Gas Detectors Ageing, Materials, Validations

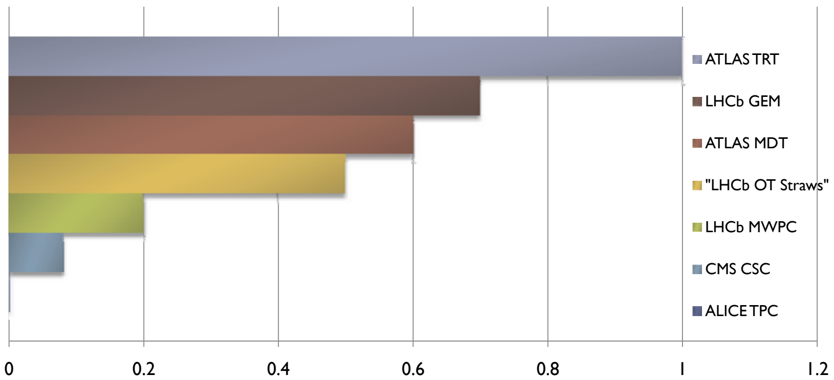
Input to RD51 WG2 (Basic detector R&D)

Mar Capeans
CERN, December 10th, 2008

Gas Detectors at the LHC

Accumulated charge per LHC year in C/cm

- 1 LHC year = 10^7 sec
- Different safety factors
- Calculated for detectors operating at nominal conditions



Acknowledgements

- Many data appearing in these slides has been provided by A. Romaniouk and S. Konovalov (ATLAS TRT)

Topics

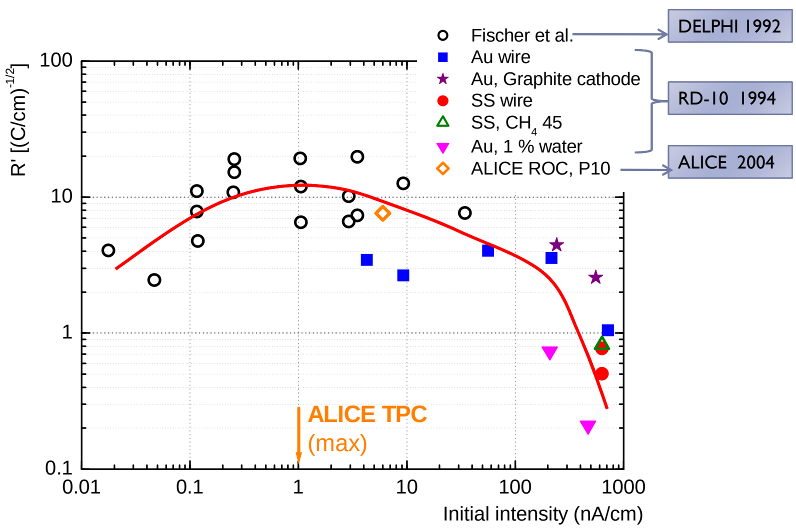
- Aging tests:
  - Parameters
- Selection of materials:
  - In contact with the gas (construction materials, gas systems components)
  - Radiation hardness

Aging tests

Parameter	Proven Influence on the result of test	
Gas Mixture	Yes	There are polymerizing mixtures (CH_x), non polymerizing mixtures (CO_2), and cleaning mixtures (CF_4, O_2, H_2O…)! Polluted Mixtures screw up all results.
Gas Flow	Yes	Effect depends on: if pollutant comes with gas flow, if it's already inside the detector, if gas etches away the pollutant!
Ionization Current Density	Yes	Less aging observed at very large current densities.
Irradiation Area	Yes	Small spots do not show the whole picture.
Irradiation Time (acceleration factor)	Yes	A reasonable compromise can be found…
Irradiation type	Yes	Specially for Malter currents.
Chamber geometry	Yes	Can generic studies be applicable to all gas detectors types?

ALICE TPC
C.Garabatos, 2004

Rate of Aging



Aging tests

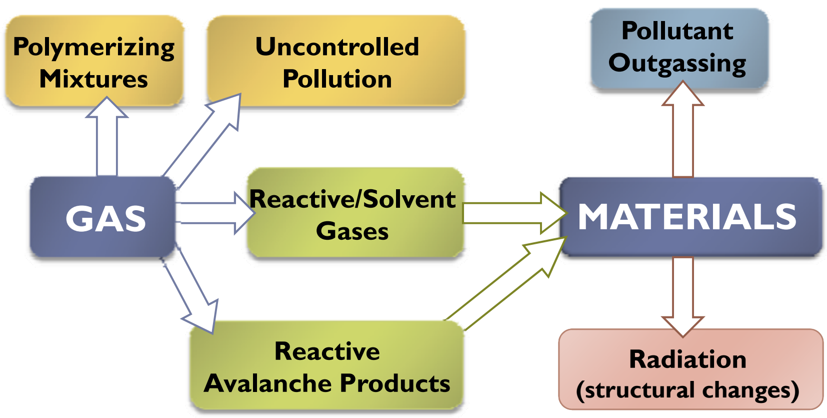
- Validation in the Lab of a detector assembly at a reasonable pace
- Small detectors: X-rays
- Large LHC μ detectors: GIF (Gamma + μ beam)

Acceleration factors used to validate detectors for 10 LHC years

Detector	Acceleration factor
Atlas TRT	x 10
LHCb OT (Straws)	x 20
CMS RPC	x 30 (and much larger)

Factors are obtained by increasing charge density; sometimes gas flow is scaled appropriately.

Contributions to the Aging Process



ATLAS TRT 2004

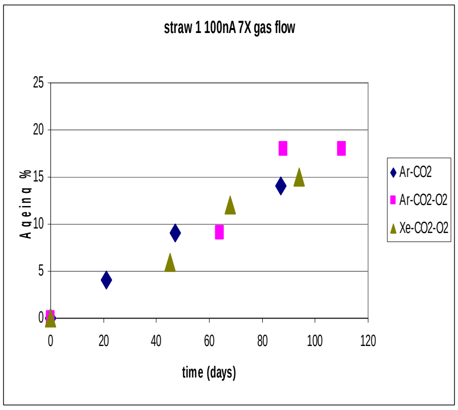
An Efficient Material Validation Strategy *(ATLAS TRT)*

- Established firmly that Si-pollution is the major danger (as opposed to hydrocarbons)
- Found a source of Silicon that delivers a constant rate of contamination inside the straws (3145 RTV)
- Measured equivalence between gain drop & amount of Si: few ppb of Si induce10% aging in 100 h
- Found test parameters to do materials tests that can deliver a reliable and fast Go/No Go response:
  - Gas mixture
  - Gas Flow
  - Current Density
  - Irradiation area
  - Test Time

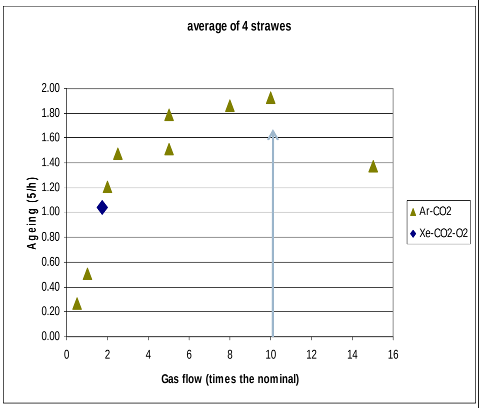
ATLAS TRT 2004

Material Validation Strategy

Aging rate in different gas mixtures

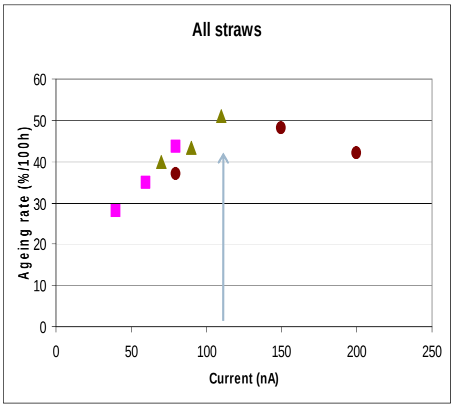


Aging rate as a function of Gas Flow

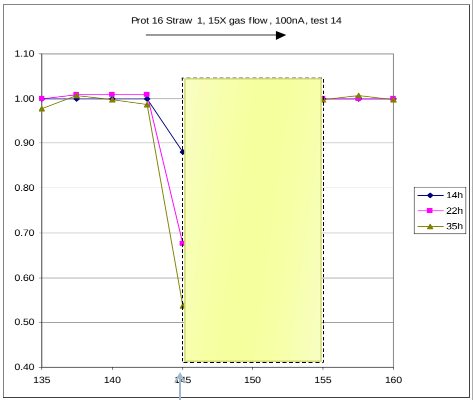


Material Validation Strategy

Aging rate as a function of Current Density



Aging rate as a Irradiation Area



An Efficient Material Validation Strategy

Test conditions are optimized to detect aging as soon as possible

Material/Component is validated if gas gain stays constant at 2% level for ~200 h

	TRT Operating Conditions	Lab Tests
Gas Gain	~ 2 x 10^4	~ 2 x 10^4
Current density	up to 0.15 µA/cm	0.1 µA/cm
Gas Mixture	Xe-CO_2-O_2 [70-27-3]	Ar-CO_2 [70-30]
Gas Flow	0.15 cm^3/min/straw	x 10 nominal
Irradiation area		5 KeV X-rays, 1-2 cm spot
Distance pollution to irradiated area		< 10 cm

ATLAS TRT &
CERN Gas Group

Validated materials (Aging tests)

- Anything in contact with the straw gas:
  - Assembly Materials
  - Gas system components (pipes, valves, pumps, connectors, fully assembled racks, etc).

  More than 80 different components (including components treated differently), used in Lab and LHC set-ups.

http://cern.ch/detector-gas-systems/Equipment/componentValidation.htm

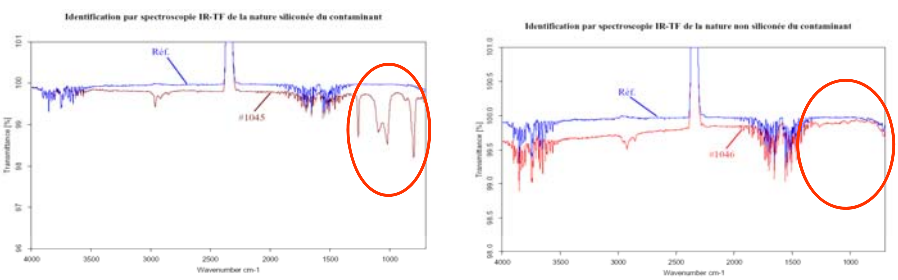
13 Mar CAPEANS Dec 10th, 08

CERN TS
S.Ilie

Validated materials (IR analysis)

Dirty Component
5% Aging in 160h test

Clean Component
No aging in 350 h test



- Sometimes IR analysis could be not conclusive
- Found few contradictions between IR and Lab Aging test
- Tested more than 60 samples

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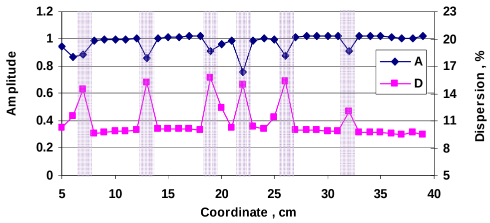
ATLAS TRT Validation set-up

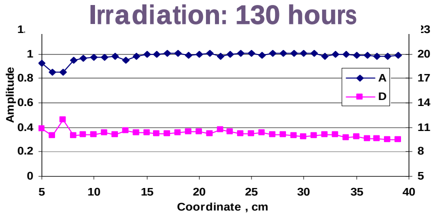
Recovery Mixtures

Straw aged in Ar-CO_2



Straw recovered in Ar-CO_2-CF_4

Irradiation: 130 hours



- Recovery confirmed
- Material attack (Fiberglass, solder tin, glass, some epoxy compounds) also confirmed!
- Performed set of tests to find the minimum amount of CF_4 and irradiation time needed to recover aged counter at LHC!
- Strategy: TRT runs without CF_4 but build a gas system that permits to use CF_4 for 'short cleaning runs'

RadHard Materials

- New detector development demand light, stiff, stable materials, thermally adequate, and reliable joining methods
  - Detector/sensor performance, Materials, On-detector electronics, Powering and data links, Fluids (gas, cooling)
- Sources of radhard materials data:
  - Suppliers
  - CERN yellow reports: http://preprints.cern.ch/cernrep/1998/98-01/98-01.html
- Test your own samples
  - Ex. Ionisos (FR)
  - They do not do post-irradiation tests (Mechanical, physical, electrical, chemical properties need to be evaluated)
  - In my view, best way to proceed is to contact SC (i.e. H.Vincke)
- This is currently a hot topic for SLHC (trackers, calorimetry)

Pre & Post Characterization of RadHard Materials

Properties	
Physical	Weight
	Water absorption
	Thermal Conductivity
Electrical	Dielectric constant
	Resistivity
	Dielectric strength
Mechanical	Tensile strength
	Elongation
Chemical	Outgassing

Studies for MPGD

- Define your cleanliness requirements (ppb?, ppm?, % ?)
- Find out 'the killer' contaminants
- Quantify Pollution (ppm) VS detector aging rate (%)
- Find an accelerated validation strategy for materials and get a dedicated set up available
- Find a reasonable acceleration factor to validate complete detector assemblies (x10?). If possible, irradiate large areas (Consider GIF++: 10 TBq ^{137}Cs source , 662 keV photons, 2Gy/h at most)

SLHC silicon trackers ~ MGy/year
SLHC Calorimeters ~ 20 kGy/year
SLHC Muon detectors ~ 0.1 Gy per year

- Find new radiation hardness materials (databases & tests outside CERN) in collaboration with other groups (to minimize cost & effort)

CERN White Paper WP7
Facilities and Component Analysis for Detector R&D

- Areas of activity of interest for RD-51
  - Generic aging set-up
  - DB of material

- Aging Set-up can me made available
- Resources needed to run the tests
- Let's evaluate together how to proceed

GIF++: Start construction during shutdown 09

NORTH AREA (H4)

Muon 100GeV/c, ~10^4 µ/spill, 10x10cm^2

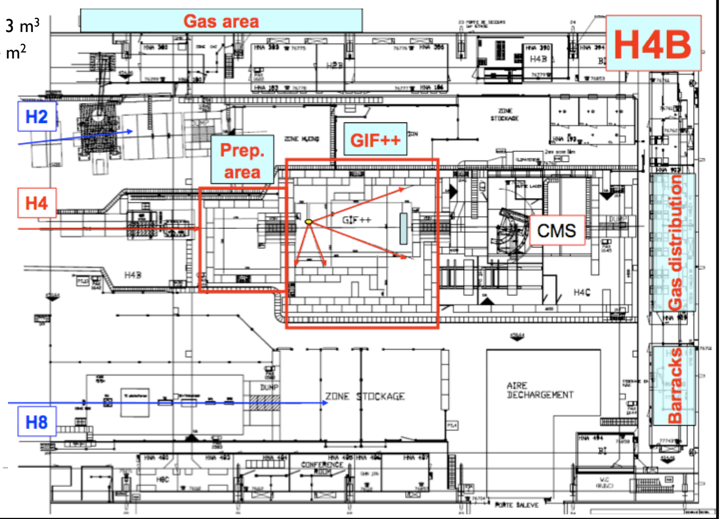
Cs^{137} (662 keV) 10TBq

Radiation area: 10 x 7.5 x 3 m^3

Preparation area: > 4 x 4 m^2

Peripheral infrastructure

Current Proposal
Nov 08



BACK UP SLIDES

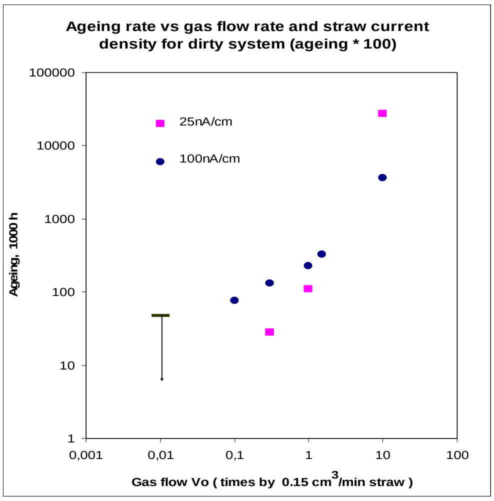
GIF++

- Timescale:
  - Evaluation of possible scenarios and Design Proposals: June – September 08
  - Preparation of a Technical Design Proposal (AB Dept): September 08 – March 09
  - Design of Final Infrastructure (not related to the particle beam): September 08 – February 09
  - Approval of Technical Specifications of the facility: April 09
  - Procurement and construction phase: May 09 – December 09
  - Infrastructure commissioning: January 10 – May 10 - Target date 'Ready for users': May 10
- Specifications: http://cern.ch/project-WP7/Documents/20080919_Specs_GIF++_V2.pdf

Current Irradiation Facilities at CERN

Facility	Particle	Majority of Users	Status	Shortfalls
IRRAD	Protons and mixed field	Silicon (tracking) detectors Electronics	In use Upgrade being studied	Parasitic to DIRAC Limited rate and space Exposure of personnel
GIF	Photons (+particle beam)	LHC Muon detectors	In use Upgrade proposed (2010)	No particle beam Limited rate Old, shutdown in 2009
CERF	Mixed field (π^+,p,K$^+$)	Dosimetry, FLUKA benchmarking, beam monitors	Used 1-2 weeks/year	Limited dose rates
TCC2	Mixed field	LHC accelerator components and electronics	Off (used 1998-2004)	Parasitic Residual dose (safety, access)
TT40	Short & intense pulses	LHC collimator studies	Used in 2004 and 2006	Space, safety Interference LHC & CNGS

Si-aging and Gas Flow



- Gas: Xe-CO2-O2 (70-27-3)

Ageing rate is considerably reduced if the gas flow rate is decreased

Probably, short living active components are created in the irradiation area (atomic Oxygen?), which at certain concentration can protect the wire against Silicon deposition