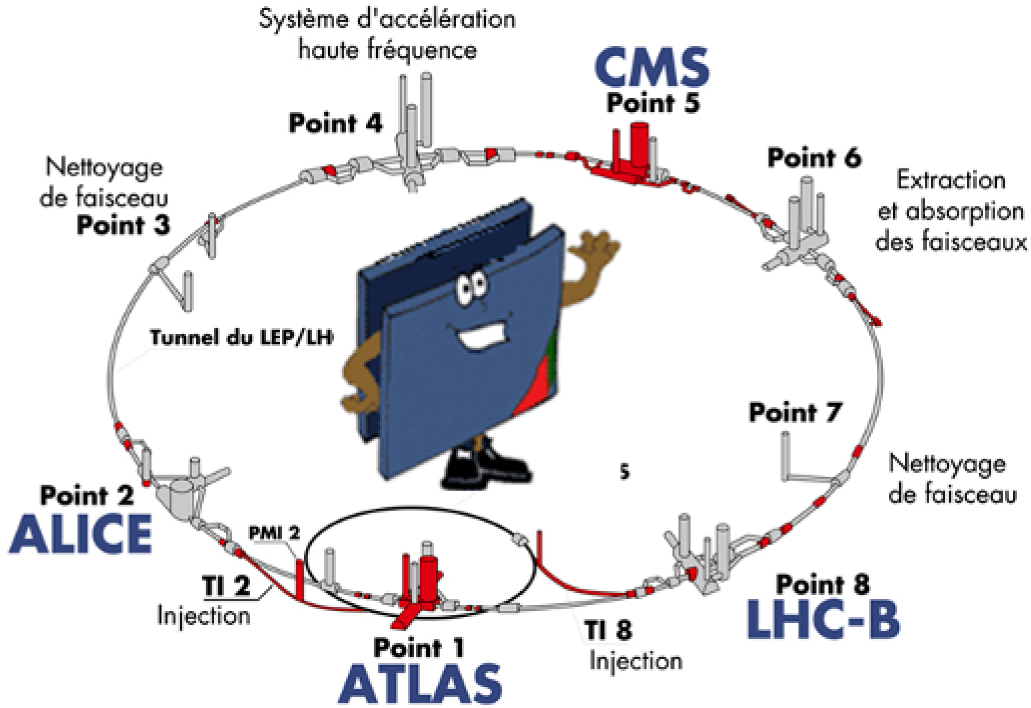
# The Resistive Plate Chamber detectors at the Large Hadron Collider experiments





Roberto Guida
PH-DT-DI

Paolo Vitulo
Univ. Pavia


CERN EDIT school 2011

# Some history

1949: Keuffel → first Parallel Plate Chamber

1955: Conversi used the "PPC idea" in the construction of the flash chambers

1980: Pestov → Planar Spark chambers – one electrode is resistive – the discharge is localised

1982: Santonico → development of the Resistive Plate Chamber – both electrode are resistive

RPC applications:

'85: Nadir (n-n\bar oscillation) – 120 $m^2$ (Triga Mark II – Pavia)
'90: Fenice (J/Ψ → n-n\bar) – 300 $m^2$ (Adone – Frascati)
'90: WA92 – 72 $m^2$ (CERN SPS)
'90: E771– 60 $m^2$; E831 – 60 $m^2$ (Fermilab)

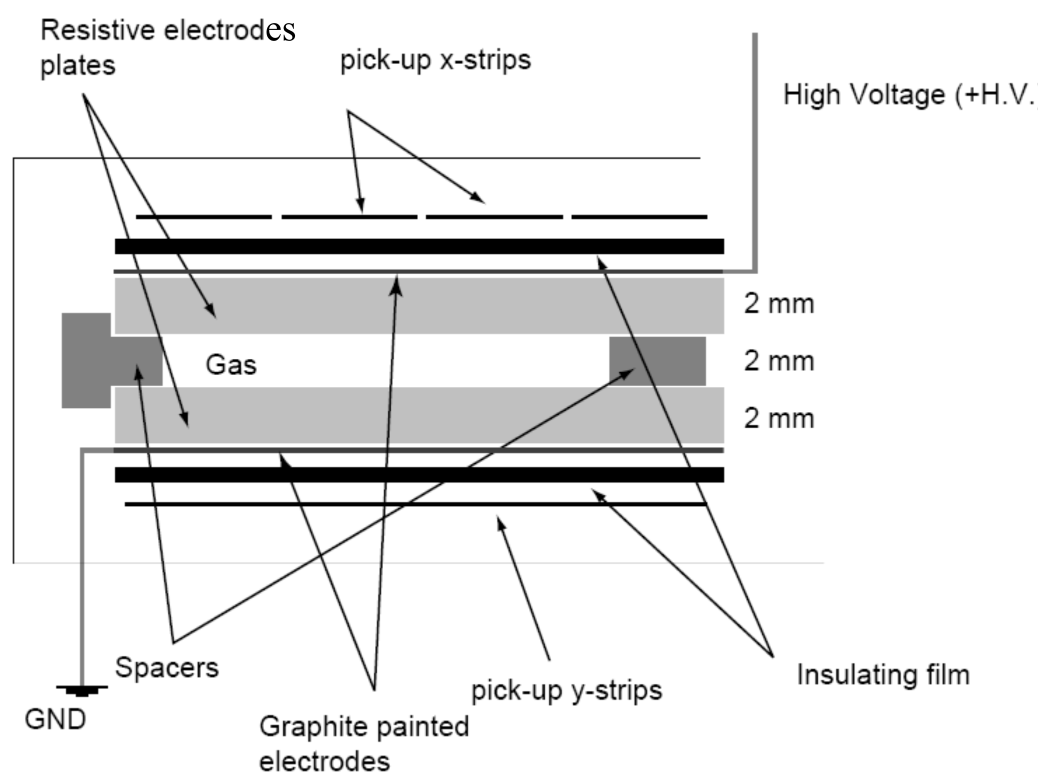
**1992: development of RPC detector suitable to work with high particle rate → towards application at LHC**

1994-1996: L3 – 300 $m^2$ (CERN-LEP)
1996-2002: BaBar – 2000 $m^2$ (SLAC)

# Identikit of RPC detectors for LHC

<u>Basic parameter for a detector design:</u>

- Gap width
- Single gap/double gap/multi gap design
- Gas mixture
- Gas flow distribution
- Bakelite bulk resistivity
- Linseed oil electrode coating



# The RPC detector

- Gap width 2 mm:

Good compromise between good efficiency, time resolution and rate capability

- More gaps:

Increase time resolution and efficiency

- Double gap design:

Best ratio induced/drift charge, therefore best signal/charge ratio

- Freon based mixture:

Higher efficiency (at the same gas gain) and lower streamer probability

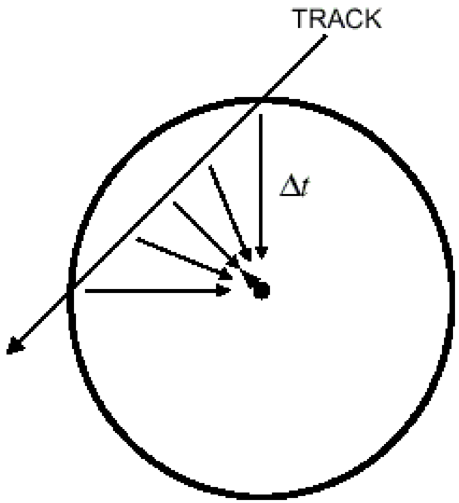
- Bakelite bulk resistivity = 1-6 $10^{10}$ $\Omega$ cm:

Good compromise between high rate capability and low current and noise

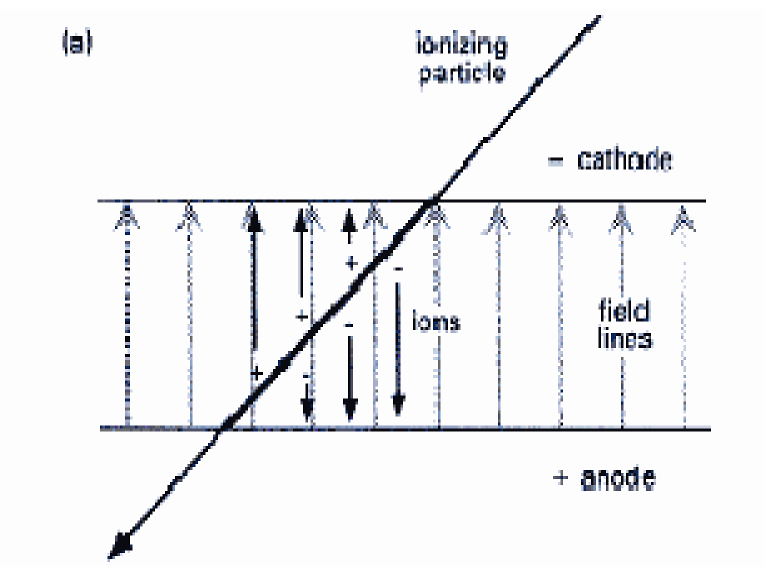
- Linseed oil treatment:

Lower current and noise rate. No ageing effect observed

# Why the RPC?




Drift chambers (cylindrical geometry) have an important limitation:
Primary electrons have to drift close to the wire before the charge multiplication starts
→limit in the time resolution ~ 0.1μs
→Not suitable for trigger at LHC




+ In a parallel plate geometry the charge multiplication starts immediately (all the gas volume is active).
+ much better time resolution (~ 1 ns)
+ less expensive (~ 100 €/$m^2$)

However:

-Smaller active volume
-Electrical discharge may start more easily
-Relatively expensive gas mixture
-Quite sensitive to environmental conditions (T and RH)

# **Lab. activity:** Switch on the RPCs

- HV scan
- Pulse height
- Pulse charge

# Towards a new operation regime

<u>Originally RPC were operated in *Streamer mode*:</u>

- Ar-based mixture
- Higher signal (100 pC) but also high current in the detector
- Voltage drop at high particle rate → loss of efficiency

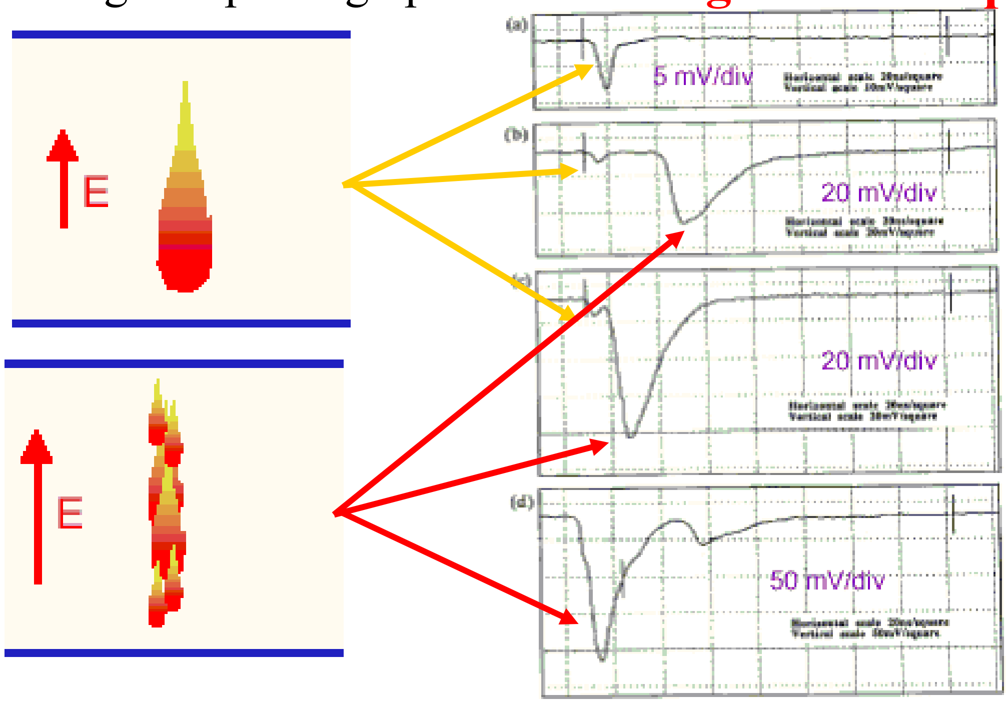
→ **poor rate capability (< 100 Hz/cm$^2$)**

<u>Operation with high particle rate possible in *Avalanche mode*:</u>

- Freon-based mixture
- lower signal (~ pC) but also lower current in the detector
- Less important high voltage drop at high particle rate → **good rate capability (~ 1 kHz/cm$^2$)**

Avalanche signal

Streamer signal




R. Santonico et al.
ATLAS Muon TDR

# RPCs for LHC experiments

Why RPCs for application in LHC experiments need a particular "care"?

- Huge (~5000 $m^2$ of sensitive area) and very expensive ($6\ 10^6$ CHF) systems (for comparison BaBar was about 2000 $m^2$)

- Very long period of operation expected (at least 10 years)

- Very high level of background radiation expected

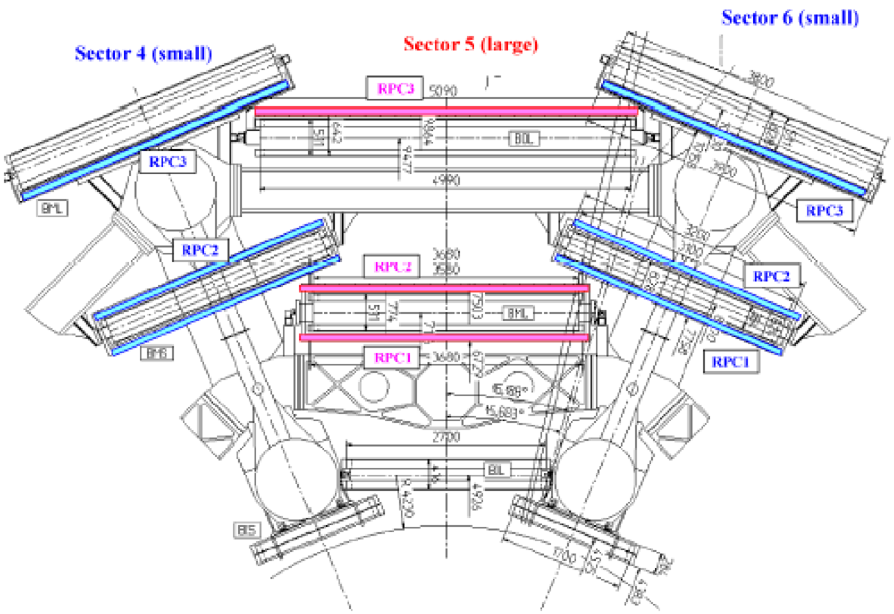
- Integrated charge never reached before:
  - 50 $mC/cm^2$ for ALICE and CMS
  - 500 $mC/cm^2$ in ATLAS

- Large detector volume → basically impossible to operate the gas system in open mode → closed loop operation → gas mixture quality

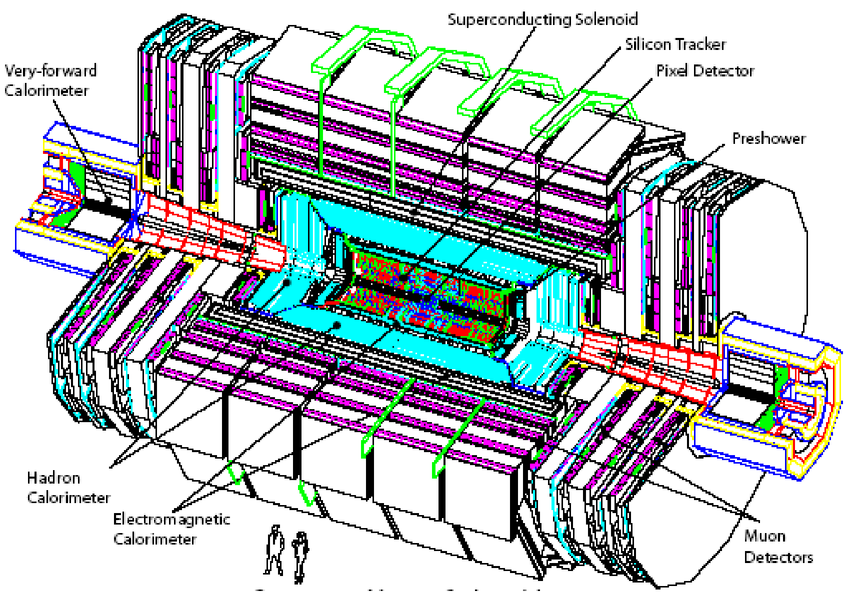
# RPCs for LHC experiments

Where are the RPCs systems at LHC?

ATLAS experiment:




CMS experiment:




- Active surface 4000 $m^2$
- Gas Volume 16 $m^3$
- Expected rate ~ 10 Hz/$cm^2$

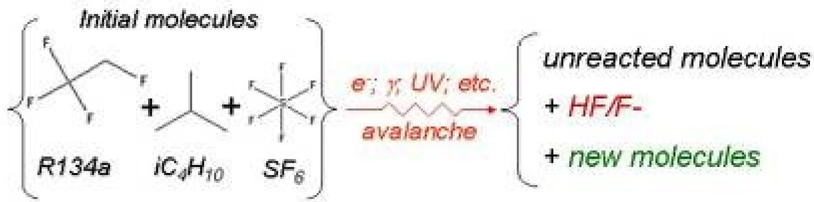
- 94.7% $C_2H_2F_4$; 5% $iC_4H_{10}$; 0.3 % $SF_6$
- 40% Rel.Humidity
- Closed loop operation

# Closed loop gas circulation

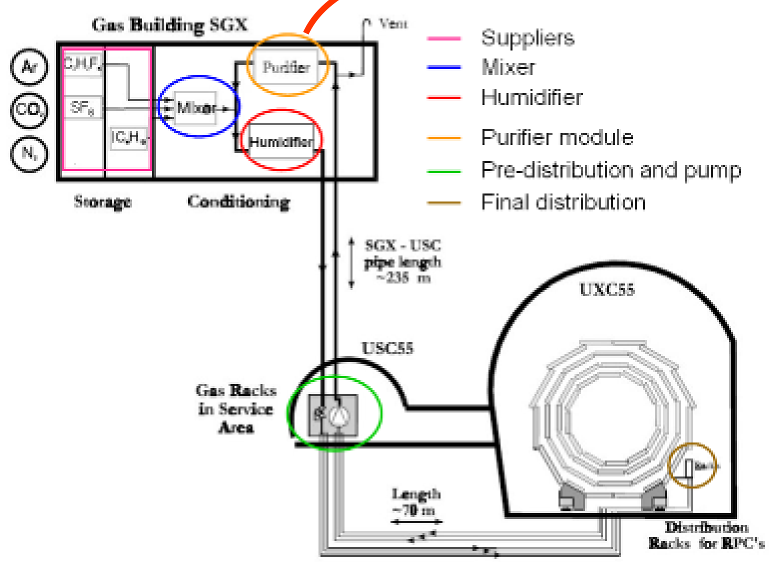
➢Large detector volume (~16 $m^3$ in ATLAS and CMS)
➢use of a relatively expensive gas mixture
→closed-loop circulation system unavoidable.

<u>Nowadays with 5-10 % of fresh gas replenishing rate → cost is ~700 €/day</u>

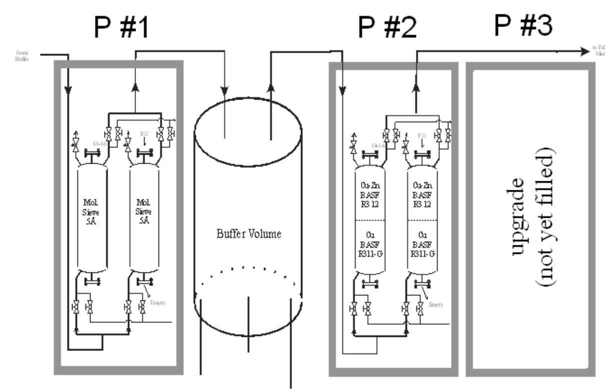
**But….**




❑Several extra-components appear in the return gas of irradiated RPCs
❑Detector performances can be affected if impurities are not properly removed

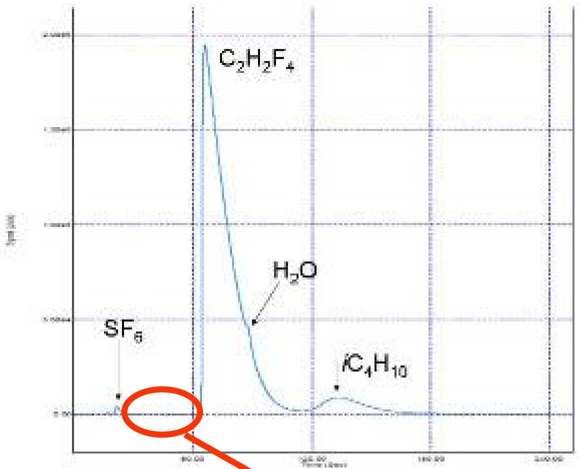



Purifiers:



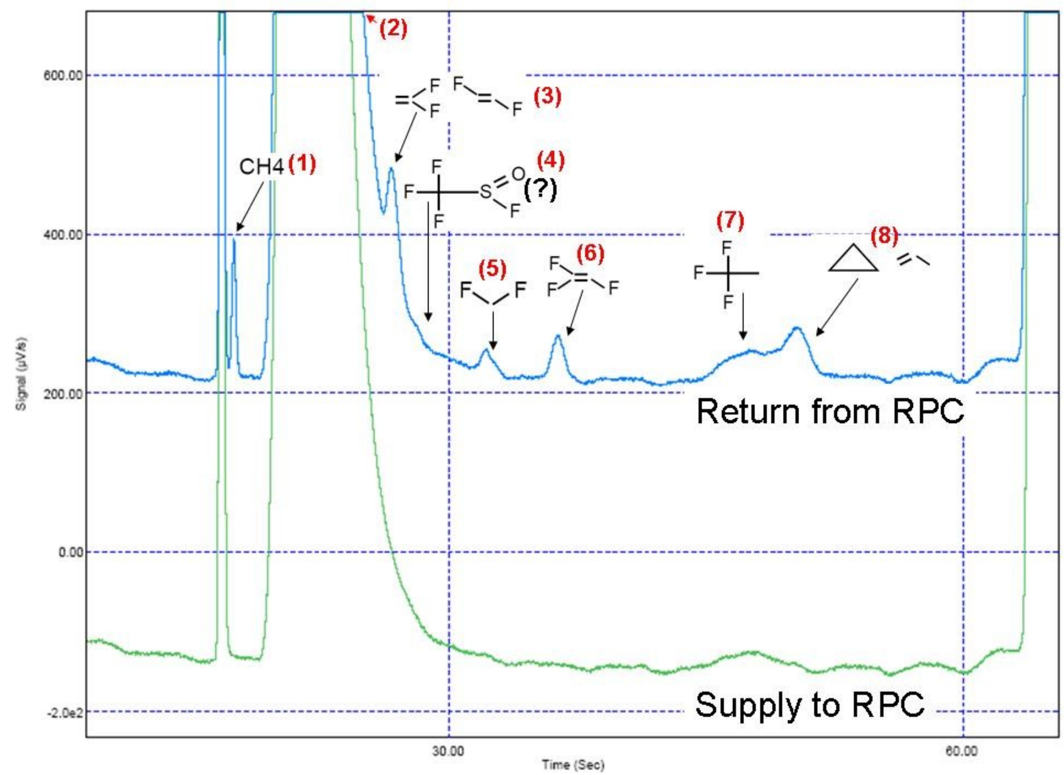

- <u>Purifier #1</u>: Molecular Sieve (10% 5 Å + 90% 3 Å); Expected lifetime 1.5 day
- <u>Purifier #2</u>: Cu-Zn/Cu and Ni-$Al_2O_3$; Expected lifetime 15 day

# Gas analysis results: chromatography




Many extra components identified in the return mixture from detector

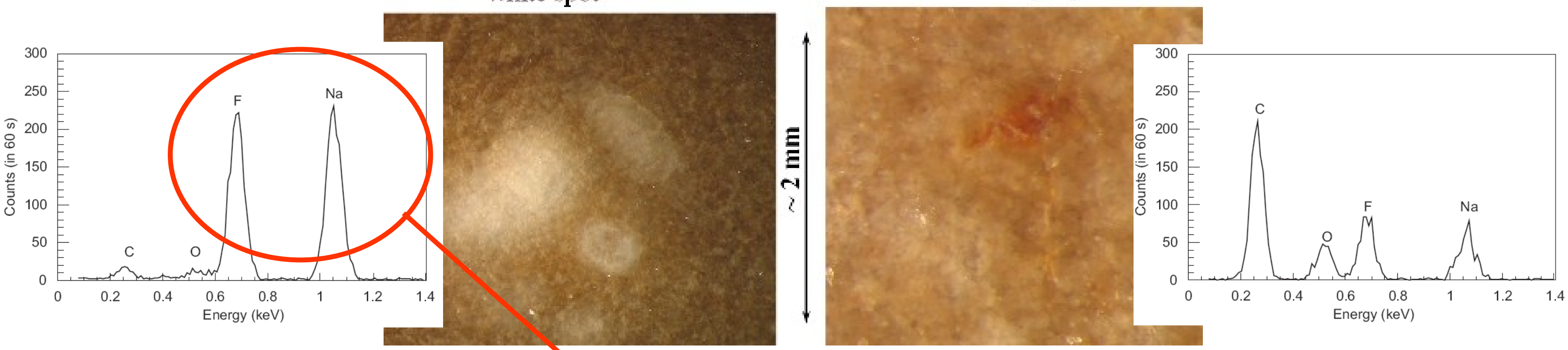
- ➢Operated with open mode gas system
- ➢Under high gamma radiation
- ✓Concentration of the order of ~10 ppm
- ✓Mainly hydrocarbons
- ✓other Freon



# Bakelite SEM results

We analyzed few bakelite samples from an RPC with relatively high current. The visual inspection of the surface shows at least two different kinds of surface defects:

"white spot" "orange spot"




With respect to reference bakelite surface:

❖High fluorine concentration

❖Na signal appeared

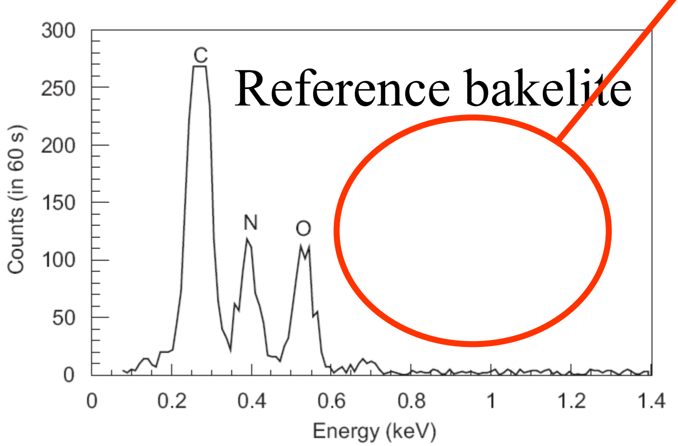
❖N signal disappeared

→

➢Linseed oil and melamine layer etched:

✓Na is used as a catalyser for phenolic resin (bulk)

✓Normal surface layer (made on melamine resin) contain N



# Operation of RPC detectors

- The operation of a large area detector is never simple.

- "Second order" problems may come from anywhere and anytime.

Few example:

- Gas quality is a crucial issue for all gaseous detectors (therefore also for RPC)

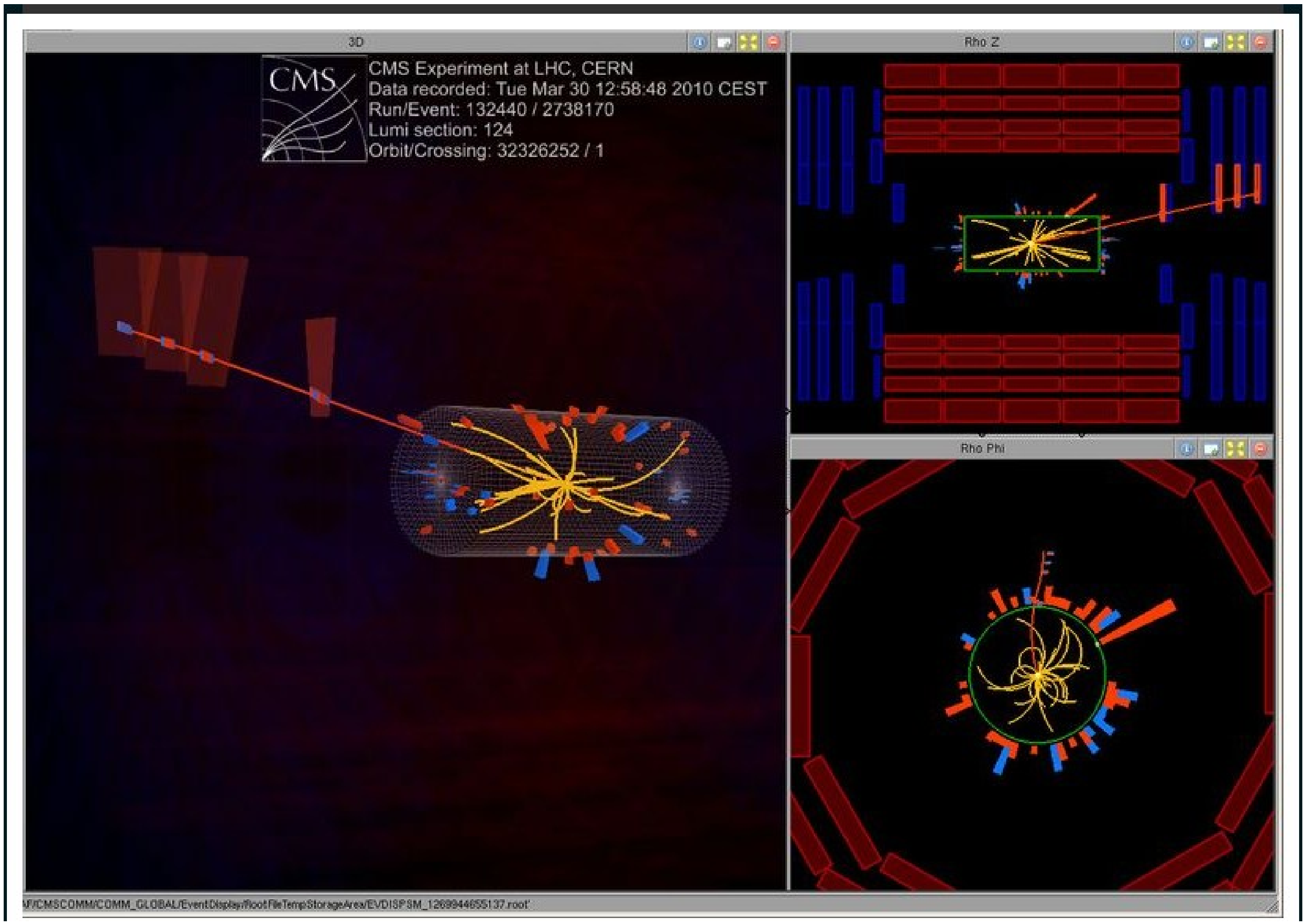
- Environmental conditions (like temperature and relative humidity) are affecting the detector performances (complex network of sensors is needed in order to understand behaviours)

- Gas leaks in the detector (unfortunately is a weak point)

*In the following, for time reason, I will discuss only an example concerning the gas quality*

# **Lab. activity:** Switch on the RPCs

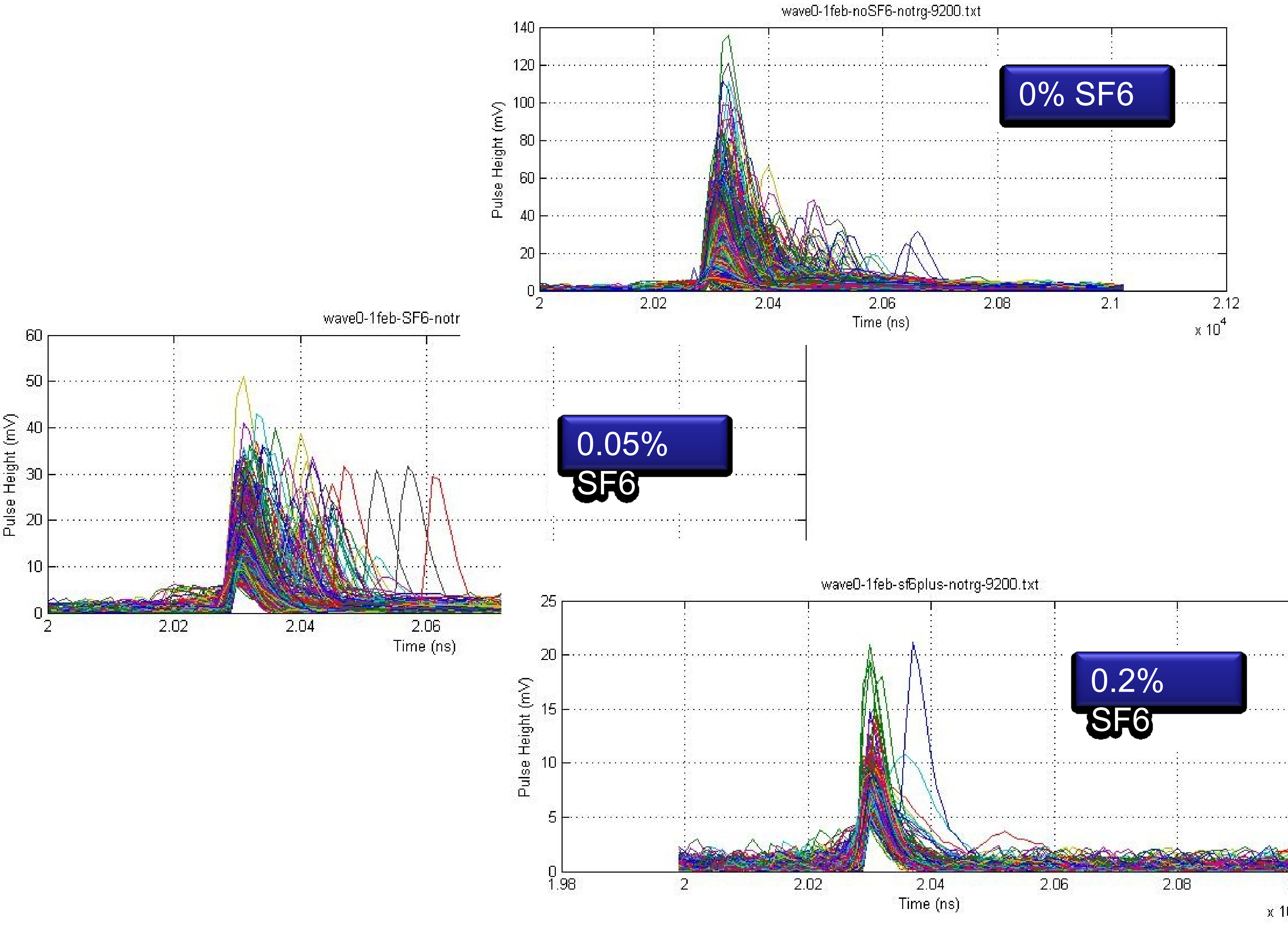
A CMS event with muon track reconstructed



# **Lab. activity:** Pulse charge spectra

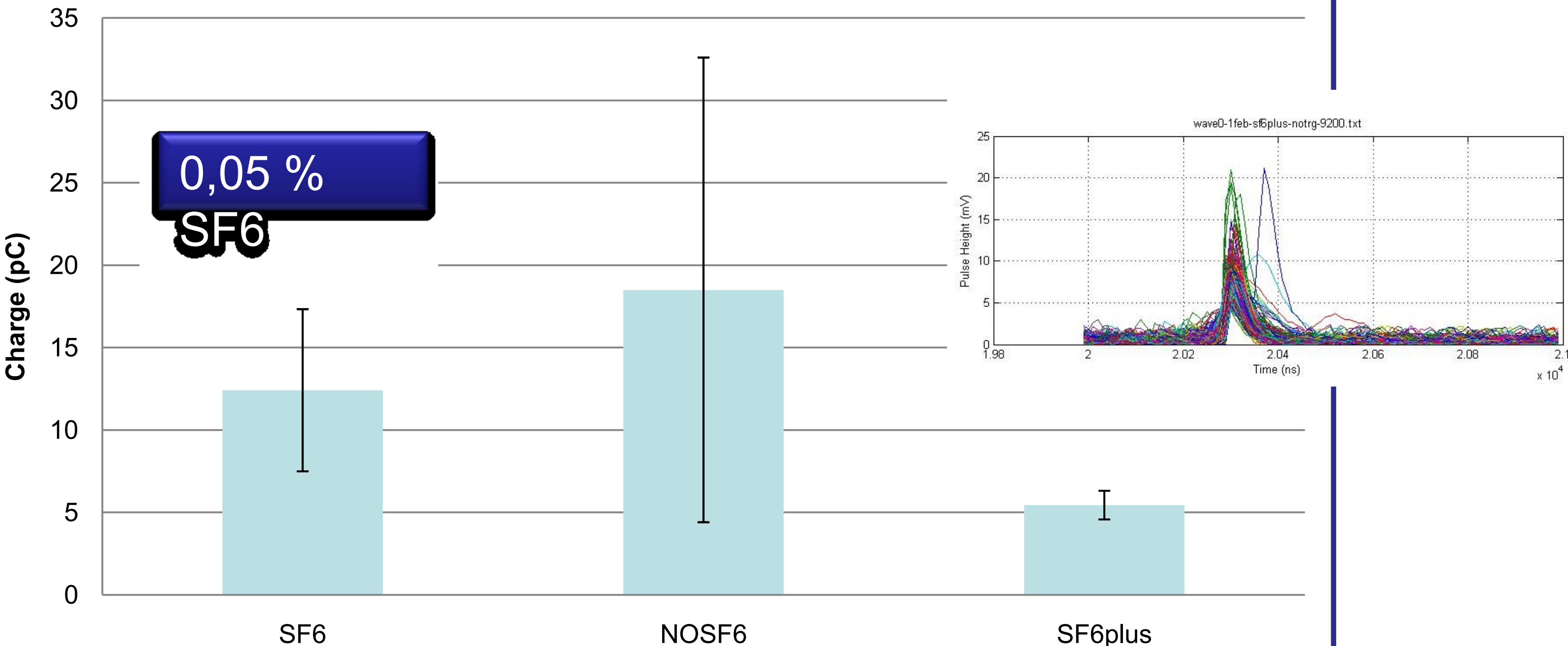
**Avalanche vs. Streamer**

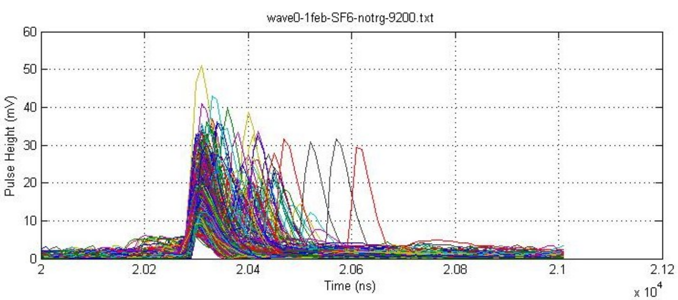
- Signals
- Time behavior
- Charge
- Noise charge spectra


wave0-1feb-noSF6-notrg-9200.txt
0% SF6
Pulse Height (mV)
Time (ns)
x 10^4
wave0-1feb-SF6-notr
0.05% SF6
Pulse Height (mV)
Time (ns)
wave0-1feb-sf6plus-notrg-9200.txt
0.2% SF6
Pulse Height (mV)
Time (ns)

# RPC average performance with and wo SF6

0,05 % SF6




0% SF6

0,2 % SF6