Materials and gases: Lessons for detectors and gas systems

Mar Capeans
CERN

Invited review talk at the International Workshop on Aging Phenomena in Gaseous Detectors

Outline

- Ageing
- Outgassing studies
- Detector Assembly Materials
- Detector Assembly Procedures
- Components for Gas Systems
- Influence of Some Gases on Ageing

The Very Basic Knowledge

- **Gaseous detectors operated in a high radiation environment can have serious operational problems due to ageing.**
- **Commonly ageing manifests as:**
  - **Loss of gas gain**
  - **Worsening of energy resolution**
  - **Excessive currents**
  - **Self-sustained discharges**
  - **Sparking**

All these are usually related to the presence of deposits coating the electrodes (anode and/or cathode).

Basic Knowledge

- **The ageing process is due to very complex phenomena that take place during the gas avalanche (~ plasma chemistry).**
- **These phenomena lead to the creation of a wide variety of species that may accumulate as deposits, conductive or insulating, on the electrode surfaces.**

Polymerization

Polymers

- Solid, highly branched and cross linked
- Excellent adhesion to surfaces
- Resistant to most chemicals
- Insoluble in most solvents

Basic Knowledge

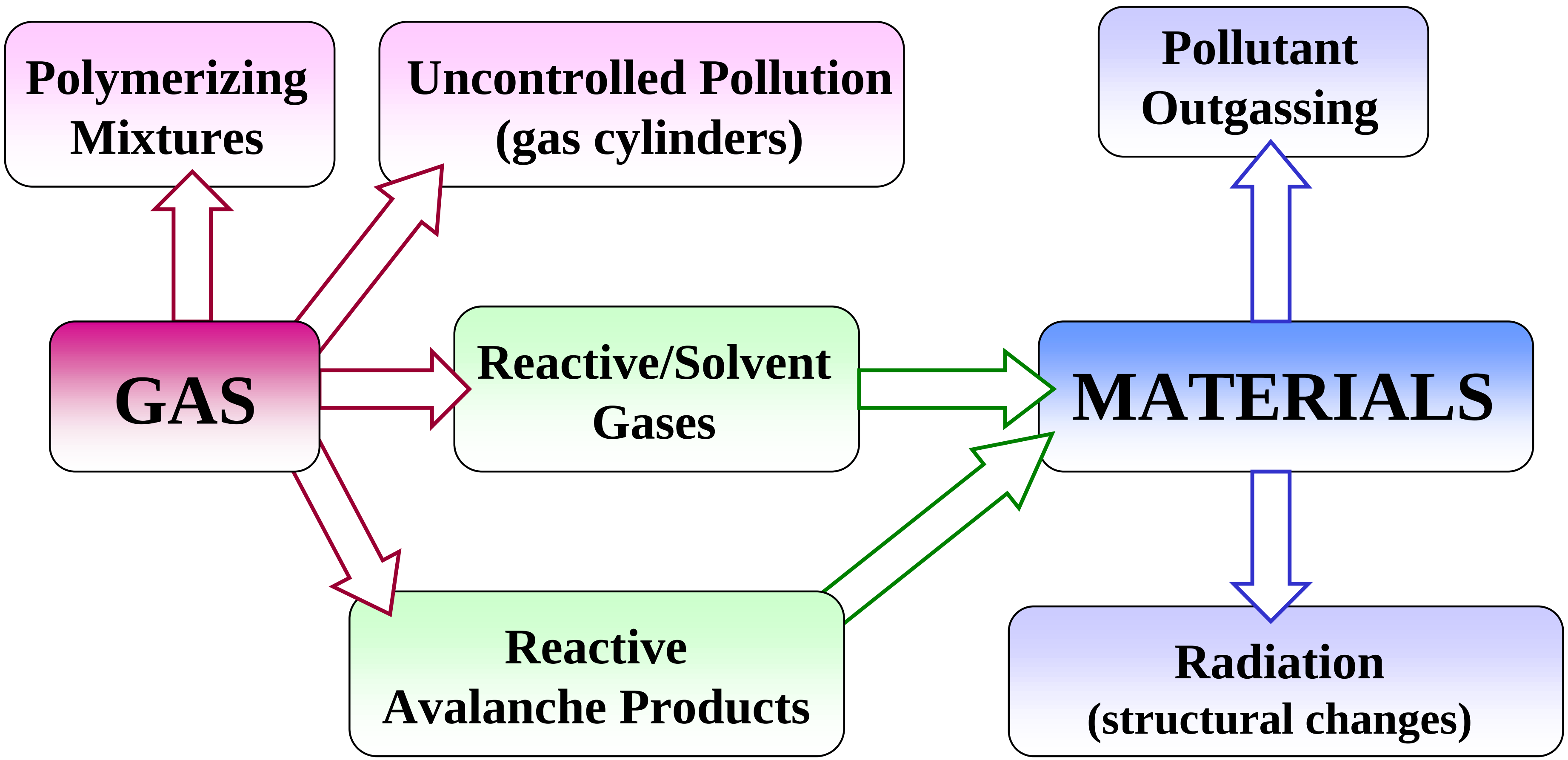
- **Measured ageing, quantitative and qualitatively, depends on many factors:**
  - **Gas gain**
  - **Gas flow & Pressure**
  - **Charge density**
  - **Geometry and configuration of electric field**
  - **Active gas**
    - → **Nature of gas**
    - → **Traces of contaminants**
- **Experimental observations are difficult to compare and/or extrapolate between one another.**

Recent experience

1986	SSC @ US	SDC Straw tubes, Pad chambers,…
	LEP @ CERN	DELPHI,…
1990	Basic R&D	RD-10, RD-28, RD-6,…
	MSGC community	RD-28, Hera-B, CMS, ATLAS,…
1994	Detector R&D for LHC	ATLAS-TRT, ATLAS-MDT, CMS CSC,…
	Hera-B construction	OTR, ITR, Muons

Still comparison and/or extrapolation is difficult but all this experience provides a solid basis for discussion

Contributions to the Ageing Process

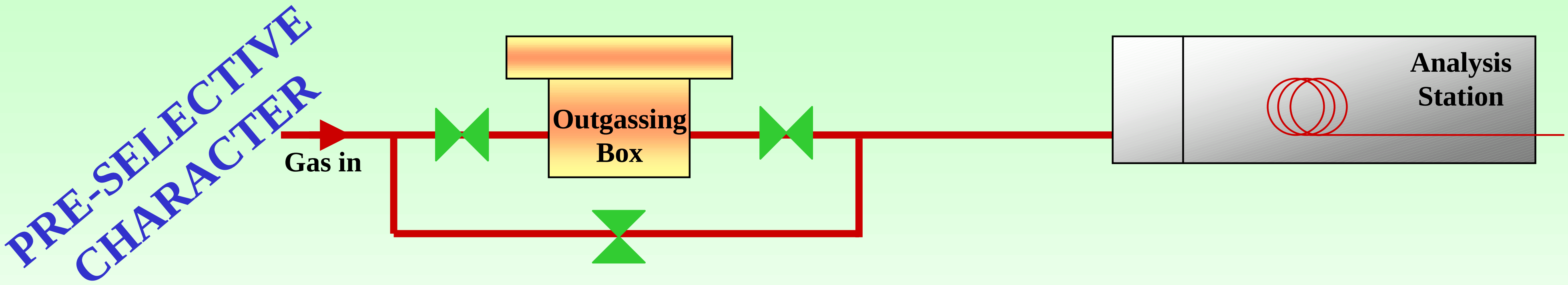


Outgassing Tests of Some Materials

- **Outgassing studies** → •Methods
- **Epoxy compounds** → •Low outgassing, Room T curing; •Rejectable, Room T curing; •Curing at T > 40 co; •Conductive
- **Adhesive tapes**
- **Leak Sealers**
- **Rigid Materials**
- **Contamination** → •User-generated; •Silicone

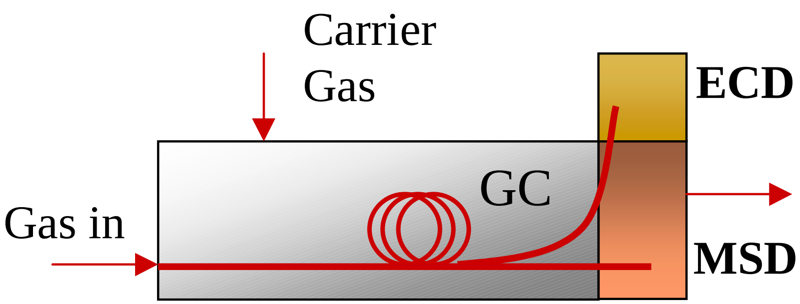
The Minimal Set-Up

Gas analysis of a sample



- Impurity detection has the intrinsic limitations of the analysis station, that may not be sensitive to all species because of:
  - low pollutant concentration
  - specific sensitivity
- Sometimes heating of the sample is needed to detect outgassing (scaling factor unknown).
- Even if outgassing is detected, it might not be harmful for the gaseous detector.

Gas Chromatography Basics



GC: oven with a capillary column.
Function: it **separates** gas substances depending on their interaction properties with the column.
Signal: a signal appears for each separated compound at some retention time, defined by the column and temperature profile.

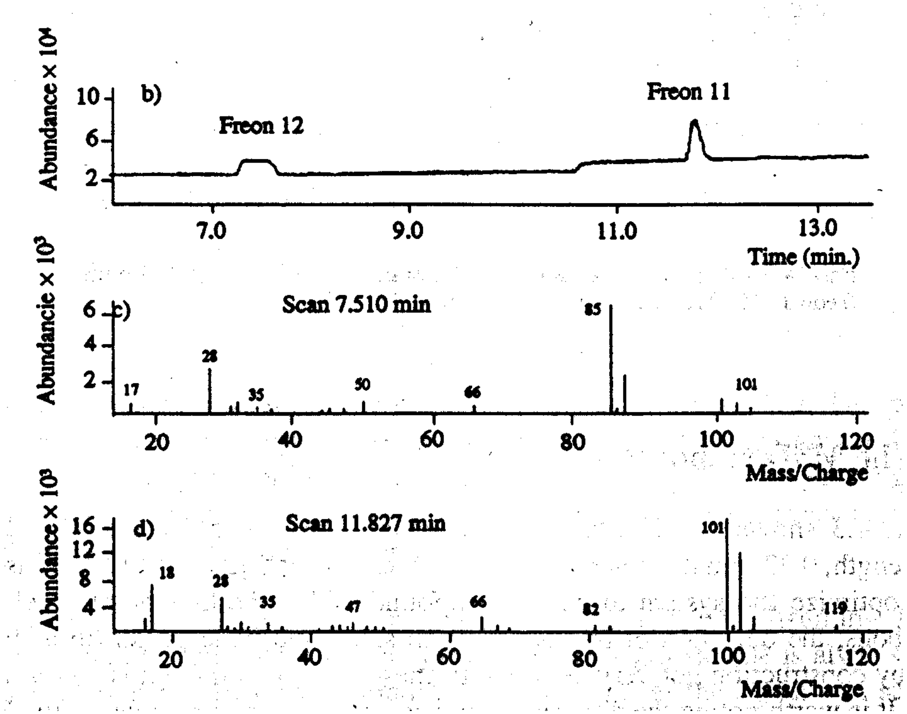
MSD: 70 eV e^- source to ionize and fragment molecules + quadrupole mass filter to sort resulting ions according to their M/Z ratio.
Function: it **identifies** each molecular compound.
Signal: ion abundance as function of retention time in the column or M/Z ratio.
Sensitivity: ~ ppm

ECD: βe^- bombard a carrier gas to form a plasma. Thermal e^- are collected applying an E-field. The decrease of the detector current due to removal of thermal e^- by recombination in presence of electro-capturing compounds gives a signal.
Function: **detection of electronegative** substances
Signal: signal amplitude vs. time.
Sensitivity: ~ ppb

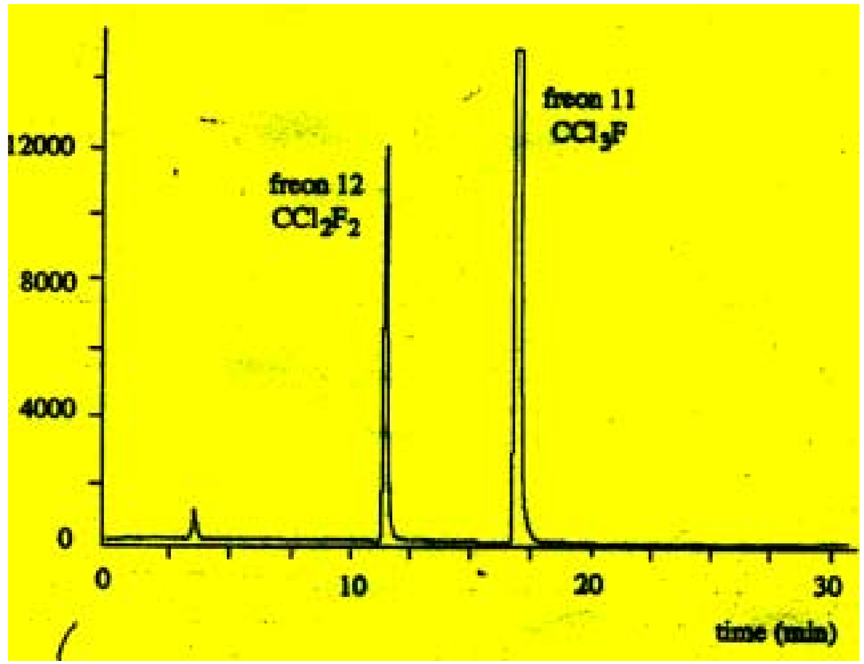
Gas Chromatography Basics

Selection of column, temperature profile and carrier gas nature and flow defines the sensitivity of the station.

MSD signal 10 ppm F12+F11



ECD signal 10 ppm F12+F11



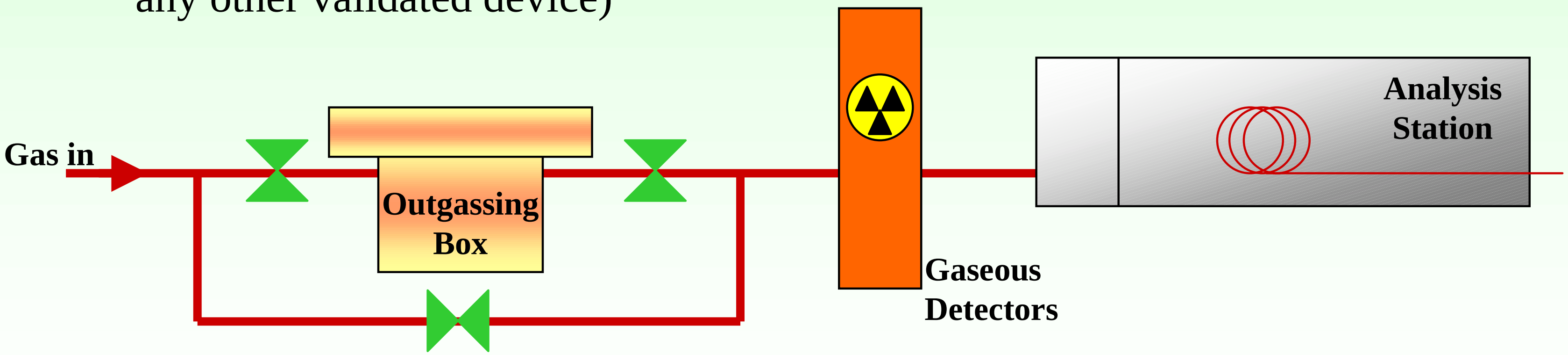
Gas Analysis + Detector irradiation

To get information about the effect of pollutants:

Gas Analysis + **Ageing Test**

Clean Gas detector
(full metal SWPC or
any other validated device)

Small prototype of final detector



Limitations: - Irradiation conditions (high dose rates)
- Time scale (~months)

TML & CVCM Method

- **Developed at NASA to search low outgassing materials for spacecraft use.**

  http://epims.gsfc.nasa.gov/og/index.cgi

PRE-SELECTIVE CHARACTER

- **Test of** conditioned micro-quantities in vacuum at stated temperatures and specific times.
- **Technique** of condensing the volatile products to determine the amount of volatile condensable materials.
- **Output:** Low Outgassing Material **TLM < 1% & CVCM < 0.1%**

% TML = Total Mass Loss	**% CVCM** = Collected Volatile Condensable Materials
It is determined from the weights before and after the temperature exposure.	It is the difference between the weight of a clean collector and of the collector having condensed materials.

Epoxy Compounds

Parameters to take into account during selection:

- Shear strength
- Elongation at break
- Viscosity
- Electrical properties
- Capillary effect
- Radiation resistance
- **Outgassing** →
  - **Material itself**
  - **User-generated (hard to trace):**
    - **Pollution**
    - **Incorrect ratio of hardener to resin**
    - **Insufficient mixing**
    - **Insufficient curing time**

Low Outgassing Epoxy Compounds
Room-T Curing

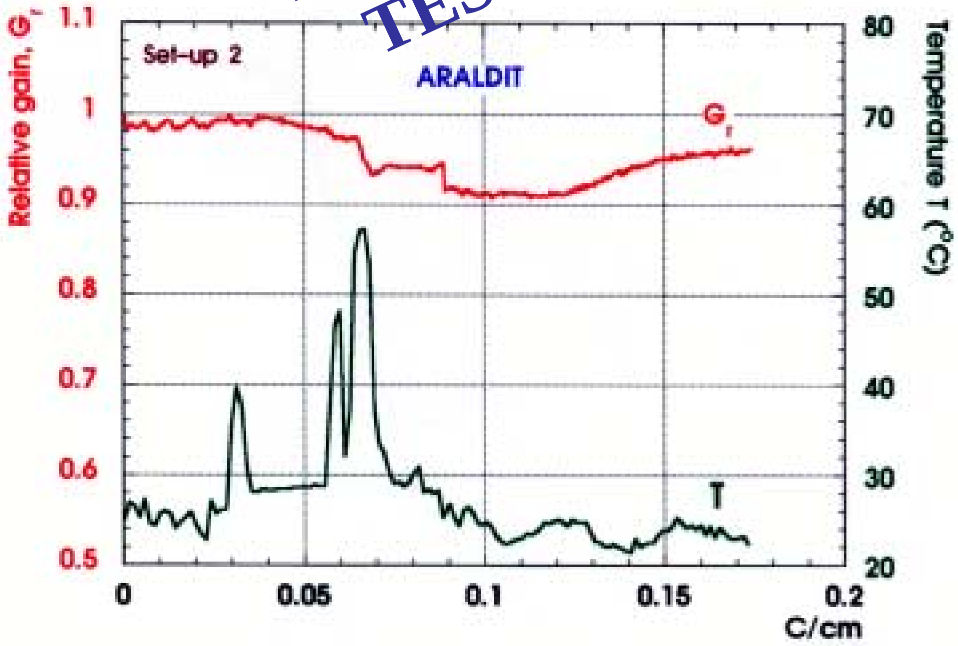
Source	Product	Outgas	Effect in G.D.	Note
CERN/GDD	**STYCAST 1266 (A+B)**	NO	NO	Long curing time
HERA-B/OTR	**STYCAST 1266 (A+Catalyst 9)**	NO	NO	In Use
CERN/GDD	**HEXCEL EPO 93L**	NO	NO	Out of production
HERA-B/ITR	**ECCOBOND 285**	NO	NO	In Use
CERN/GDD ATLAS/TRT	**ARALDITE AW103 (Hardener HY 991)**	NO	NO	In Use
ATLAS/TRT	**TRABOND 2115**	NO	NO	In Use

‘Rejectable’ Epoxy Compounds
Room-T Curing

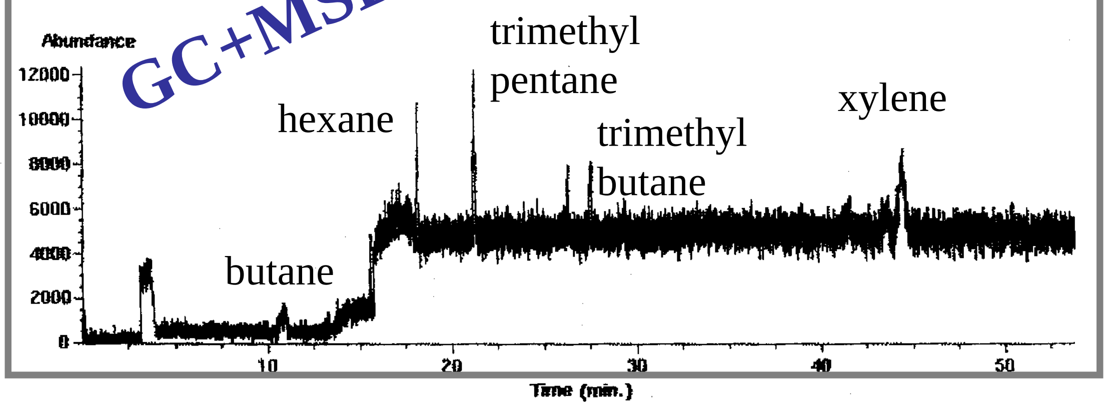
Source	Product	Outgas	Effect in G.D.	Result
CERN/GDD ATLAS/TRT	**ARALDITE AW 106 (Hardener HV 935 U)**	YES		**BAD**
CERN/GDD	**DURALCO 4525**	YES	YES	**BAD**
CERN/GDD	**DURALCO 4461**	YES	YES	**BAD**
CERN/GDD	**HEXCEL A40**	YES	-	**BAD**
CERN/GDD	**TECHNICOLL 8862 + (Hardener 8263)**	YES	-	**BAD**
CERN/GDD	**NORLAND NEA 155**	YES	-	**BAD**
CERN/GDD	**EPOTEK E905**	YES	-	**BAD**
CERN/GDD	**NORLAND NEA 123 (UV)**	YES	-	**BAD**

TESTS OF ARALDITE AW 106 (+HV953U)

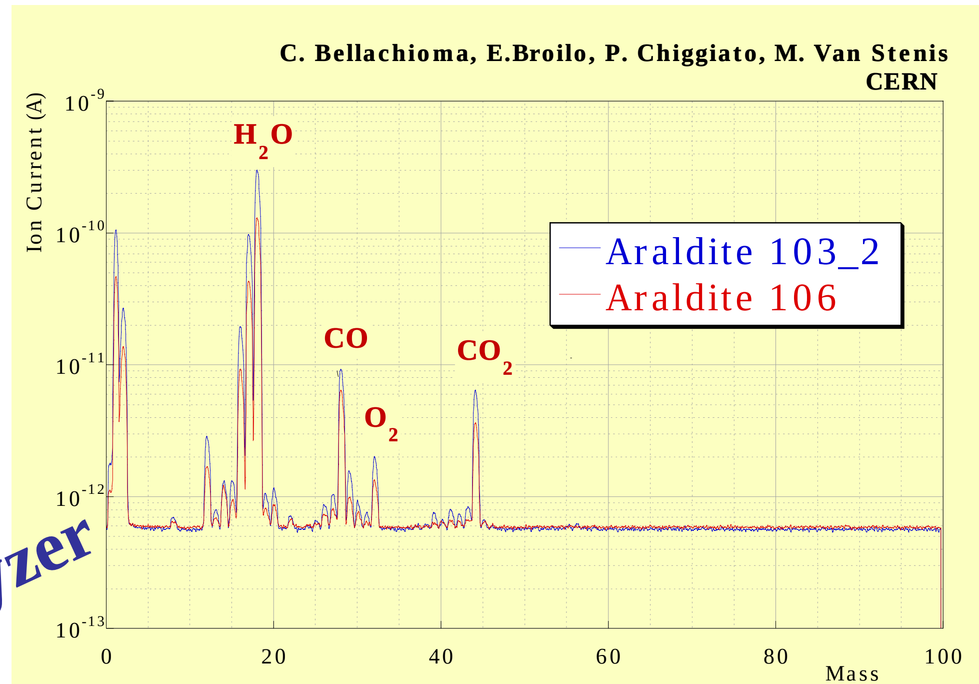
AGEING TEST



GC+MSD



ION Analyzer



NASA TEST (@CERN)

TML **3.26%**
CVCM 0.02%

Epoxy Compounds Curing at T > 50 ºC

Source	Product	Curing T (ºC)	Outgas	Effect in G.D.	Result
CERN/GDD	**EPOTECNY E505 SIT**	50	YES	NO	**OK**
HERA-B/ITR	**EPOTEK H72**	65	YES*	NO	**OK***
CERN/GDD	**AMICON 125**	85	NO	-	**OK**
CERN/GDD	**POLYIMIDE DUPONT 2545**	65	NO	-	**OK**
ATLAS/TRT	**RUTAPOX L20**	60	NO	-	**OK**
CERN/GDD	**ARALDITE AW 106**	70	YES		**BAD**
CERN/GDD	**LOCTITE 330**		YES	YES	**BAD**
CERN/GDD	**EPOTECNY 503**	65	YES (Silicone)		**BAD**
CERN/GDD	**NORLAND UVS 91**	50	YES	-	**BAD**

Conductive Epoxy Compounds

Source	Name	Outgas	Effect in G.D.	Result
CERN/GDD	**TRADUCT 2922**	NO		**OK**
HERA-B/OTR	**SILBER LEITKLEBER 3025 (A+B)**	NO	NO	**OK**
ATLAS/TRT	**TRABOND 2902**	NO	NO	**OK**

Adhesive Tapes

Source	Name	Outgas	Effect in G.D.	Result
HERA-B/OTR	**SCOTCH 467 MP**	YES	-	**BAD**
HERA-B/OTR	**TESAFIX 4388**	YES	-	**BAD**

Outgassing Tests of Leak Sealers

Source	Material	Type	Outgas	Effect in G.D	Global Result
CERN/GDD	**VARIAN Torr-Seal**	Solvent-free epoxy resin	NO	NO	**OK**
CERN/GDD	**RHODORSIL CAF4**	Caoutchouc Silicone RTV	NO	NO in very small quantities	**OK ?**
CERN/GDD	**DOW CORNING R4-3117 RTV**	Silicone based	YES	NO in very small quantities	**OK ?**
HERA-B /OTR	**LOCTITE 5220**	Polyurethane-based	YES	-	**BAD**

Rigid Materials

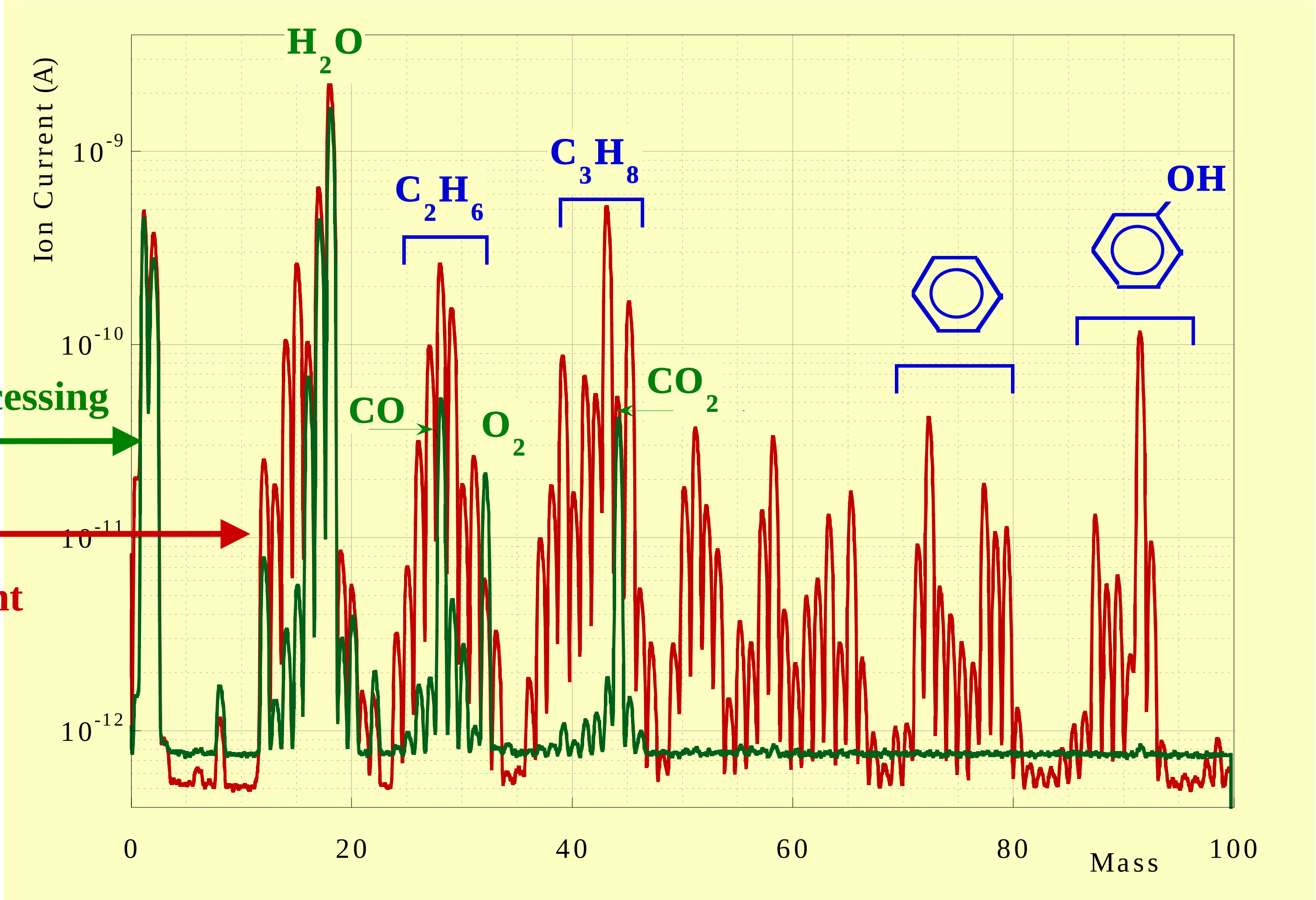
Source	Name	Type	Outgas	Effect in G.D.	Result
CERN/GDD	**STESALIT 4411W**	Fiberglass	YES	NO	**OK**
CERN/GDD	**VECTRA 150**	Liquid Crystal Polymer	YES	NO	**OK**
CERN/GDD	**PEEK Crystalline**	Polyeteherether ketone	NO	NO	**OK**
ATLAS/TRT	**ULTEM**	Polyetherimide	NO	-	**OK**
ATLAS/TRT	**C-Fiber**	C-fiber	NO	-	**OK**
ATLAS/TRT	**POLYCARBONATE**	C-fiber	NO	-	**OK**
HERA-B/ITR	**FIBROLUX G10**	Fiberglass	YES	-	**BAD**
HERA-B/ITR	**HGW 2372 EP-GF**	Fiberglass	YES	YES	**BAD**
CERN/GDD	**RYTON**	Polysulphur phenylene	YES	YES	**BAD**
CERN/GDD	**PEEK Amorphous**	Polyetherether ketone	YES	-	**BAD**

User-generated Outgassing

2-component Polyurethane (Nuvovern LW)

PU
Adequate processing

PU
1 component expired



C.Bellachioma, E.Broilo, P.Chiggiato, M.V.Stenis
CERN

Comparison CVCM, Chromatography, Ageing Test

SAMPLE	NASA	GC	Ageing test
Stycast 1266	BAD	OK	OK
Araldite 103	BAD	OK	OK
Araldite 106	BAD	BAD	BAD
Eccobond 285	OK	OK	OK
Nuvovern LW PUR	OK	OK	OK
ULTEM	OK	OK	OK
VECTRA 150	OK	OK	OK
Kalrez	OK	OK	OK
Epotek 905	BAD	BAD	
Dow Corning RTV	BAD	BAD	

Consult NASA database to select materials, before doing the time-consuming tests

NASA Database: More than 1600 entries for adhesives, 500 entries for rubbers and elastomers, 800 entries for potting compounds, etc…

Silicone Contamination

- Silicone has been systematically found coating aged chambers.
- Silicone has a high natural affinity for most materials.
- Silicone has the tendency to migrate.
- Silicone is relatively inert chemically and unaffected by most solvents, therefore among the most difficult surface contaminants to remove.
- Silicone is etched away by F-species.

Possible Sources:

- Silicone rubber sealants
- Silicone potting and encapsulation compounds
- Silicone adhesives
- Silicone Vacuum Grease (O-rings, mould-release agents)
- Silicone oil (bubblers, diffusion pumps)
- Polluted gas cylinders
- Detergent residues (sodium metasilicate)
- Glass and related products (glass fibres used for reinforcing resins)

Accidental Silicone Contamination

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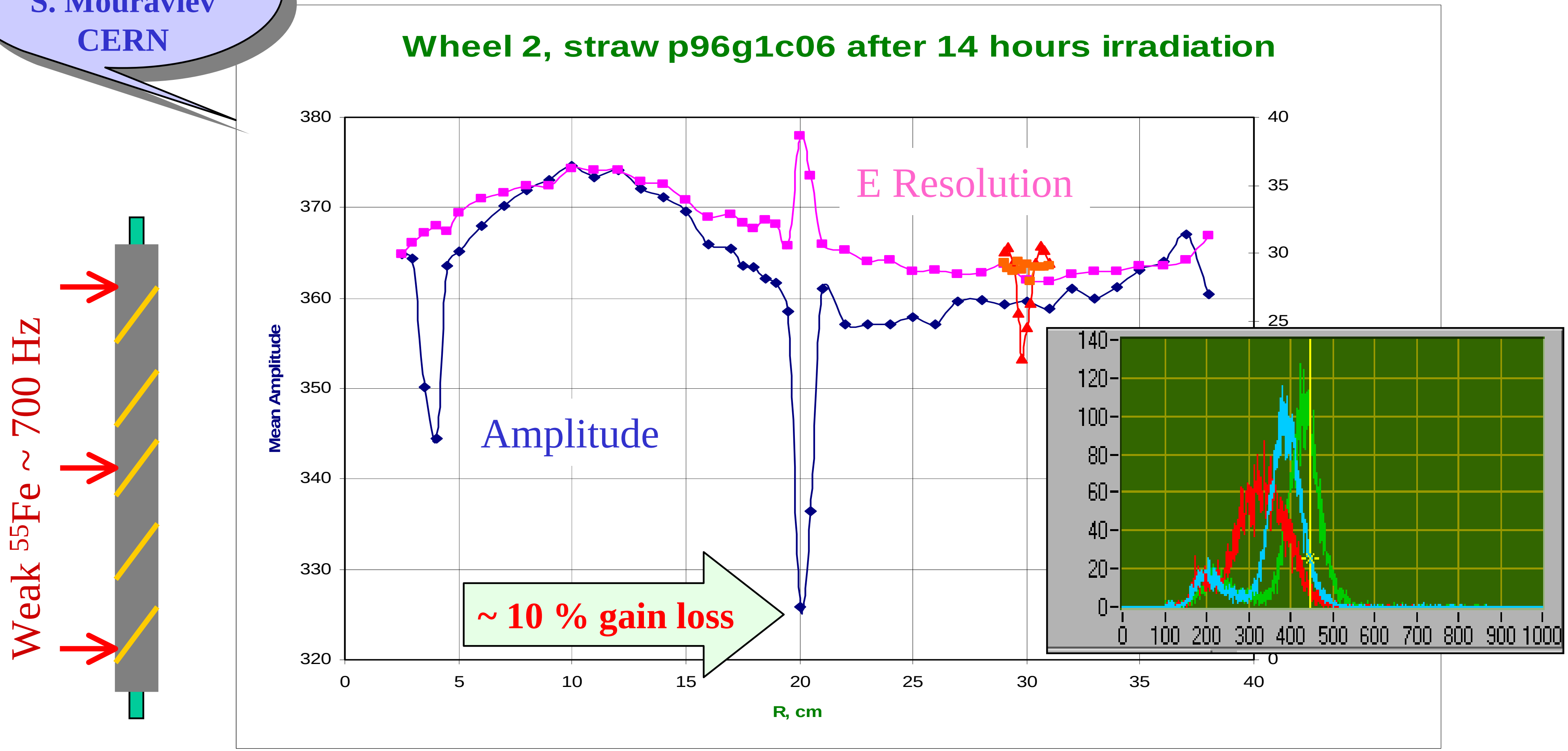
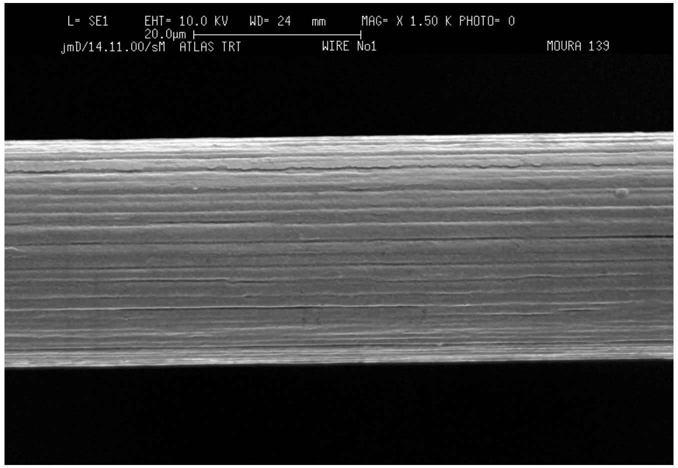
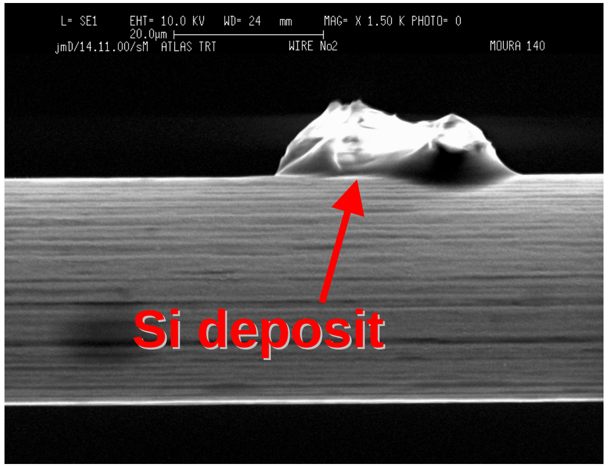


Silicone Contamination



Clean wire



Irradiated spot

Region between
two irradiated spots

Silicone Source:
Silicone-based lubricant used accidentally during straw tube manufacturing by the manufacturer.
Mass production straws are free of pollution (no lubricant at all).

Silicone Contamination: Si-bubbler

MSGC in
clean gas system

Add Silicon-oil bubbler
to chamber exhaust

GDD Group
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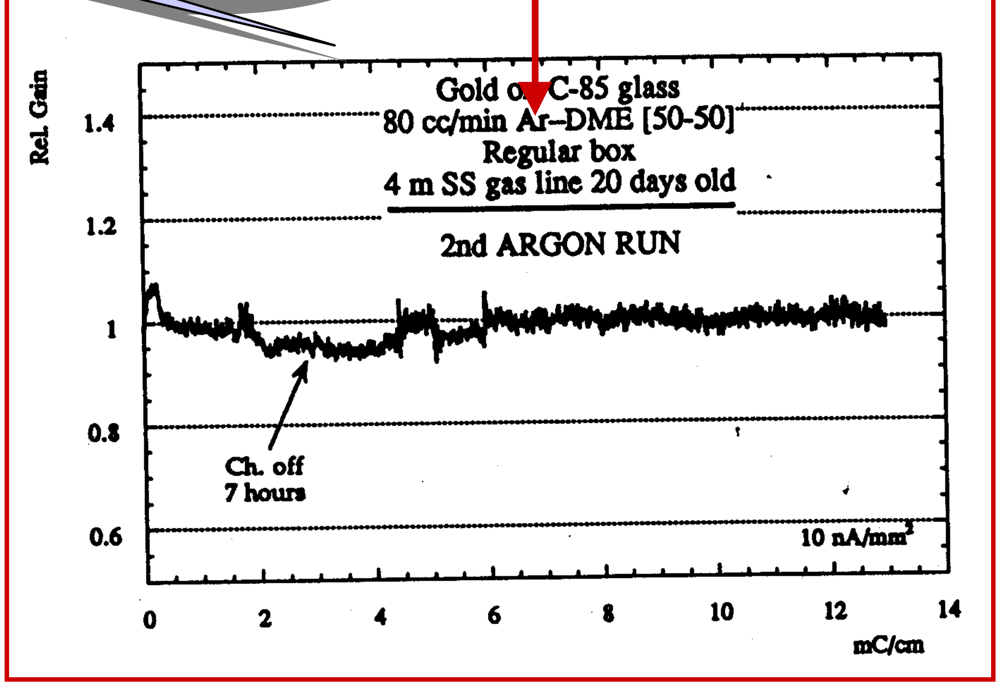
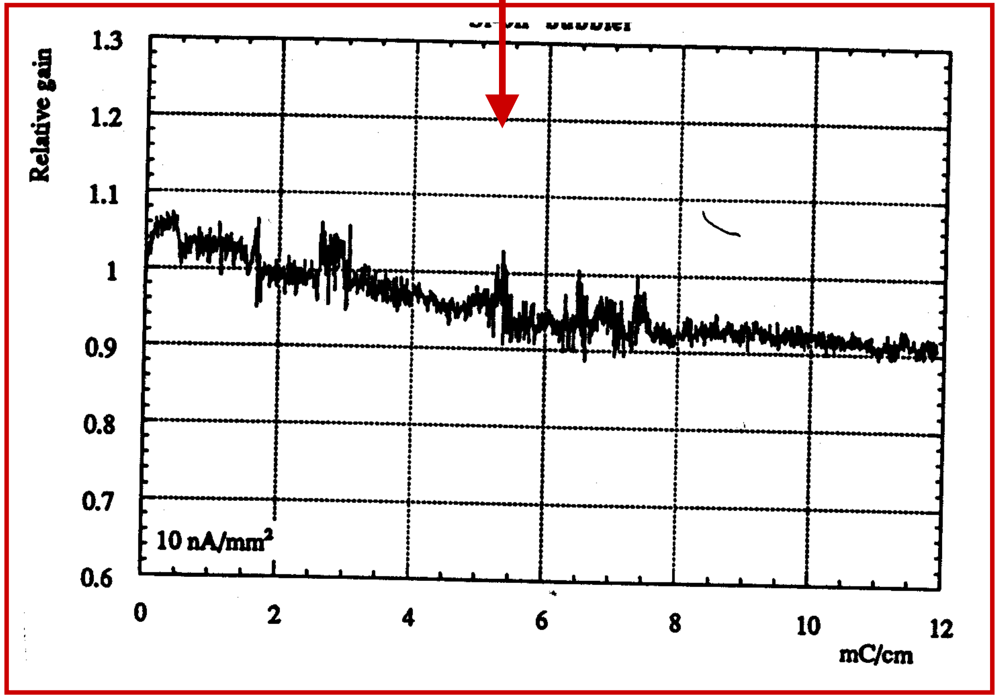




Detector Assembly Procedures

Contaminants during the assembly process such as dust particles or an invisible film of organic material **can make the best-designed detector fail.**

- **Assembly area**
- **Equipment**
- **Personnel**
- **Assembly Procedures**

Assembly Area

The assembly area must be isolated from other manufacturing areas, and usually following clean room standards.

WHICH LEVEL?

Hera-B/OTR Desy

4 assembly sites located worldwide:

Nb. of particles > 0.3 µm in a 0.1 cubic foot of air

Office: 440000
Std hall: 770000

Area 1: 1 - 20
Area 2: 1 - 15
Area 3: 760000
Area 4: 520000

Detector: drift tubes of small diameter
Gas: Ar-CO_2-CF_4
Rate ~ 3×10^5 Hz/cm^2, dose ~ 100 krad/y

All modules behaved equally well during HV testing and running in the Hera-B environment.

Equipment

Some equipment should be avoided **or protected**

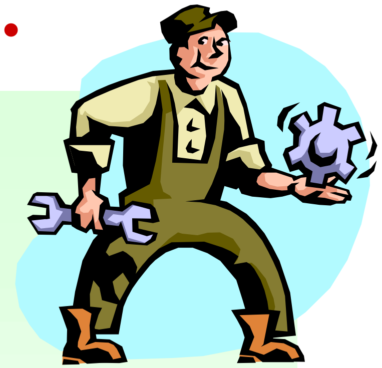
Examples of contamination are:

- **Tools with lubricated shafts, cranes…**
- **Soldering or brazing equipment that require heating of volatile fluxes**
- **Motors and vacuum pumps with outgassing oils**
- **Some electronic equipment contain capacitors, resistors, etc coated with organic or insulating materials that outgas**

Personnel

Usual source of contamination.

Need careful and exhaustive **training.**



Examples of contamination are:

- **Street clothing (source of lint)**
- **Hair, make-up, fingernails (source of oil and particulates)**
- **Many hand creams and cosmetics (contain silicones)**
- **Saliva**
- **Fingerprints (source of fat, possible cause of corrosion in some metals, etc)**

Assembly process

It has to:

- **Be well specified and stable**
- **Be rechecked periodically**
- **Include specification for the storage of parts**
- **Include procedures about:**
  - **cleanliness of assembly components**
  - **verification of cleanliness**
- **Include tracing capability**
  - **operator ID, assembly step, material batch, environmental parameters, etc**

About Gas System Components

Compatibility Aspects

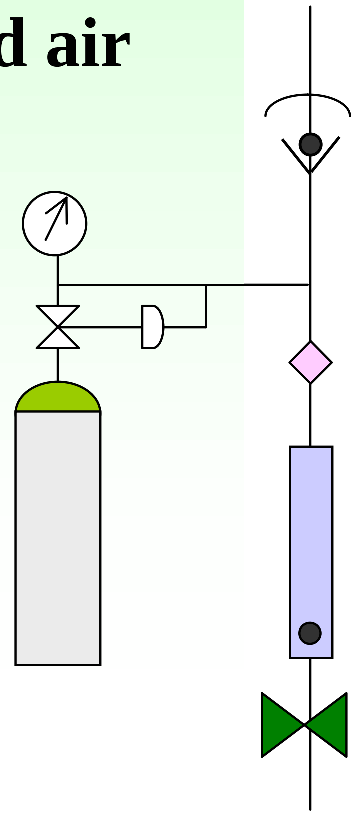
Clean Components

The Golden Rule

- Validation
- P-regulators
- Flowmeters
- Valves
- Connectors
- Piping
- Elastomers

Gas systems used for:

- **Assembly procedures**
  - **Wiring, etc**
  - **Cleaning of components (N_2 or compressed air guns)**
  - **Cooling of assembly set-ups**
  - **Polymerization of glues**
  - **Others**
- **Acceptance tests at the laboratory**
- **Final gas systems in experimental area**



Compatibility

- **Materials VS Ageing**
- **Chemical compatibility with operating gas**
- **Purity and cleaning of components**
- **For final gas systems:**
  - **Radiation**

    Test of electronic components
  - **Magnetic field**

    Avoid electro-magnetic valves, electro motors, relays.

    Check control valves, pressure sensors, power supplies, etc.

Valves

Ageing test of the same MSGC (Ar-DME 90-10) in 2 gas systems

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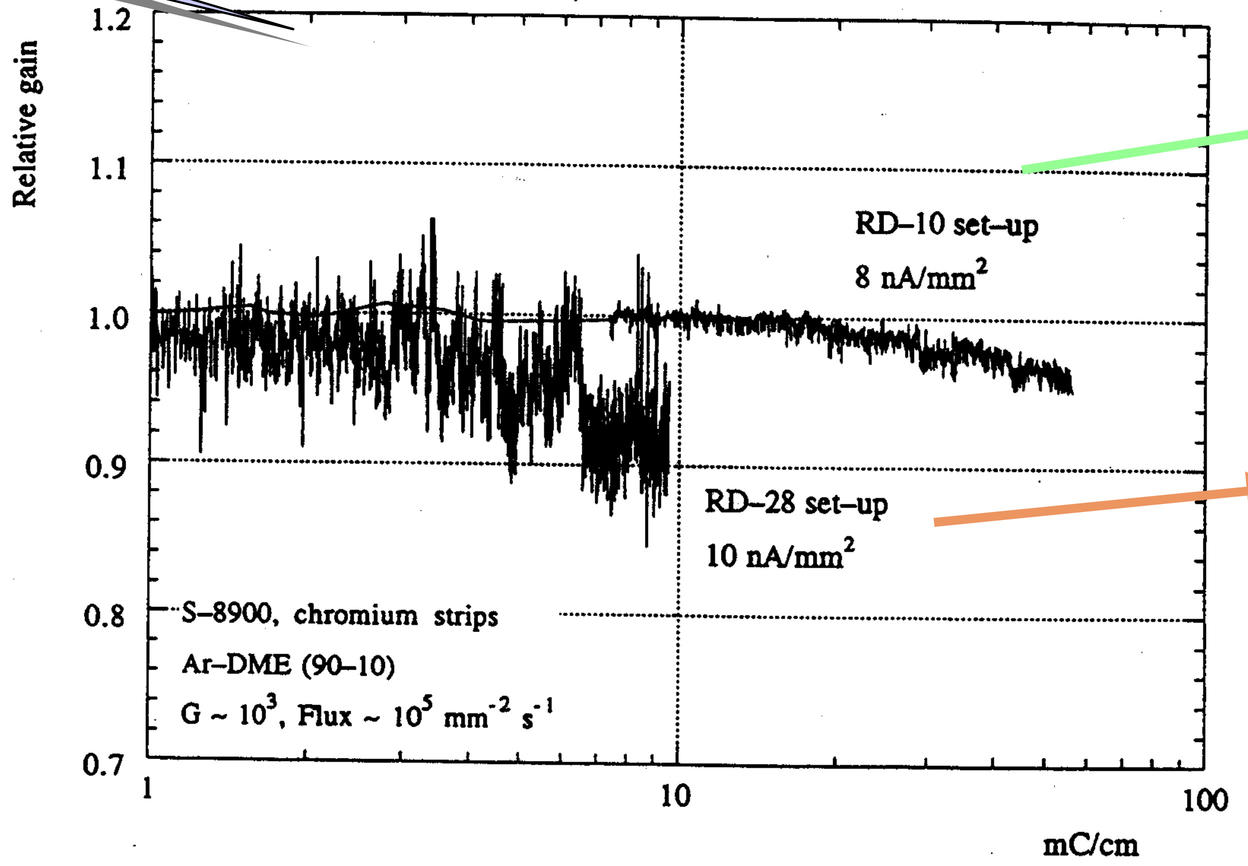


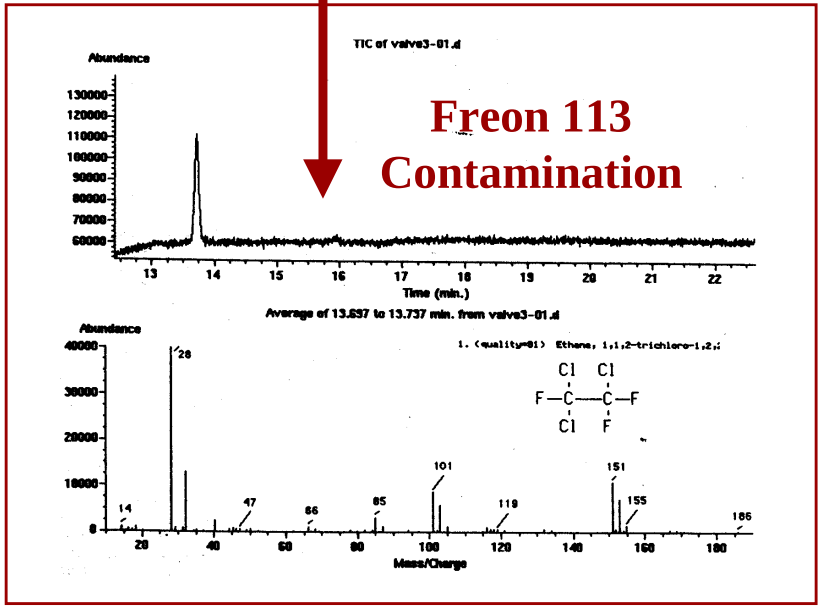
1
ultra-clean
full metal
Kemraz

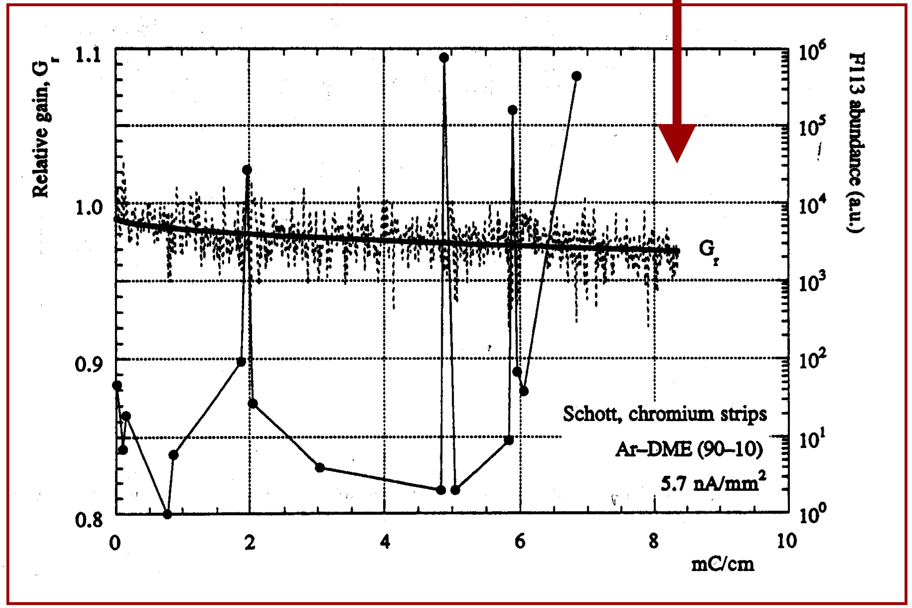
2
standard cleanliness
Viton joints
std metal valves
Cu-exhaust
Torr-Seal sealing

Valves

Systematic study (GC) to search the origin of pollution

- Isolate components of the std. gas system
- Manual SS ball-valve (PFTE joint) found suspicious
- Take valve to ultra-clean setup
- Ageing Test + accelerated rate of outgassing





Search for Clean Components

The ATLAS-TRT approach:

ATLAS/TRT
CERN

- **Problem:**

straw tubes are very sensitive to silicone pollution

- **Approach: use only clean components**

  Market-survey to look for clean gas components equivalent to ultra-high purity standards in terms of very low outgassing rates and absence of lubricants (especially silicone-based).

  The requirements have to be discussed with the companies.

Search for Clean Components

Components → Validation of Components

- Cylinder P-regulators
- Filters
- Flowmeters
- Valves
- Exhaust
- Piping
- Connectors

Straw tube AGEING Tests

- Nominal gas:

  $Xe\text{-}CF_4\text{-}CO_2$ 70-20-10
- Time Length: 1000 hours
- Dose:1 mm collimated source ^{55}Fe, 5 KHz

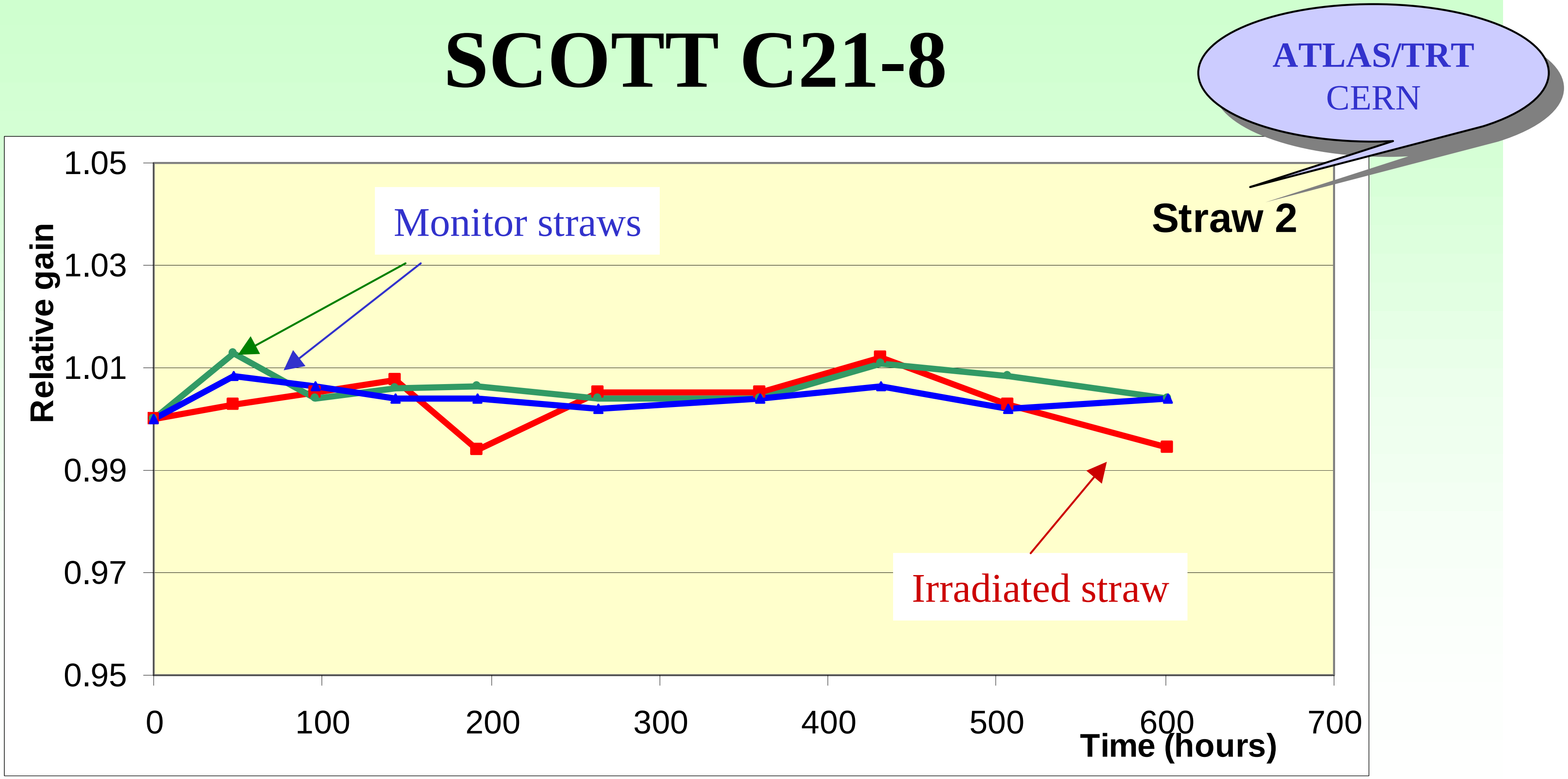
Pressure Regulators

Studied in detail 15 different models from ~10 companies.

Knowledge	**Price** CHF
Ultra-high purity applications (semiconductor industry): Lubricant-free certified & excellent surface quality. **Reducing our requirements (in terms of surface quality):** **- Brass option at *SCOTT Specialty Gases (model C21-8)*** ***-Parker Veriflo line (model IR4002)***	> 2000 **~ 600**
High purity applications: Lubricant-free certified, but experience tell us that it might NOT be true. **Some companies produce affordable, clean products:*TESCOM (serie04)***	>1000 **~ 600**
Standard applications: They might be certified lubricant-free by suppliers… For safety, **they always need additional cleaning**	**~ 300 - 600**

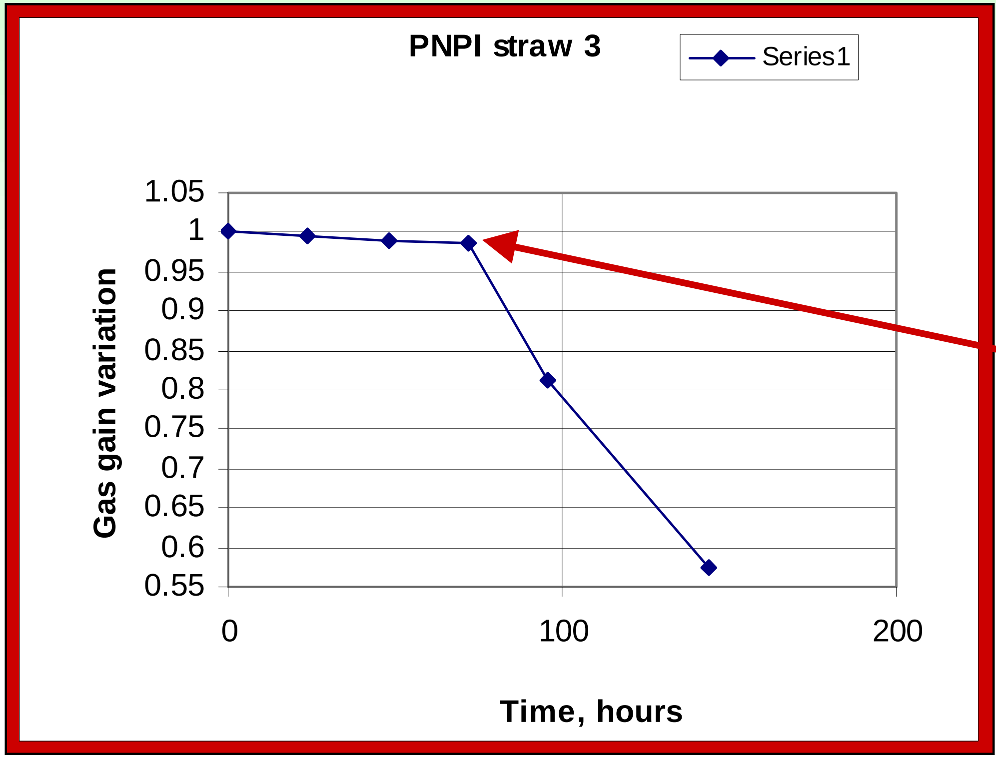
Pressure Regulators

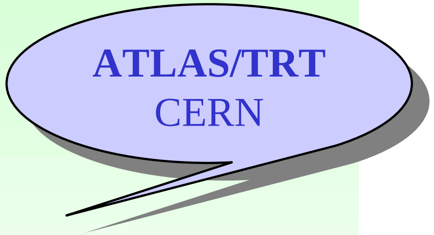
Validation of P-regulator dual stage SCOTT C21-8



Flowmeters

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





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

Flowmeters

Cleaning flowmeters

Ultrasonic cleaning of dismounted pieces.

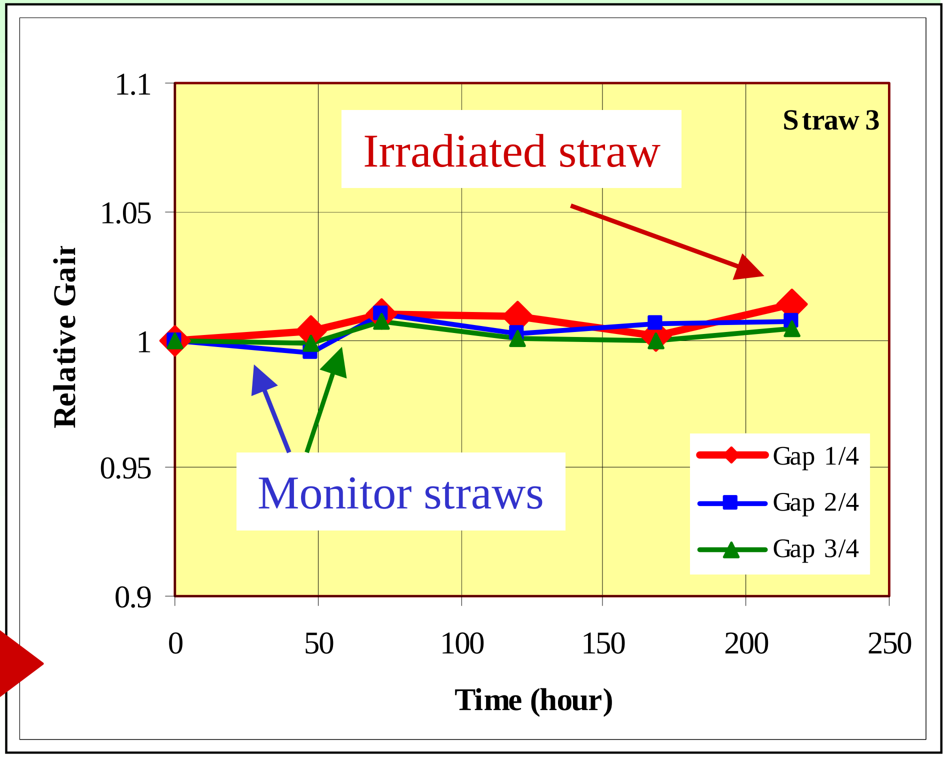
ATLAS/TRT
COMPASS
CERN

REMOVES GREASE !

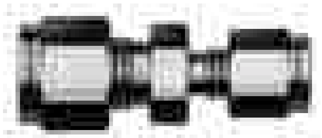
By M.Bosteels (CERN):

15’ Ultrasonic bath Isopropyl alcohol
15’ Ultrasonic bath Isopropyl alcohol
15’ Ultrasonic bath ultra pure water
20 h at 70-80 °C

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



Connectors



Unions, elbows, nuts, etc…

Company	**Note**
SWAGELOK	Certified lubricant-free. If additional SC-11 cleaning, price is 25% higher.
GYROLOK	Risk of paraffin contamination
SAGANA	To avoid '*risk of contamination*' items should be order as "oxygen degreased" (= acetone baths). Price: + 20%

Mount system following clean procedures: protective clothing, clean storage, no open ends, etc

Follow manufacturer directions to the letter

Never mix one brand or metal with another one

BASICS

Piping

Plastic Pipes: PTFE, NYLON, PVC, PU, etc

High gas permeability High desorption rate	Insulating Elastic Cheap Low density

- **Metal Pipes:** Copper, Stainless Steel

CLEANING

Expensive Difficult handling	0 gas permeability 0 outgassing

Outgassing Tests of Plastic Pipes

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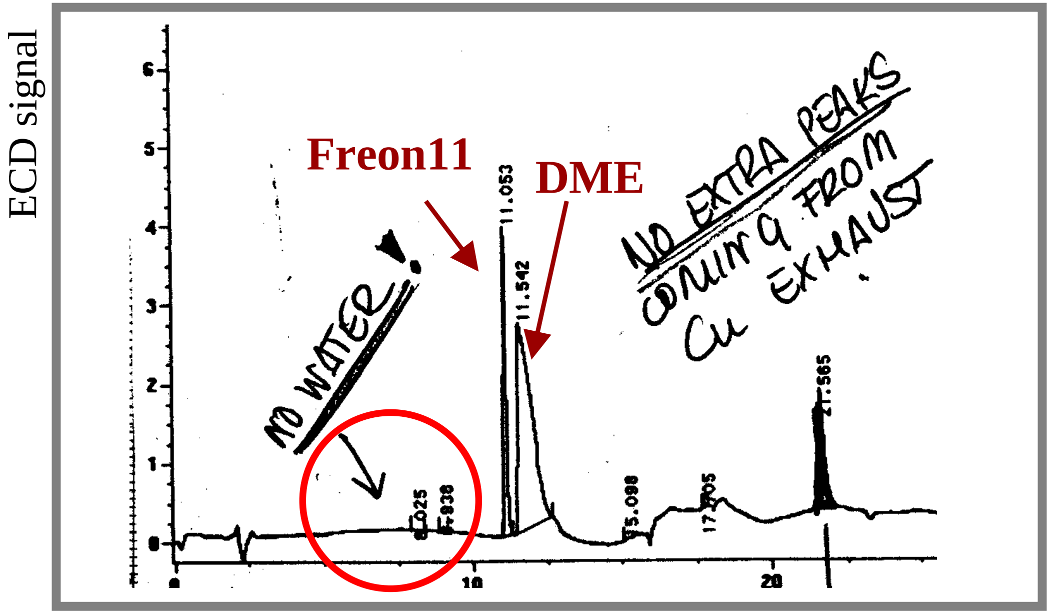
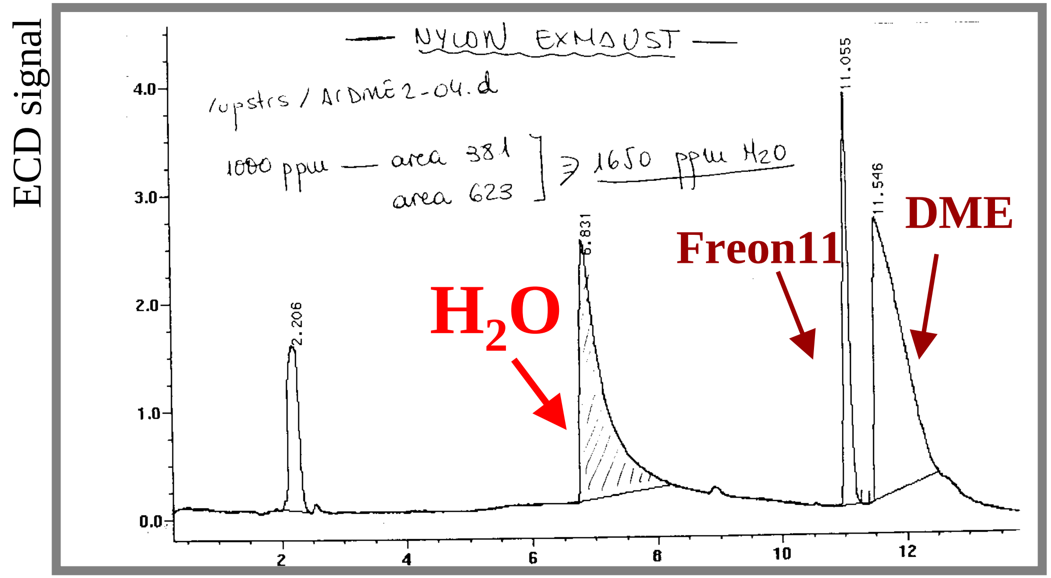
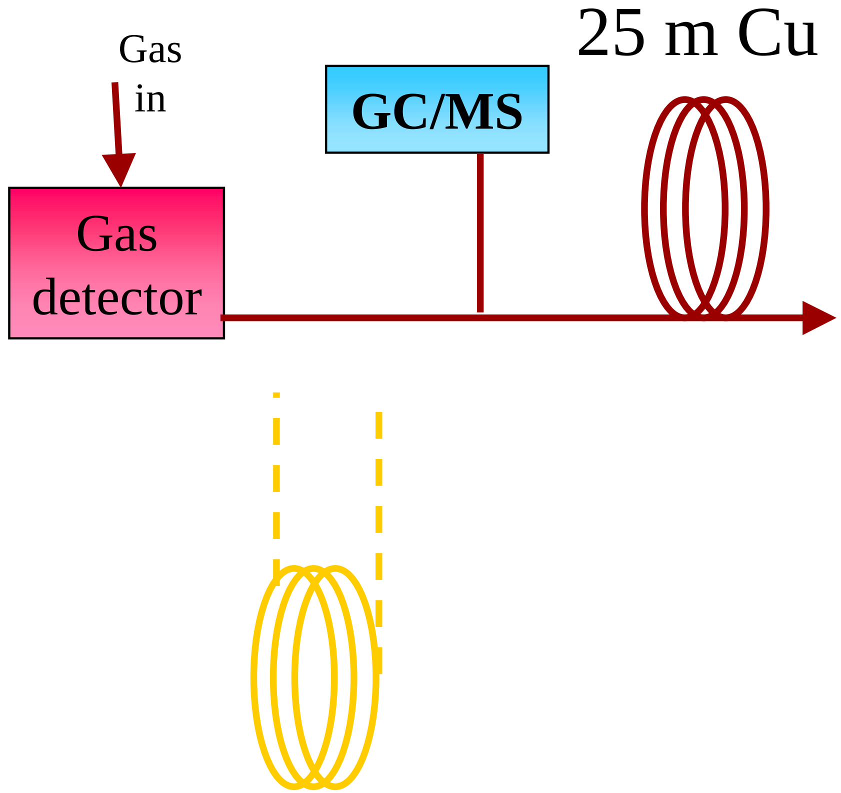
Material	Type	Outgas	Effect in Gaseous Detector	Global Result
PP	Polypropylene	NO	NO	**OK**
RILSAN NYLON	Polyamide	Water	NO	**OK***
PEEK Crystalline	Polyetherether ketone	NO	NO	**OK**
PEEK Amorphous	Polyetherether ketone	YES	-	**BAD**
PEE		YES	-	**BAD**
PUR	Polyurethane	YES	-	**BAD**

Water v. & Nylon Pipes







+ 20 m Nylon Pipe

~ 1700 ppm H_2O

Outgassing Tests of Elastomers

GDD Group
CERN

Material	Type	Outgas	Effect in Gaseous Detector	Global Result
KALREZ	Fluoropolymer	NO	NO	**OK**
VITON	Fluorinated copolymer	YES	YES	**BAD**
EPDM	Copolymer ethylene propylene	YES	-	**BAD**
PVDF	Fluorinated polyvinyldene	YES	-	**BAD**

About system components…

- It is common to find that manufacturing specifications and product descriptions do not contain enough information.
- Once an adequate product has been found, it is difficult to asses the cleanliness conditions for large quantities.

The Golden Rule

- **Define your cleanliness requirements**
- **Avoid pollution during assembly**
- **Flush gas through the open system**

AS SOON AS POSSIBLE
AS MUCH AS POSSIBLE

Influence of Some Gases on Ageing

Hydrocarbon mixtures

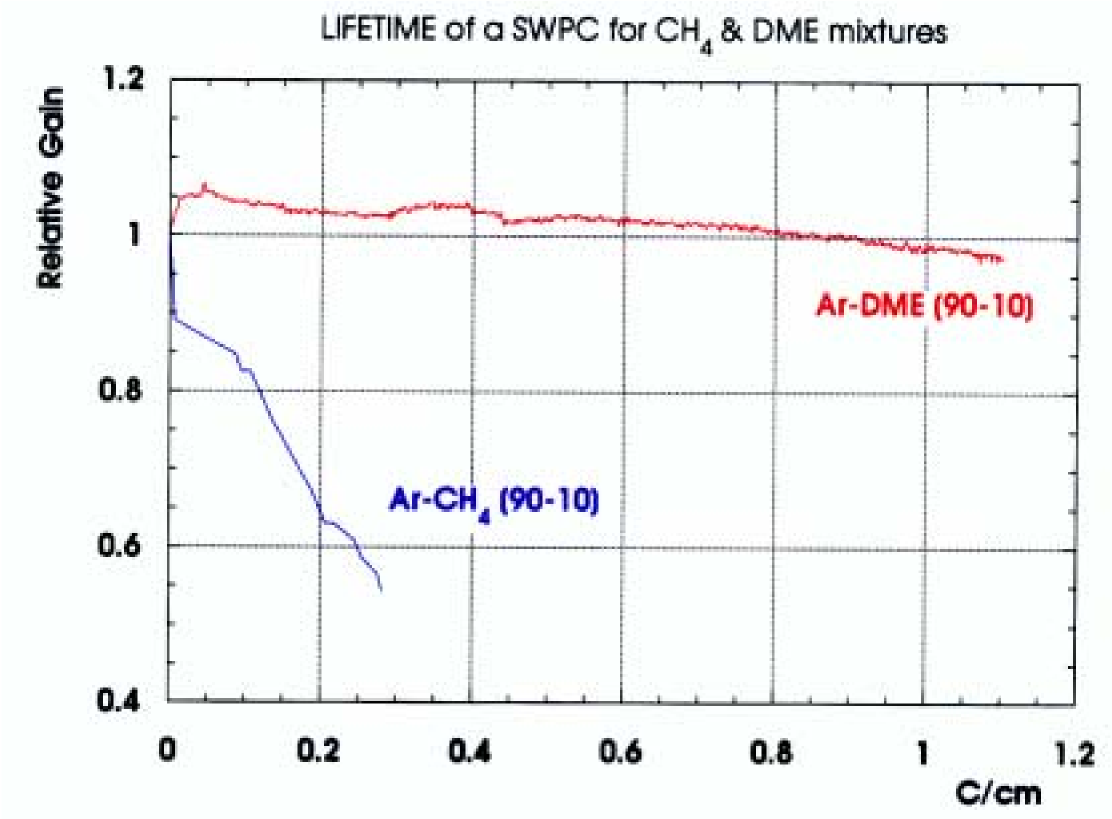
DME & CO_2

CF_4

Hydrocarbons

Polymerization guaranteed

- Polymer formation directly in the avalanche process.
- Effect is more pronounced under spark/discharges.



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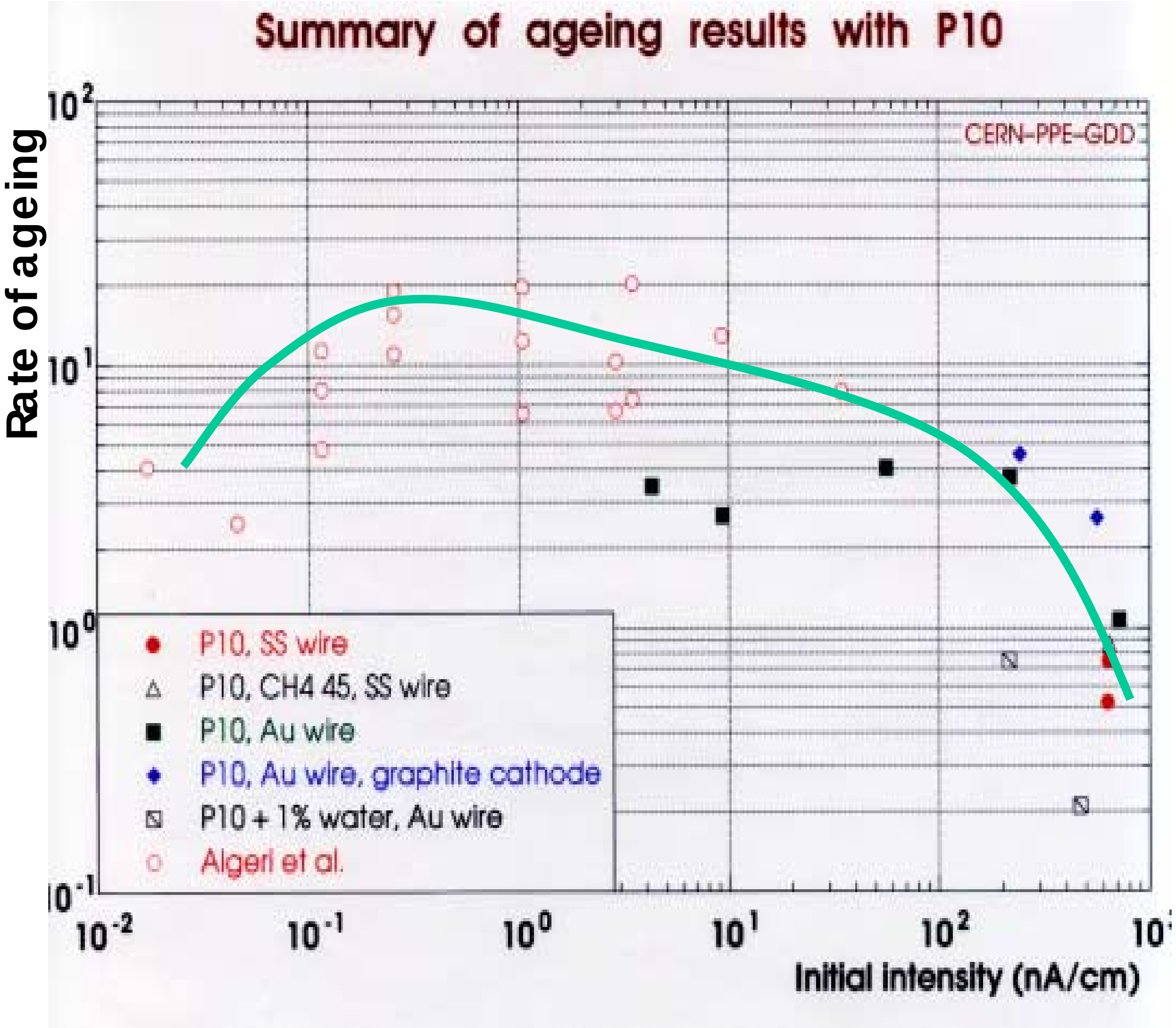
Hydrocarbons



RATE OF AGEING:

- ✓ **It depends on the charge collection rate.**
- ✓ It is independent of electrode material & purity of methane for a given set of irradiation conditions.
- ✓ It improves if water (% level) is added.

DME

Advantages

- Small Lorentz Angle
- High primary ionization
- Low Z
- Good quenching properties (safe operation at high gains)
- Wide efficiency plateau
- Rad hard

Disadvantages

- DME is very reactive
- Sensitive to traces of pollutants

CH_3-O-CH_3

DME

DME is reactive. A careful selection of materials for detector construction and gas system is mandatory.

SWELLING (%) in liquid DME for 2 hours

LDPE (foil)	- 0.6
Vectra	0.0
PEEK Cryst. (pipe)	+ 0.3
Kalrez (joint)	+ 1.6
PE	+ 1.8
Kel-F (joint)	+ 4.0
PCTFE (joint)	+ 4.0
PVDF (joint)	+ 5.0
Kapton (foil)	+ 5.4
PEEK Amorp. (pipe)	+ 8.7

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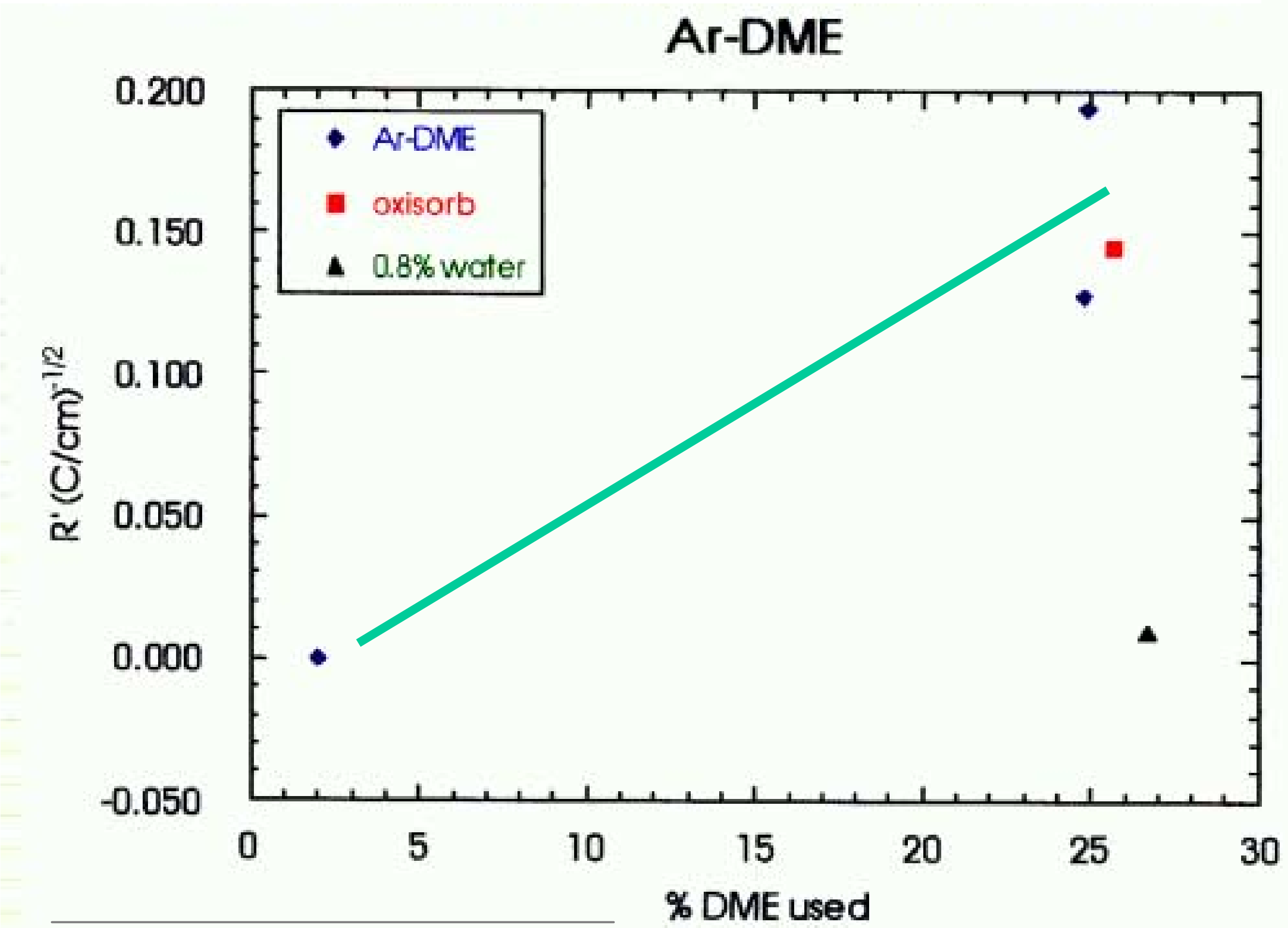
DME

Ageing rate as a function of DME cylinder consumption



Pollutants in cylinder at ppm level:

- Ethene C_2H_4
- 1-propene C_3H_6
- 1-butene C_4H_8
- Air
- F12 (CCl_2F_2)
- F11 (CCl_3F)
- Water

Other Possible Pollutants:
Material outgassing (Teflon, PVC, Neoprene, Viton, etc), residuals of cleaning solvents, etc

DME

- **High sensitivity to traces of pollutants at ppb level (difficult to control)**
- **High reactivity with materials (such as Kapton, widely used in Micro-pattern Gas Detectors)**

DME has been widely replaced by CO_2 the cost being:

Increase of High Voltage

Larger energy of discharges

CF_4

Attractive properties

(even for mixtures with a relatively small fraction of CF_4)

- Very high e^- drift velocities
- Low diffusion constant
- High primary ionization
- Good ageing properties

Disadvantages

- Etching properties
- Cost (implies gas recirculation for large systems)
- Low E-resolution due to e^- attachment

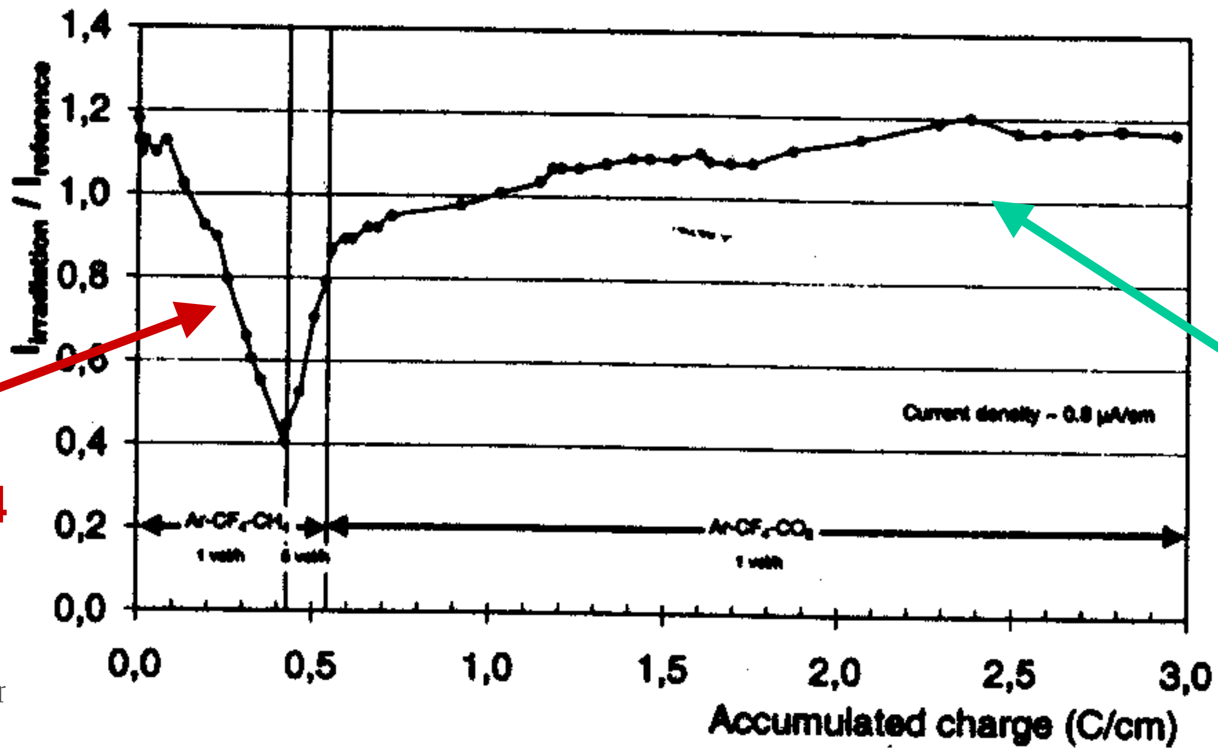
CF_4: Etching/Deposition balance

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**



Hera-B/OTR
DESY

Ar-CF_4-**CO_2**

Effect of Water on CF_4-mixtures

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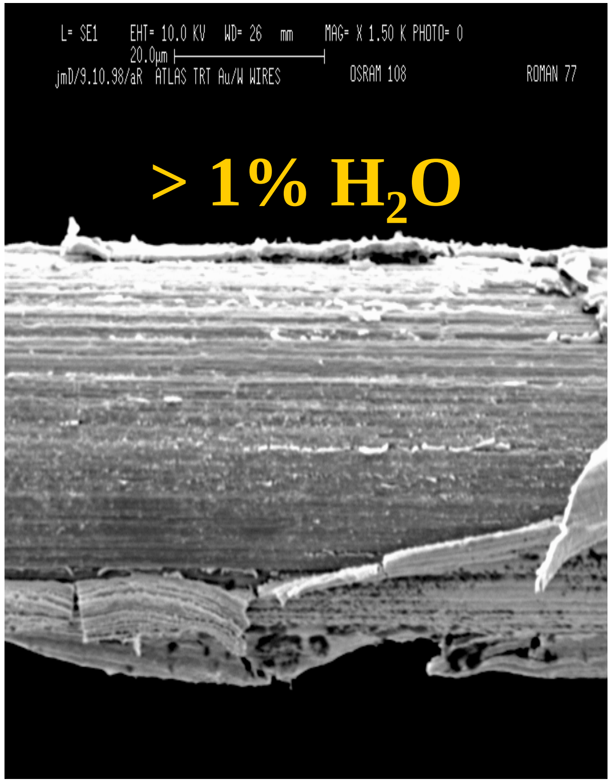
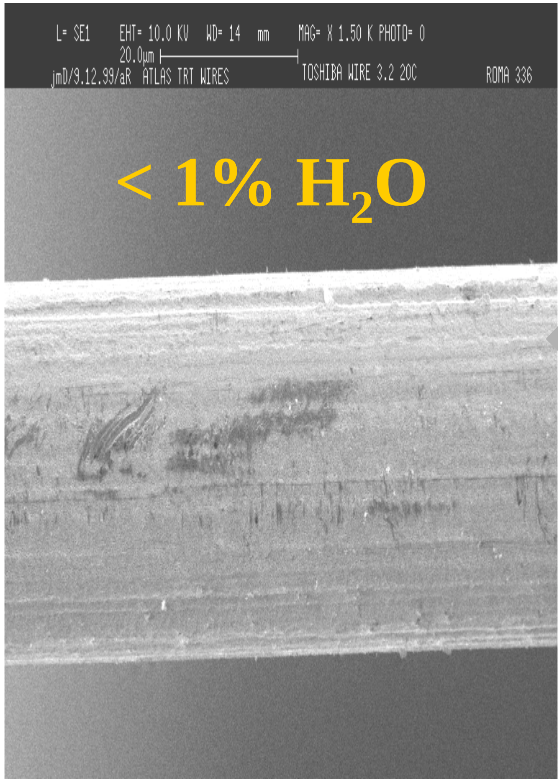
Au/W wire





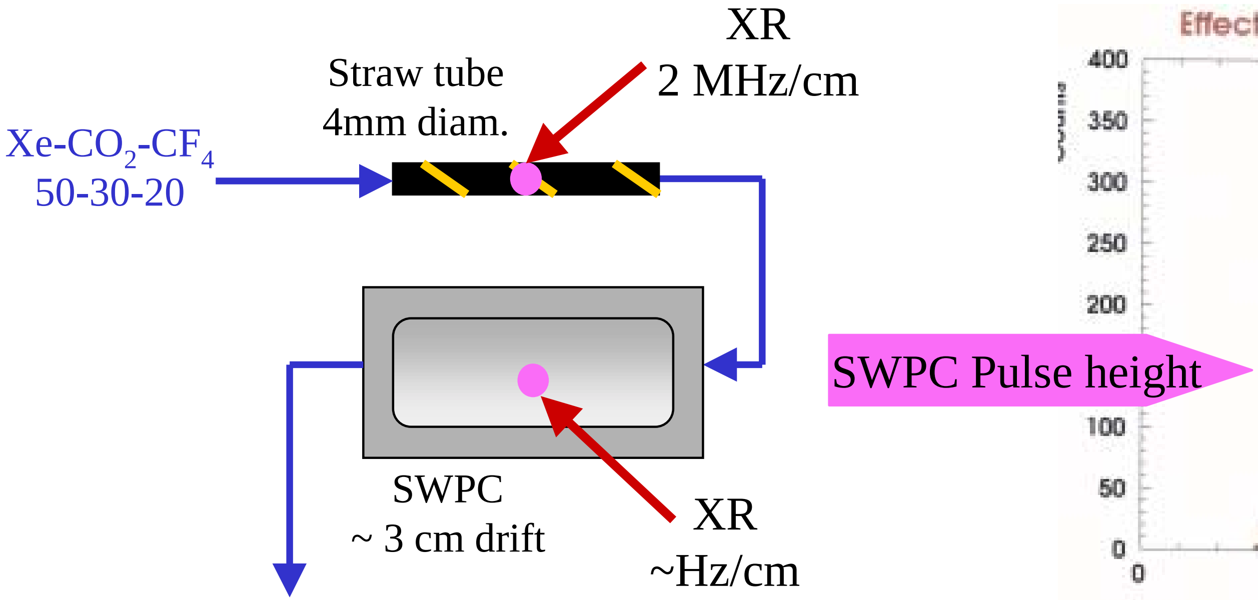
CF_4

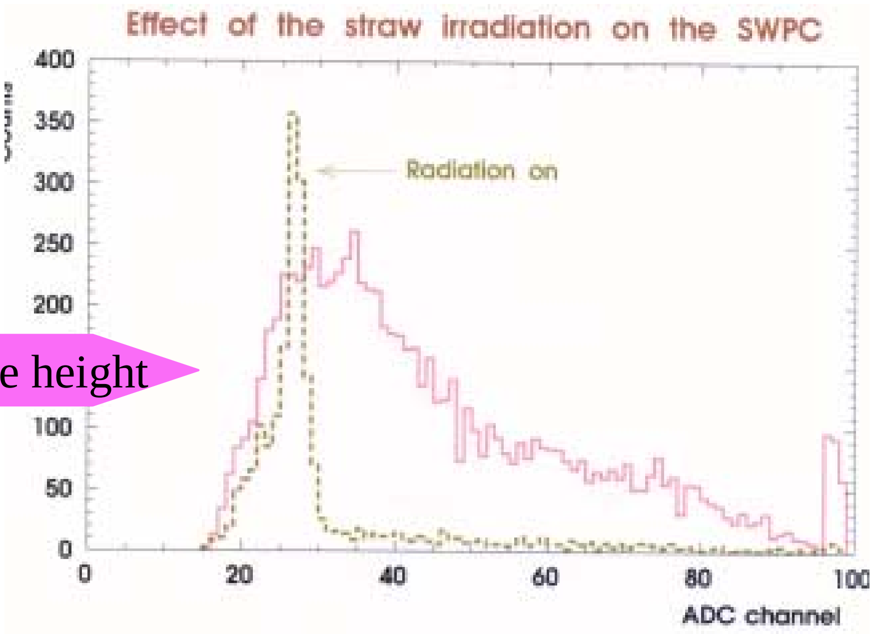
Strict Control of Pollutants

20 C/cm

CF_4 Etching

- CF_4 dissociates in F and CF_x radicals (~ stable species).





- They have enough energy to break chemical bonds in polymers.
- Polymer is reduced to stable, volatile products.
- These products are removed from electrodes by the gas flow.

CF_4 Etching

Effect on assembly materials:

- Active species react with some metals (Al, Tin) and some insulator materials (Fiberglass).
- F species react with Si, which is distributed all around (polymerization trigger)

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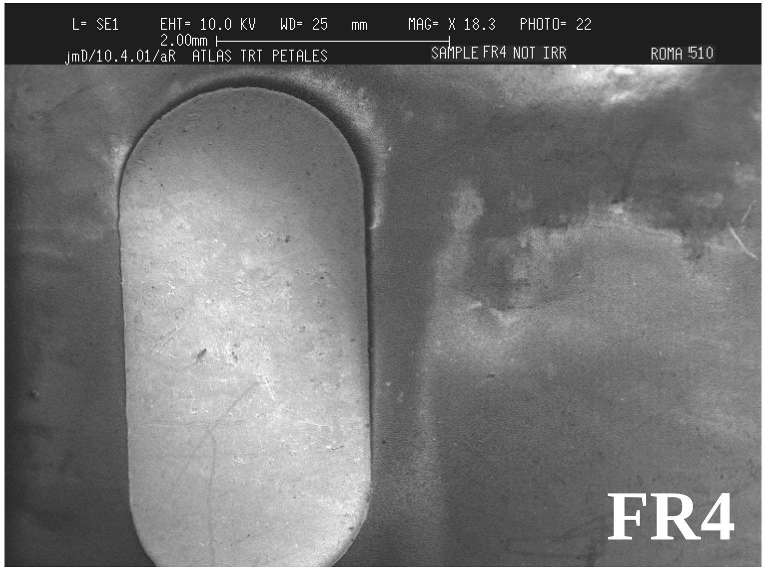

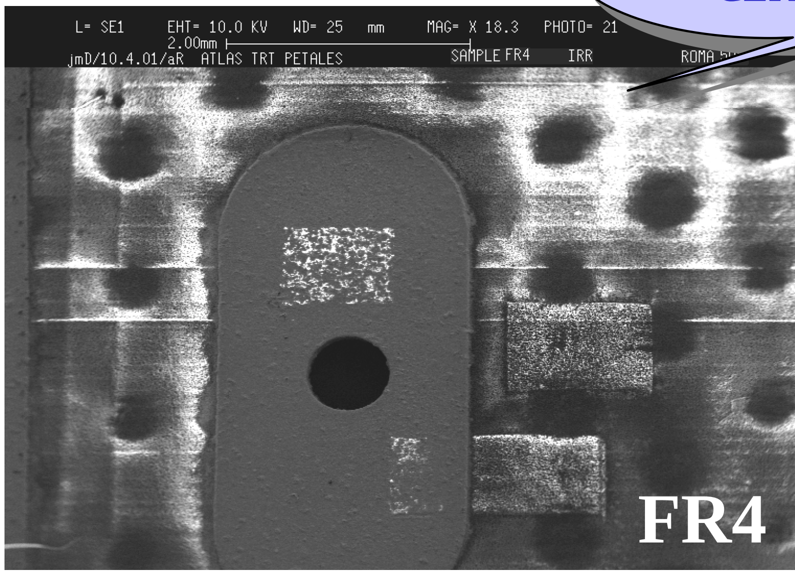

After radical exposure

Materials and gases:
How to build invincible detectors and gas systems

Extensive R&D is needed,
as the experience of other groups is useful but has only a **pre-selective** character.

Detector R&D

- **Efficient R&D defines:**
  - **Gas mixture**
  - **Gas purity**, which implies also careful selection of gas system components (test stations & final system)
  - **Gas gain**
  - **Assembly materials**
  - **Assembly procedures** (avoid user-generated contamination)
- The **long-term capability** of a detector can only be extrapolated to real conditions if final prototypes are:
  - Tested under conditions as close as possible to the final ones, and strictly controlled
  - Large irradiation area & charge density as close as possible to final experiment

Conclusions on Materials

- There is no good or bad material. A **material is adequate** or not for a very particular type of detector and conditions of use.
- Existing data, obtained either from systematic outgassing studies or experience gained with detectors, has only a **pre-selective character.**
    - A list of **low outgassing assembly materials** exists, that includes epoxy compounds, rigid materials, sealants, elastomers, …
    - The effect of **materials that outgas at the ppm level** has to be tested for each particular case. That is the case for materials such us Viton, Teflon, Polyurethane, etc
- It seems rather universal that **Silicone compounds** that easily migrate (lubricant-type) should be avoided, especially with some gas mixtures (F species).

Conclusions on Gases

- Noble Gas + **Hydrocarbon:**
  - Not trustable for long-term high rate experiments
  - It is accepted that oxygen containing additives can improve detector lifetime in such mixtures
- Noble Gas + **DME**:
  - They are radiation hard when careful material selection has been done
  - Halogen contamination at ppb level shortens detector lifetime. It is difficult to monitor
- **CF_4** -containing mixtures:
  - They are very attractive in terms of ageing due to the fine polymerization-deposition balance phenomena
  - They need strict control of pollutants (H_2O)
  - F-radicals are rather stable and able to attack some materials. They are capable of etching away Si-compounds that may trigger strong polymerization processes

IF IN DOUBT DON'T USE IT