Gas Detectors Aging

Review

Mar CAPEANS

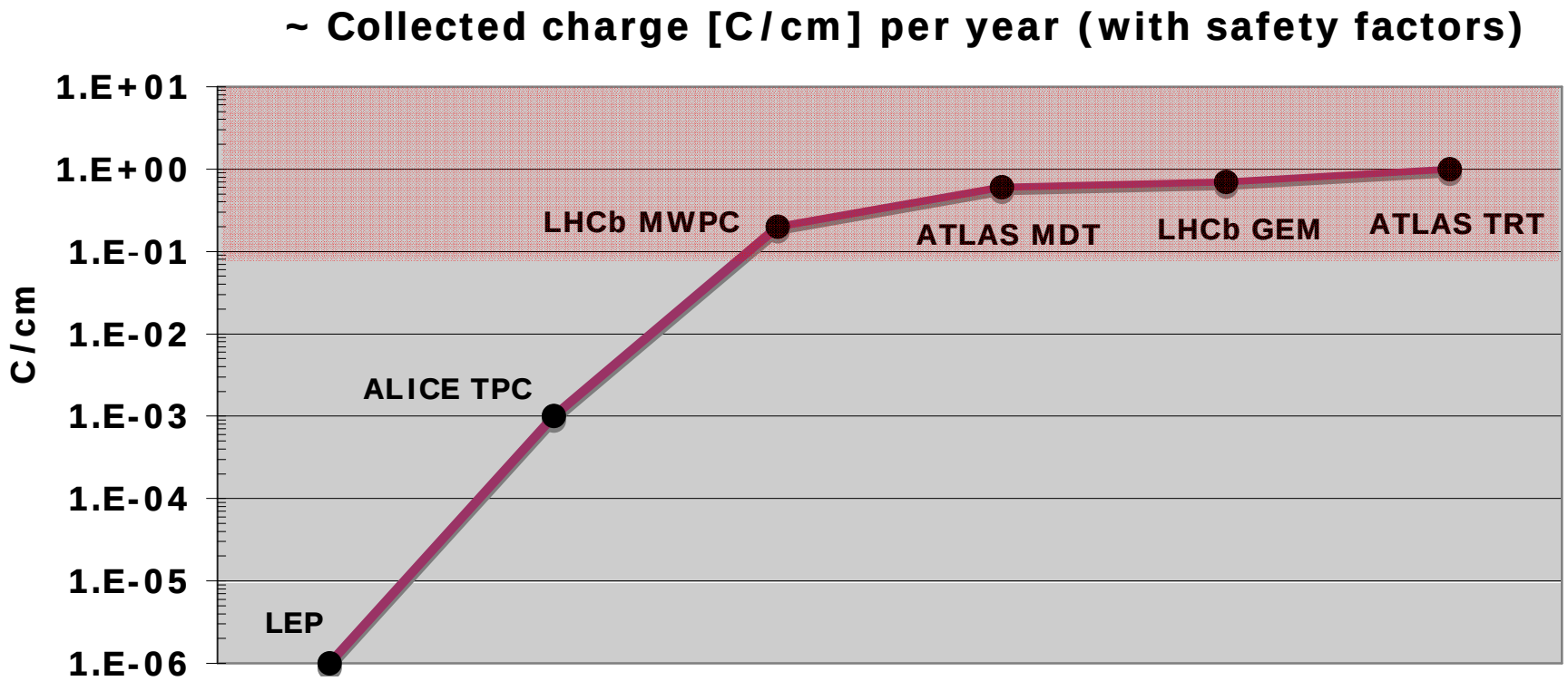
CERN

Micro Pattern Gas Detectors. Towards an R&D Collaboration
CERN, 10th-11th September 2007

Gas Detectors Aging

- First reported ~1950
- Common, critical issue for MWPC ~ 1970
- First compilation: *"Workshop on Radiation Damage to Wire Chambers",* Berkeley ~ 1986
- Crucial studies for the development of LHC detectors, Systematic Studies: *RD-10 (Generic) & RD-28 (MSGC)* ~1990
- Last compilation: *"International Workshop on Aging Phenomena in Gaseous Detectors",* DESY, Hamburg ~ 2003

Integrated charge per year



Signs of Aging in Wire Chambers

SIGNS OF AGING

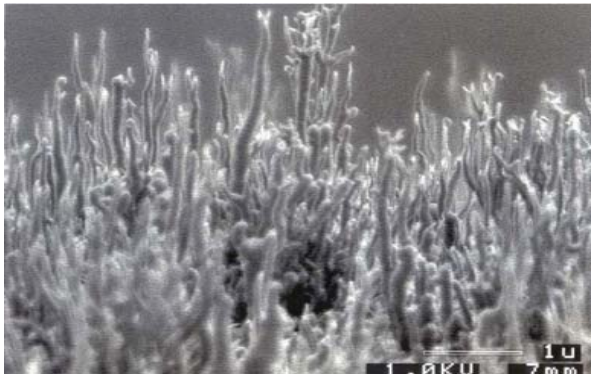
- Loss of gas gain and reduction of the plateau
- Loss of energy resolution
- Electron emission (Malter Effect)
- Sparking
- Self-sustained discharges

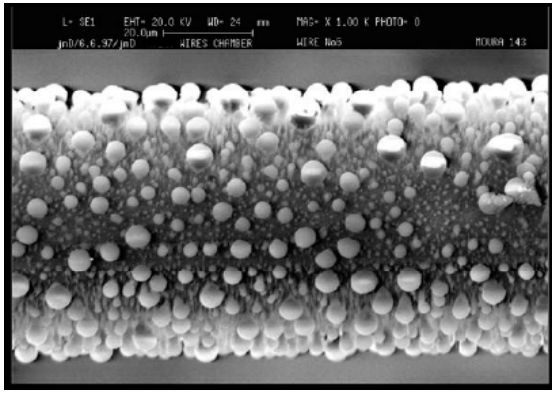
CAUSE

- Deposition of polymers on the anode and/or cathode surfaces

EXPLANATIONS

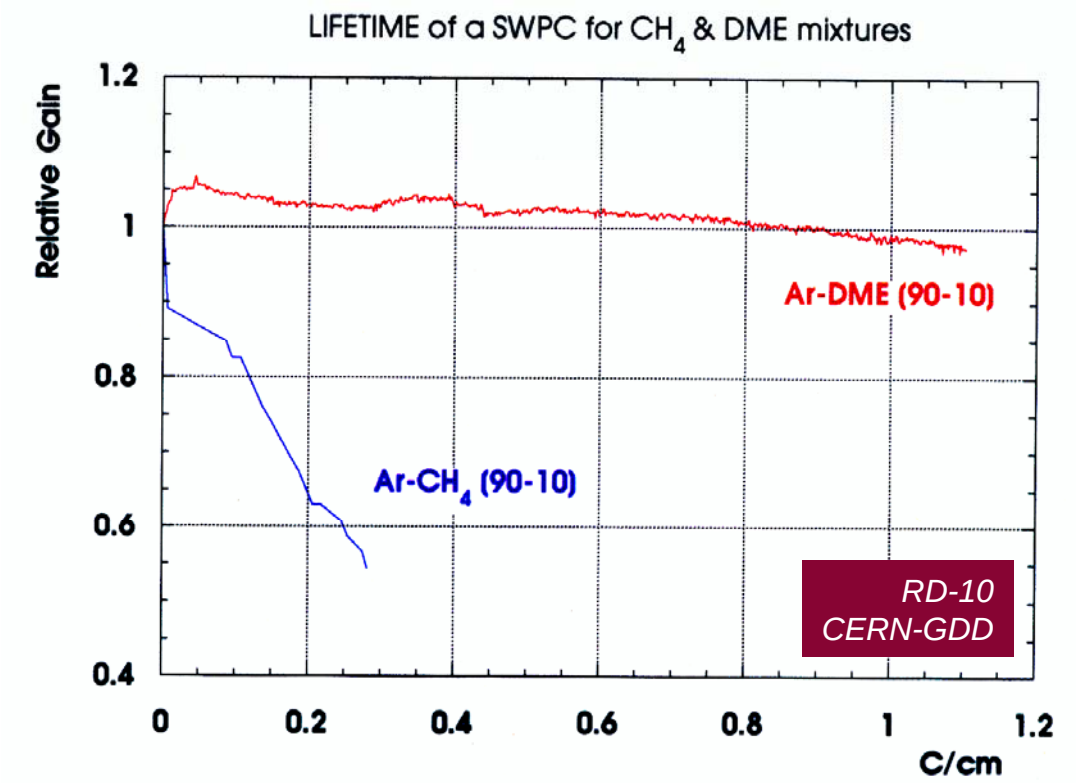
- Pollutants
- Use of polymerizing mixtures (with hydrocarbons like CH_4, iC_4H_{10}…)





Solutions to Wire Chamber Aging (1)

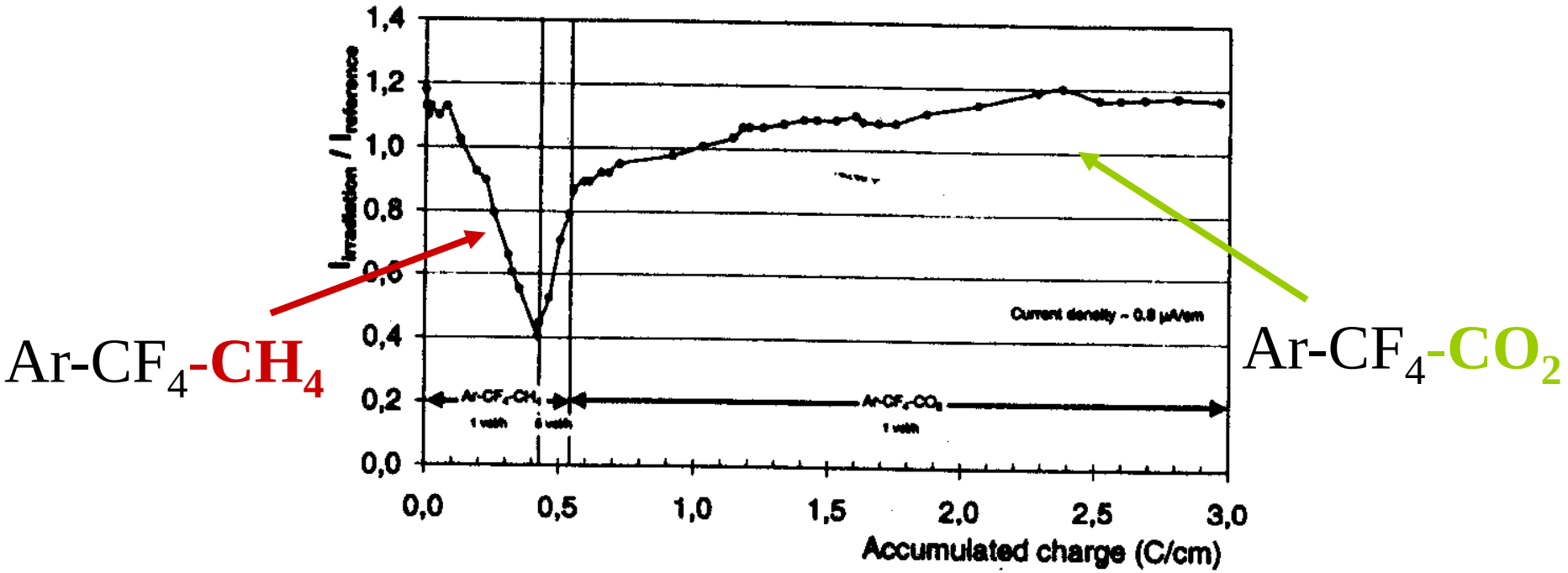
- Replace HC-mixtures by non polymerizing mixtures
  - Ar-DME
  - Noble Gas + CO_2
  - + CF_4



Solutions to Wire Chamber Aging (2)

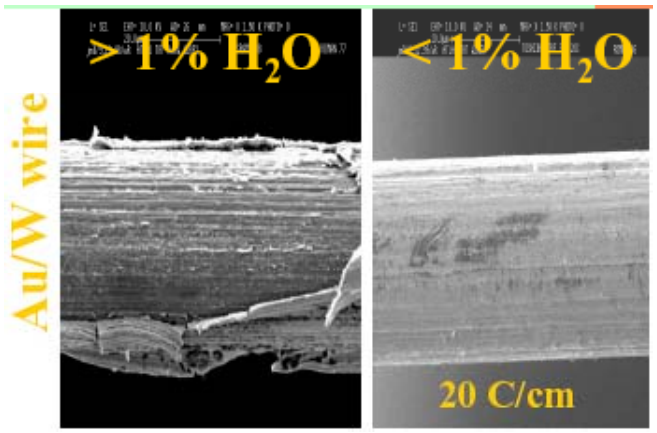
Complexity of CF_4-based gases:

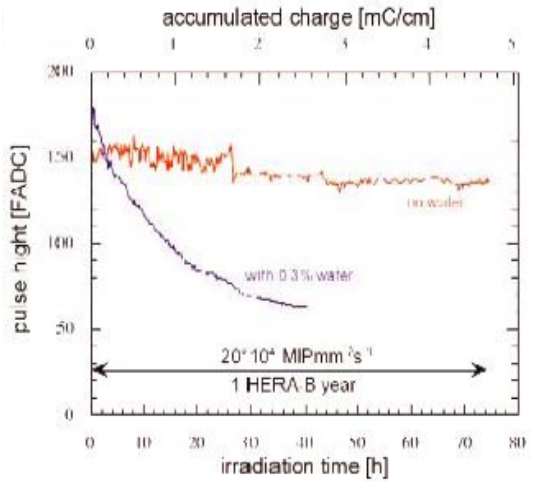
- Hydrogenated atmospheres may lead to deposition VS etching in oxygenated atmospheres
- In presence of water may lead to creation of HF



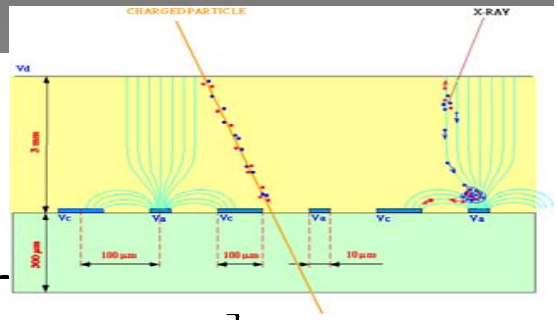
Solutions to Wire Chamber Aging (3)

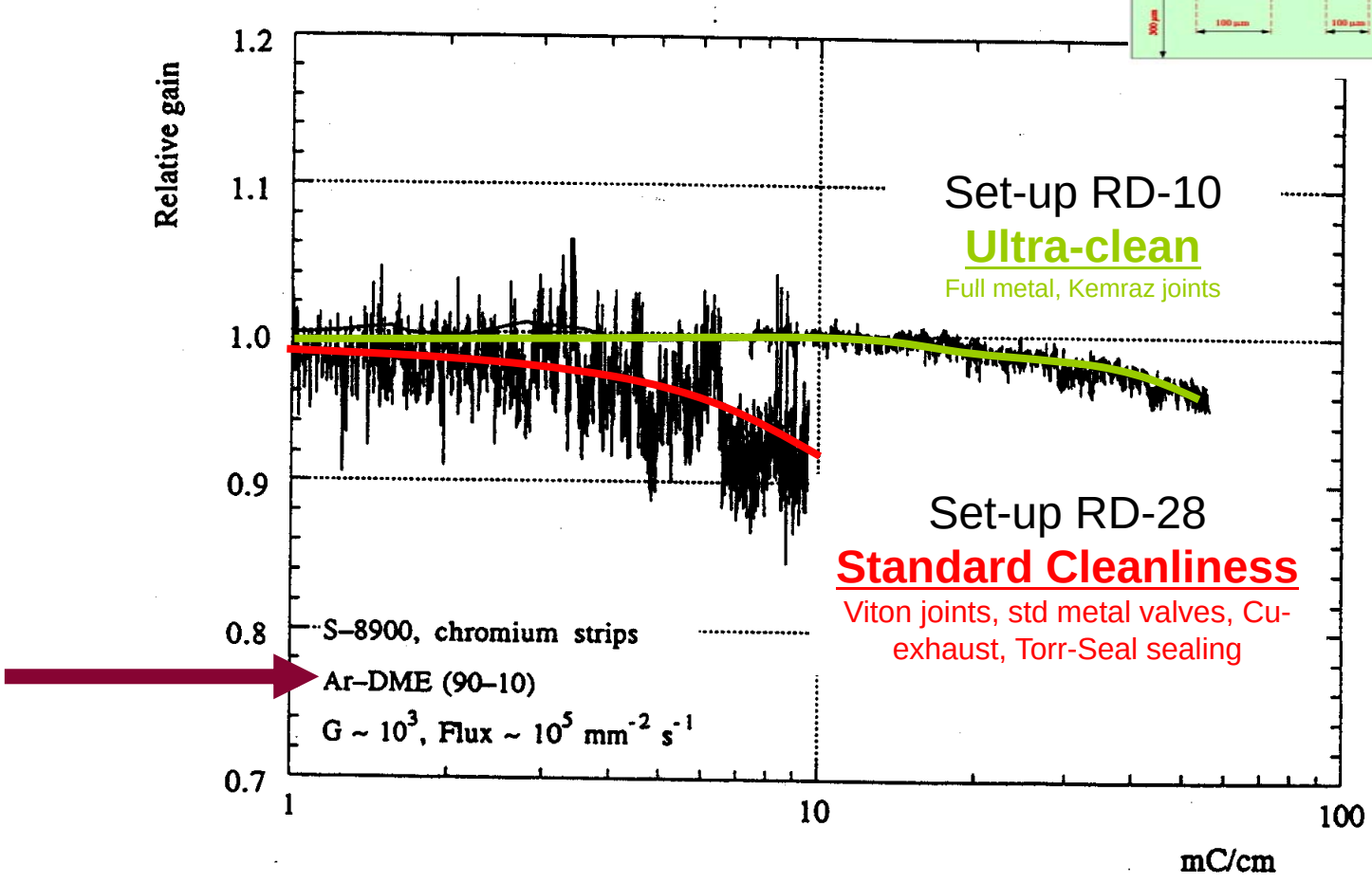
- Use additives in the gas mixture
  - Alcohol and Ethers: accumulate at anode or cathode, UV absorption
  - Oxygen: reacts with HC, products are volatile and get away with the gas flow
  - Water: as above, and also increase of surface conductivity. *It can also be very bad!*





Signs of Aging in MSGCs



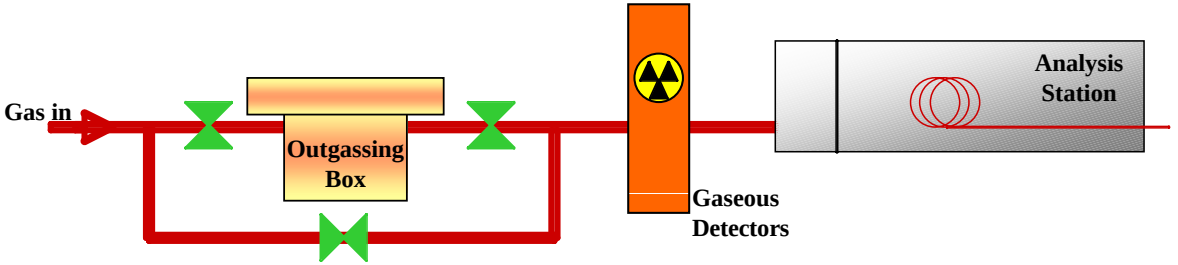


Solutions to MSGC Aging

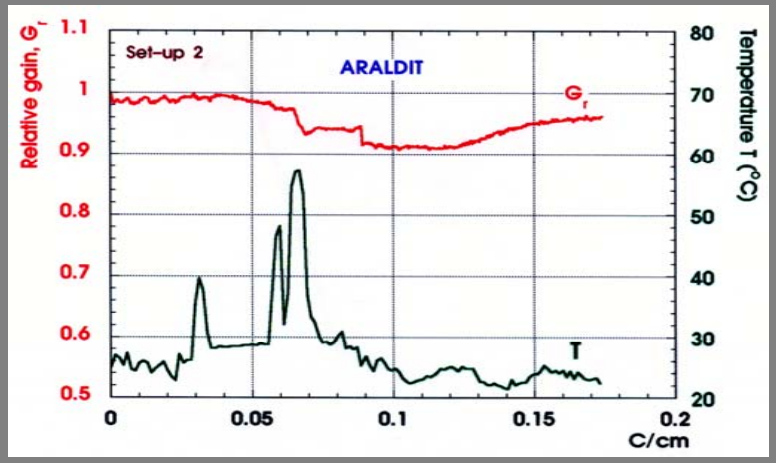
- In addition to using non-polimerizing gas mixtures…
- Control pollutants in contact with the gas
  - High purity gases
  - Assembly materials
  - Ultra-clean gas systems

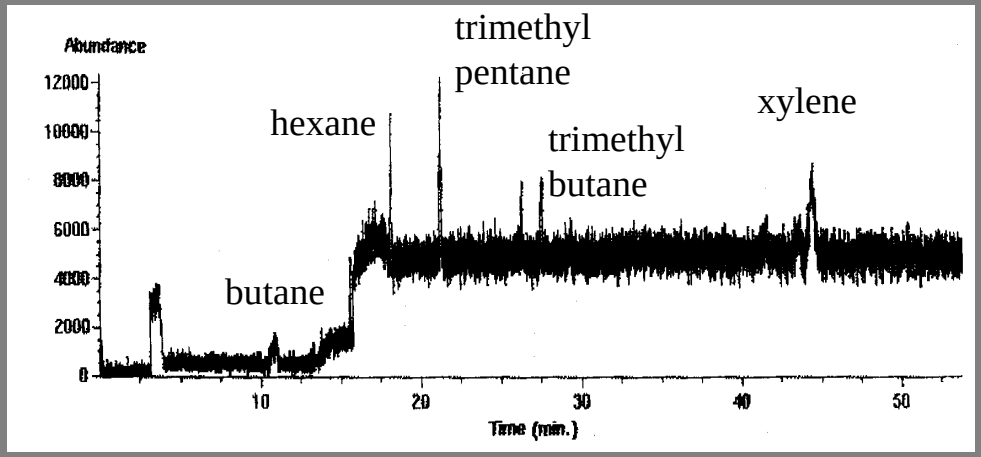
Studies on Assembly Materials

- Radiation Hardness (Old CERN-TIS)
- Outgassing studies + Aging Tests (RD-10, CERN-PH/GDD)



Ex: **ARALDITE AW106/HV953U**





Studies on Assembly Materials

- Tables for:
  - Epoxies and adhesives
  - Leak sealers
  - Rigid materials
  - Common contaminants (silicone, user-generated, etc)
  - O-rings…

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

Low Outgassing room-T epoxies

RD-10 CERN-GDD

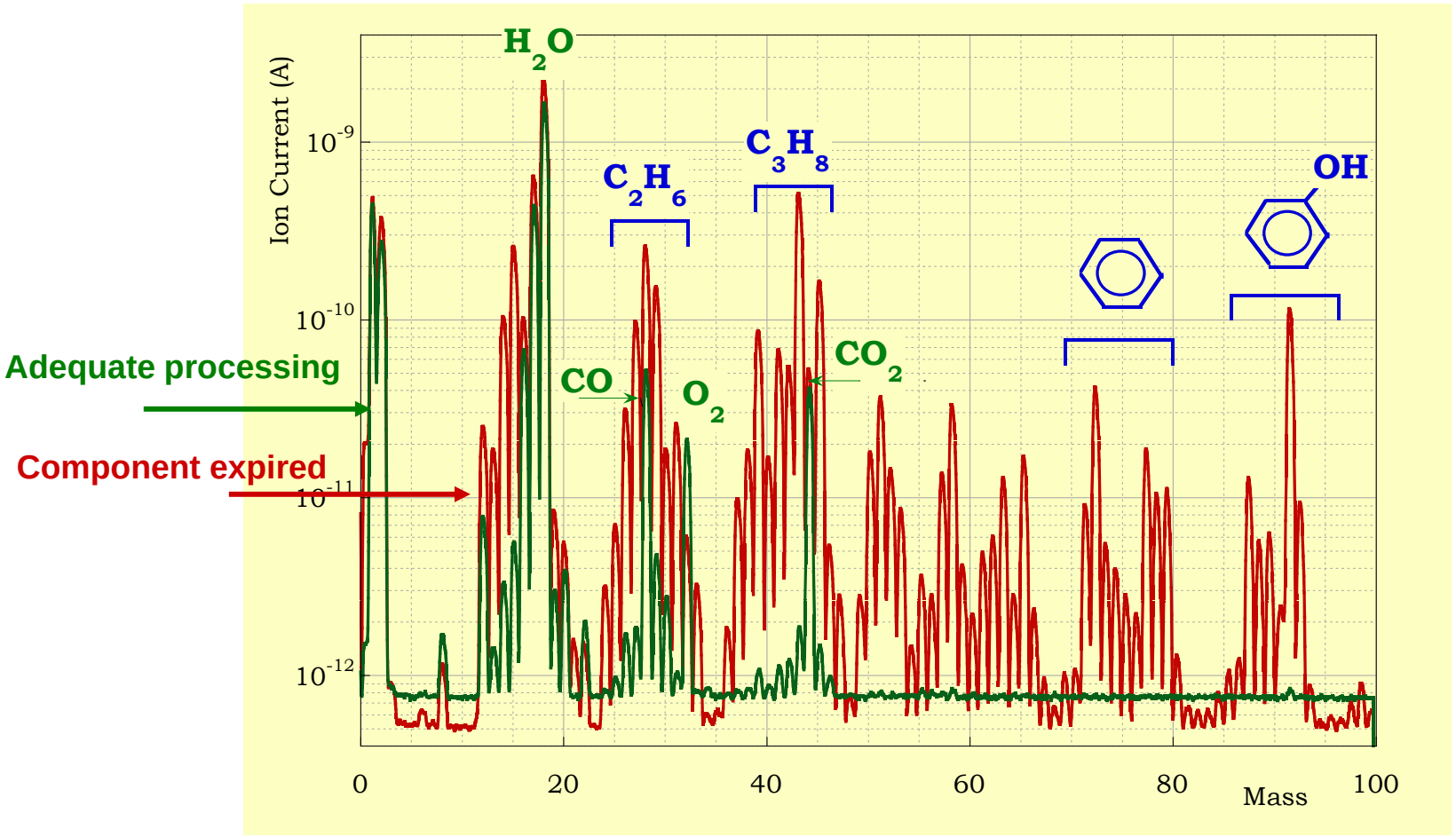
Source	Product	Outgas	Effect in G.D.	Result
CERN/GDD ATLAS/TRT	**ARALDITE AW 106 (Hardener HV 935 U)**	YES		**BAD**
CERN/GDD	**DURALCO 4525**	YES	YES	**BAD**
CERN/GDD	**DURALCO 4461**	YES	YES	**BAD**
CERN/GDD	**HEXCEL A40**	YES	-	**BAD**
CERN/GDD	**TECHNICOLL 8862 + (Hardener 8263)**	YES	-	**BAD**
CERN/GDD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

Outgassing room-T epoxies

Studies on Assembly Materials

CERN-GDD

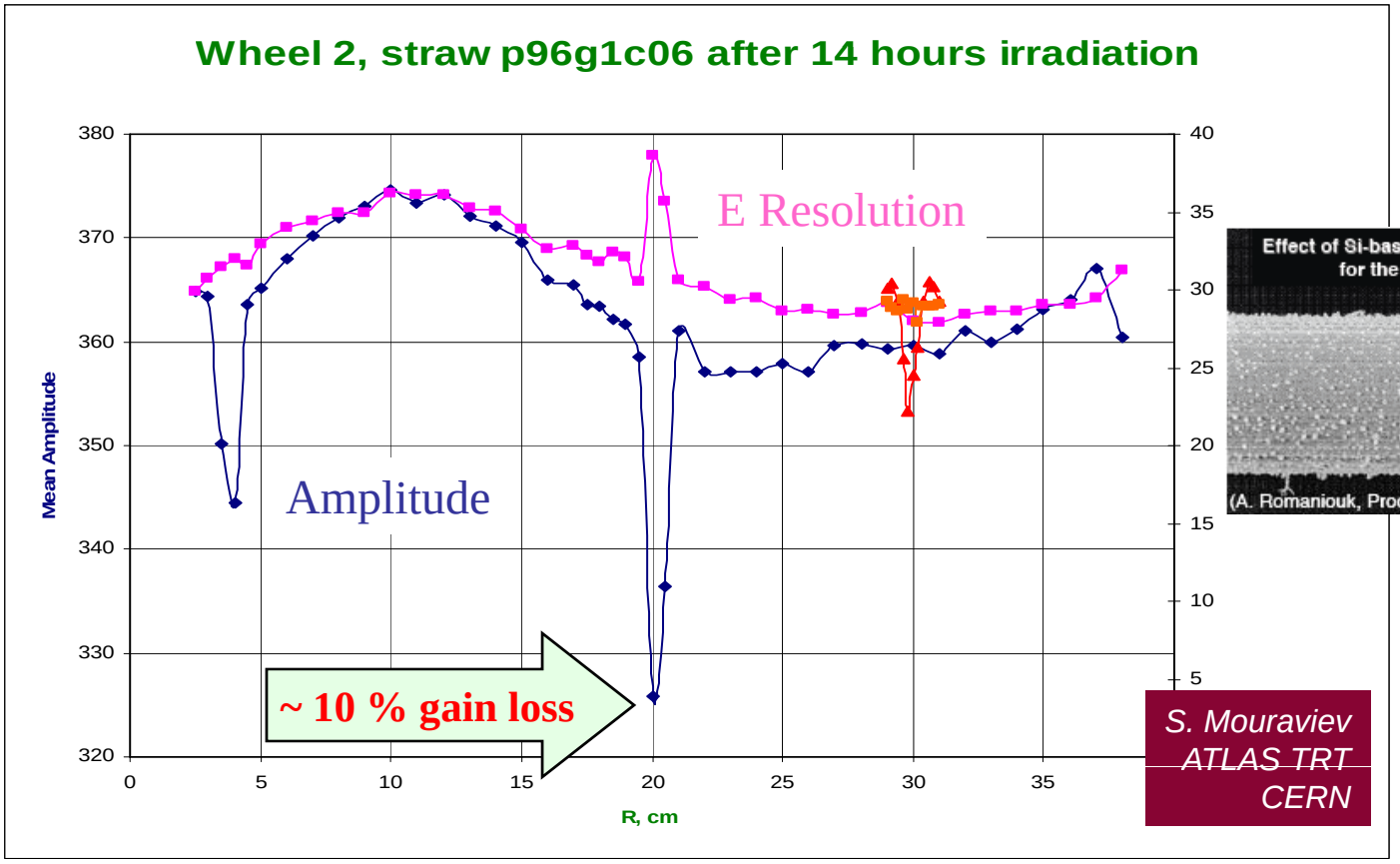
2-component Polyurethane (Nuvovern LW)

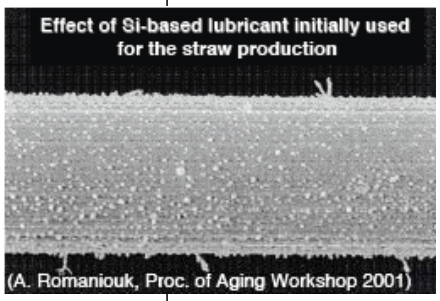


C.Bellachioma, E.Broilo, P.Chiggiato, M.V.Stenis
CERN

Studies on Assembly Materials

Accidental **Si-contamination** of Straw Tubes
10% gain drop in 14h, weak ^{55}Fe irradiation





S. Mouraviev
ATLAS TRT
CERN

Studies on Gas Systems

- Search for components (Cylinder P-regulators, Filters, O-rings, Flowmeters, Valves, Bubbler fillings, Piping, Connectors, etc):
  - Material compatibility with gas mix
  - Low Outgassing
  - Specially, silicon-free

Lists of validated components available at CERN PH-DT1 Gas Section WEB

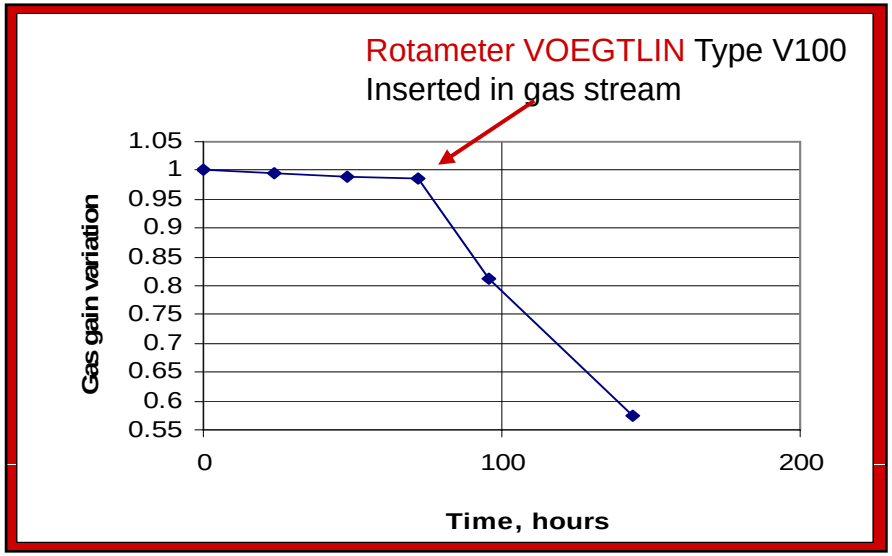
http://detector-gas-systems.web.cern.ch/

M. Capeans CERN-GDD

Piping for gas systems

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**

S. Konovalov ATLAS TRT

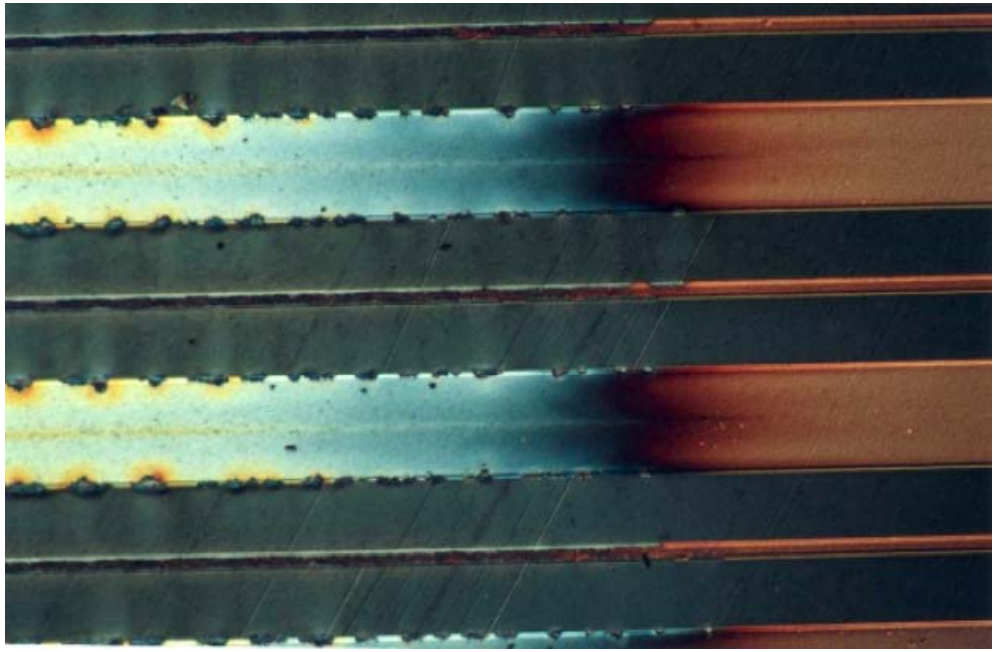


Signs of Aging in MSGCs

CAUSE

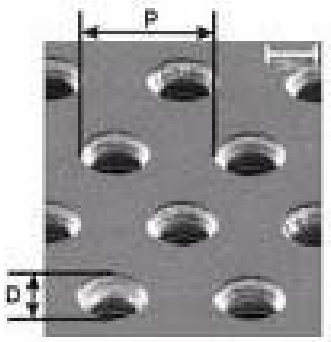
- Deposition of polymers on the anode and/or cathode surfaces
- Micro-discharges

RD-28
CERN-GDD



MSGC turned out to be prone to <u>irreversible damages</u> because of induced discharges

Stability of MPGD detectors

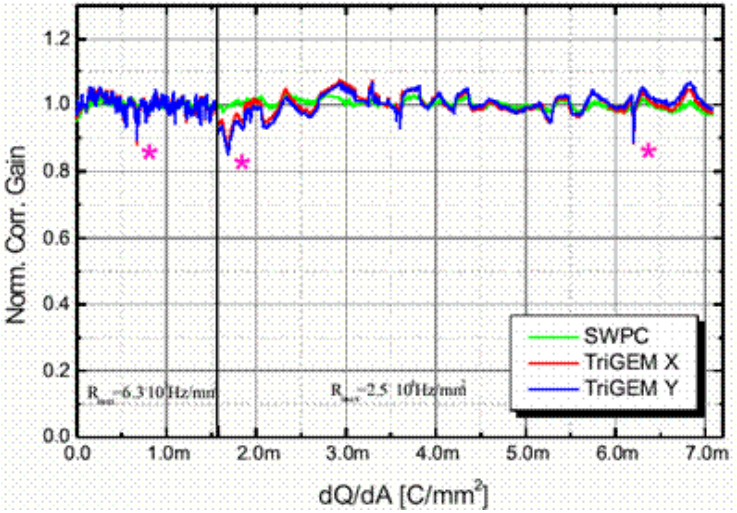


- Discharge Rate
- Charging-up
- Long-term stability ~ Aging

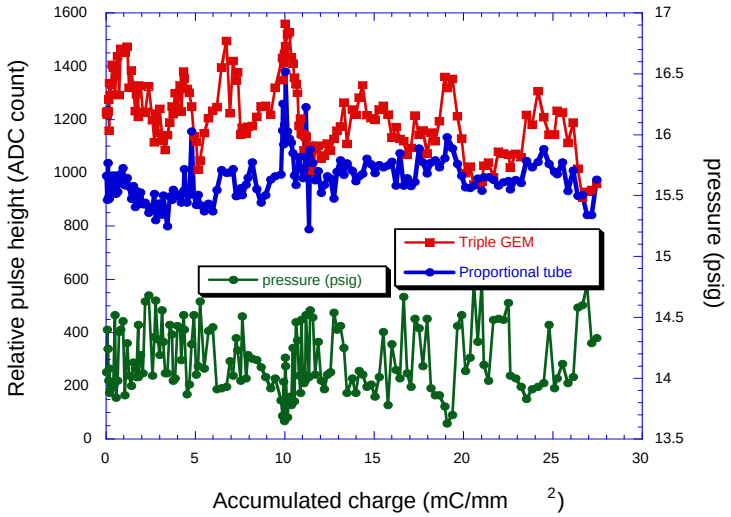
Signs of Aging in GEMs

- **Usually NONE, because of:**
  - **The separation of gas amplification (inside the holes) and the readout stage**
  - **Small efect of polymerization deposits on the electric field**

Large area 3-GEM+PCB
for COMPASS at CERN



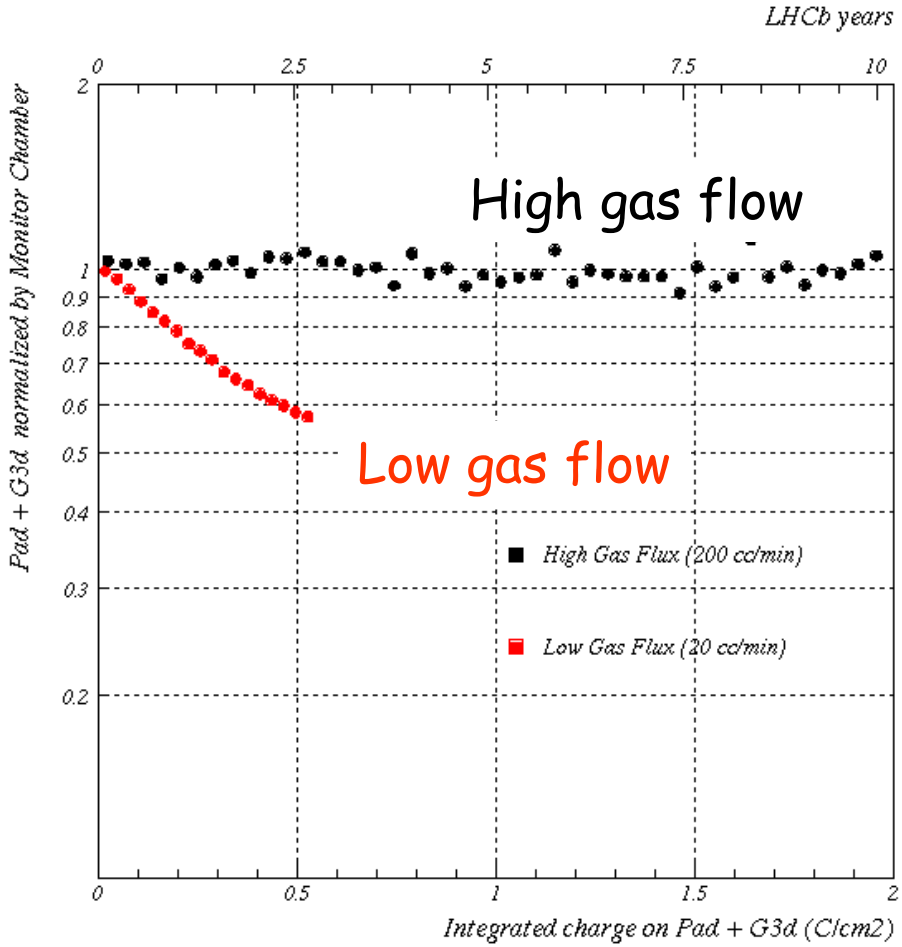
3-GEM+PCB at Purdue



Signs of Aging in GEMs

- Very high γ rate
- Very low gas flow $Ar/CO_2/CF_4$ (45/15/40)

LHCb 3-GEM in CF_4-based mixtures
F. Murtas, LNF & Cagliari INFN



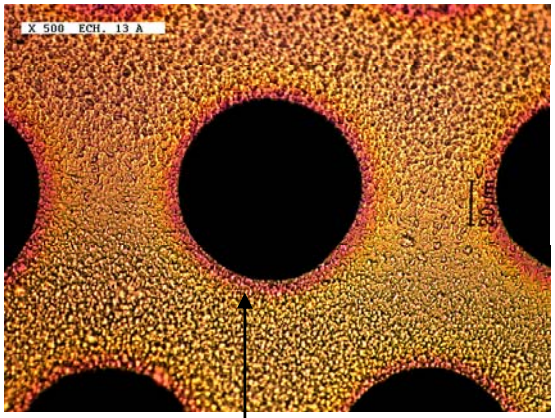
Signs of Aging in GEMs

CAUSE

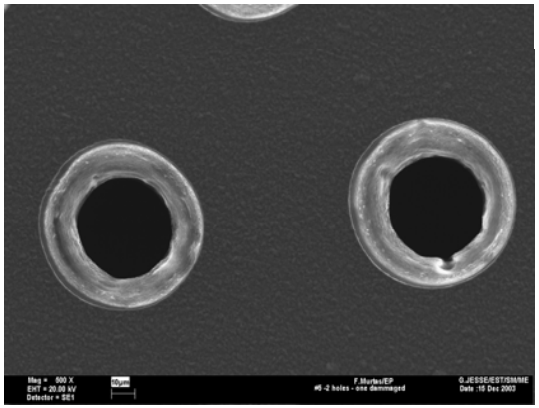
Too low gas flow of $Ar/CO_2/CF_4$ (45/15/40): creation of stable HF, leading to F-etching and F-deposits on the 3rd GEM

- Widening of Copper holes (gain reduction)
- Kapton etching and Cu-F deposits (charging-up and rate capability reduction)
- … but 3GEM-detectors still exhibit good time and efficiency performances when later operated in nominal conditions, at the expected LHCb rates.

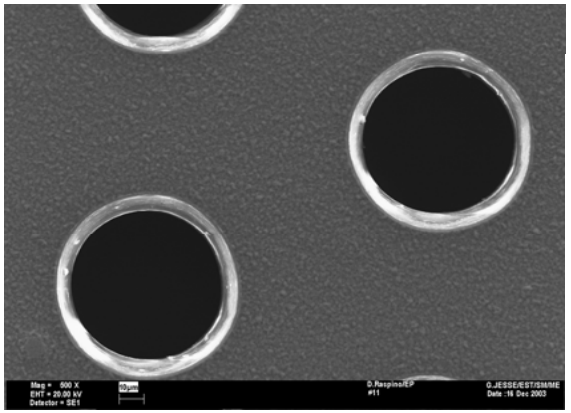
LHCb GEM in CF_4-based mixtures
LNF & Cagliari INFN



F-layer on bottom side



Before irradiation



After irradiation
F-etching

Aging Tests

- Aging depends on the total collected charge, Q [C]

$$Q = M\ R\ T\ ne$$ *(Gain x Rate X Time X Primaries)*

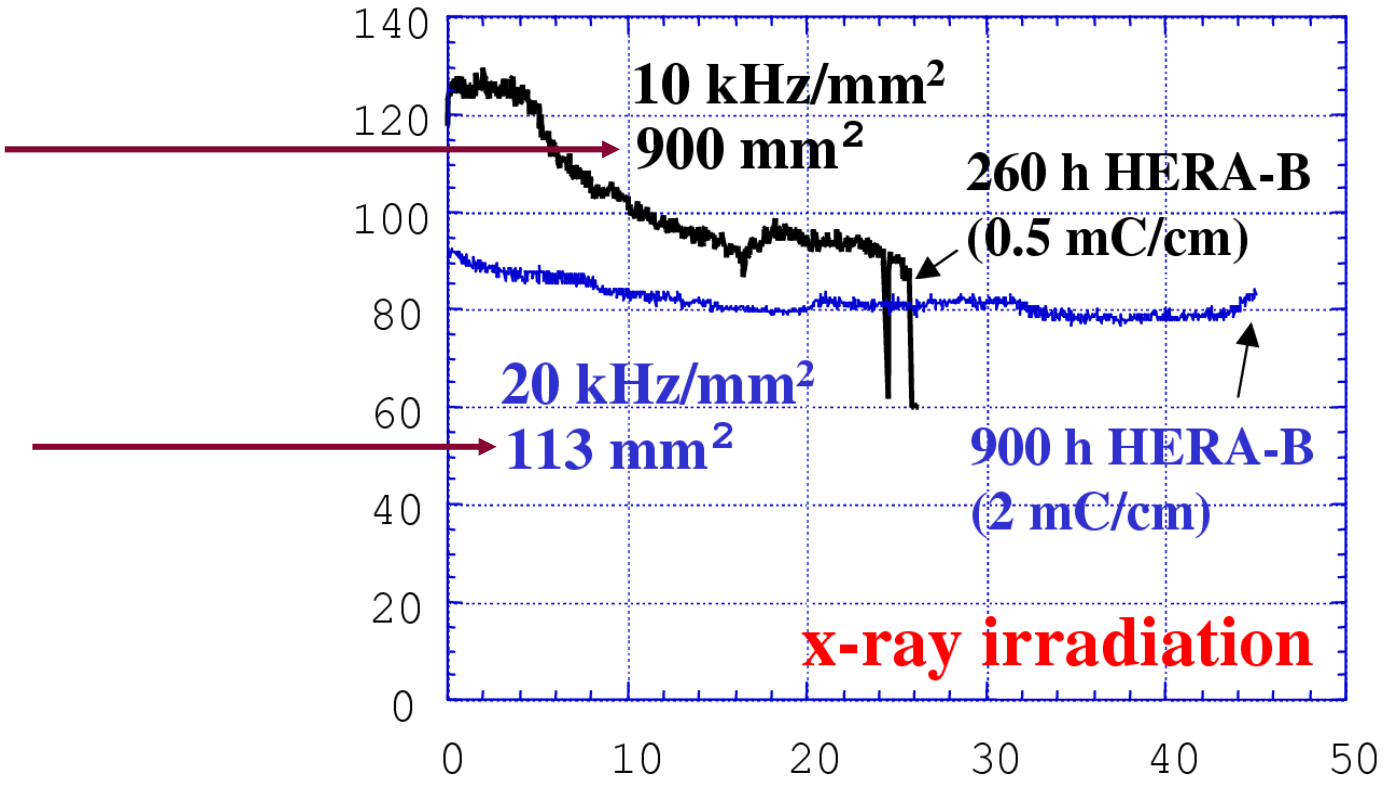
C/cm of wire or strip (MWPC, MSGC)

C/cm2 (RPC, GEM)

- Aging also depends on:
  - Gain, E field strength, dose rate, type of particle, irradiated area, gas flow, …
    There are simply too many variables in the problem, therefore a single variable such as C/cm cannot express precisely aging rate
- Does extrapolation/interpolation work?

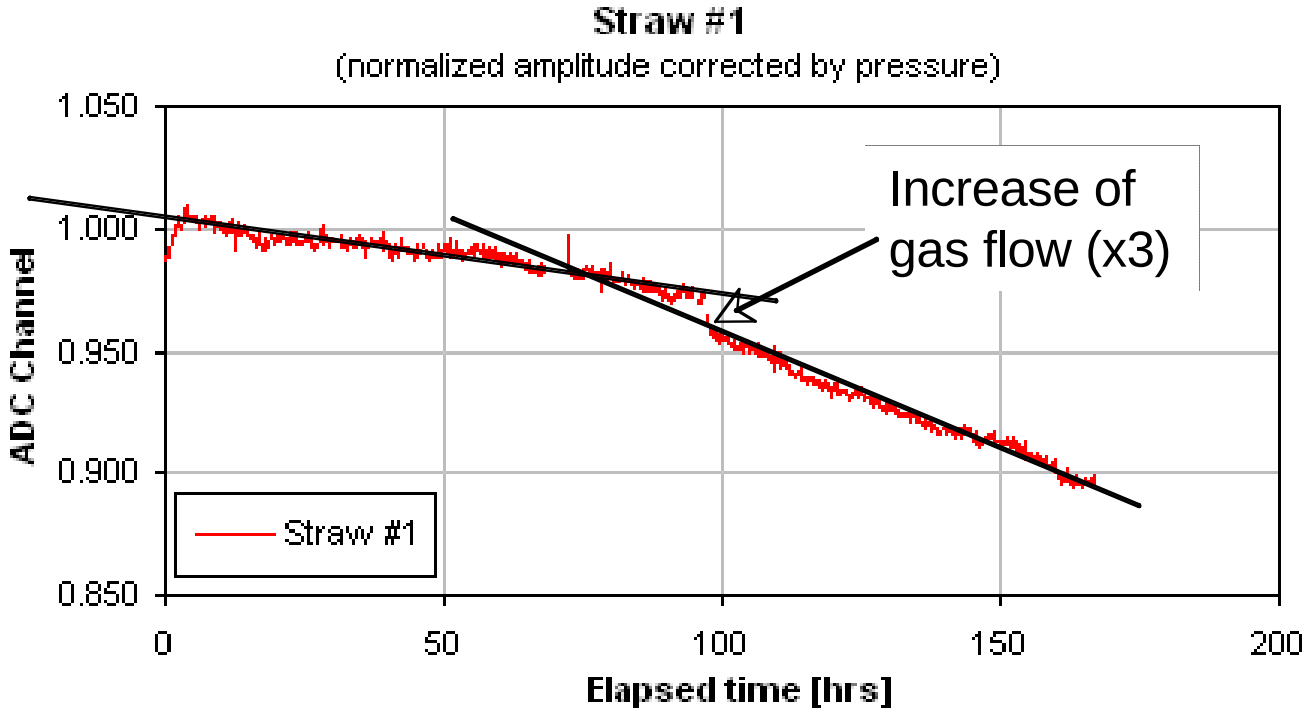
Aging VS Irradiation Size

C. Richter
HERA-B MSGC+GEM
Heidelberg

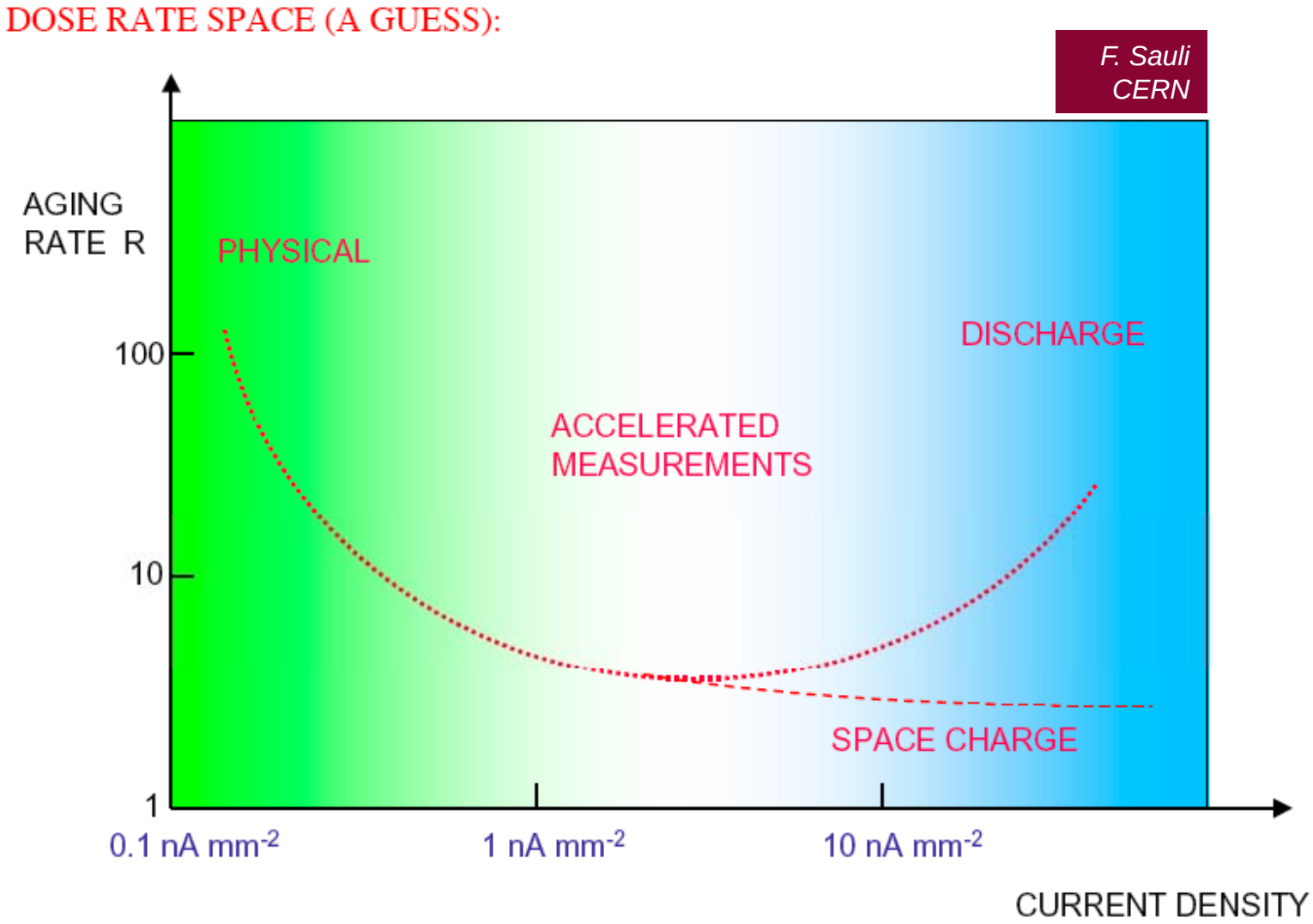


Aging VS Gas Flow

P. Cwetanski
ATLAS TRT Straw tubes
CERN



Aging VS Dose Rate



The Most Followed Recommendations

- Avoid HC mixtures
- Use $CF_{4....}$ Then, for high rate applications, reduce the concentration of CF_4 as much as possible
- Use clean assembly materials
- Use clean gas systems
- Test any new material/component.
  - *Lots of work on validation has been made, in the lab and the experimental sites.*
- Test in conditions as close as possible to the final ones (gas flow, gas system, large detector areas, particle type, etc)
  - *Lots of studies at large irradiation facilities (e.g.CERN-GIF) with prototypes and mass produced chambers*

Challenges Ahead

- Large Area MPGDs open new challenges:
  - Large area irradiation
  - New detector materials: minimum material budget, rad-hard and outgassing-free
  - New assembly procedures
  - For large experiments: distributed, cost-effective, mass production procedures
- LHC: very large inner trackers and muon systems (on closed-loop gas systems) in unprecedented high radiation environment
  - Little knowledge about mitigation and/or working remedies: need work on optimization of detectors performance and gas systems operation
- All these applies to the gaseous detectors needed for SLHC and ILC