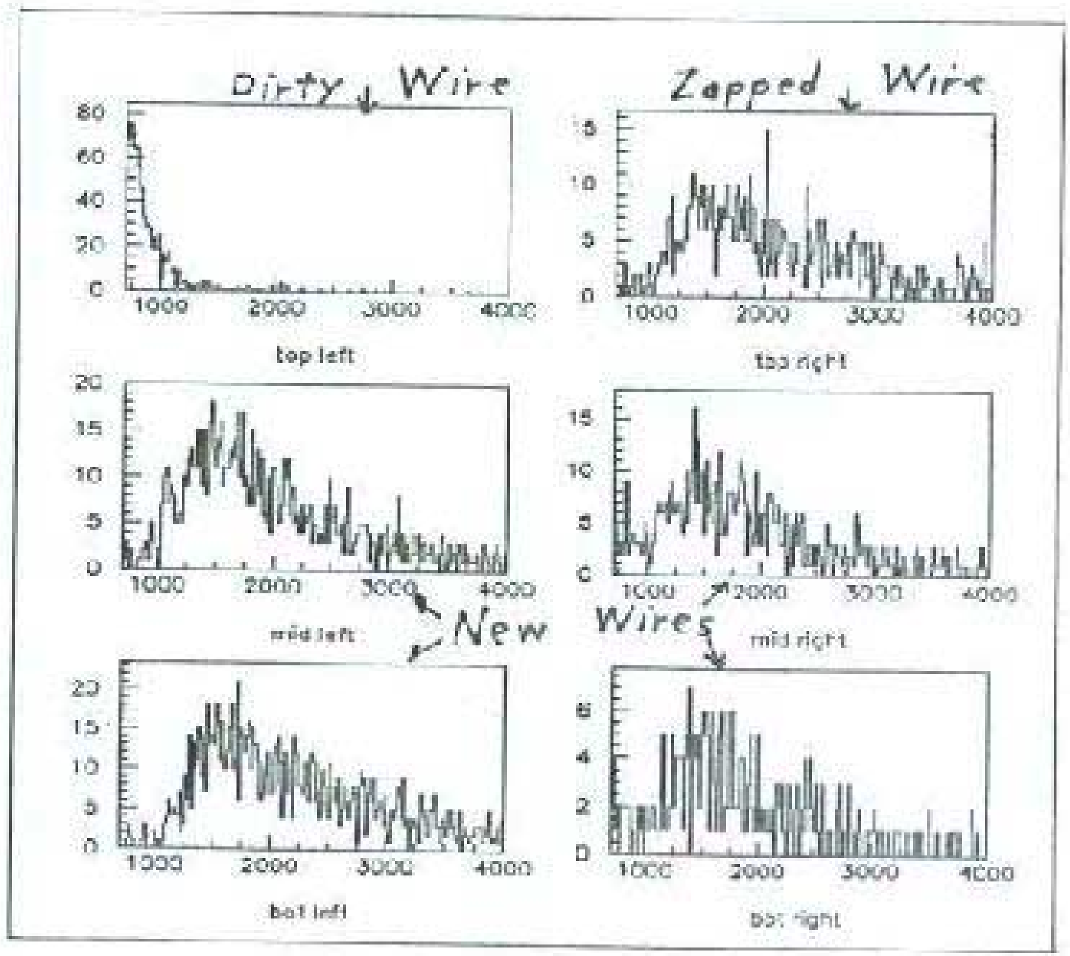
S. Korpar et al, IEEE Trans. Nucl. Sci. NS-46 (1999)317
D. Skrk, DESY Aging Workshop 2001

WIRE ZAPPING

ZAPPER Schematic



- Operating Voltage Range: 3500 - 6280 volts
  - 75" 228"
- Stored Energy: 9.5 J - 31 J

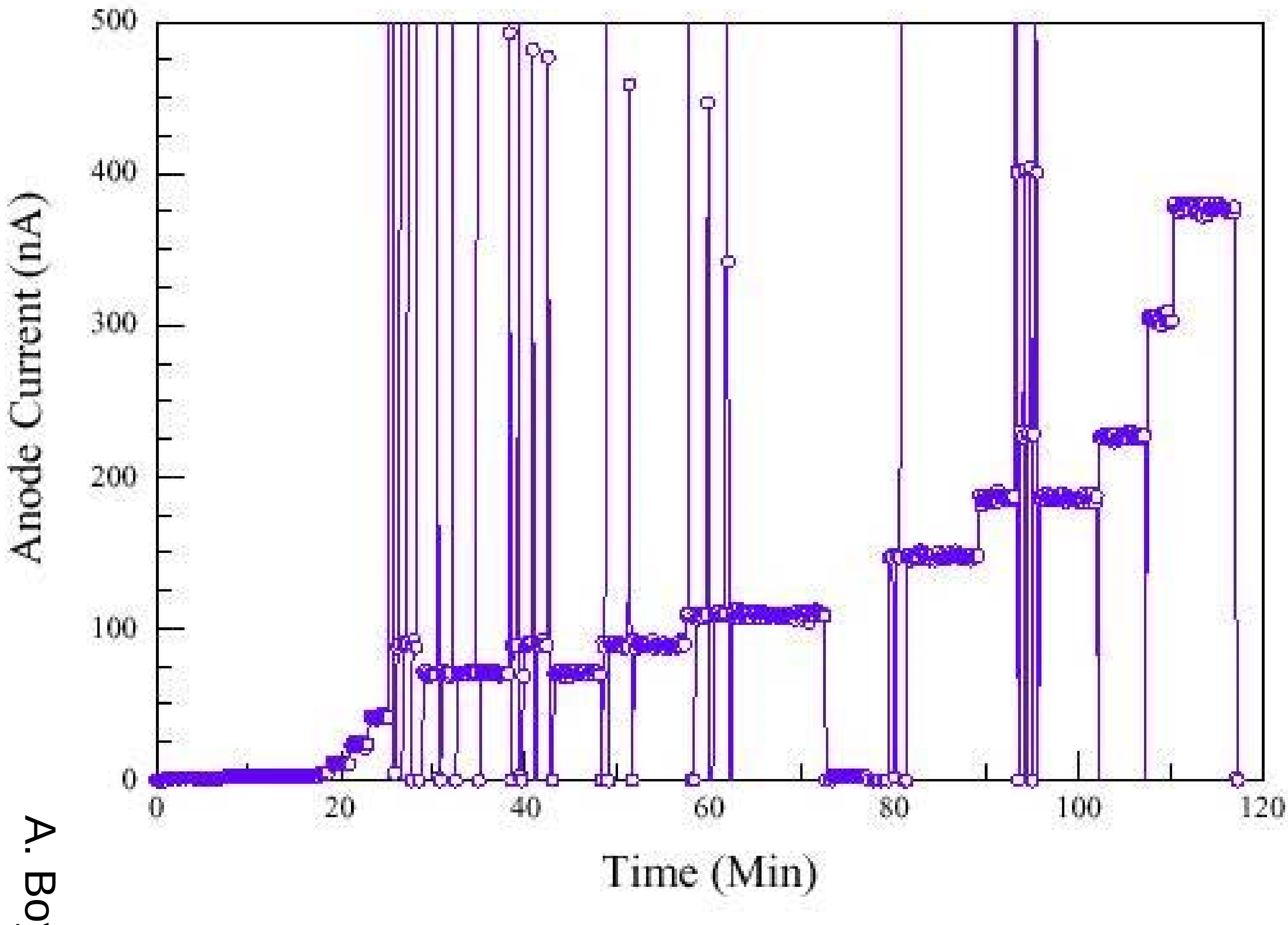


T. Marshall

Additive: O_2

Shows the anode current versus curing time. When the Fe^{55} source is increased too quickly, Malter breakdown occurs. But after repeated attempts the higher current becomes steady, reaching 375 nA (29 nA/cm) at the maximum source strength.

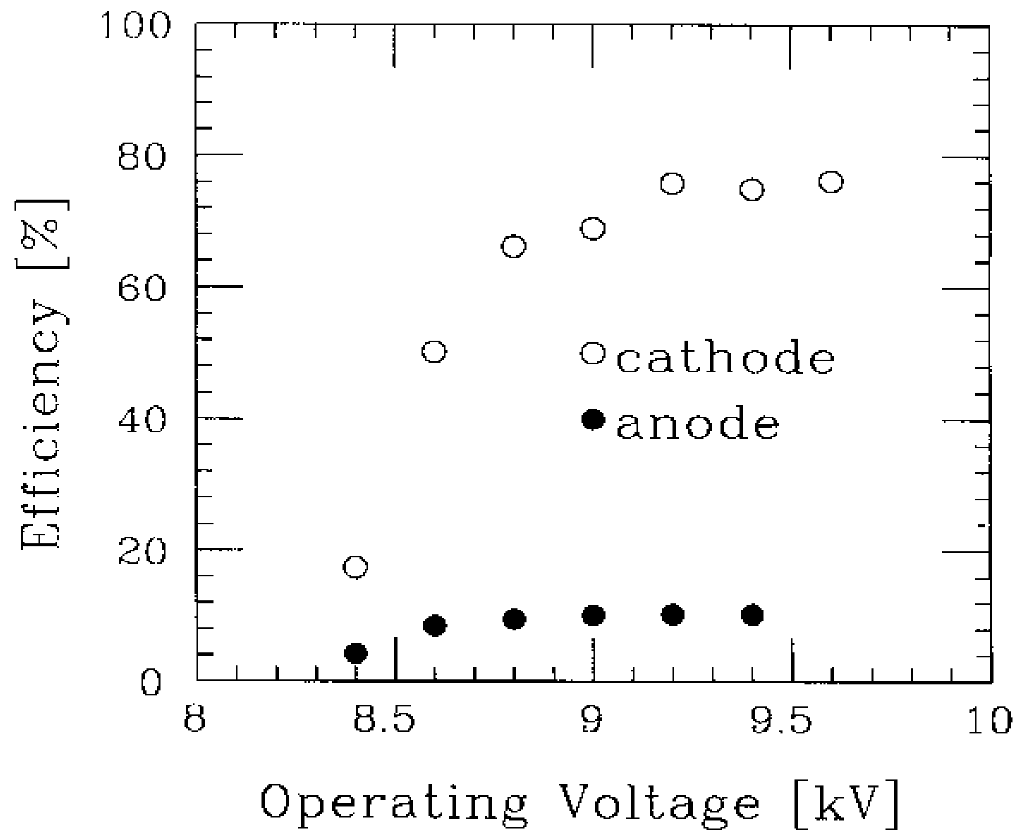
Chamber Curing With 500 ppm Oxygen



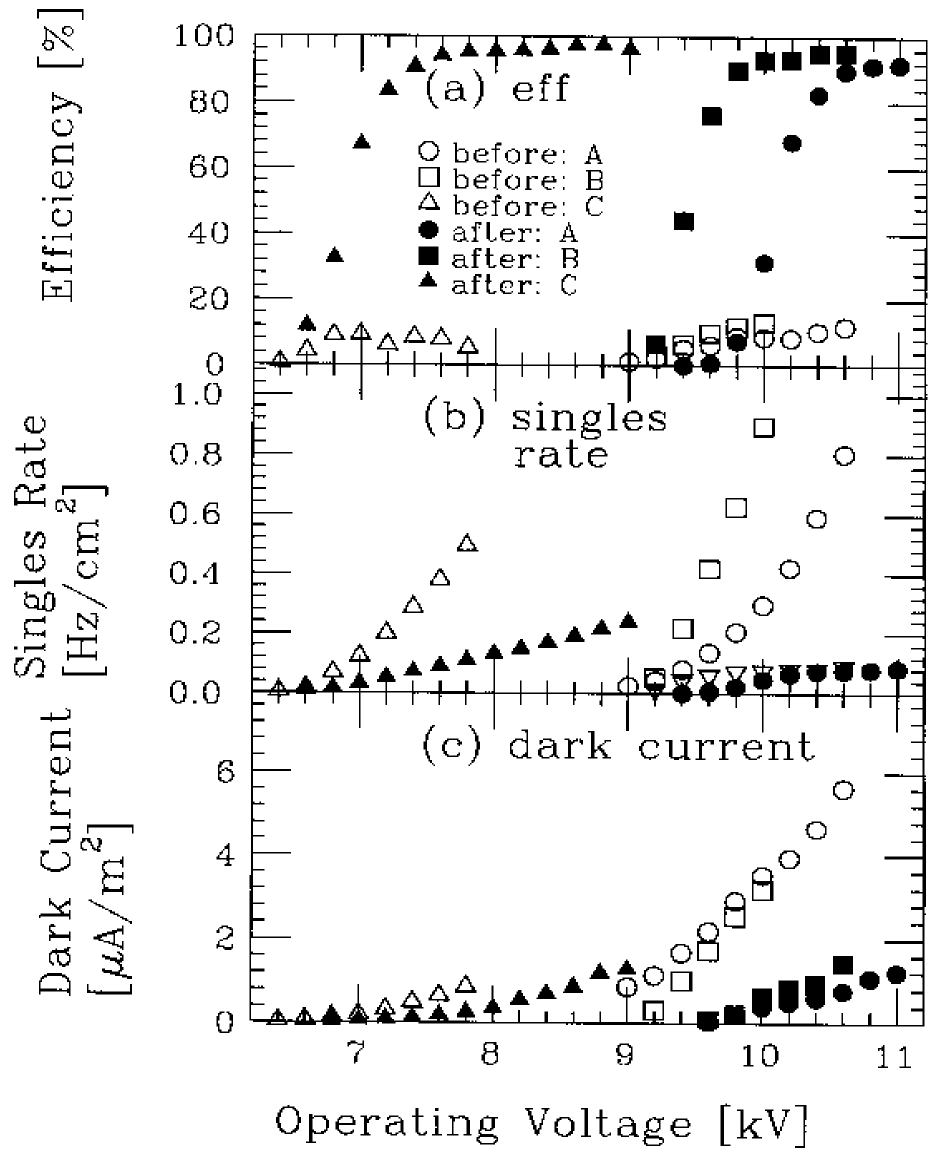
A. Boyarski

RECOVERY OF GLASS RPCs WITH AMMONIA

SCRUBBING ANODE OR CATHODE PLATE:



FLUSHING WITH NH_3 AND TRAINING:



H. Sakai et al, to be published in Nucl. Instrum. Methods A

MECHANISM of AGEING and DEVELOPMENT

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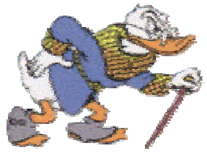
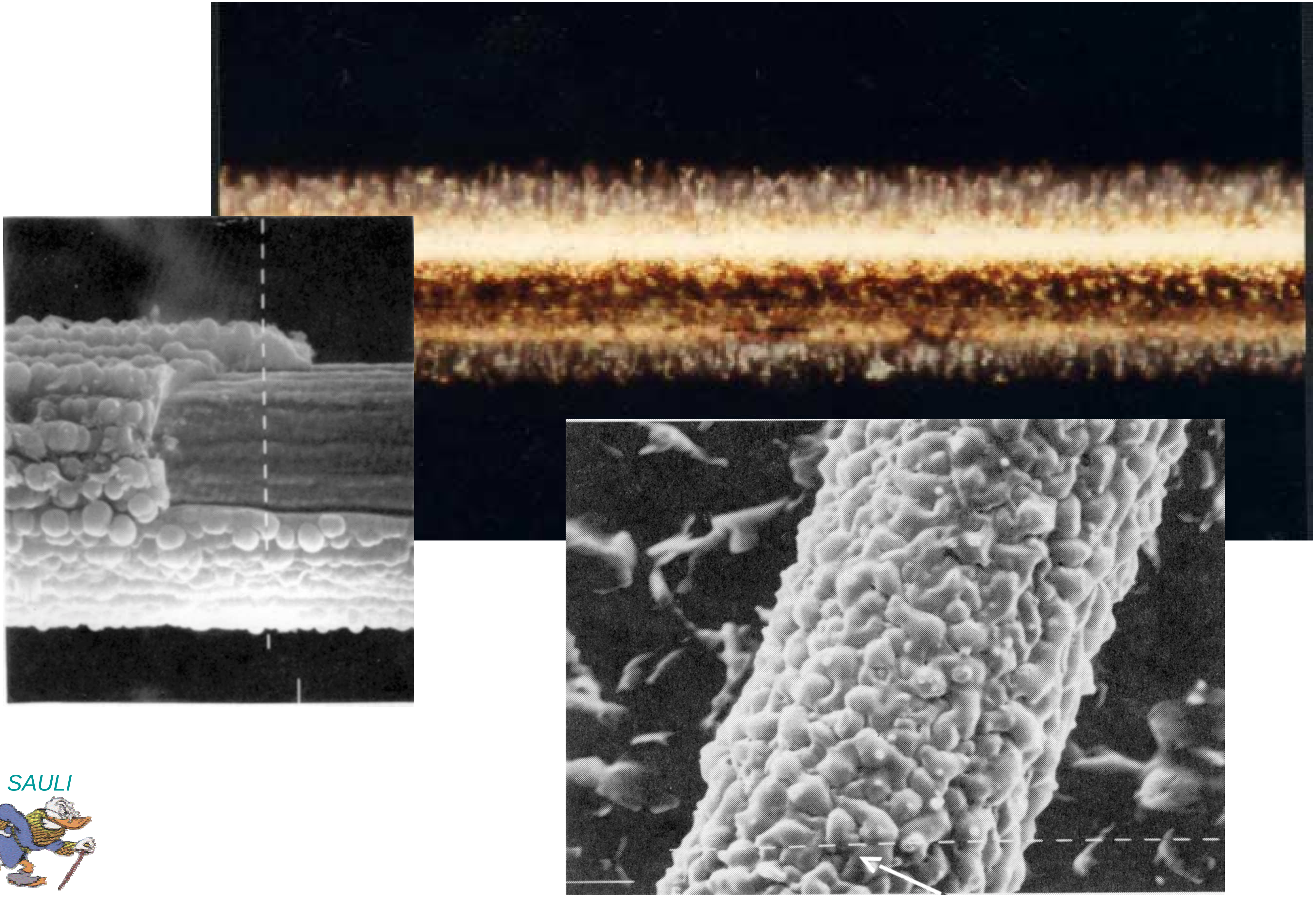


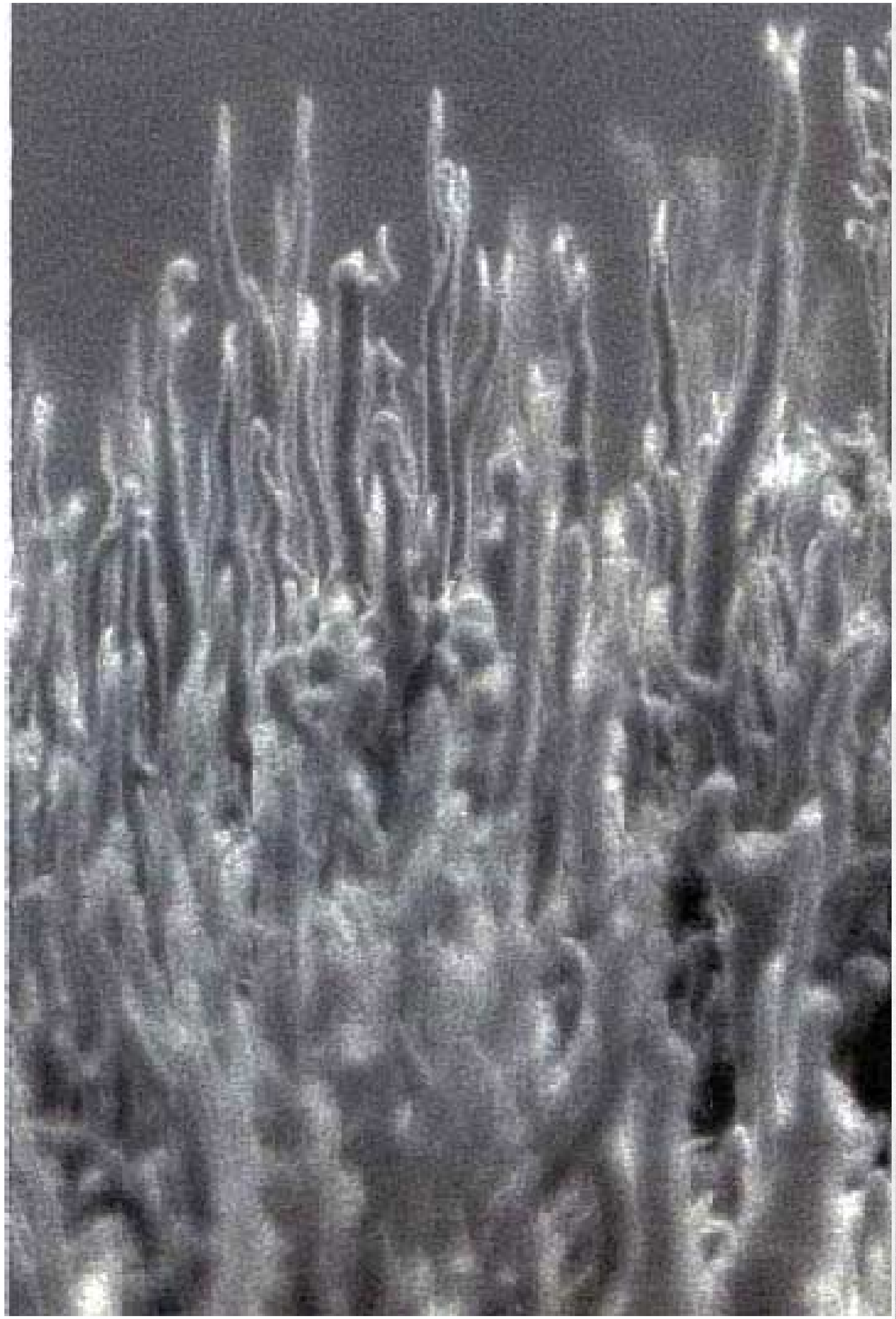
AGING 2001

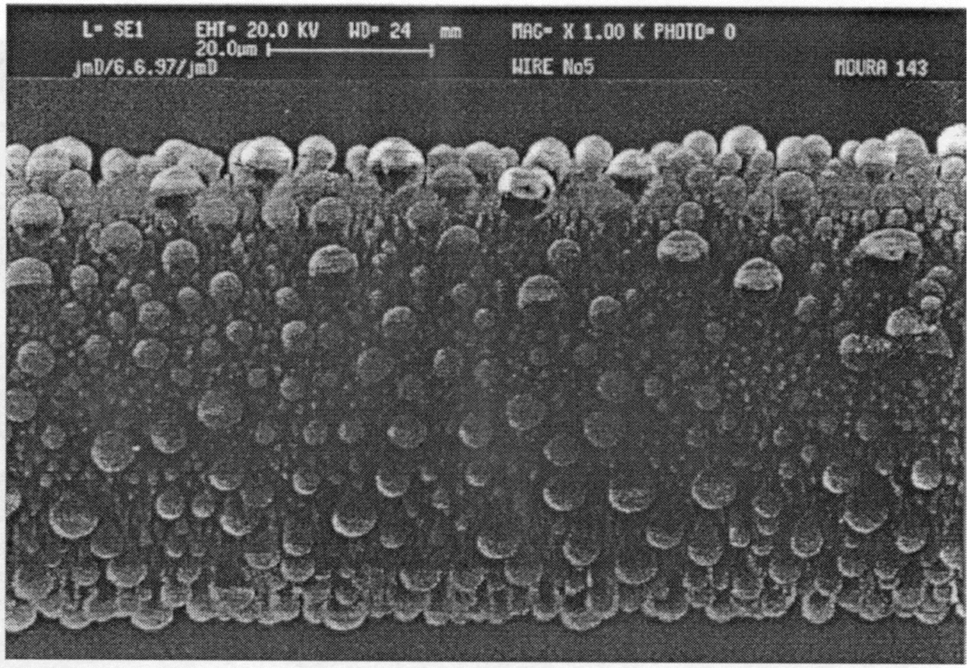
MAD

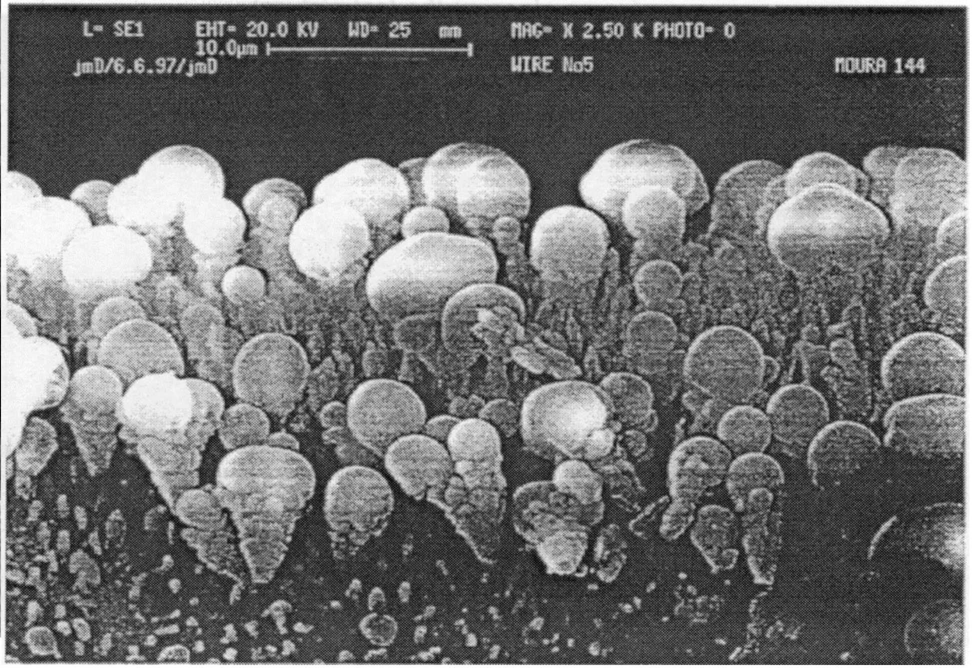
POLYMER FORMATION OR ORGANIC CHEMISTRY?



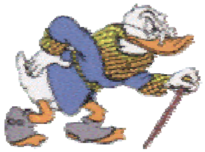
SILICON LIFE?





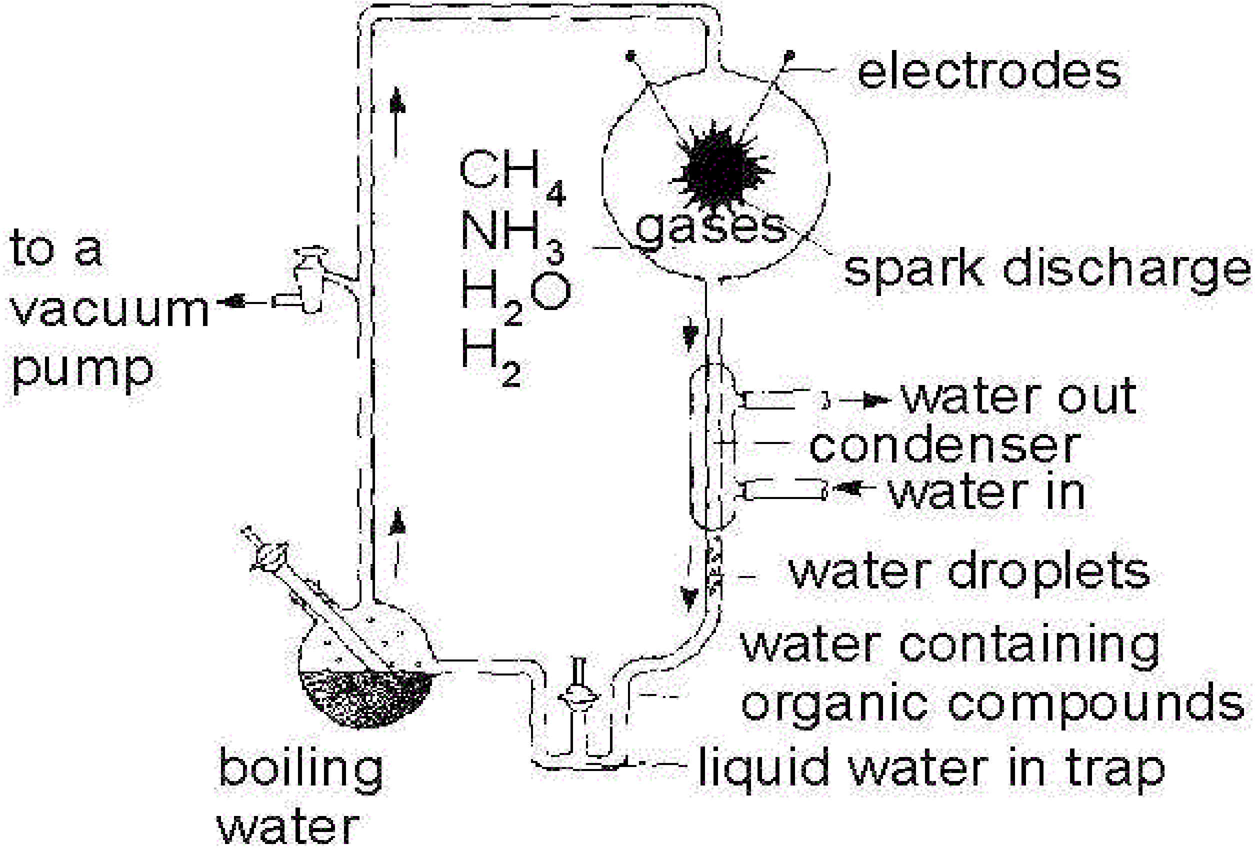


F. SAULI

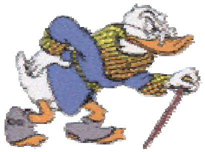


AGING 2001

GAS DISCHARGES - THE ORIGIN OF LIFE?



S. Miller, Science 117 (1953) 528



Space invaders

Is Earth under attack from hoardes of alien bugs?

A THIRD of a tonne of extraterrestrial bacteria could be raining down on Earth every day. The controversial claim comes from scientists who say they have found microbes living more than 40 kilometres above the Earth's surface.

Ever since the 1970s astronomers Fred Hoyle and Chandra Wickramasinghe have backed the idea that Earth was seeded with life from space. They think microbes hitch-hike around the Universe on comets. Although the bacteria would spend much of the time frozen, radiation from the Sun would warm a comet's surface when it got close enough, making it shed microbes that might just fall to Earth.

Now Wickramasinghe says he's caught some extraterrestrial bacteria in the act. In January, he and his colleagues at Cardiff University and the Indian Space Research Organisation in Bangalore launched a balloon from Hyderabad in southern India. Strapped to the balloon were several steel containers that were sterilised and evacuated before launch.

As the balloon rose through the atmosphere, the containers collected air samples at four different altitudes over a range of 20 to 41 kilometres. When the balloon landed, four containers with air samples and two unopened canisters were sent to David Lloyd, a microbiologist at Cardiff University.

Lloyd says that no microbes had contaminated the unopened containers. But he found that all four containers that were opened high in the atmosphere contained clumps of bacteria. "We found a mixture of alive and dead microbes," says Lloyd.

The researchers found similar numbers of bacteria clumps at every height they tested, Wickramasinghe told an astrobiology session at an engineering meeting held in San Diego last week. "If this was blown up from the ground, you'd get a tail off at higher altitudes," he says.

He says finding bacteria above 16 kilometres is intriguing because of an atmospheric "barrier" called the tropopause. Here, the atmosphere flips from getting colder with height to getting warmer. This cuts off convection currents that might otherwise carry microbes from the ground into the atmosphere.

"It acts like a lid," adds Ian Colbeck, an aerosols expert at Essex University in Colchester. "The only particles that can get near it are from volcanic eruptions, and bacteria probably wouldn't survive the heat. I can't see any way they'd have their origin on the ground."

Mark Burchell, a planetary scientist from the University of Kent at Canterbury, is more cautious. "There aren't good models for how high bacteria can be swept up," he says. "He may have extended the range of life on Earth, because 41 kilometres would be remarkable. But if it's from space, it'd not just be remarkable, it'd be astonishing."

Wickramasinghe estimates that if each clump of bacteria contains 100 bacteria, one third of a tonne of extraterrestrial bacteria could be falling on Earth every day. He is now trying to grow the microbes he collected and identify them. **Ian Sample**

Did life on Earth arrive from outer space?

The Frankenstein method

BOLTS of lightning that strike the ground may help bacteria adapt and evolve. Experiments suggest that electrical currents help soil bacteria exchange DNA.

Scientists commonly use electricity to increase the permeability of bacterial cell membranes, making it easier to insert DNA. Now Sandrine Demanèche's team at the University of Lyon has provided the first evidence that nature may have been wise to this trick all along.

The researchers seeded soil samples with the *E. coli* bacterium, as well as fragments of DNA containing genes for antibiotic resistance. They zapped the soil with a simulated lightning strike, and found that many of the bacteria had acquired the resistance genes.

Bacteria are already known to take up and use foreign DNA released into the environment when other organisms die. Scientists knew this "horizontal gene transfer" occurs naturally in soil, but thought it was relatively rare. However, recent genomic research indicates that this gene take-up is widespread and has played a major role in the evolution of the bacterial genome.

"This result might help explain the discrepancy between the very low observed rates of gene transfer and the apparently wide distribution of DNA sequences among bacteria," says team member Timothy Vogel.

Lightning may seem relatively rare, but there are about a hundred flashes a second around the planet. Ground strikes almost always create currents in the surrounding soil similar to those from the simulated bolts, Vogel says. **Scott Norris**

More at: Applied and Environmental Microbiology (vol 67, p 3440)

BIG BOLT: lightning may spark evolution