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First results of an aging test of a full scale MWPC prototype for the LHCb muon system

LHCb Muon Collaboration

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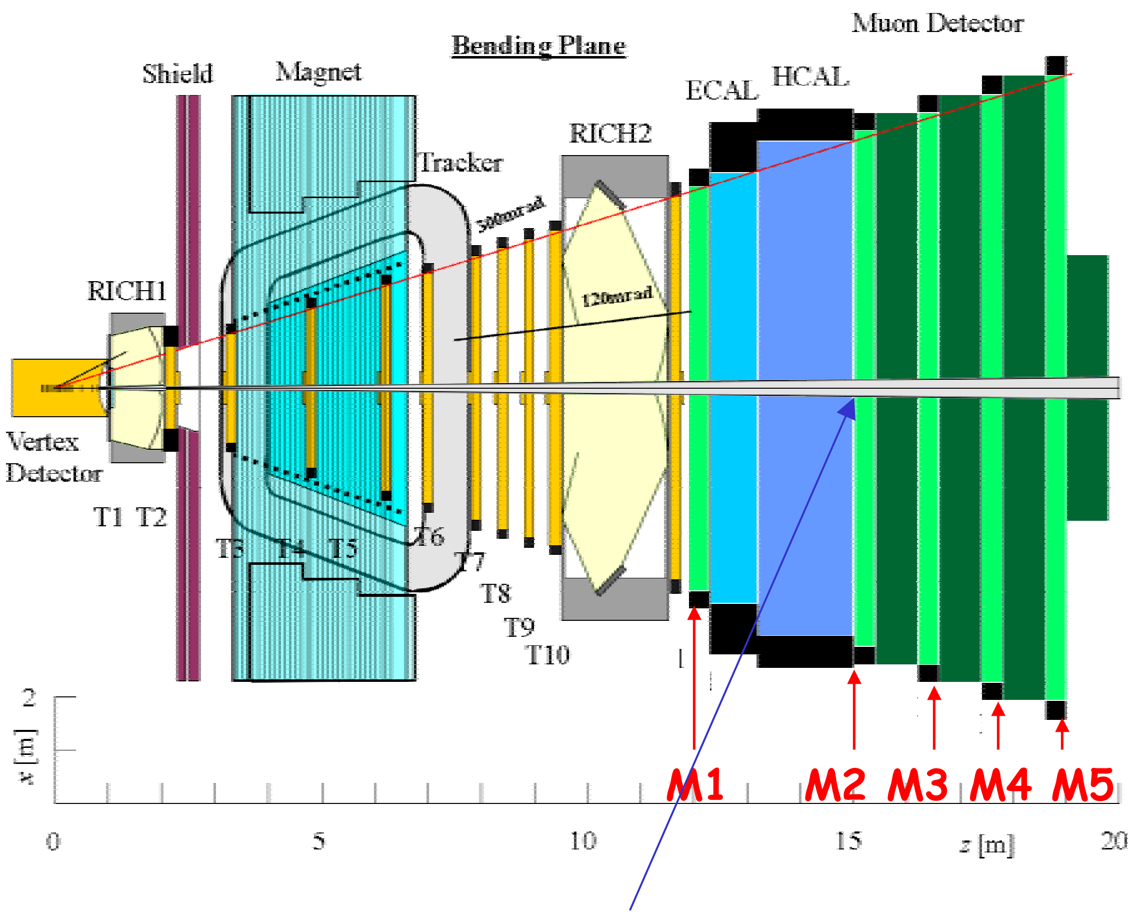
The LHCb Spectrometer



Position of the irradiated chamber in the detector

- 5 Muon stations, subdivided in 4 regions of varying particle flux
- 435m^2 of detector area with 1380 chambers
- **Detector Technologies:**
  - RPC in the outer part of M4 and M5 (48% of area)
  - MWPC in the rest of the detector, besides inner part of M1 (52% of area)

MWPC Parameters and Aging Requirements

The basic chamber parameters:

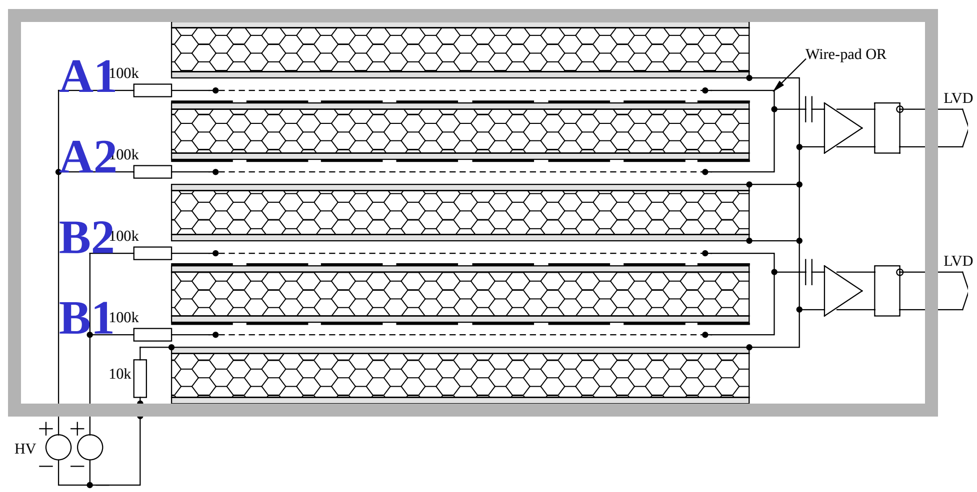
Parameter	Design value
No. of gaps	4
Gap width	5 mm
Anode-cathode distance	2.5 mm
Wire spacing	1.5 mm
Wire diameter	30 μm
Operating voltage	3-3.2 kV
Wire surface field	260 kV/cm
Cathode surface field	8 kV/cm
Total wire length per gap (m)	~99.5
Chamber volume (cm^3)	3000
Sensitive area (cm^2)	1500
Gas flow rate (l/hour)	2.75
Gas gain	$\sim 10^5$

Materials used for the chamber construction:

Stesalit
Fr4 (fire resistant fiber glass epoxy with copper clads
Gold
Araldite 2011
Adekit A 145/50
Naturel rubber gasket
One side glued kapton foil.

Aging requirements:

- Particle flux : 37 kHz/cm^2
- Integrated charge for 10 years of LHCb operation:
  0.5 C/cm on the wires and
  1.7 C/cm^2 on the cathodes



Chamber cross-section with the four gaps.

Gas Properties

Gas mixture: Ar / CO_2 / CF_4 (40%, 50%, 10%)

Gas purity: Ar 46 CO_2 40 CF_4 45

Gas pipes: stainless steel for supply, copper for exhaust

Open loop gas system is used to supply the chamber.

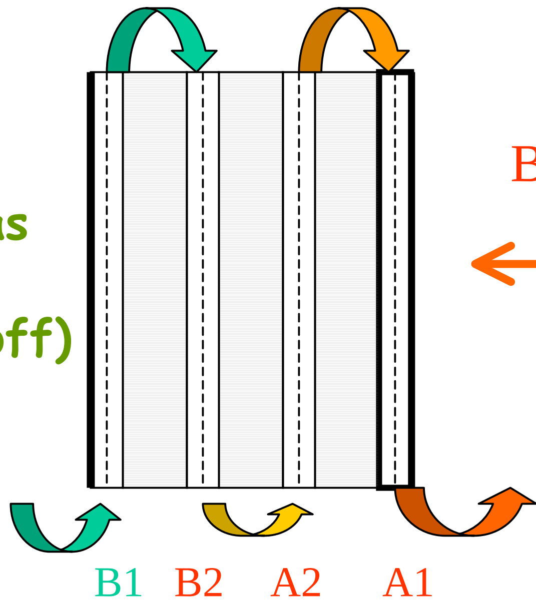
The chamber gaps are connected with gas in series from B1 to A1

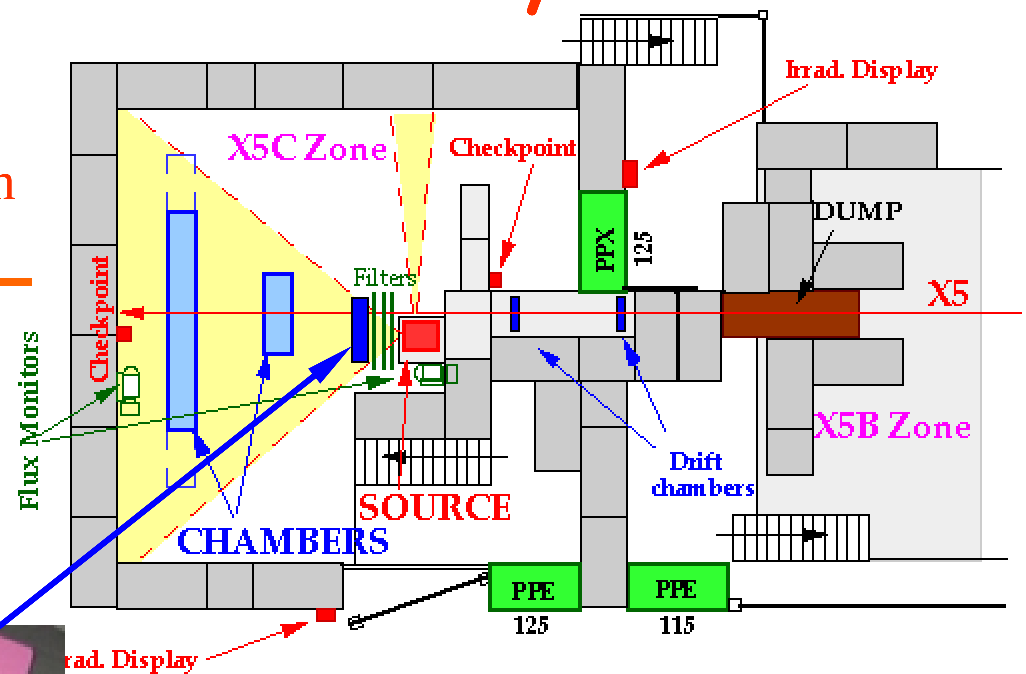
The gas flow rate and the gas mixture composition are controlled remotely with electronic mass flow meters. To mix the components the standard CERN mixing rack was used.

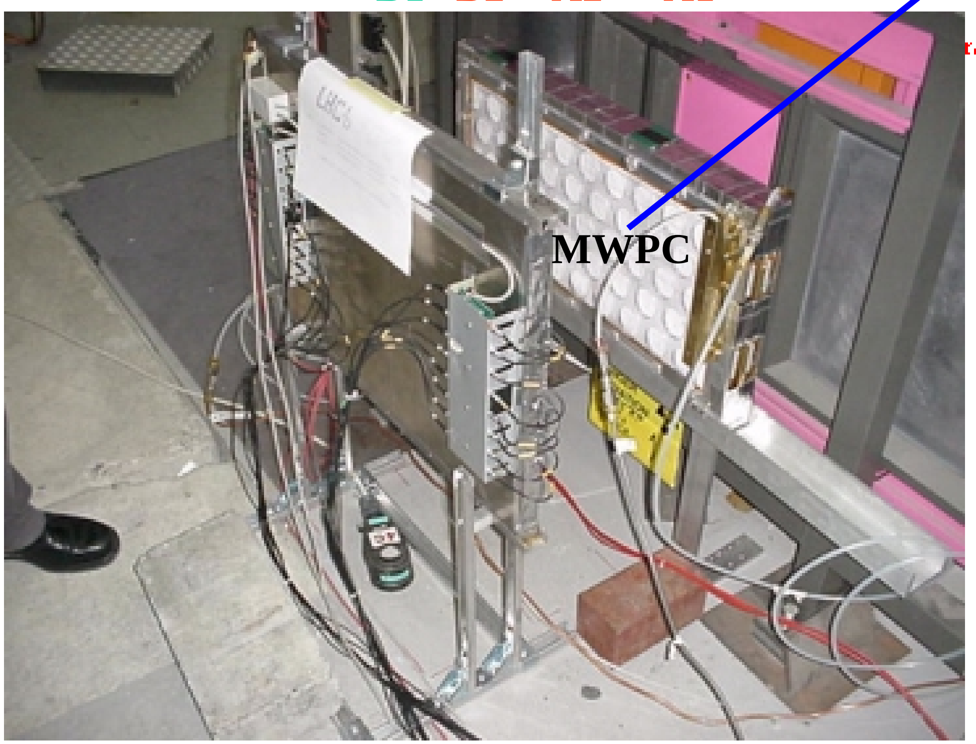
Gas leaks are of about 7 cm^3/min or $\sim 10^{-3}$ of the chamber volume.
The O_2 admixture is at the level of 400 ppm.

Gamma Irradiation Facility

B1 used as reference gap (HV off)







^{137}Cs

Eγ =662 keV

Strength = 675 GBq in Feb 2001

Chamber position: close to the source (count rate ~30 kHz/cm^2)

To finish the test in a reasonable time we need to increase the gap current from ~280 to ~500 μA.

Chamber status before the test

Gain uniformity measured with source

Gap	A1	A2	B2	B1
Average Current (nA)	27.8	28.3	26.8	35.4
Current Variation (nA)	18.6	8	2.5	21

→ The inner A2, B2 gaps are more uniform than outer A1,B1.

Gas gain of the gaps measured with the GIF and Americium source (in brackets)

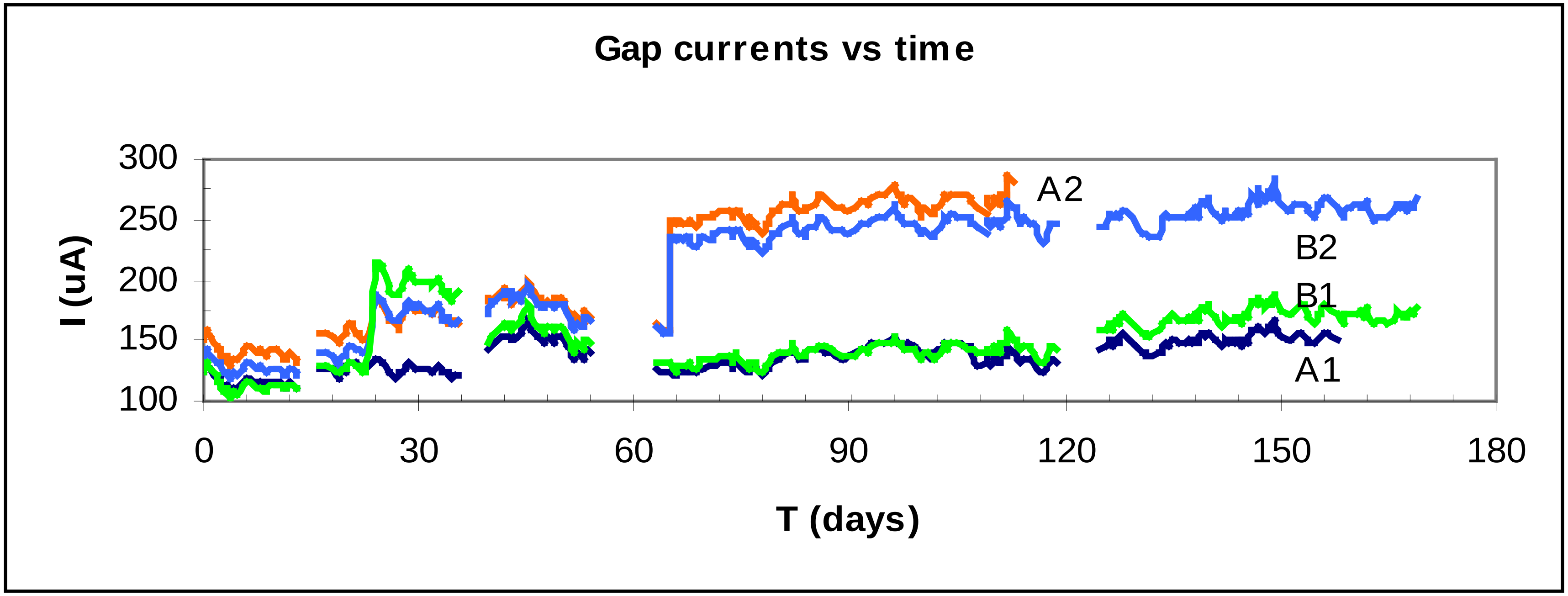
	A1/B1	A2/B2	A2/B1
A1	0.68 (0.78)		
A2		1.01 (1.06)	1.19 (1.17)

The cathode pad to ground resistances are in the range 200-500 GΩ.

Monitored Chamber Parameters

- **Relative gas gain:** through the ratios of the gap A1,A2,B2 currents to the reference B1 current. The B1 gap is under HV only for a very short time per day and always flashed with the fresh gas.
- **Dark currents** including self-sustaining current following the beam off (the chamber drawing discharge current). The dark currents are measured with current monitors with a resolution of about 1 nA.
- **Ground to cathode pad resistances**
- **Pressure, temperature and humidity** are controlled manually and remotely.

Test History



The linear current density is less than 0.03 µA/cm.

7.2.01: The test starts

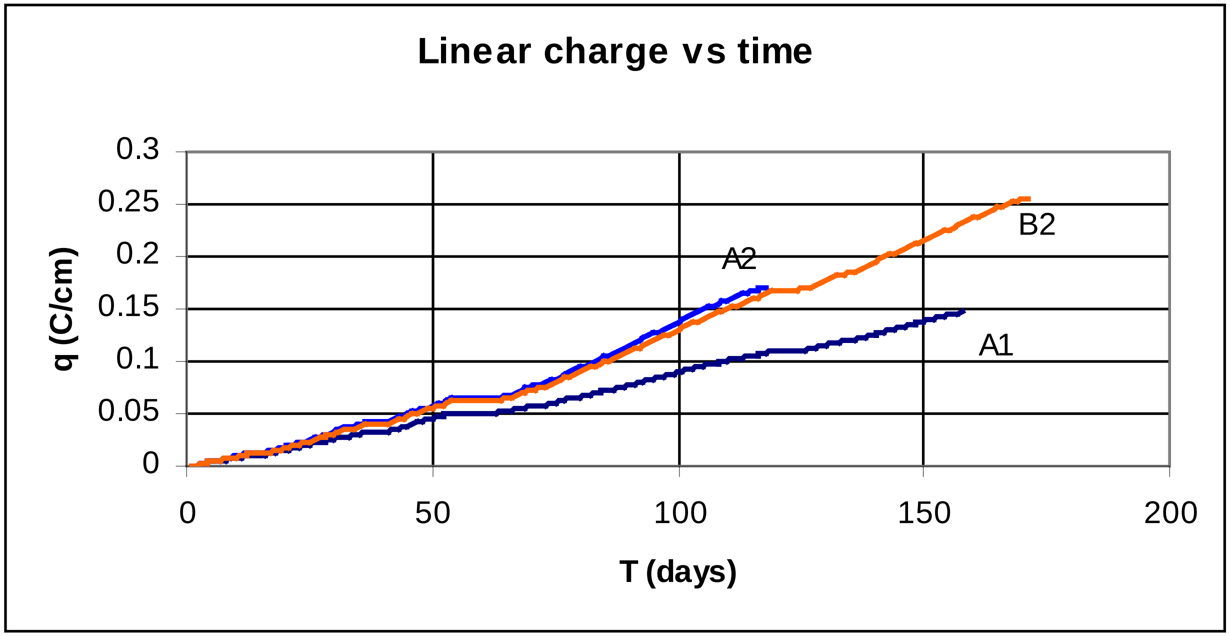
4.6.01: Broken wire in gap A2.

16.7.01: Gap A1 turned off due to HV trip.

27.7.01: End of test. Chamber opened for investigation.

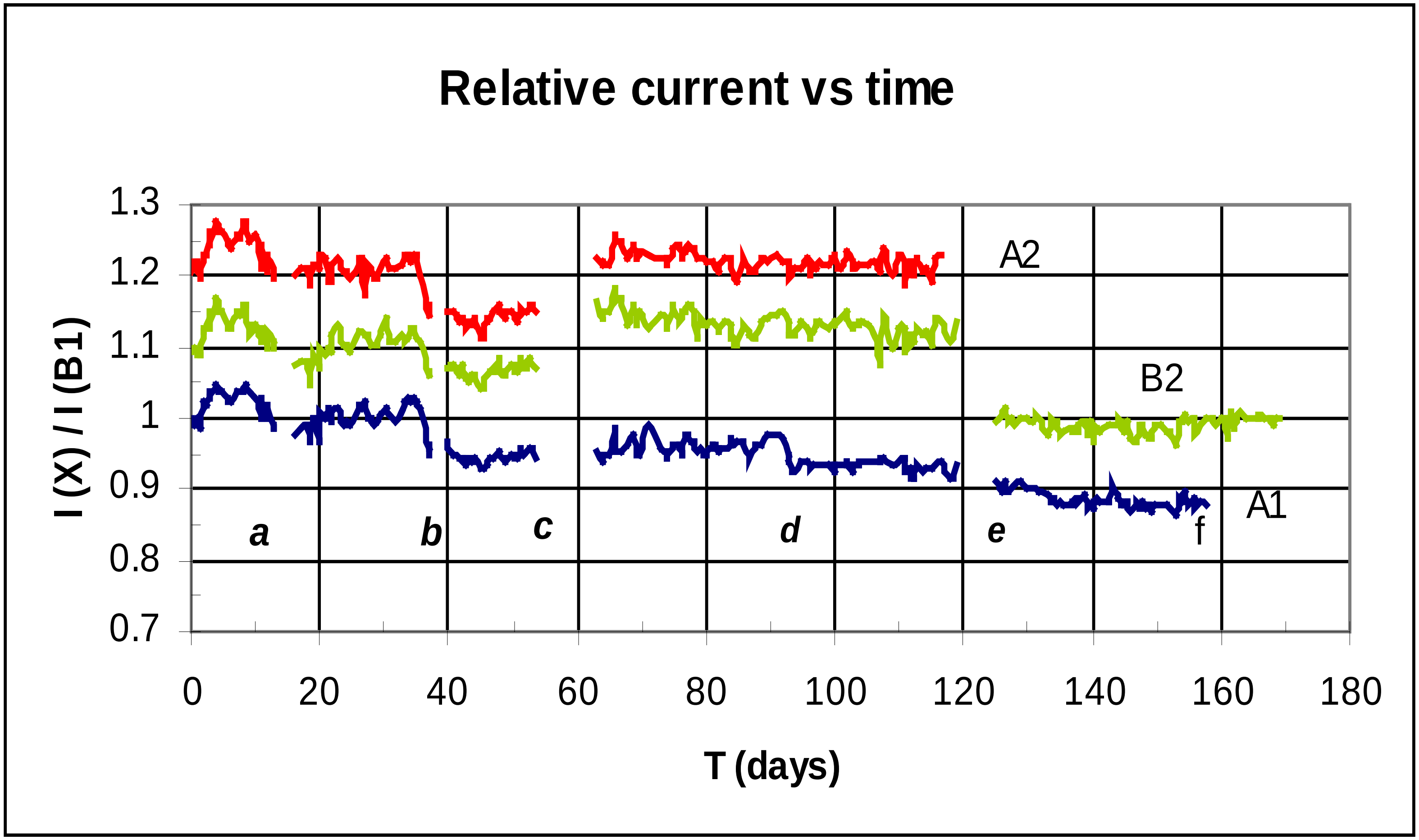
Test Results

The linear charge integration



The final charges collected and connected values

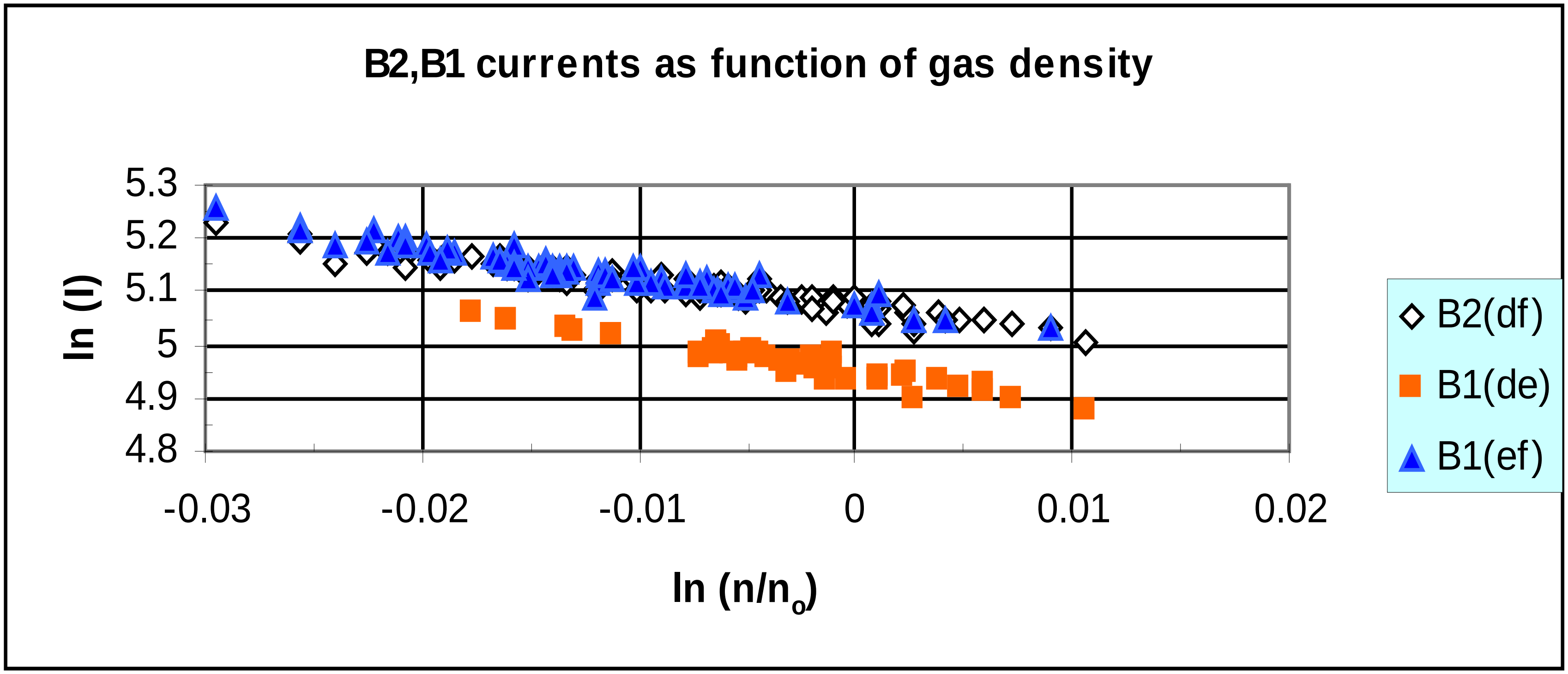
Gap	**A1**	**A2**	**B2**
Total charge (C)	1470	1700	2540
Linear density (C/cm)	0.15	0.17	0.255
Cathode density(C/cm^2)	0.49	0.57	0.83
LHCb years	3	3.4	**5.1**



- The A1,A2,B2 are the relative $I(X_i)/I(B1)$ currents (X_i A1,A2,B2).
- All curves have some flat parts.
- The jumps between the flat parts have the same sign (+/-) for each gap

→ They can not be attributed to aging.

The de/ef step is related with the spontaneous change of the B1 gain at the point e. The reason is the too large flexibility of the outer panel of gap B1.



Gain comparison with the Americium source

Date	04.02.01	10.04.01	20.08.01	23.08.01
A1/B1	0.79 ± 0.04	0.72 ± 0.03	0.65 ± 0.04	0.67 ± 0.04
A2/B1	0.8 ± 0.03	0.82 ± 0.03	0.8 ± 0.03	0.74 ± 0.03
B2/B1	0.76 ± 0.03	0.76 ± 0.03	0.77 ± 0.02	0.75 ± 0.03

No deterioration of the gaps A2 and B2 is seen. The tendency of the gain decrease for the A1 gap is not significant due to lack of accuracy.

The pad to ground resistances decreased strongly (10-100 times) in a very short time (~0.7 LHCb years) and varied afterwards only due to humidity variations (variations well within the requirements).

The initial and final dark currents show a minor increase which will not prevent a successful operation of the chamber in the muon detector .

Gap	A1	A2	B2	B1
Initial current(nA)	1.3	1.2	1.6	1.2
Final current(nA)	3	9	3	1.5-3

Discharge current

The appearance of discharge currents following the GIF turn off was counted and the current range was measured. The table gives the number of tests, the frequency of discharge current appearance, and the corresponding probabilities.

Gap	**A1**	**A2**	**B2**
Current (uA)	0.5	0.4-3	0.5-1
Test number	182	140	218
Discharge appearance	1	11	14
Probability	0.00	0.078	0.064

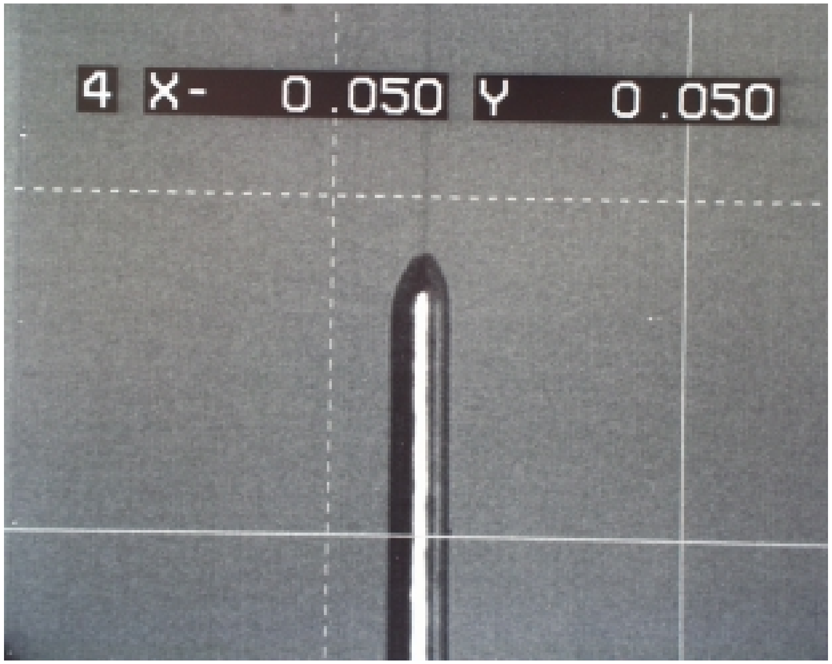
The observed currents are a result of insufficient cleaning the cathode surfaces.

Anode Wire Investigations after the Test

- Anode wires stayed fairly clean.

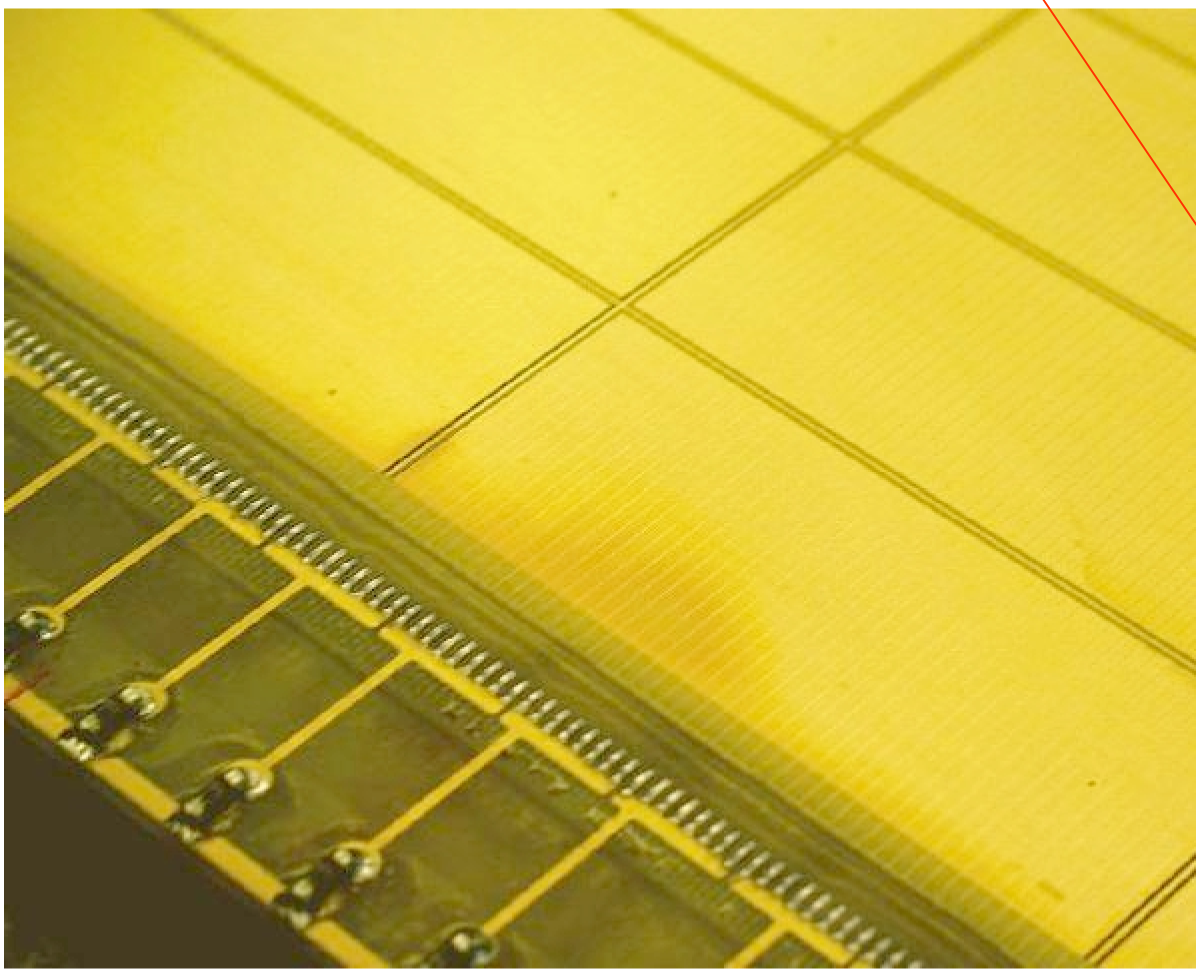
- There is some minor deposit (black dots) sporadically scattered near two brownish spots on the cathodes. The amount of the spoiled wire surface is negligible ($<10^{-3}$).

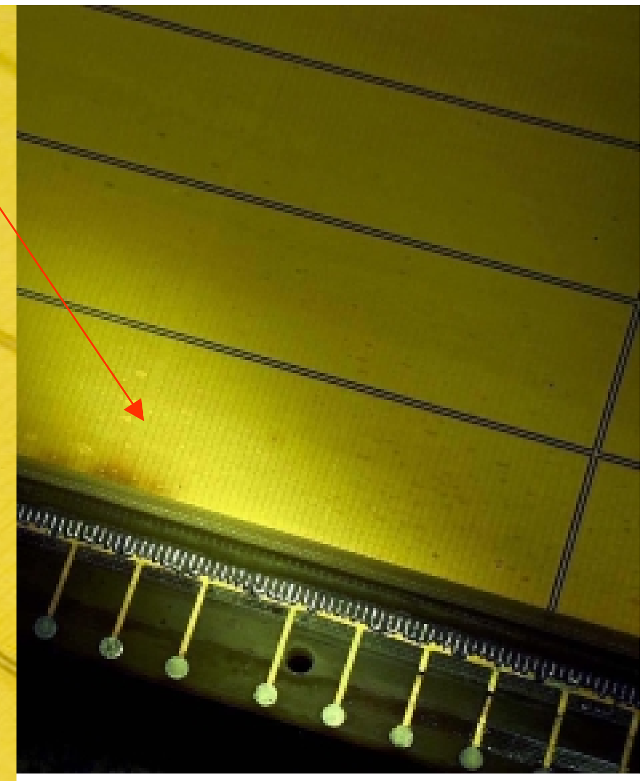
- One wire broke (out of 2400). The reasons are not clear.



Cathode Investigations after the Test

Gap A1: The brownish region near the wire fixation bar is a result of HV instabilities of the wire plane. A similar spot has been observed in gap A2 near the wire fixation bar where the wire was broken.

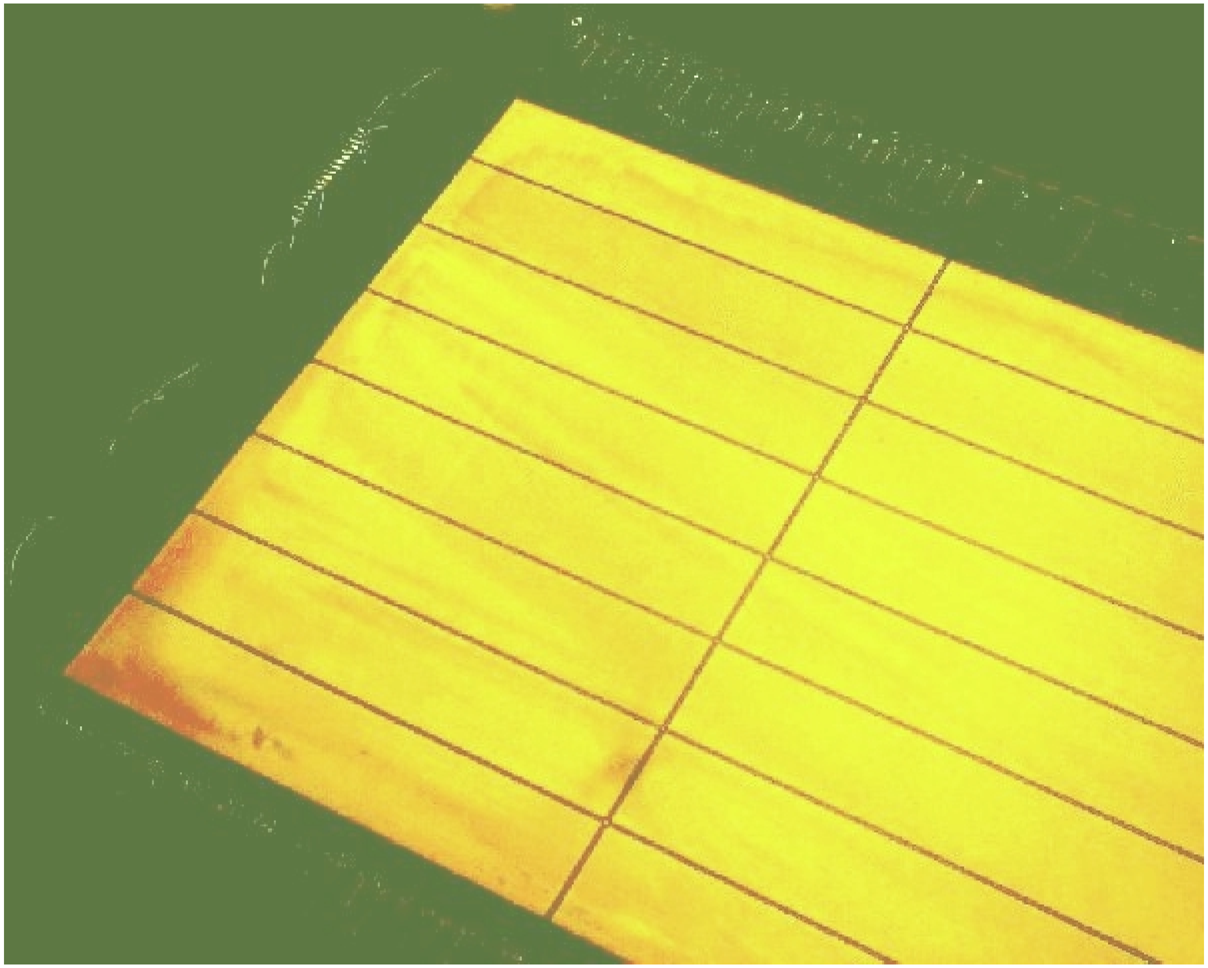




Cathode Investigations after the Test

The cathode deposit is observed on all the cathodes. The cathode of gap A2 is shown. The deposit is at a distance of 5-10 mm from the gap border. The deposit layer has the tracks of cleaning procedure.

The brownish spot on the border between two pads is probably result of sparking.

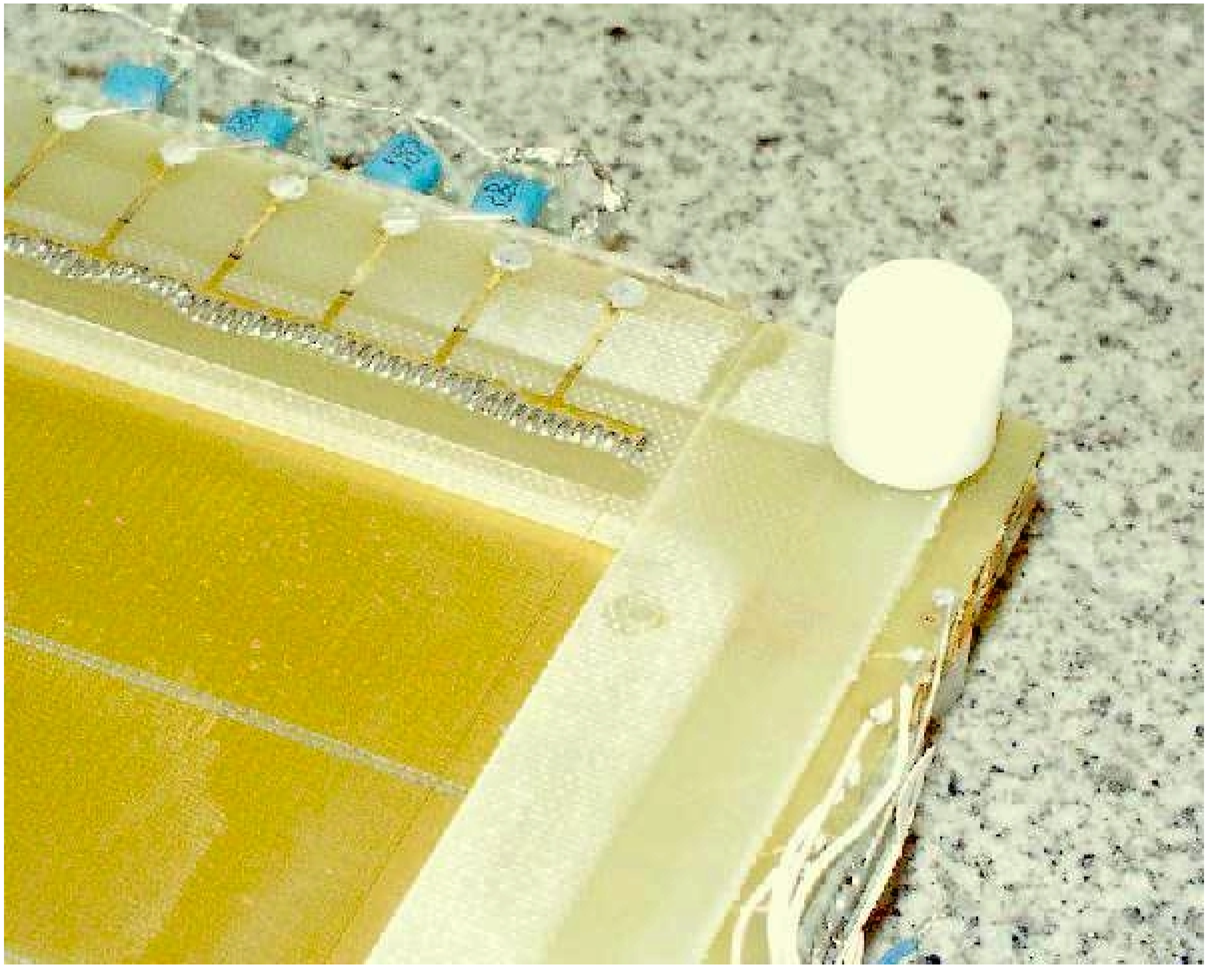


Etching effect of FR4

Corner of the A1gap. The chemical activity of the gas appears as the etching of the FR4 surface. The etched surface shows the basic structure of the material after the thin surface layer disappeared.

The etching is seen outside the gap following the gas leak flow.

The etching is absent in the reference gap.



Conclusion

1.The analysis of the data after an irradiation corresponding to 5 LHCb years does not show any deterioration, which would prohibit the use of these chambers in the LHCb experiment in this time range.

2. Gold plated cathode surfaces provide a good protection against cathode aging.

3. An insufficient cleaning procedure can provoke growing deposits.

4.The interaction of the gas mixture with FR4 needs more investigation. Add water vapor to the gas mixture (?)

5.The breakdown of one wire and the HV instability of the A1 gap is a clear indication that the HV operational conditions should be optimized (HV could be reduced by increasing the Ar content of the gas mixture).