# Results on Long Term Performances and Laboratory Tests on the L3 RPC system at LEP

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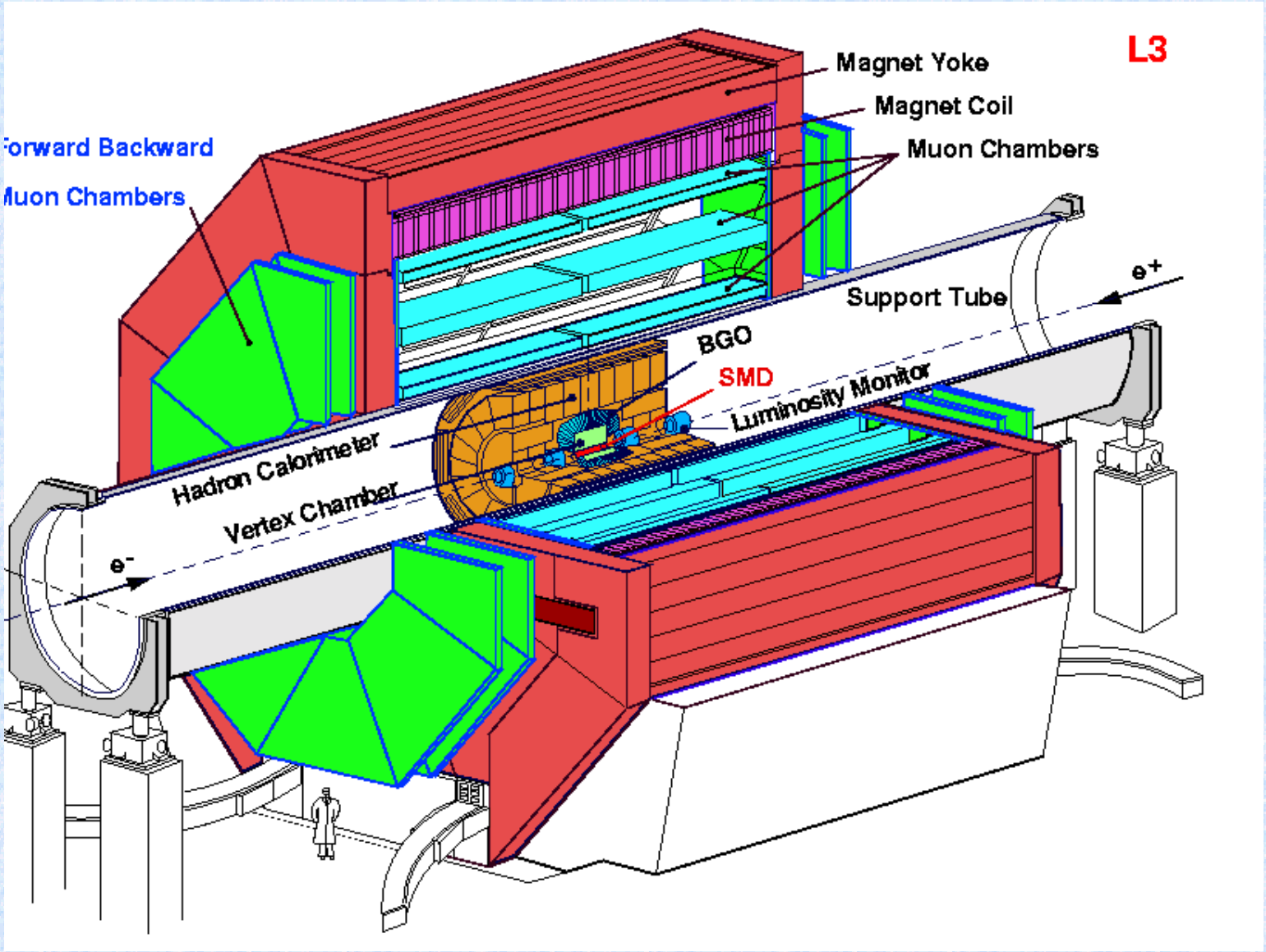
# Outline

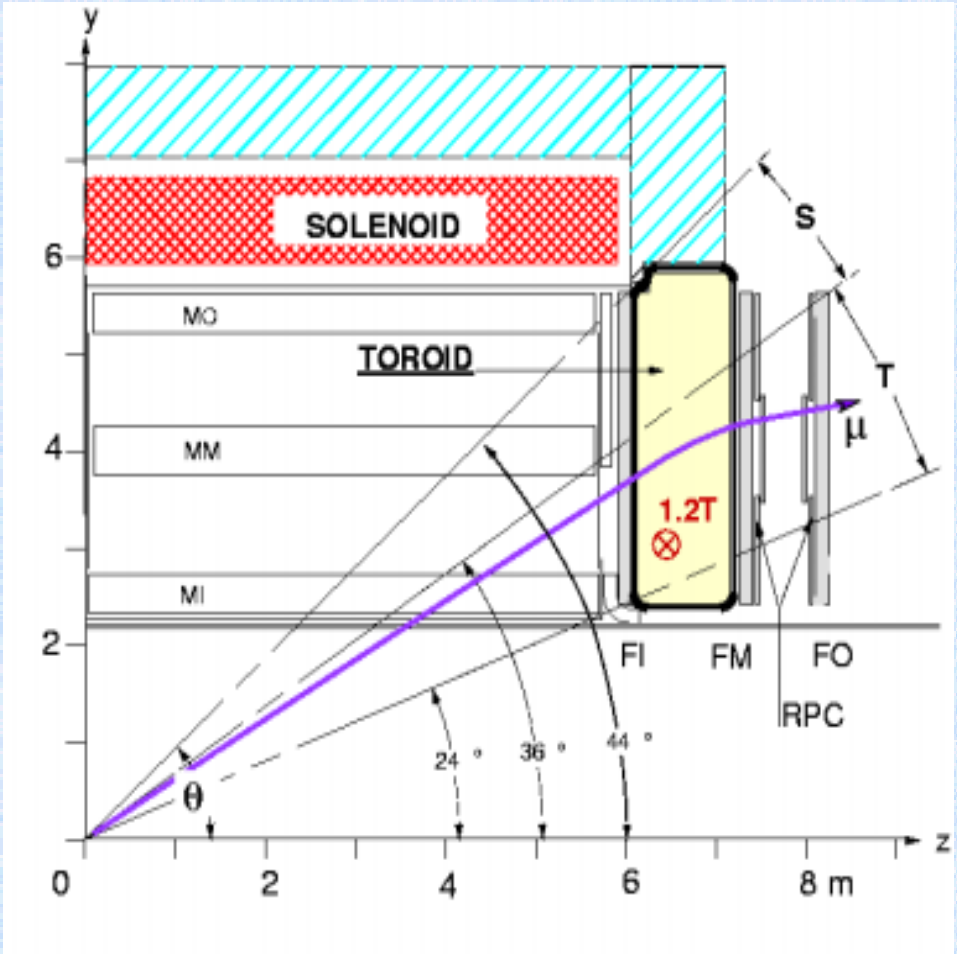
- The L3 F/B muon spectrometer and the RPC trigger system
- The  RPC detector
- The RPC performances in L3
- The RPC test in Napoli
- Conclusions

# The L3 Detector



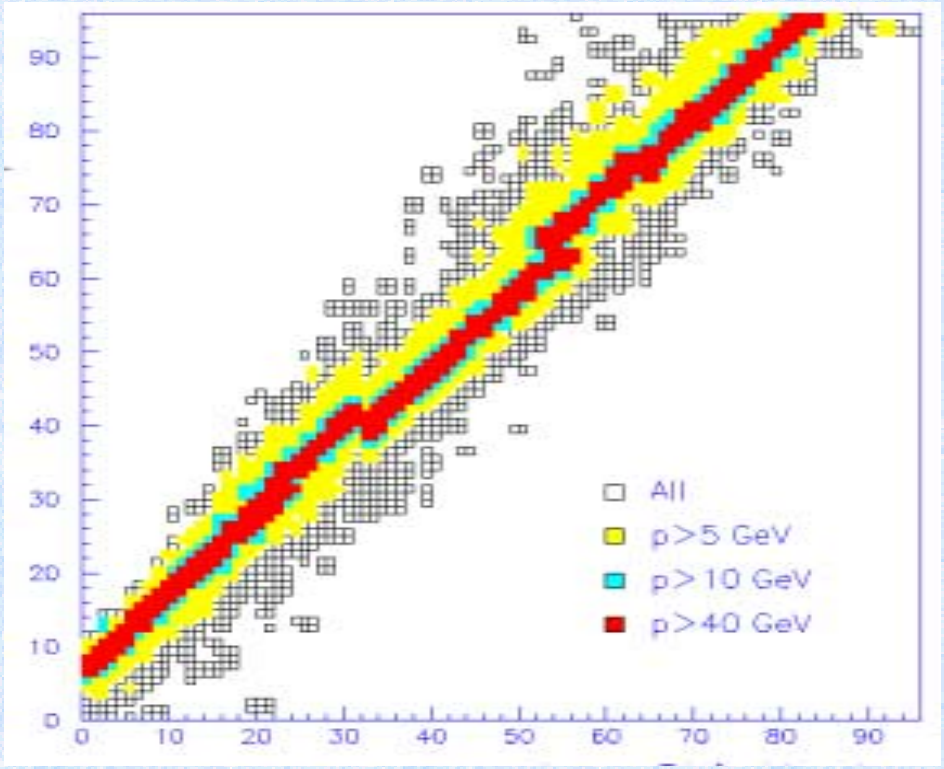
# The F/B Muon Spectrometer

*Muon momentum determination at small angles*




- The Muon Trigger of the F/B spectrometer is given by the RPC system
- Each side of the spectrometer is made of 8 octants subdivided in 2 modules
- Each module has 2 RPC layers, (composed of 3 RPC chambers) placed in between the external (FM/FO) drift chambers layers
- 96 strips per RPC layer
- Total of 192 bi-gap (300 $m^2$) RPC, 6144 strip channels (space) and 768 TDC channels (time)

# The RPC Trigger

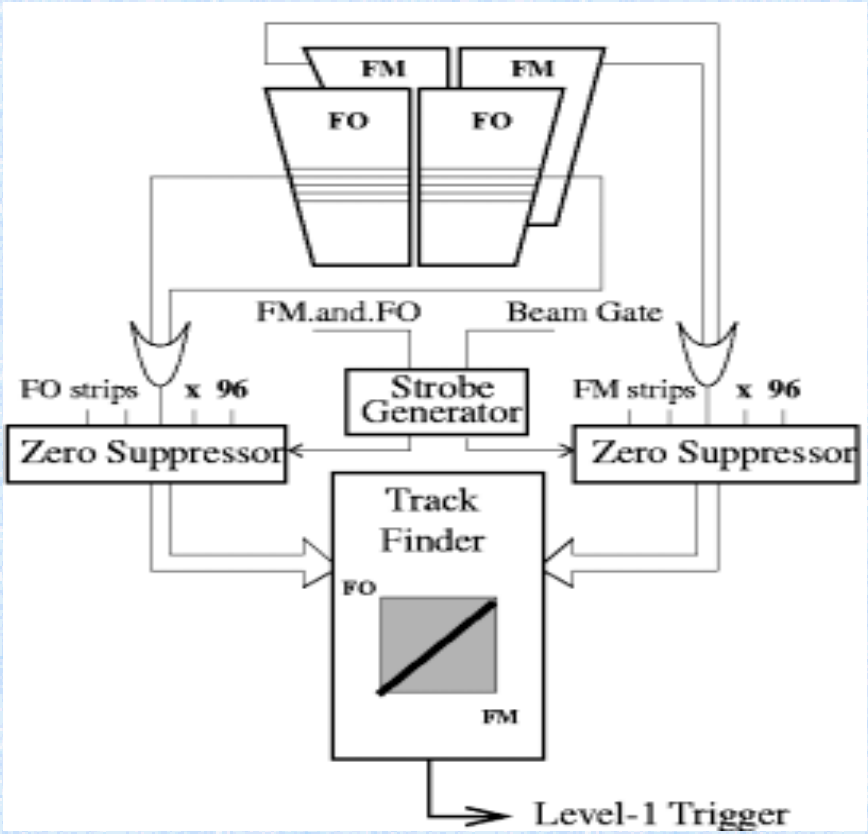



- The 96 x 96 strips of the two RPC layers define a Trigger Matrix
- Muons coming from the interaction vertex populate a region (road) whose width depends on the their momenta

• The roads are programmed into the trigger electronic modules (Track Finder)

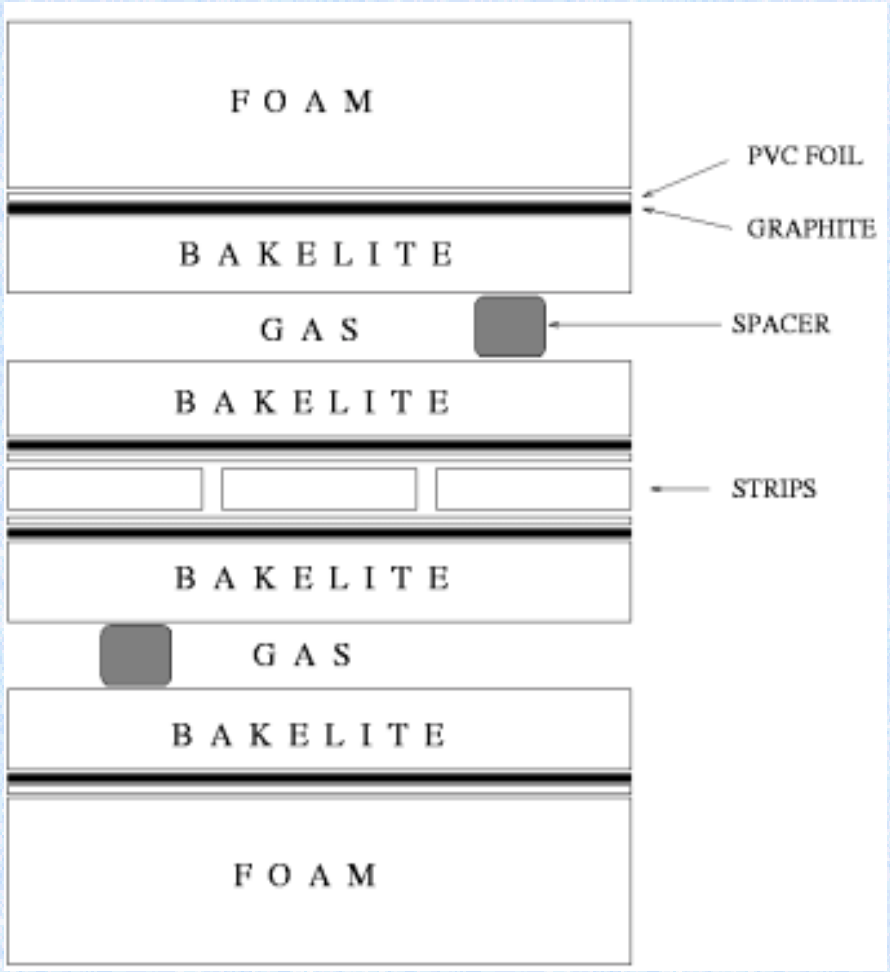
*Typical total trigger time 1.5 μs*

*Average F/B Trigger Rate O(1) Hz*



# Bi-gap RPC description

Cross Section of a Bi-gap RPC
(not in scale)



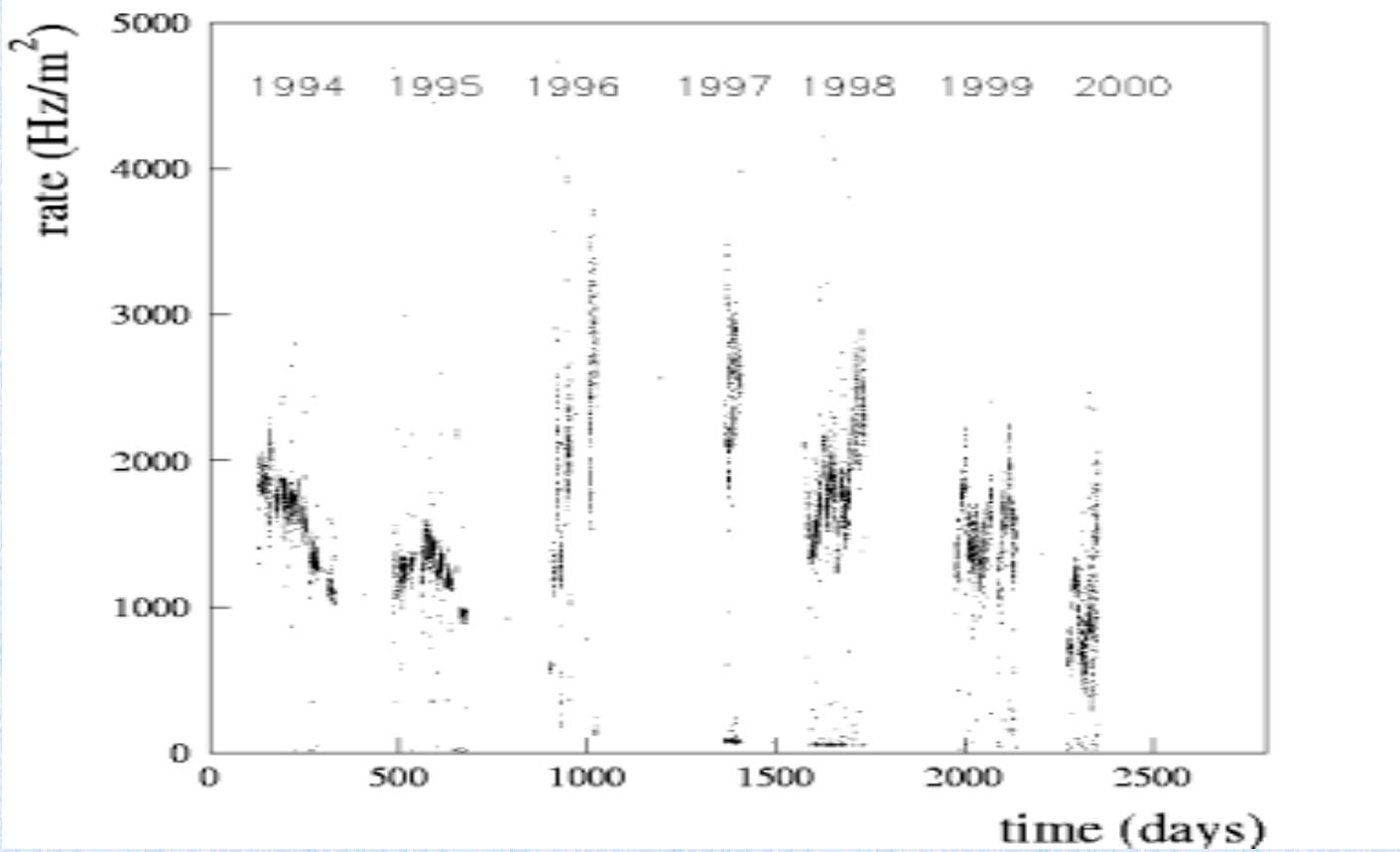

- The L3 RPC consists of two gas gaps with independent HV and a single pick-up plane operating in streamer mode
- The electrodes are the 2 mm thick bakelite layers ($\rho = 2.10^{11}\ \Omega$ cm) painted with graphite on the external surface and varnished with linseed oil (with the technique used until '98) on the internal one.
- Gas gap thickness is 2 mm with a grid of spacers for planarity
- Gas mixture:
  - (94-95): Ar (58%), Iso (38%), Freon (4%)
  - (96-00): Ar (59%), Iso (35%), Tetrafluorethane (6%)

# RPC Performances in the years

- 1994 – 2000. Analysis of L3 Physics Data
  - Data: Dimuon tracks ($Z \rightarrow \mu^+\mu^-$) or single muon tracks off Z resonance
  - Measurements: Detector Efficiency, Trigger Efficiency, Multiplicity, Time and Space Resolutions
  - Monitoring: Single rates and drawn currents
- 2001 (September). Analysis of the tests performed in a dedicated test station in Napoli laboratory
  - Data: Cosmic Rays
  - Measurements: Detector Efficiency
  - Monitoring: Single rates and currents

Preliminary

# RPC Singles Rates

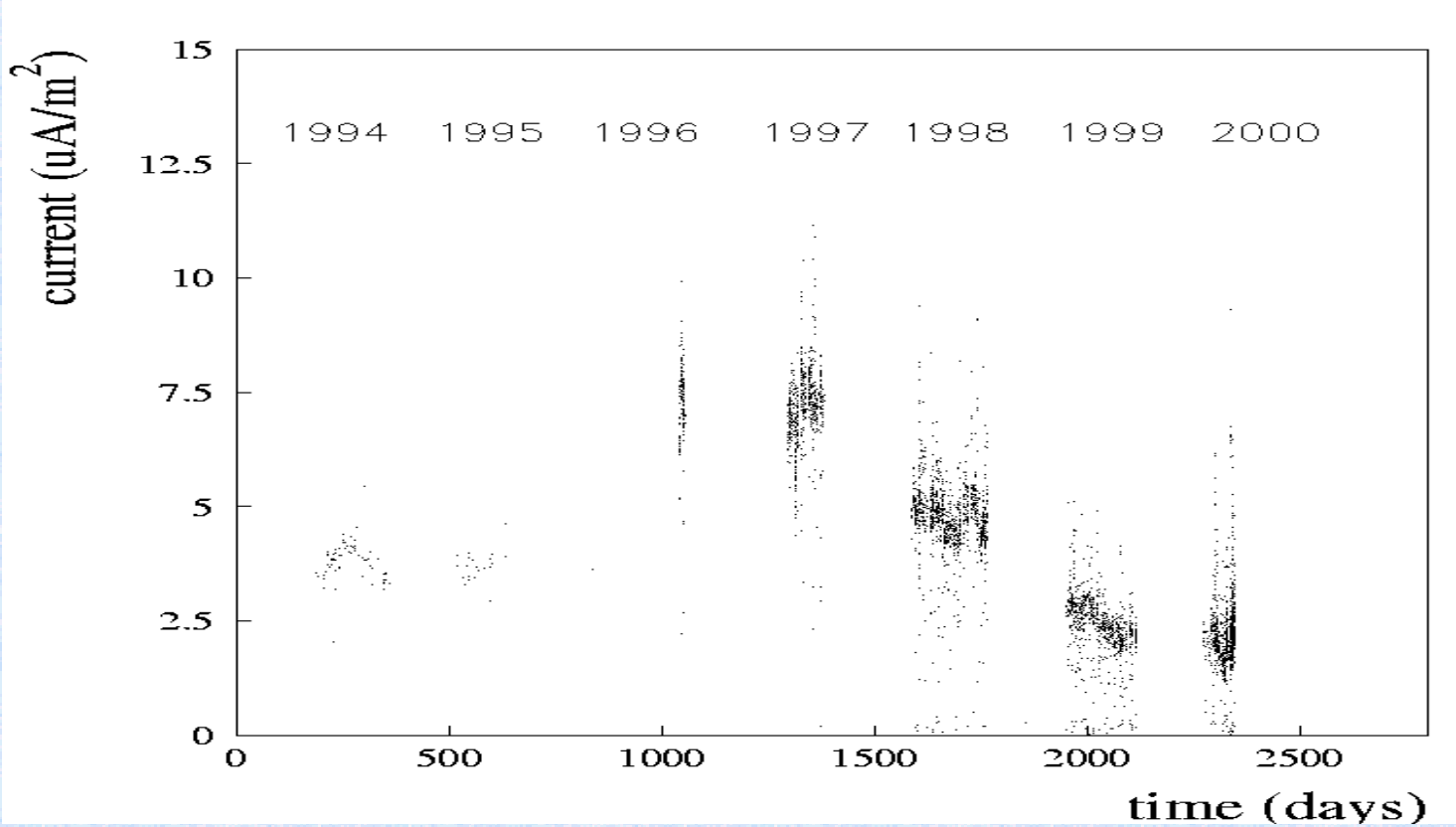



Constant reduction of the rate in the years

Variation between ’95 and ’96 due to the gas change

Mean rate on 300 m$^2$ bi-gap ≅ 2kHz/m$^2$

# RPC Currents



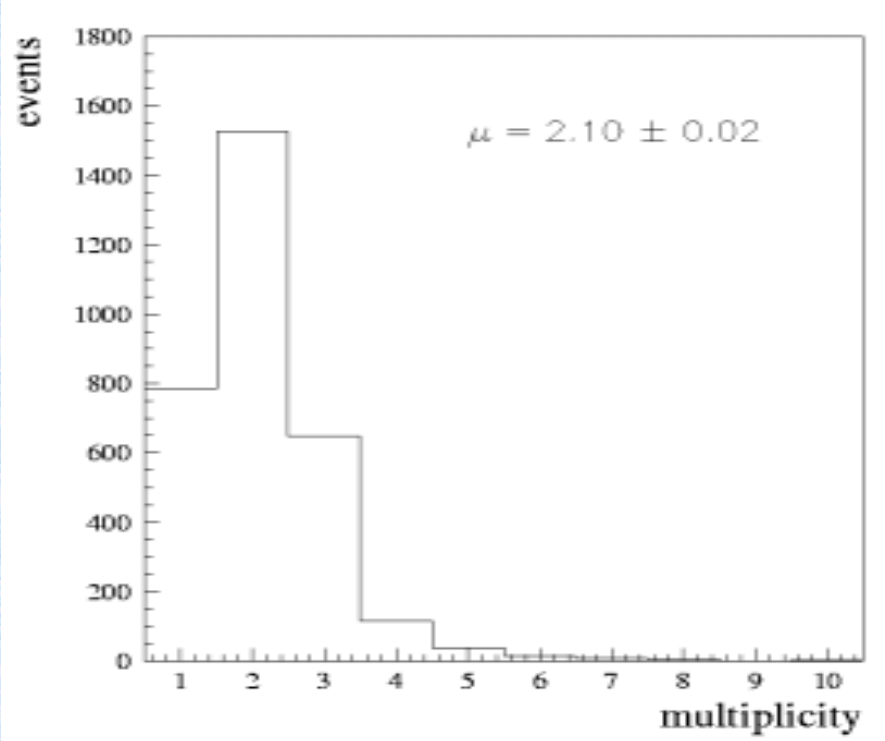

Currents are monitored on 32 HV channel

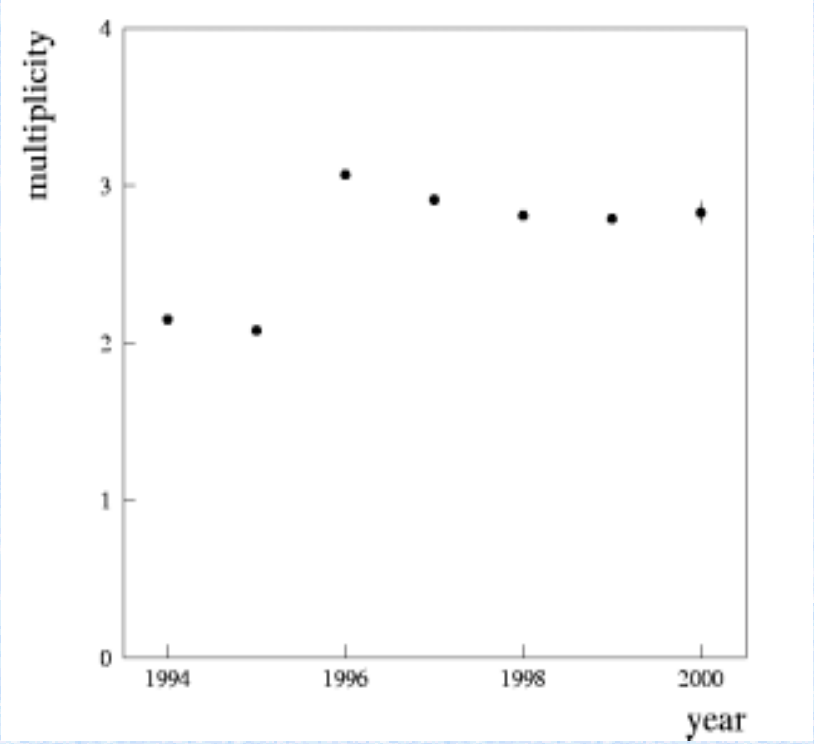
Same trend as single rates

Mean current on 300 $m^2$ bi-gap $\cong$ 5 $\mu A/m^2$

# RPC Clusters Multiplicity

Cluster defined as a set of contiguous strips
The number of strips is the Cluster Multiplicity

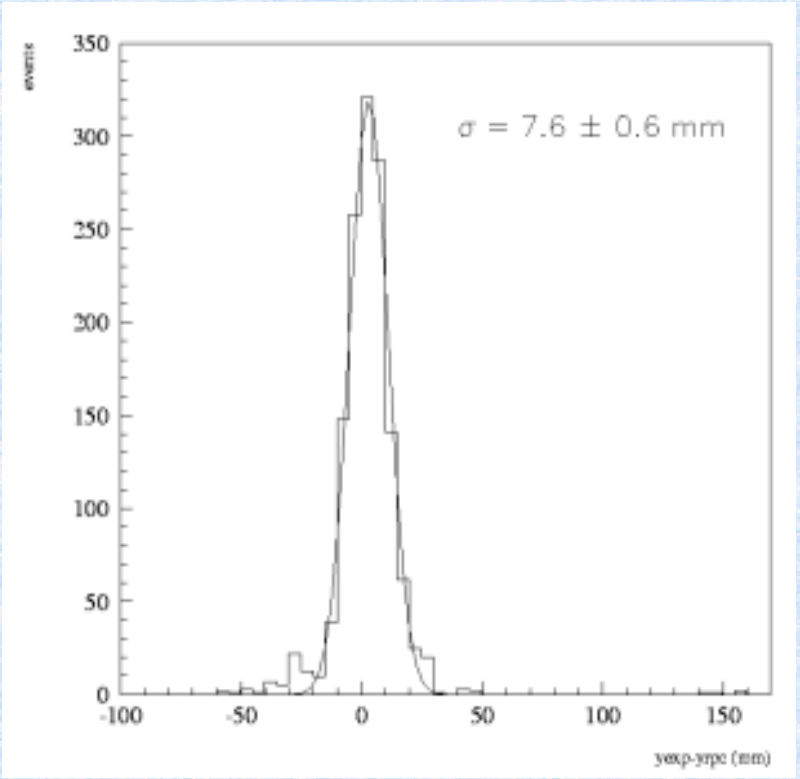


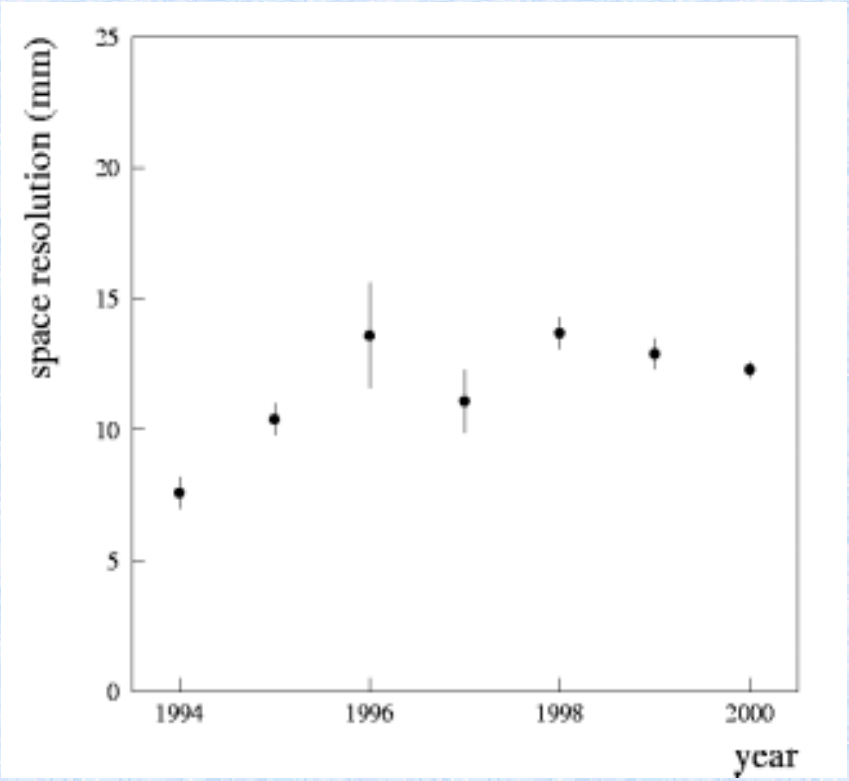




- Large slope of muon tracks
- Discharge in 2 gas volumes

- Broad charge distribution
- Signal induced on more strips

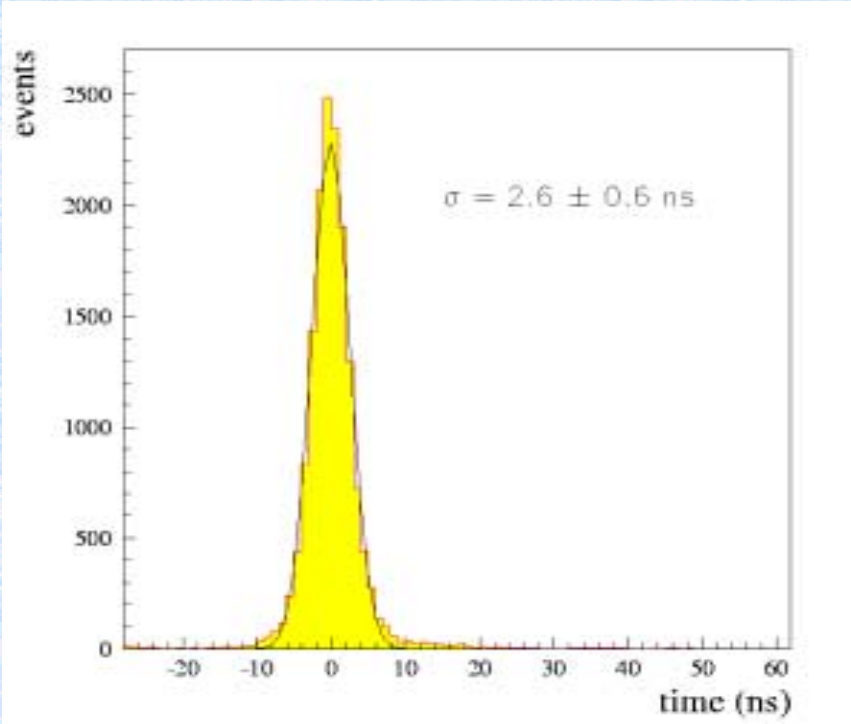
# RPC Space Resolution

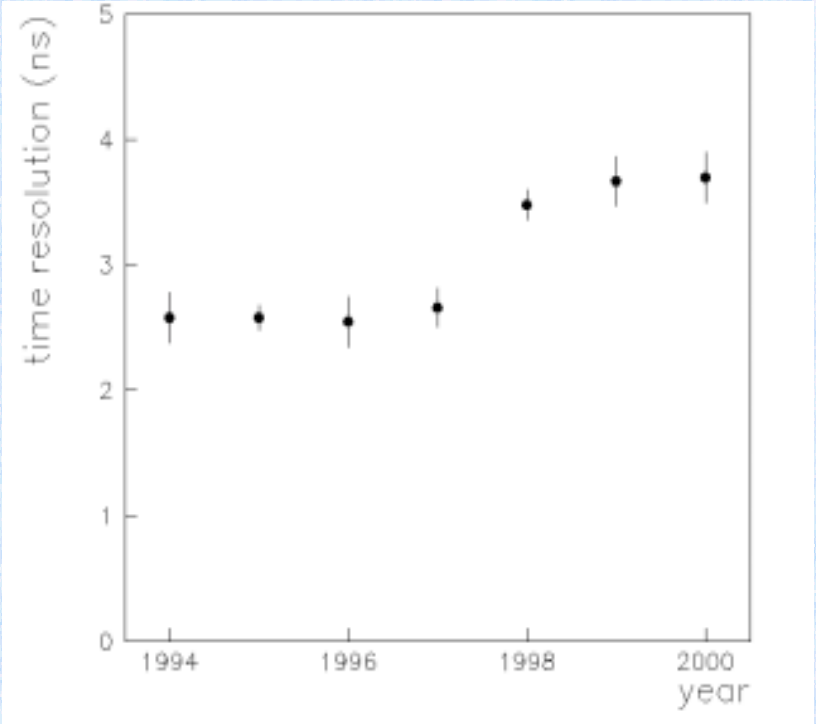



- RPC used for position measurement. Space Resolution ≅10 mm
- Space Resolution given by the comparison of the muon track impact point on the RPC and the center of gravity of the RPC cluster

# RPC Time Resolution

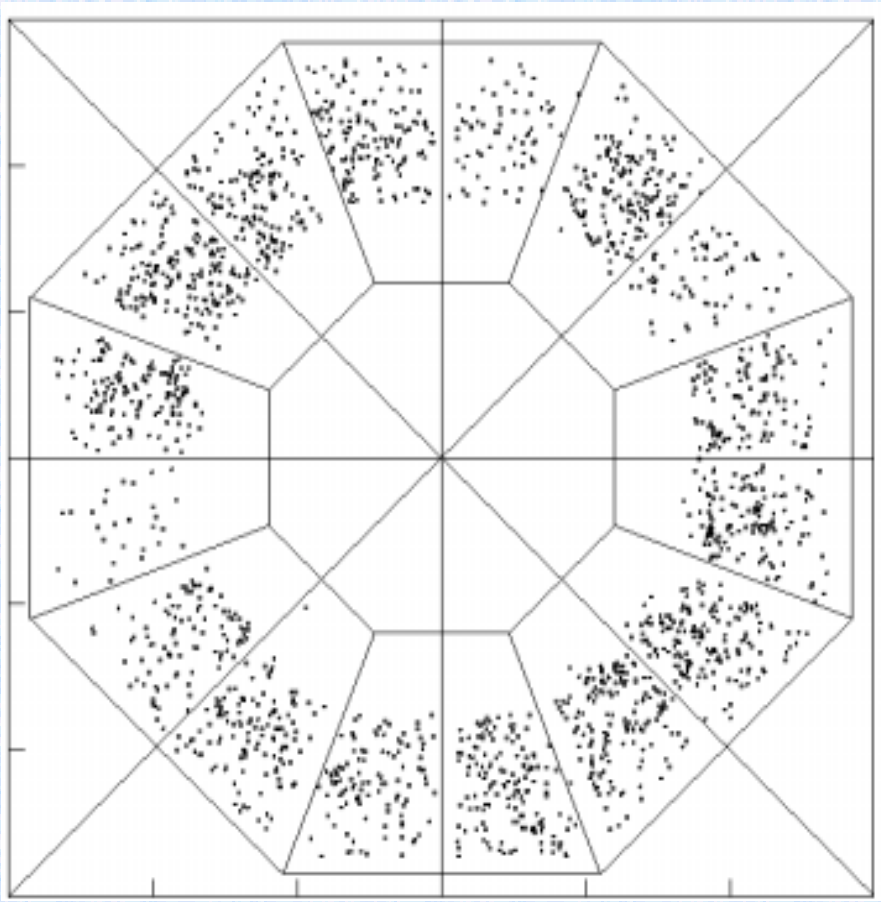



- RPC used for time measurements. Time Resolution ≅ 3 ns
- RPC Time Resolution determined after correction for:
  - Time of flights of the muons
  - Propagation time of the signal along the strips
  - Different cable lengths and electronic response (T0 cal)

# Bi-gap RPC detector efficiency (1)

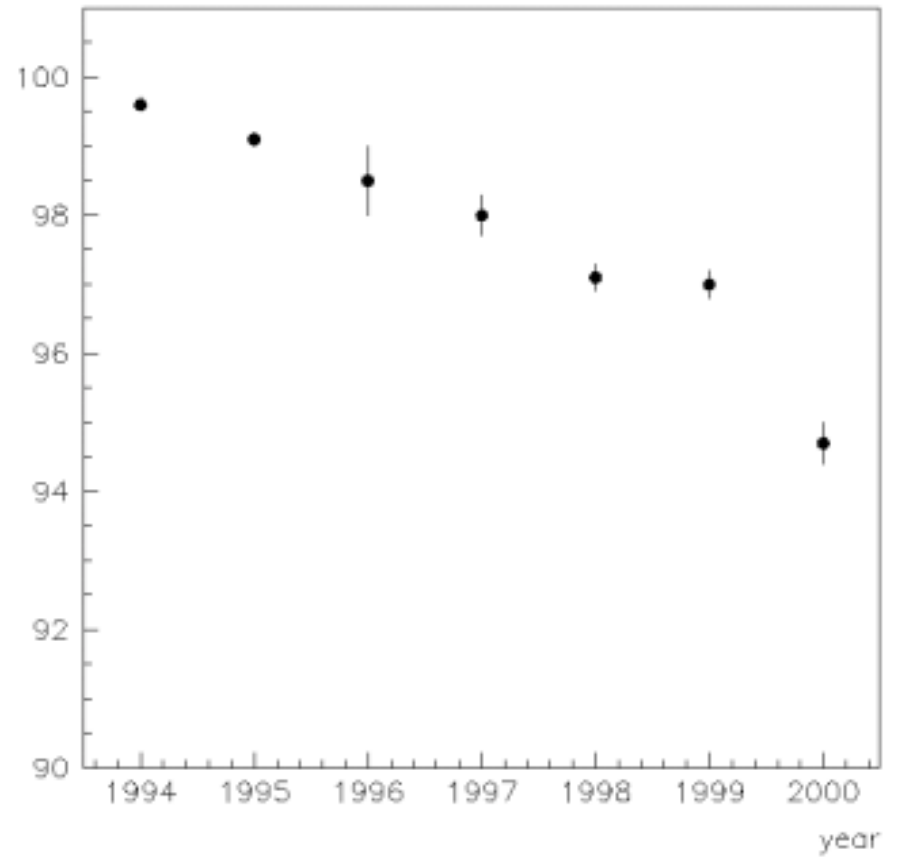
- Detector Efficiency determined by the presence of a strip cluster for each muon track impact point on the RPC
- We measure the global RPC efficiency over all the detector and the RPC efficiencies per octant and per chamber



Example of muon tracks impact point on the FO plane of the spectrometer

# Bi-Gap RPC Detector Efficiency (2)

Global efficiency distribution



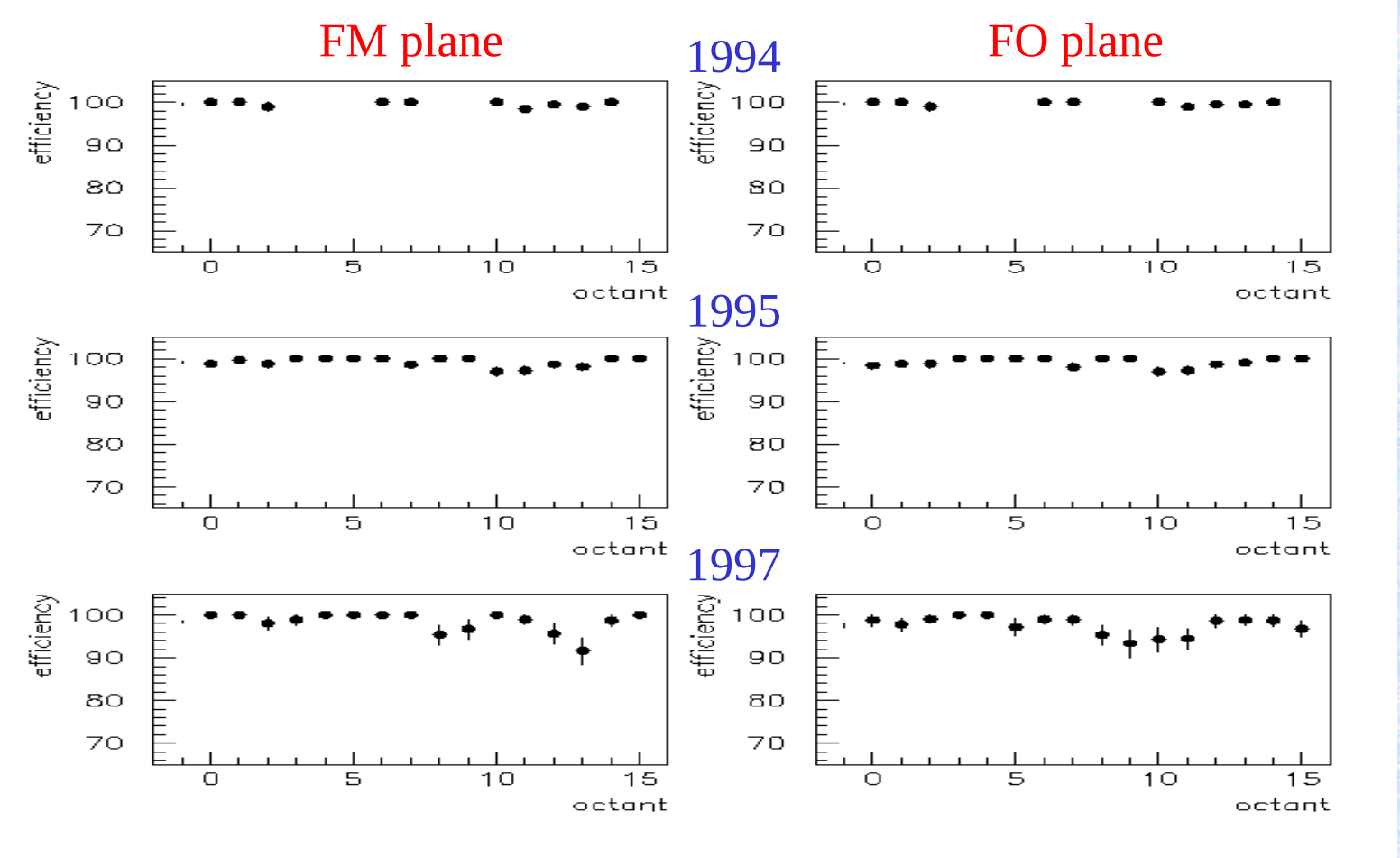

Loss in Efficiency due to:

- Gas Leak (partially fixed during shut-downs)
- Electronic Failures (beam lost on the detector, fixed during controlled access)
- Change of the Gas (reduction of the HV working point in some chambers due to high currents).

We must investigate in more details

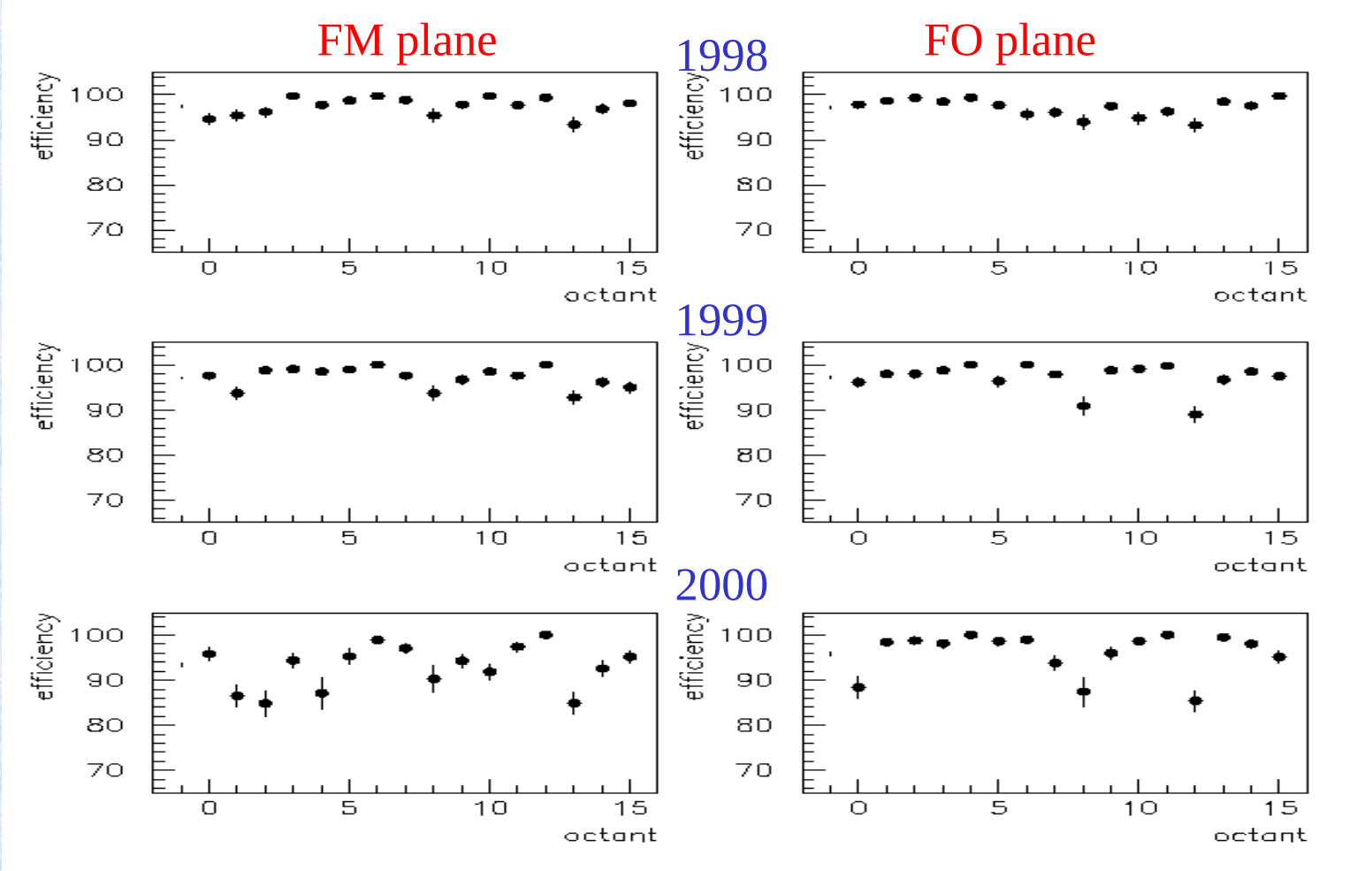
# Bi-gap RPC detector efficiency (3)

## Octant efficiency distribution



# Bi-gap RPC detector efficiency (4)

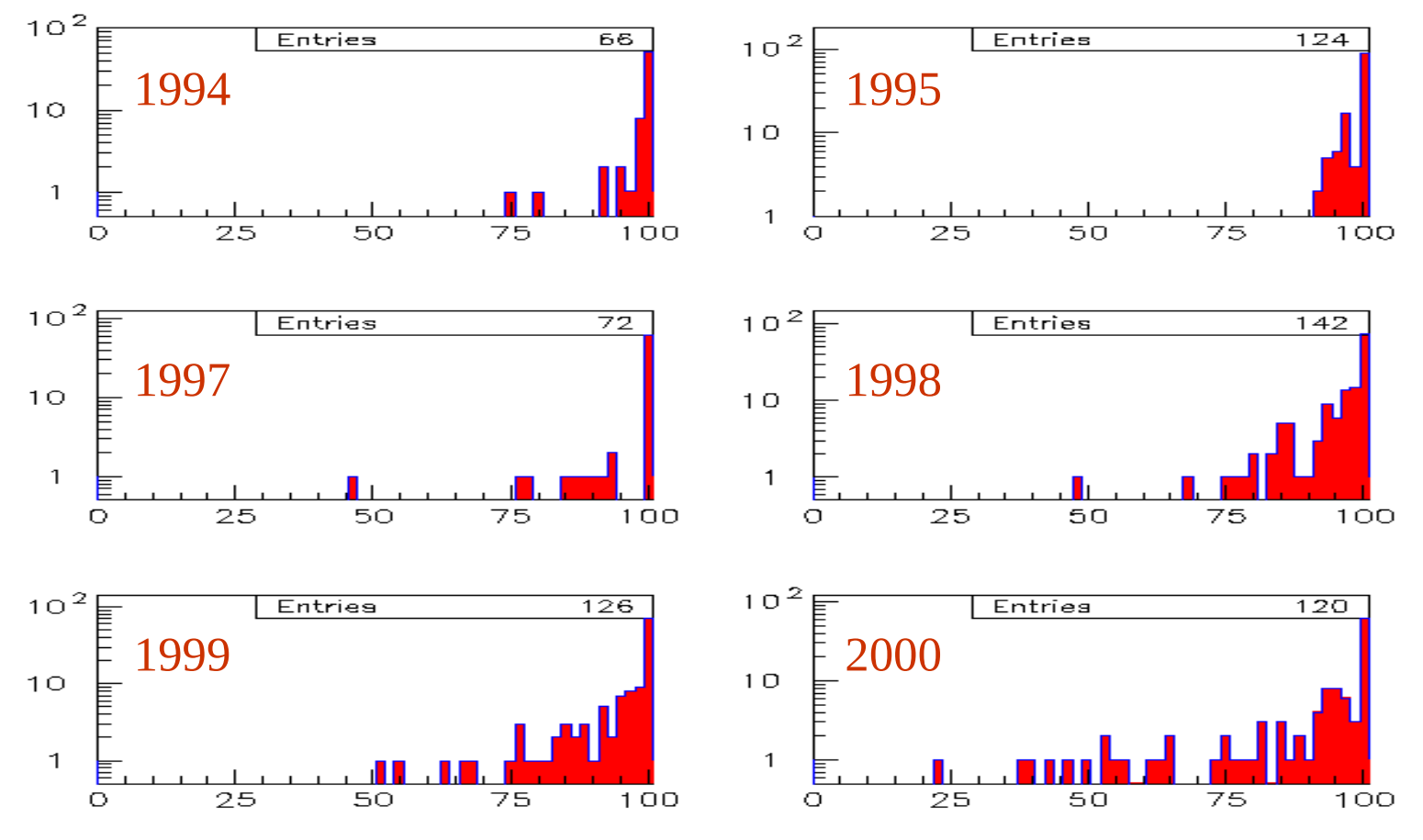
## Octant efficiency distribution (cont'd)



# Bi-Gap RPC Detector Efficiency (5)

## RPC chambers efficiency distribution

See Log Scale




75 % of the RPC with efficiency > 90% in 2000

Small number of muon tracks. Needs measurement with cosmic rays

# RPC Test in Napoli (1)

After L3 dismantling 10 RPC (20 gaps) have been shipped to Napoli and tested

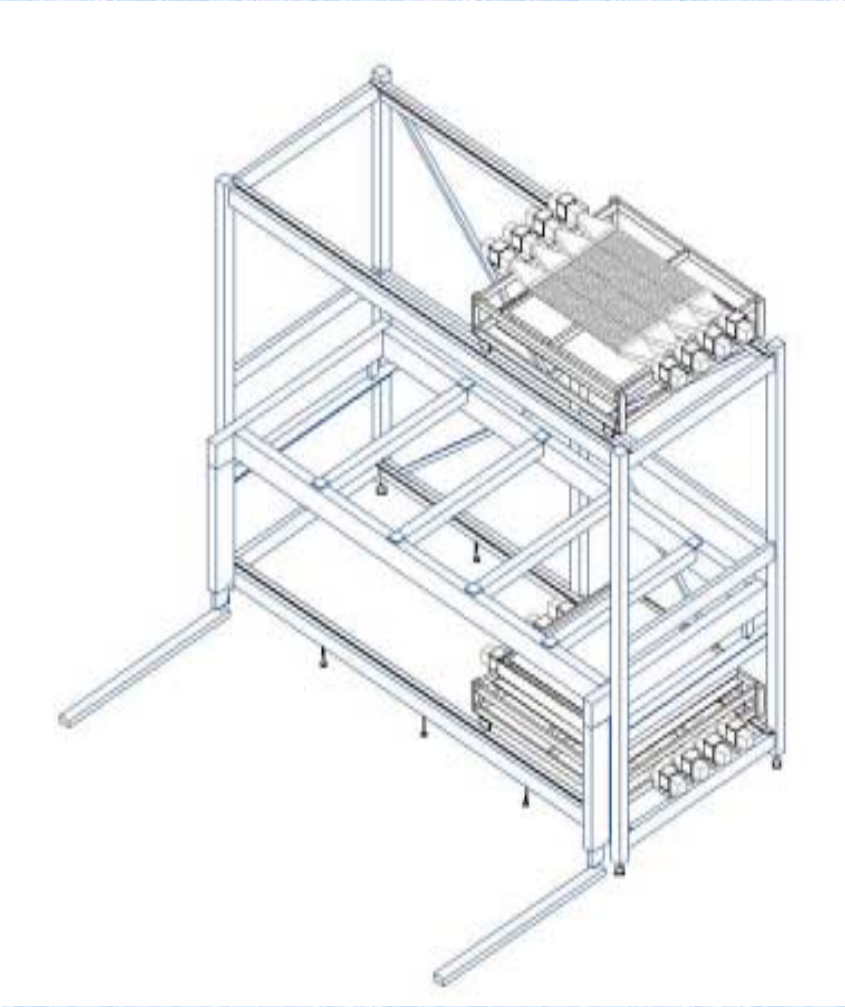
Peculiarity of the test with cosmic rays using the test station in Napoli

- Very high statistics samples

  ⟹ Efficiency measurements O(0.1%) precision
- Single Gap Efficiency measurements
- Tracking system with high resolution for scan of the RPC surface for local inefficiency (radiography)
- Plateau and HV working point determination

# RPC Test in Napoli (2)

# The Test Station (1)



The Test Station is composed of:

- Tracking System
  - 4 + 4 layers of Drift Chambers for 2D measurements with resolution of about 1 mm
- Trigger System
  - 4 + 4 Plastic Scintillators
- DAQ and off-line reconstruction and analysis system

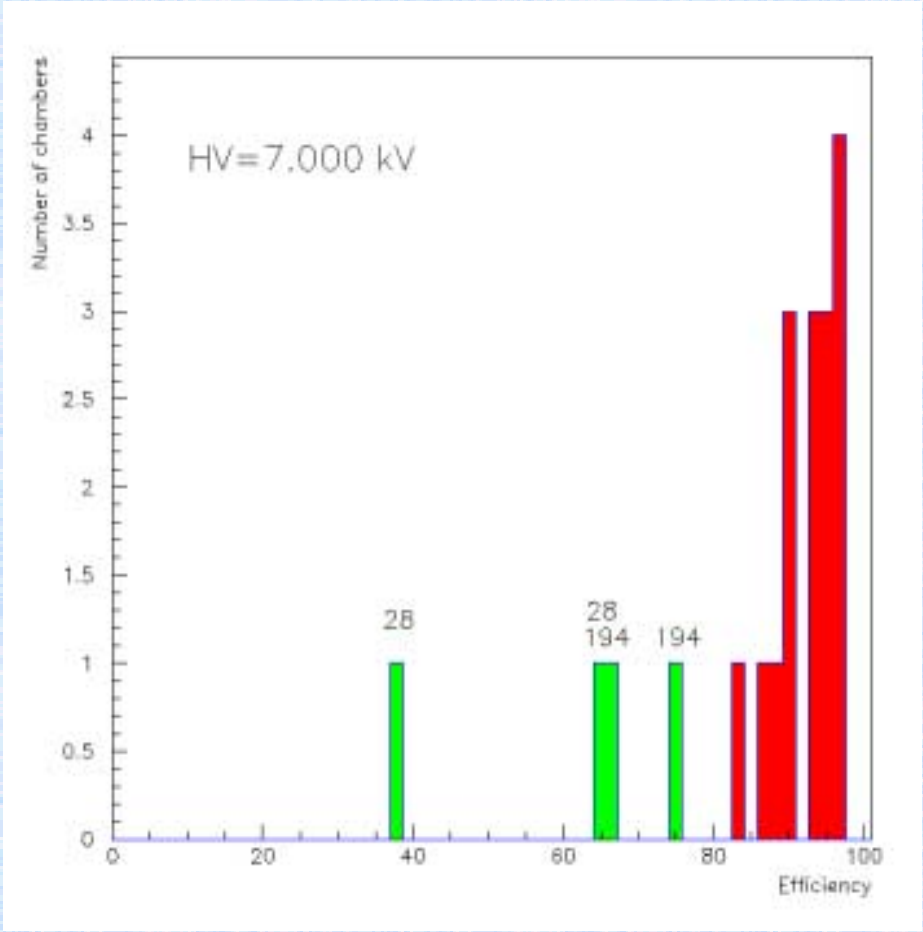
Two modules of 4 layers of tracking chambers and 4 scintillators of 1 $m^2$ size are placed on the top and bottom of the station.

In between the RPC to be analysed

# The Test Station (2)

# RPC Efficiency (1)

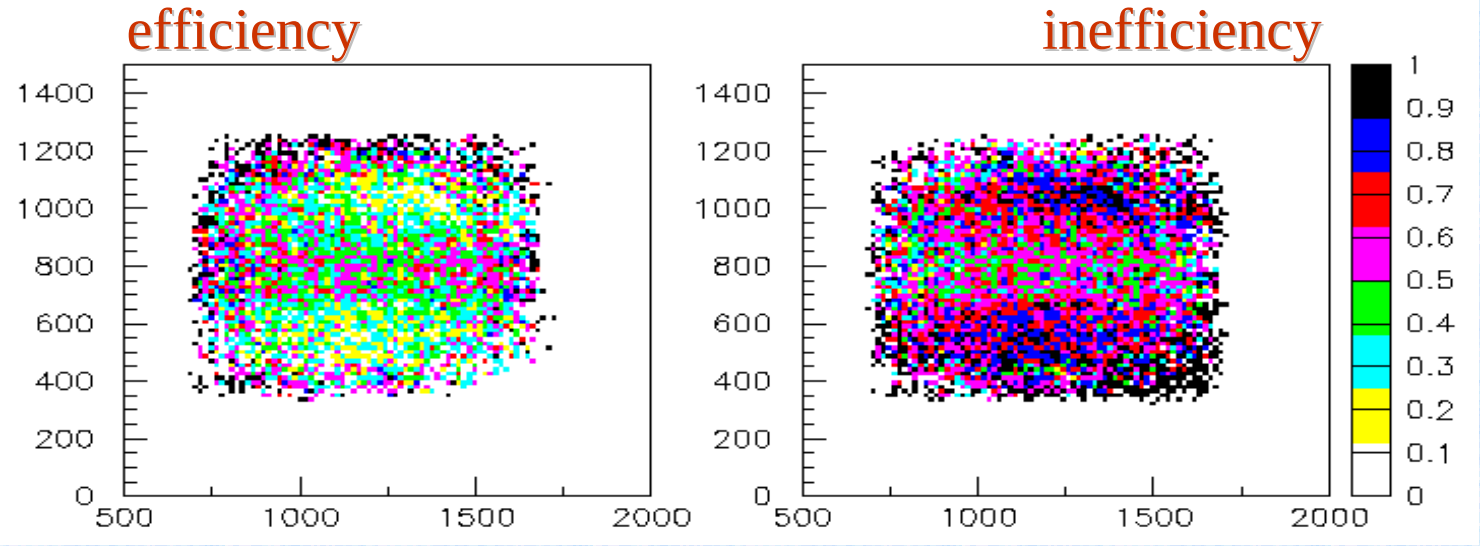
Single Gap efficiency



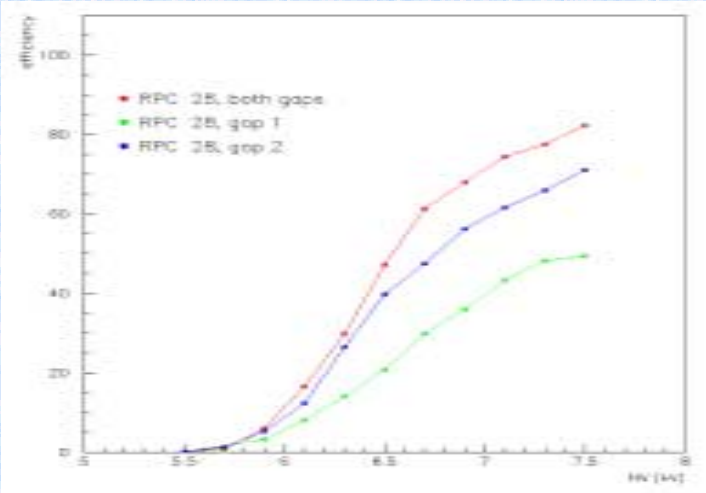

- The four gaps with low efficiency belong to two RPC (#28 and #194) with known and equal problems
- One of this RPC has been open and analysed in more details
- 15 gaps have efficiency ≥ 90%

# RPC efficiency (2)

Radiography of the RPC #28

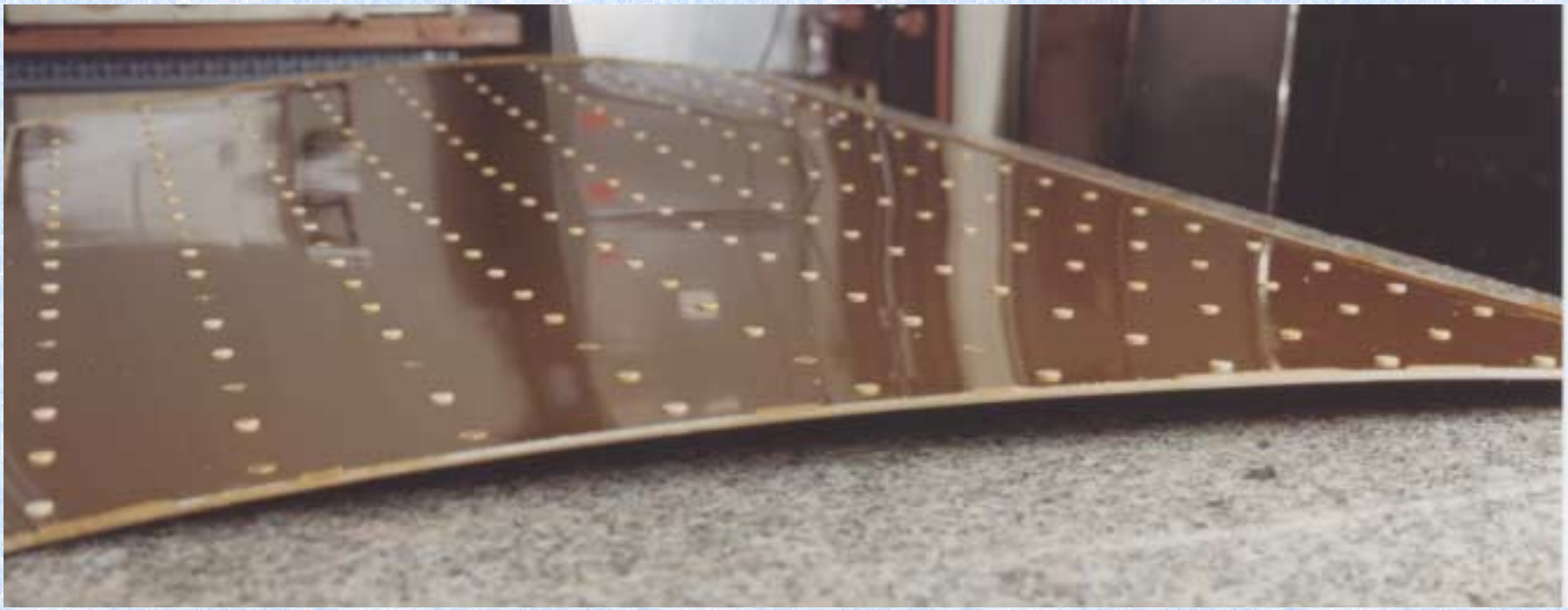



- Gap with low uniform efficiency
- RPC removed from the mechanical structure and open.
- The bakelite plates show mechanical stress with break of the frame



# Inside the RPC (1)

## Internal surface of the gap of RPC #28

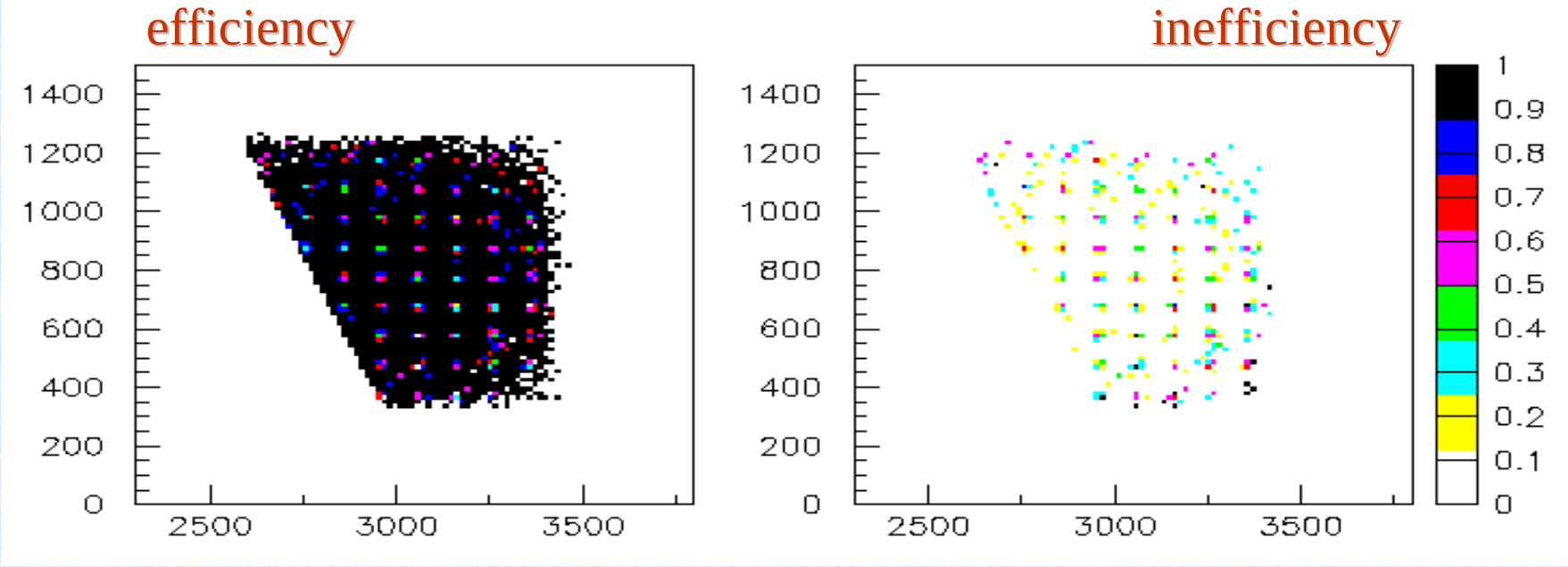


It is clearly evident from the picture the mechanical stress of the gap as well as the grid of spacers

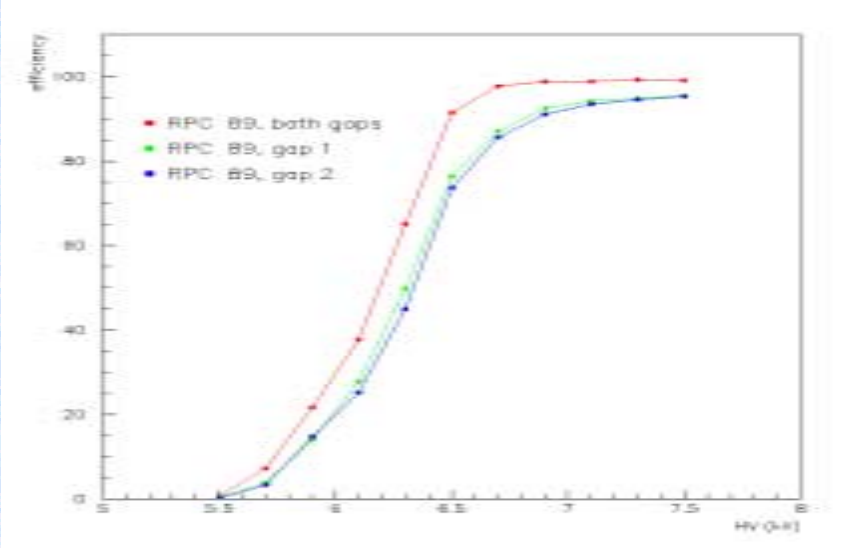
# Inside the RPC (2)

- The surface is dry and not sticky
- No evidence of  either burnings or oil drops

# RPC efficiency (3)

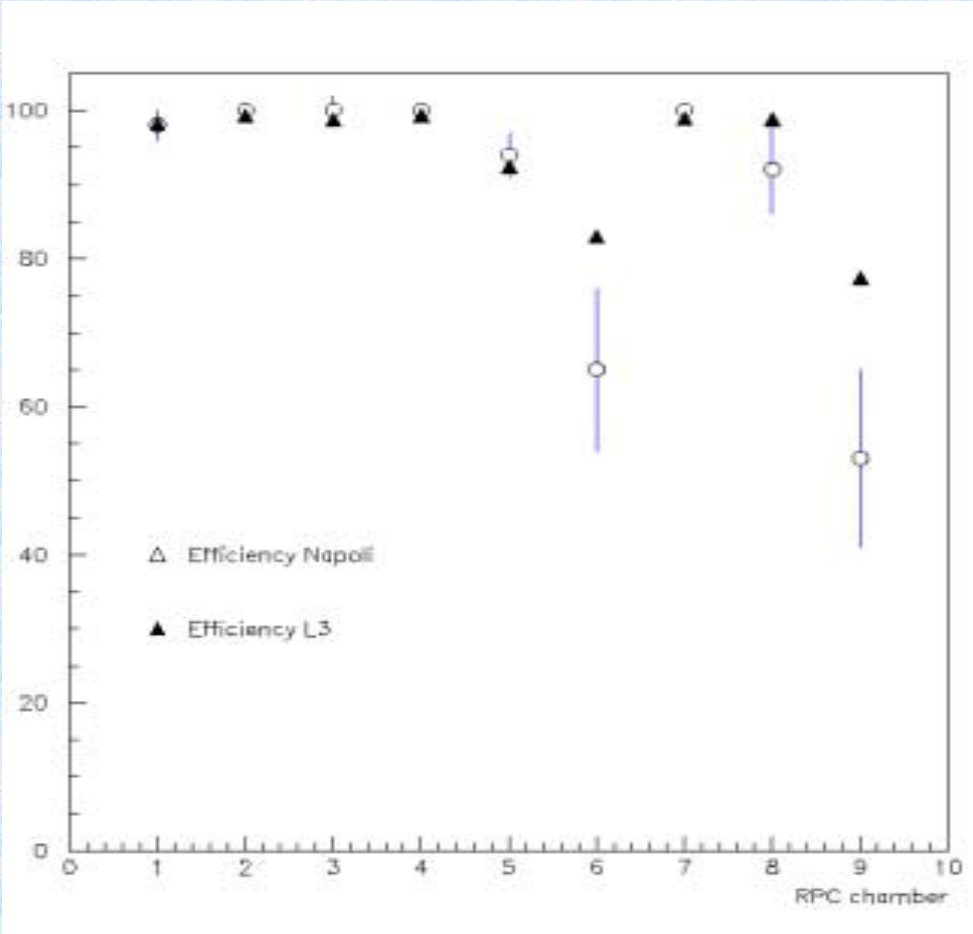



- Example of high efficiency gap ( > 90%)
- Spacers clearly visible in both efficiency and inefficiency plots
- The RPC open doesn't show any mechanical stress of the bakelite plates



# RPC Efficiency (4)

Double Gap Efficiency




- Comparison between Napoli and L3 results can be done only with bi-gap efficiencies
- Efficiency measured in Napoli with higher statistics are in good agreement with values measured in L3 which are sometimes underestimated. This could be due to the impossibility of direct control of the single RPC chambers

# Conclusions

- The performances of the RPC system of the L3 detectors are shown together with the results of the test in Napoli laboratory
- Good agreement between L3 and Napoli results on the bi-gap efficiencies
- Single gap efficiencies show a good behaviour of the RPC after seven years of running. Of the 20 single gaps tested in Napoli 15 have efficiency > 90% and 4 of them have low efficiency due to mechanical problems.
- We are confident for the RPC use in future LHC experiments