Performances of RPCs in the BaBar experiment

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for the BaBar collaboration

The IFR collaboration of the BaBar experiment

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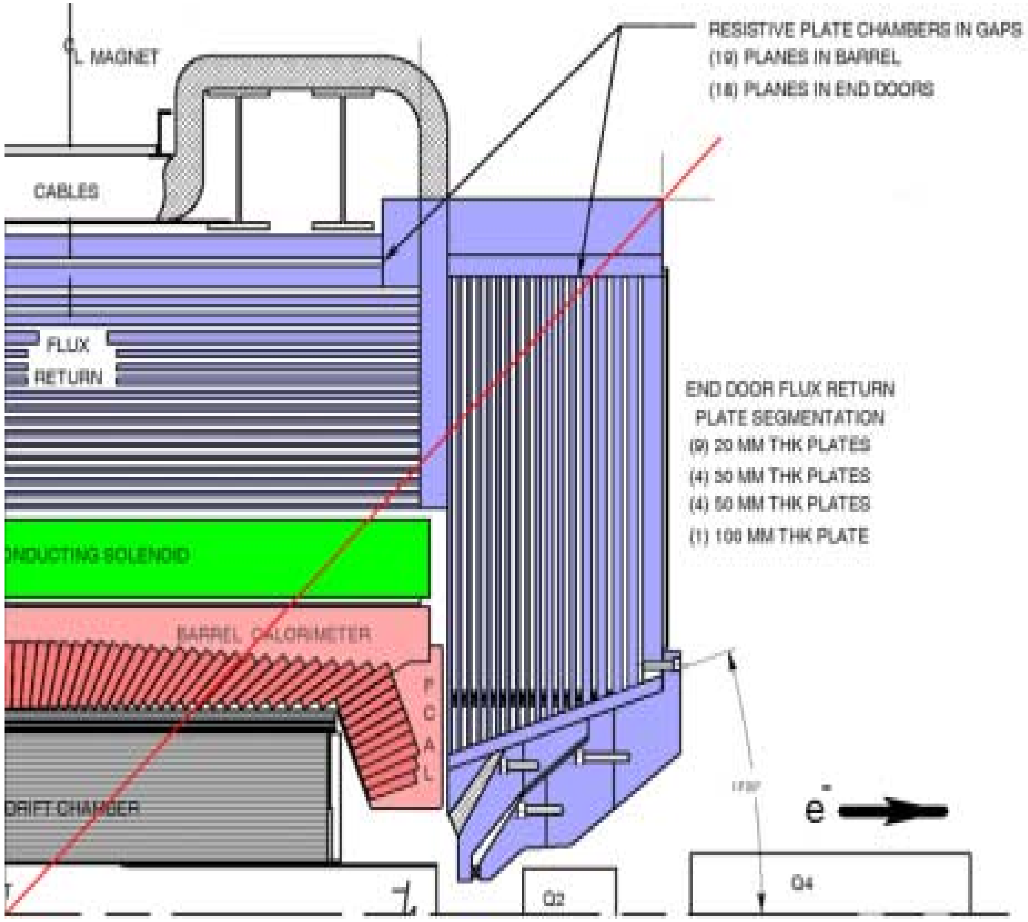
■ CONSULTING EXPERTS
- j. Va'vra - **SLAC**
- M. Lazzari - **Turin**

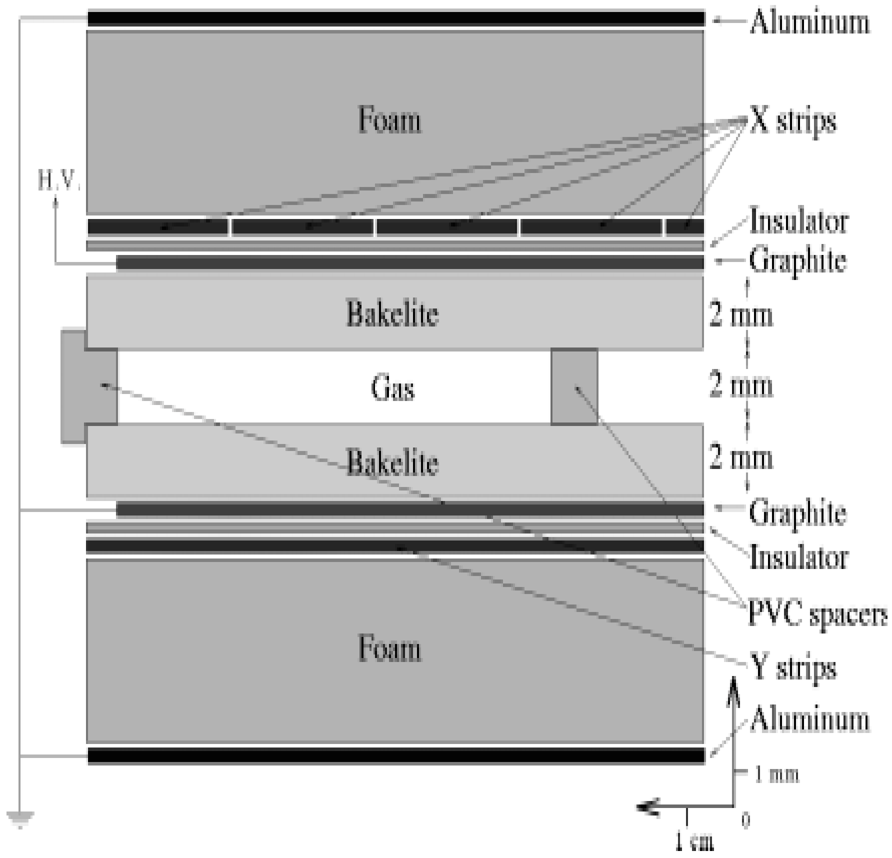
The Instrumented Flux Return (IFR)

- IFR:
  - 342 barrel RPCs
  - 432 endcap RPCs
  - 32 cylindrical RPCs
- Total surface covered: about 2000 m^2
- Gas mixture:
  - Argon 60.5 %
  - Freon 35 %
  - Isobutane 4.5 %
- Electronics:
  - about 50000 channels
  - threshold about 40 mV



RPC used in the IFR

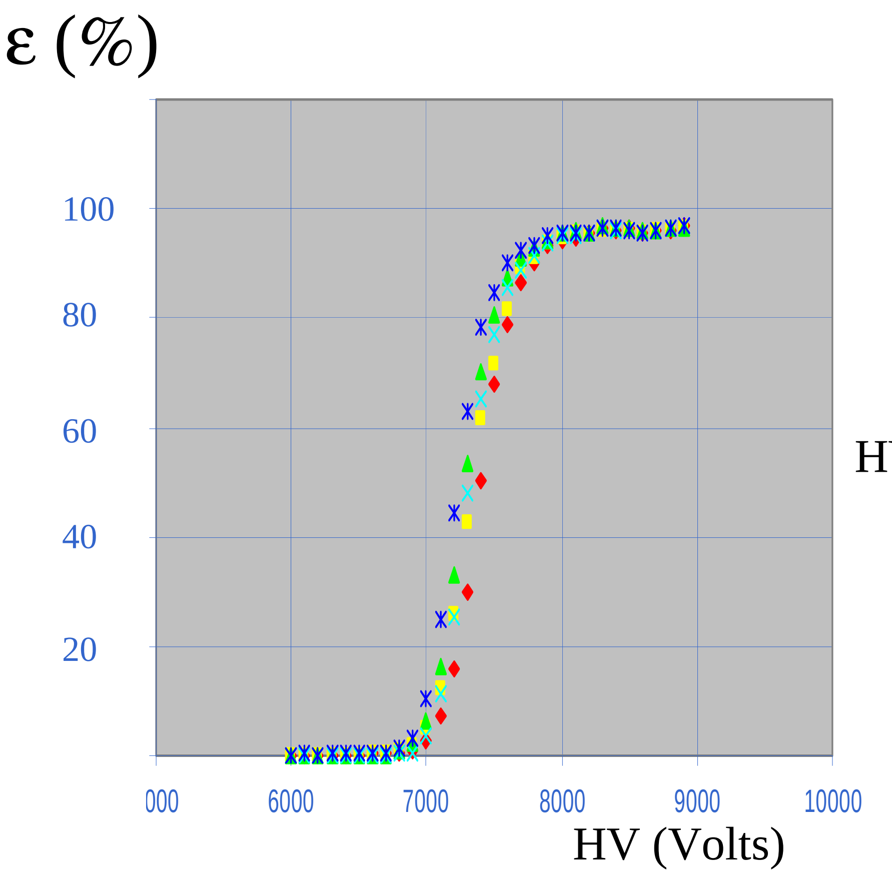
- RPC operating in streamer mode
- bakelite resistivity: 10^{11}-10^{12} Ω/cm
- Graphite resistivity: about 100 KΩ/
- RPCs filled 3 times with a mixture of 70 % linseed oil and 30 % n-pentane. Air flushed for 60 hours after each filling
- differences respect to L3 experiment:
  - new shape of spacers
  - single gap vs bigap
  - double readout
- gas flow 2 volumes per day

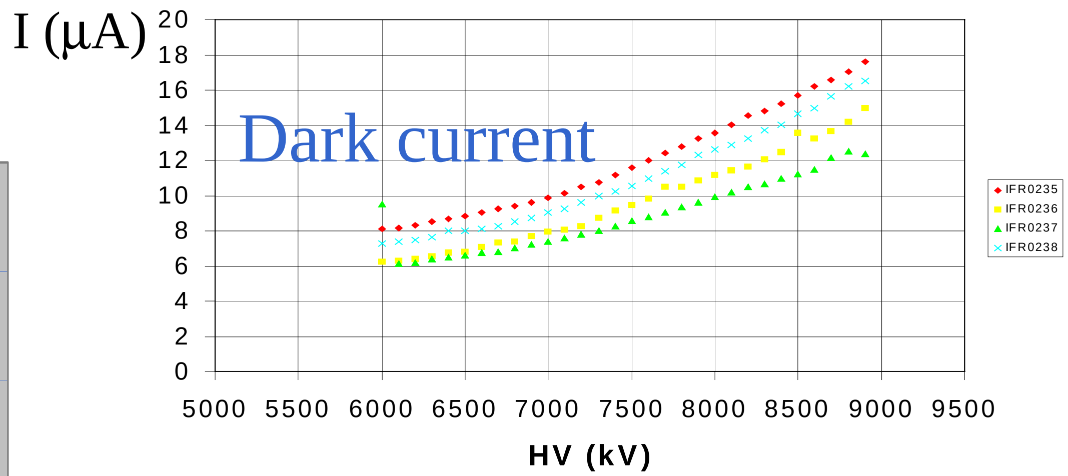


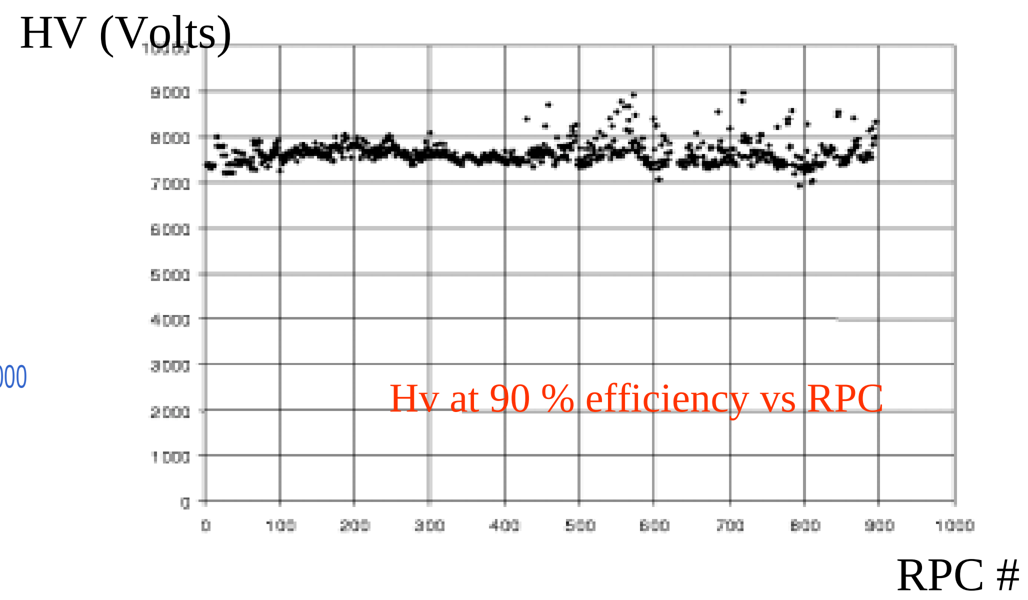
Brief IFR history

- RPCs produced at General Tecnica Factory (7/96 - 11/97)
- All the chambers have been tested in Frascati:
  - dark current
  - single rate
  - efficiency
- sent to SLAC, assembled more chambers in single layers and tested again (12/96-12/97)
- chamber insertion 6/97-12/97
- first cosmic tests on the detector 12/98

RPC performances at Frascati Test station







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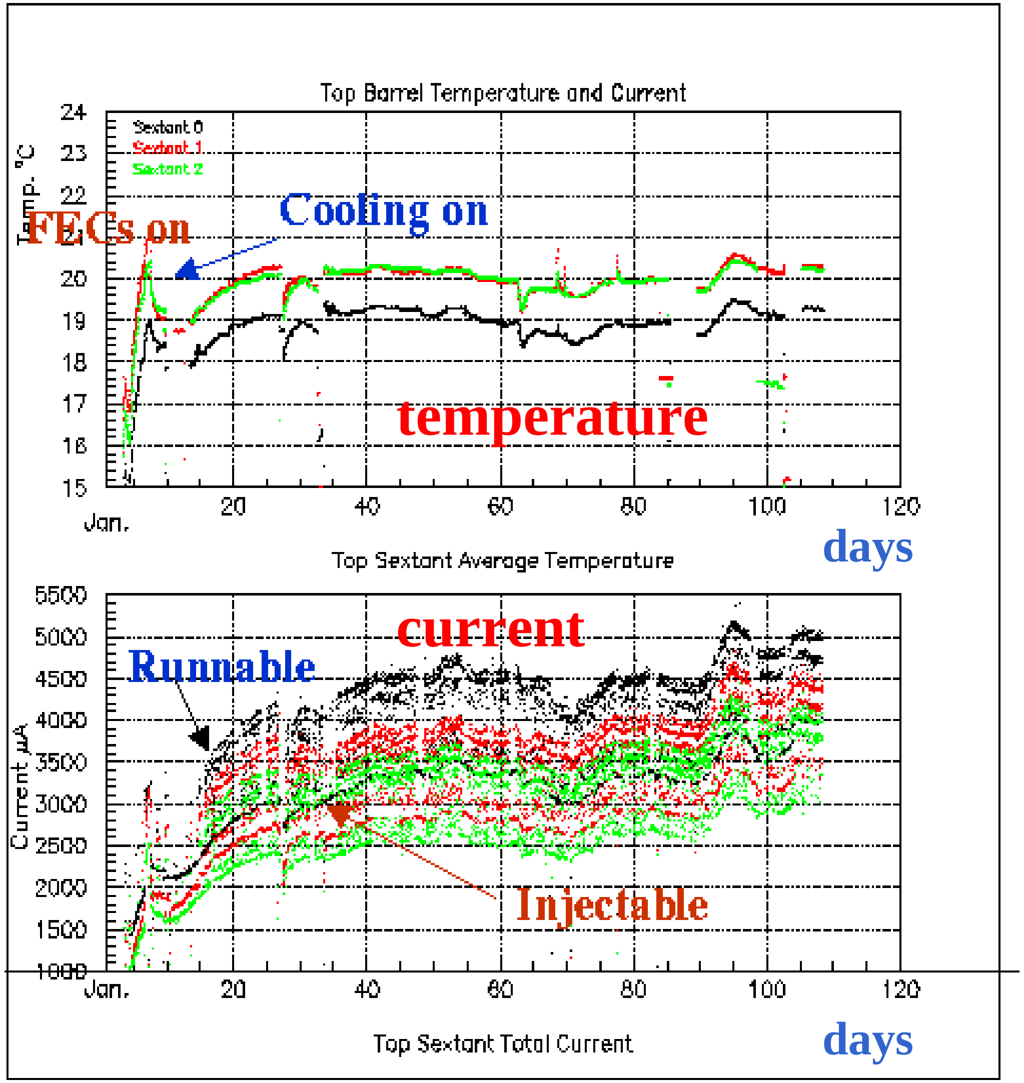
Summary of the first results

- Single rate < 1 KHz/m^2
- Currents 3-20 μA
- Excellent detection efficiency (> 96 %)
- No correlation found between performances and bachelite resistivity
- Similar results found in tests done at SLAC

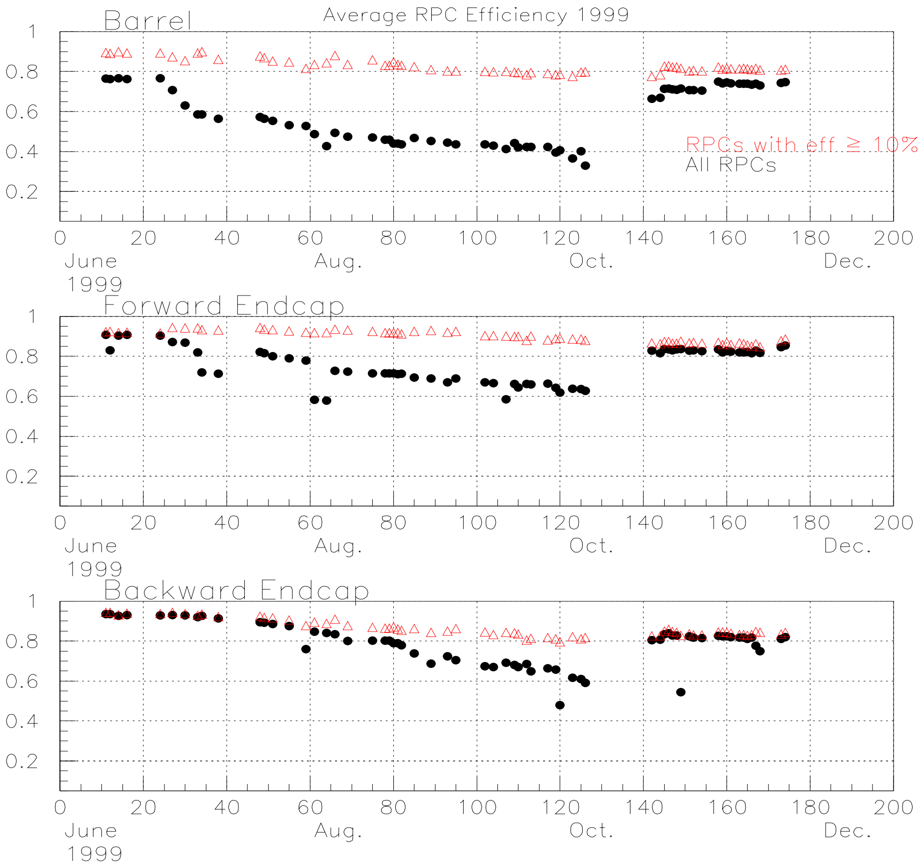
Temperature effects

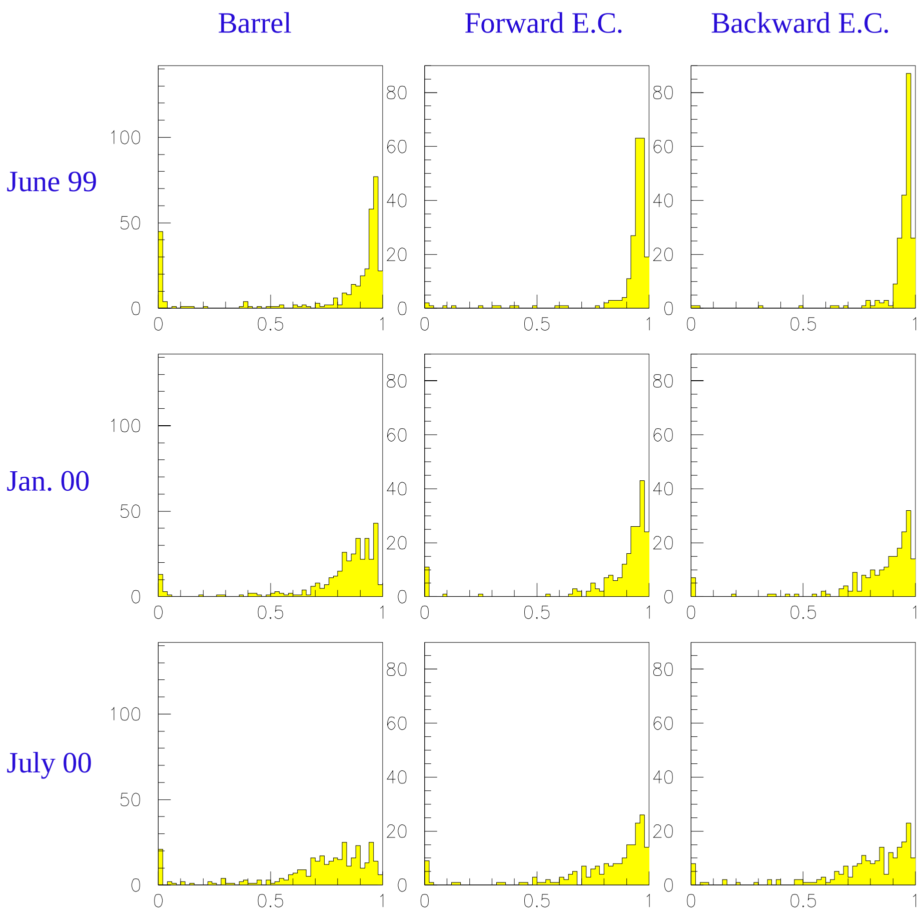
- At beginning of summer 1999 was clear that the environment temperature was greater than expected (about 28-31 °C degrees in the experimental hall, 29-33 °C inside the iron slots of the IFR)
- RPC dark currents start to increase
- Chambers with dark current greater than 200 μA were disconnected
- Cooling system installed in October 1999 and completed in the endcap by January 2000
- Temperature stabilised at 19-21 degrees inside the detector
- disconnected chambers were reconnected



Efficiency history

1999





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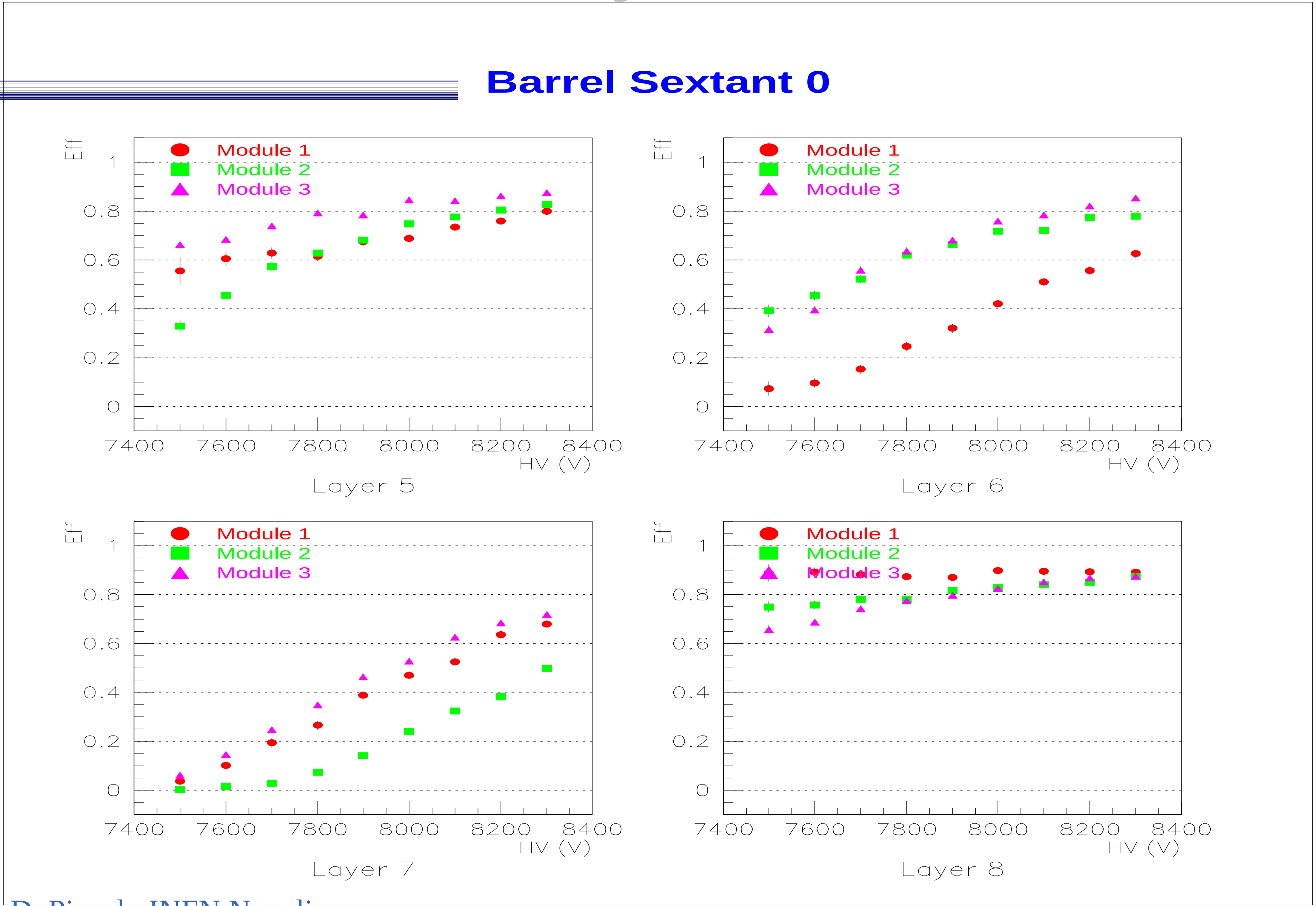
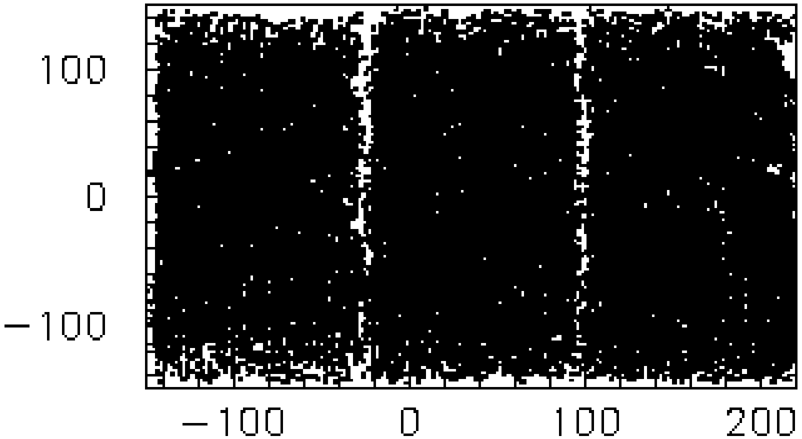
Efficiency vs HV

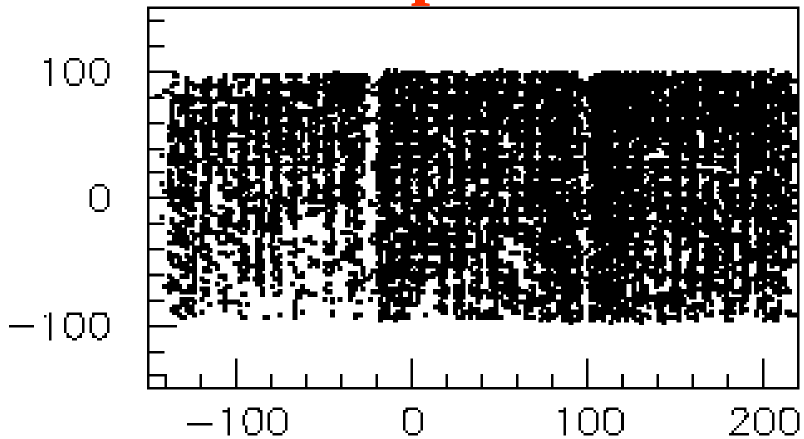


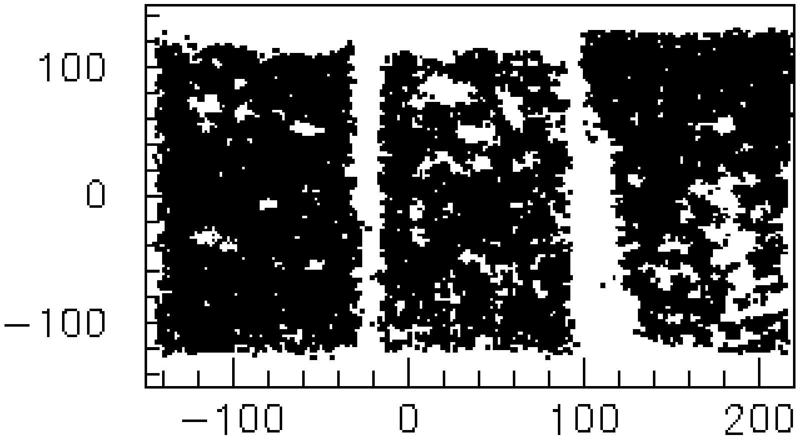
Efficiency map

Good RPC



Spacers !





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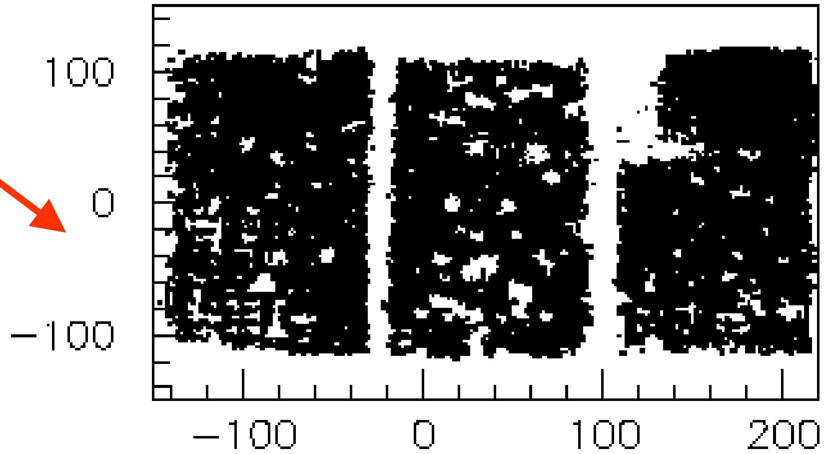


Tests done

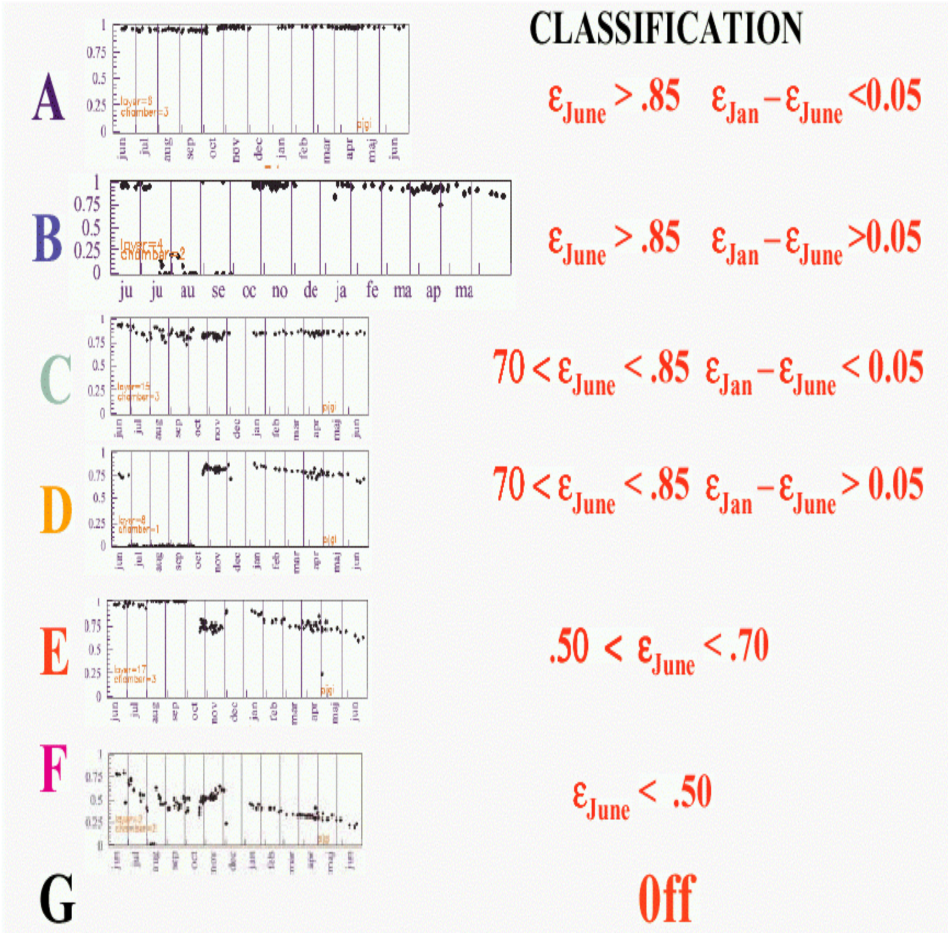
Physical removal of RPC is very hard. Several tests have been carried on the detector:

- Increased gas flow
- lowered discriminator threshold
- put weights over inefficient regions

No effect !

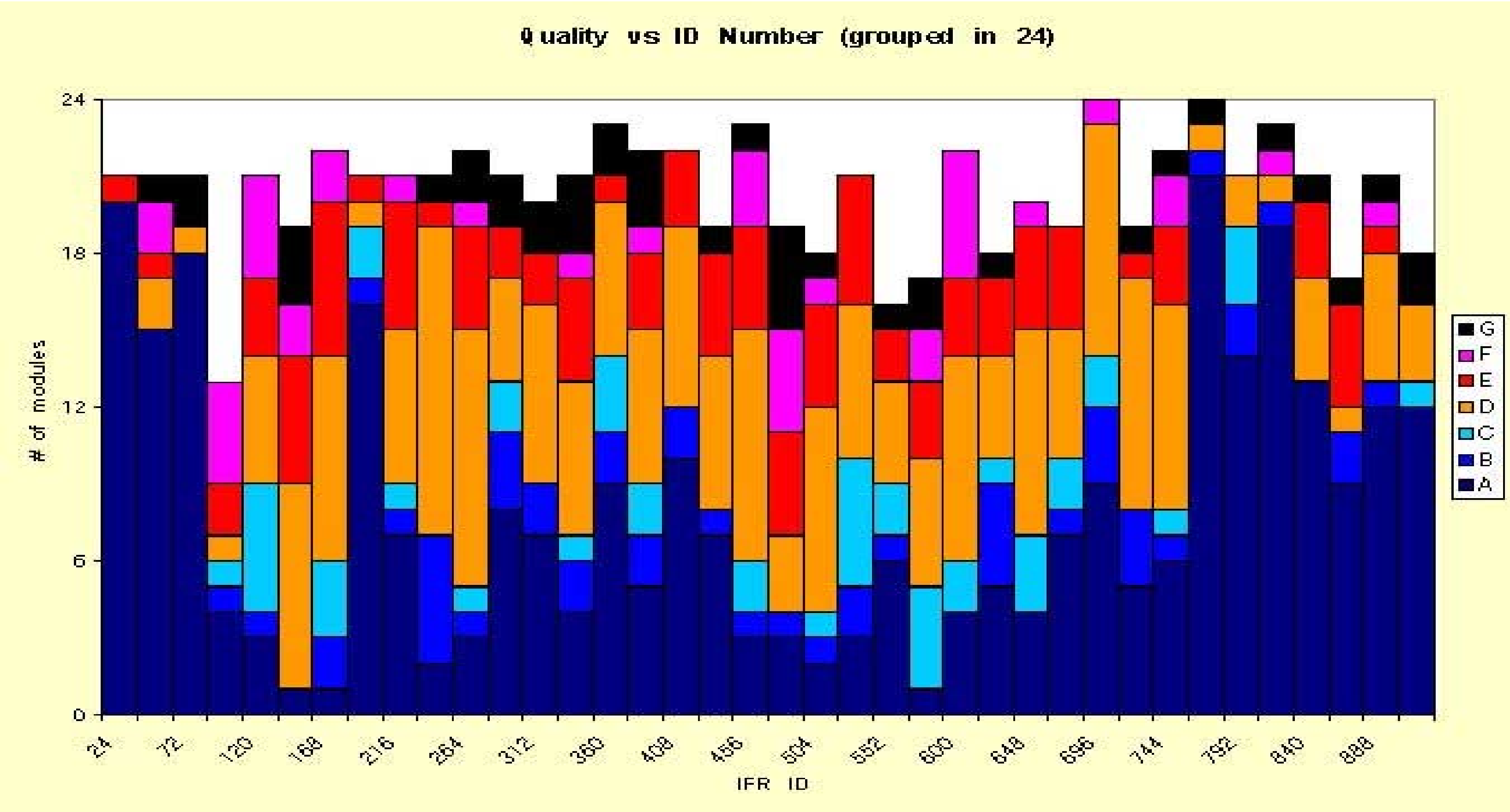
Gas composition was regularly tested: **stable**

Classification of RPCs as function of the measured performances shows several different behaviours



RPC classification

Quality distribution vs production batch



bad RPCs

Good RPCs

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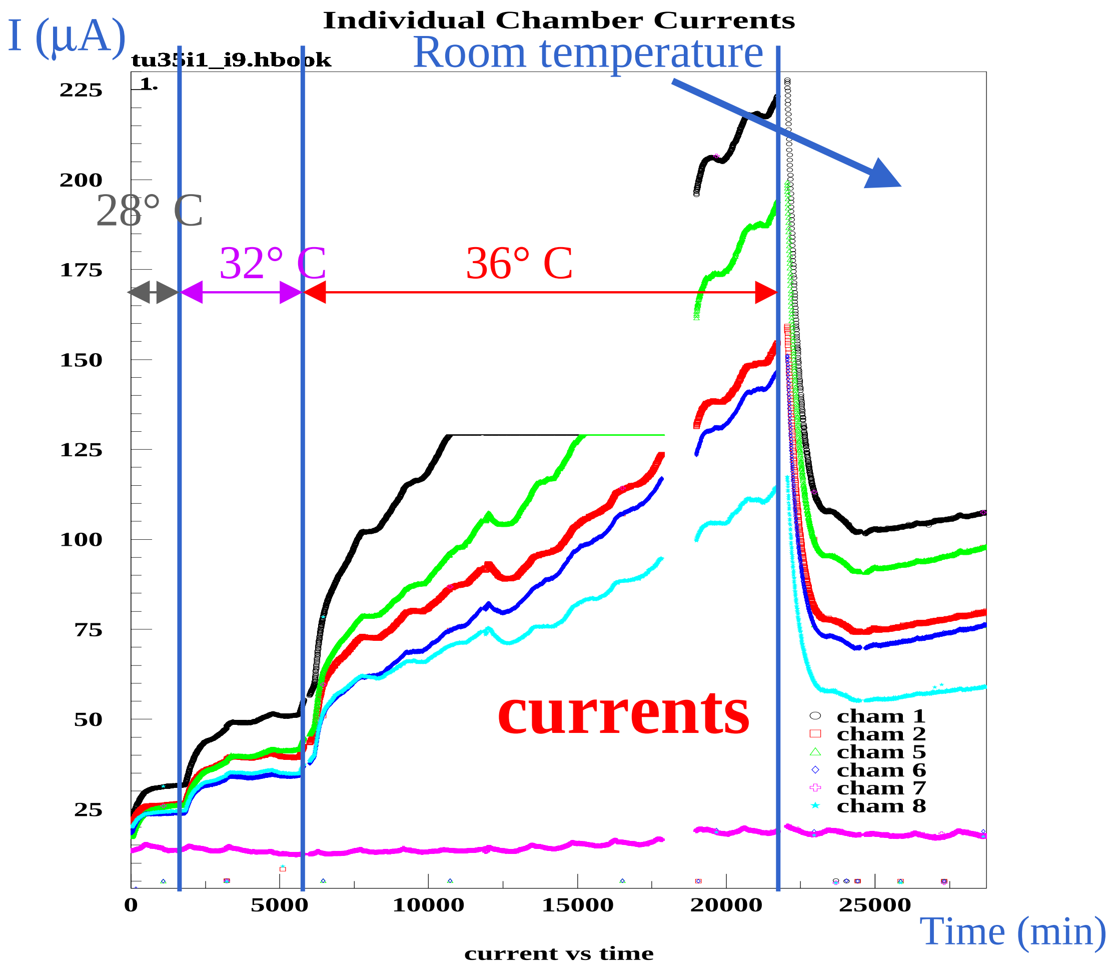
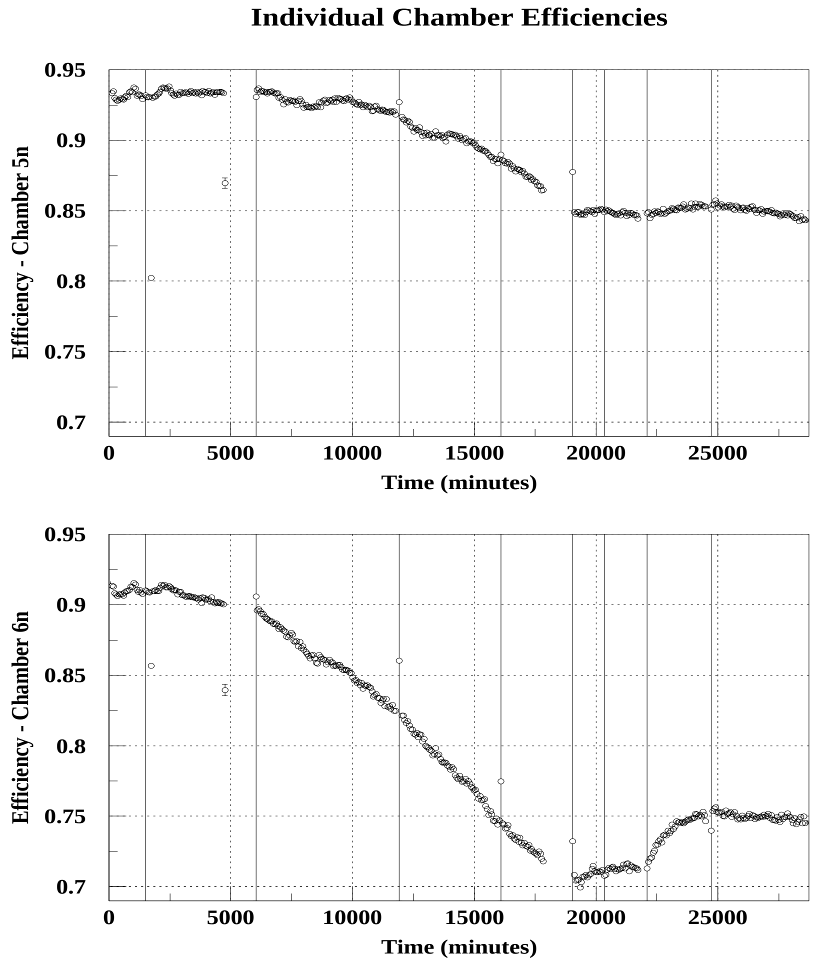
Test station and R&D

- In order to try to reproduce the effects seen in Babar, several test station have been set-up: SLAC, Frascati, Napoli, Oregon.
- Main goals:
  - study current vs temperature correlation
  - reproduce efficiency reduction after temperature cycling
- Interesting results from SLAC test station:
  - 9 RPCs post babar production were tested inside an oven
  - RPCs were subjected to heating cycles at 36° C.
  - permanent effects both on dark current and efficiency seen after few days

SLAC test stand results





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Autopsy of the RPC tested at SLAC

- Several drops of oil found all around the bakelite surface
- most of these drops span between the 2 mm gap

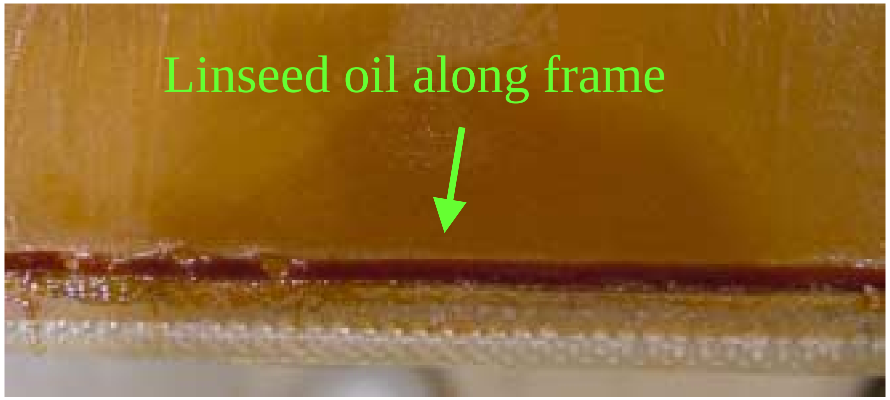
Autopsy of RPCs on the babar experiment

- At the end of 2000, 12 chambers of the forward endcap have been replaced with RPCs of new production:
  - New RPCs developed for Atlas, CMS, Argo ... have less oil inside.
  - 12 babar chambers replaced available for tests and autopsy
- Several old RPCs have been opened in order to study the oil surface
  - same drops of oil as in chamber tested in lab
  - the oil seems not polymerised, it is sticky

Autopsy of RPCs on the babar experiment

RPC 70 % efficiency

Oil drops spanning gap

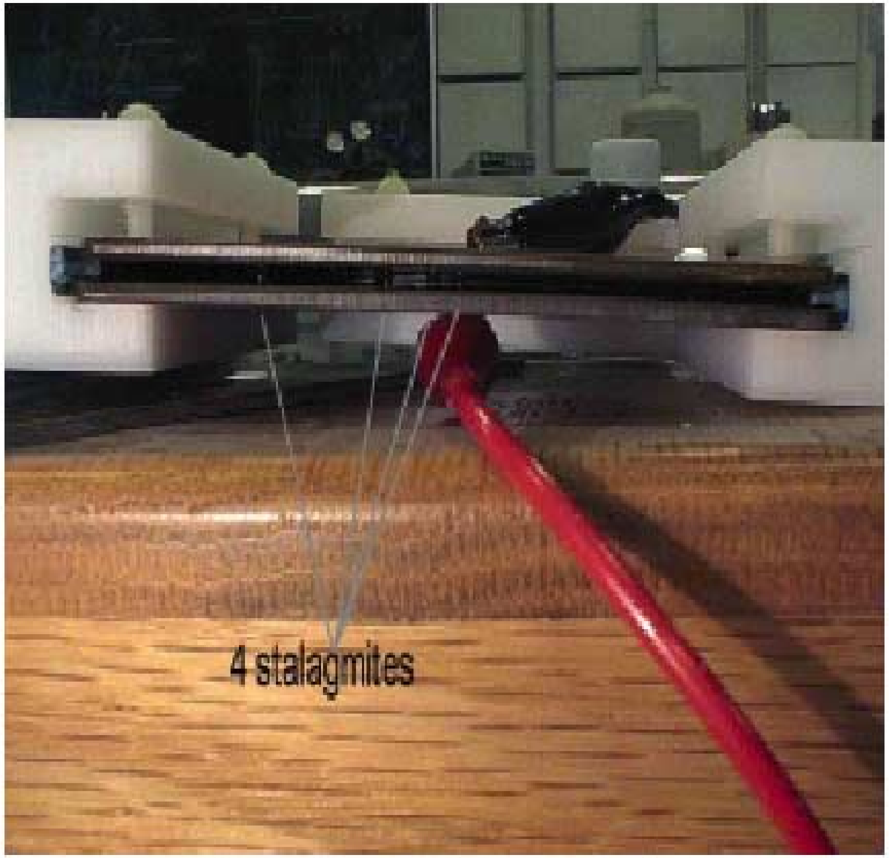


RPC studies

- The RPC problems seem to be related to the missing polymerisation of the linseed oil and the formation of oil droplets under the action of high temperature and high current

- Several studies have been carried out to understand the problems

Oil stalagmite formation



Analysis of RPC components

- Jerry Va'vra made several tests on single components of the RPC to study behaviour under temperature cycling
  - bakelite
  - fresh linseed oil
  - g-10 (RPC frame)
  - polycarbonate (RPC buttons)
- No long term effects have been found. All the processes are reversible
- Analysis of a sample of linseed oil taken from a babar RPC shows lower resistivity:
  - ($2.1 \cdot 10^8\ \Omega \cdot$ cm vs $76.7 \cdot 10^8\ \Omega \cdot$ cm of fresh linseed oil)
  - heating at 60° C in air increase the resistivity

- Jerry Va'vra suggest that the linseed oil could be decomposed under the action of high currents.
- Molecules inside linseed oil R-COOH could dissociate under HV in H^+ $R\text{-}COO^-$ this could increase conductivity
- water coming from tubing of BaBar gas system could enhance the process

Chemical analysis of linseed oil

M. Lazzari

- Linseed oil basics:
  - Mixture of triglycerides, formed by one molecule of glycerol and three molecules of linear fatty acids
- The oil layer is cured forming a hard stable film because of oxidation followed by polymerisation
- Photons can break some bonds creating free fatty acids with lower molecular weight

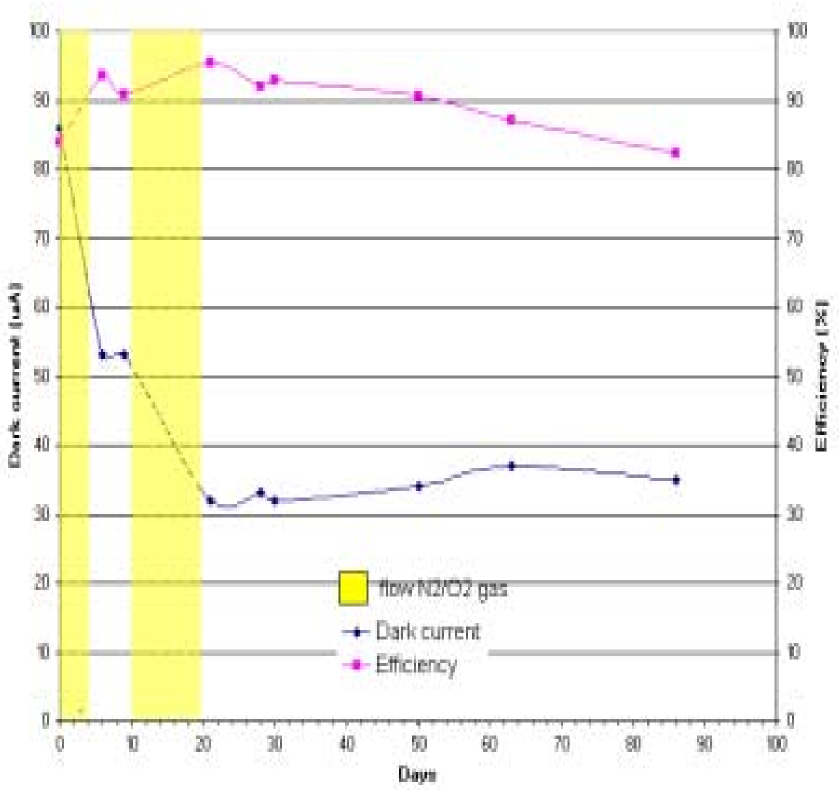
- Chemical Analysis Fourier Transform Infrared Analysis (FTIR)
  - extraneous compounds found in some chamber
    - free fatty acids
    - phthalates
- Free fatty acids and phthalates inhibit the polymerisation of the oil
- More studies should be carried out in order to correlate linseed oil properties and RPC performances

Attempts to recover damaged chambers

Changguo Lu made several tests on damaged BaBar RPCs to try to recover performances. The idea is:

- Current goes through linseed oil (droplets, frame, buttons) and short electrodes reducing locally the electric field.
- Not cured linseed oil has lower volume resistivity
- Oxygen treatment could increase oil resistivity → dark current reduction, efficiency improvement

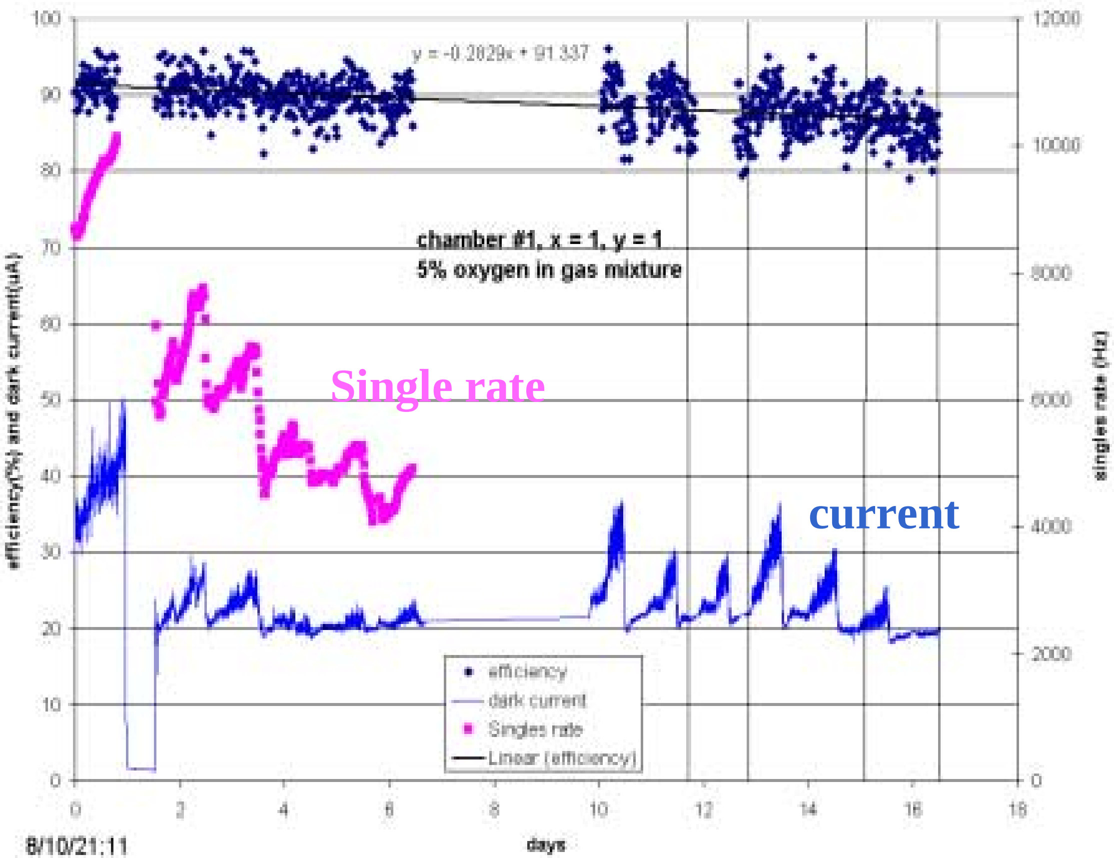
The answer seem: NO long term improvement



Short term oxygen treatment doesn't help. Repeated operations could work, but after enough time efficiency go back to initial value

Attempts to recover chambers (.. Continue)

Flowing O_2
inside the gas mixture:
initial benefits
are lost during time.

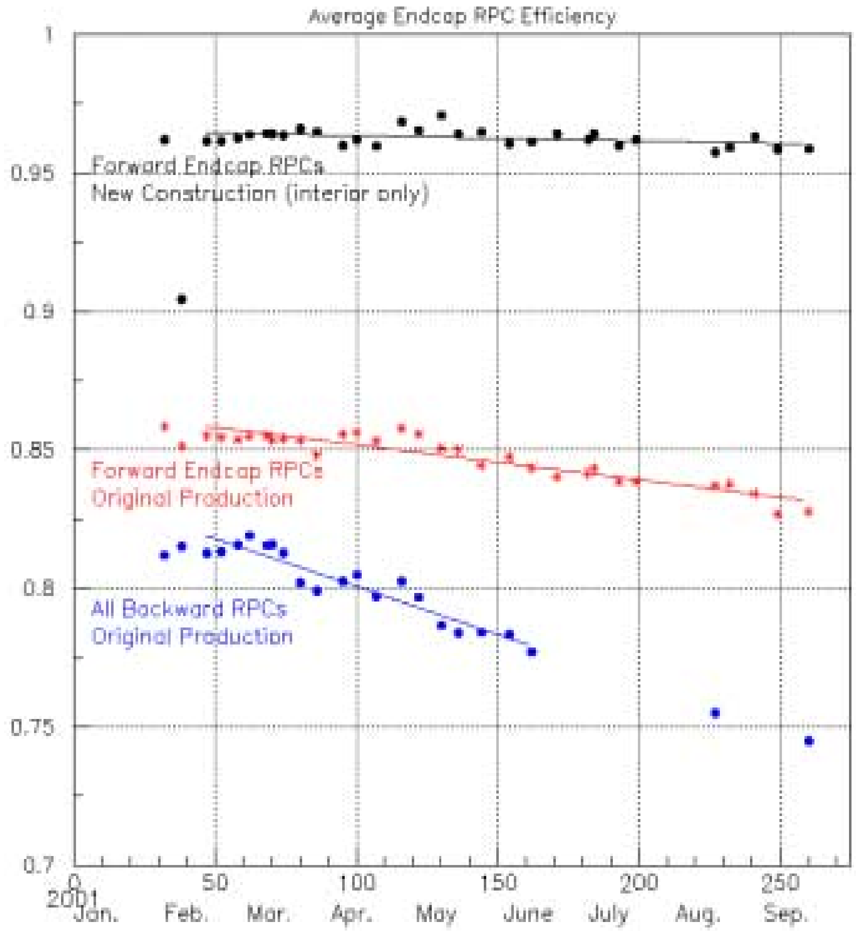


Performances of the new RPCs

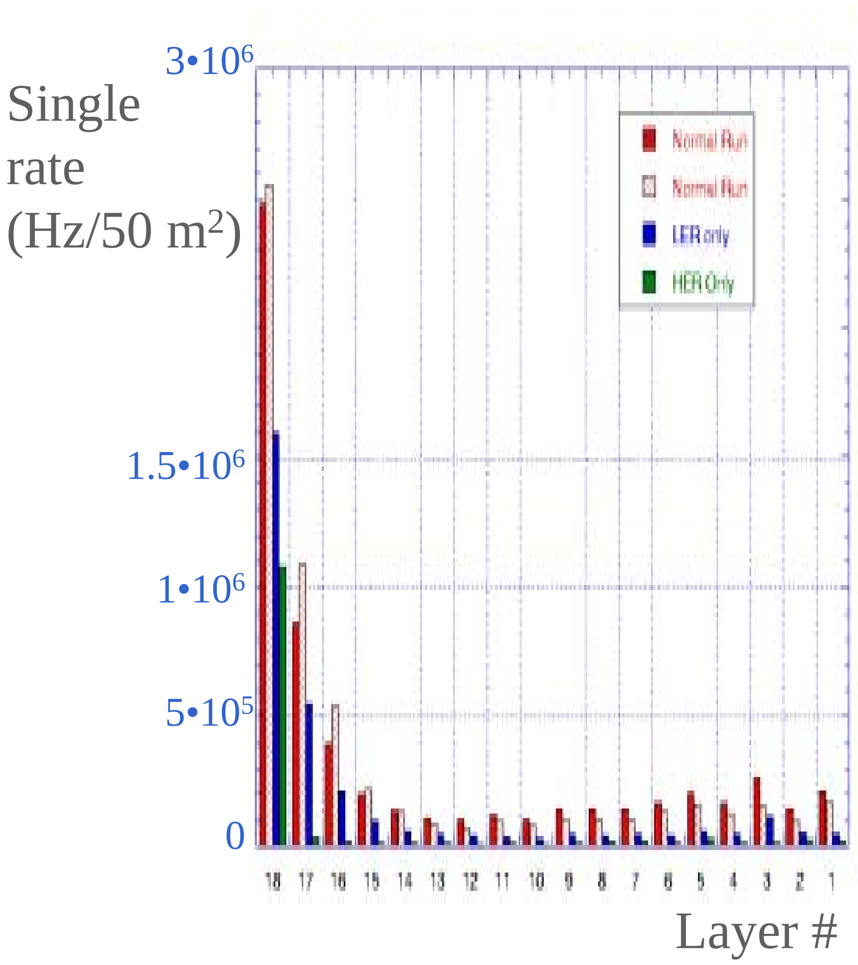
- The New RPCs tested inside the IFR endcap have been produced with few small differences:
  - new bakelite treatment (smoother surface) developed for Argo and LHC
  - new oiling procedure:
    - 60 % eptane, 40 % linseed oil (vs 30 % n-pentane, 70 % linseed oil)
    - single filling (vs 3)
  - As a result the oil layer thickness was about 6 μm, hard and dry

New RPCs performances

- New RPCs are working since 9 months
- We should divide the sample of New RPCs in two subsamples:
  - innermost layers (no beam background)
  - outermost layers (photons and particle showers coming from beam)
- Innermost layers show very good performances: low dark current, high detection efficiency
- outermost layers suffer from high background.



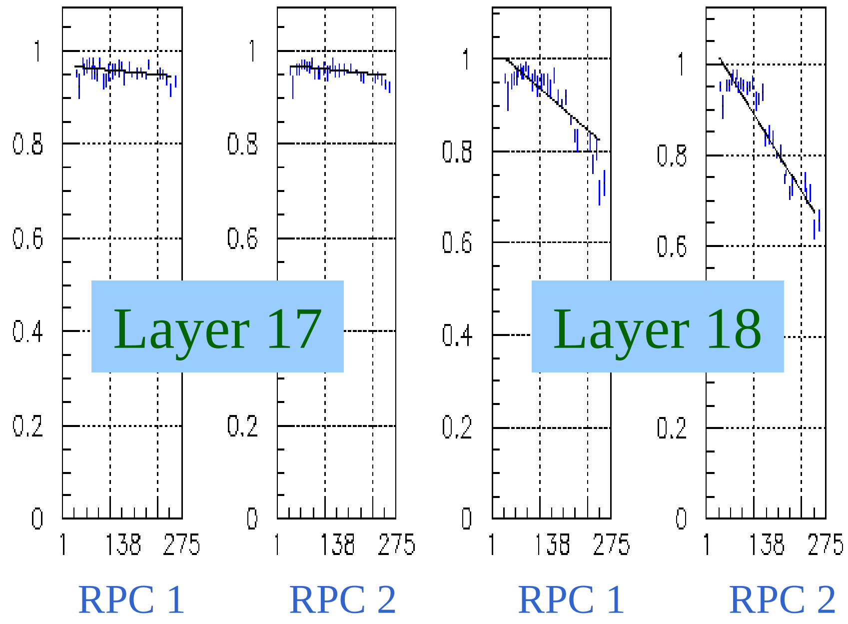
New RPCs Outer layers performances



High background is present on outer layers

- Single rate still high without beam. Layer 18: 35 Khz/m^2
- Efficiency is going down
- Investigation is in progress

EFFICIENCY VS TIME (DAYS)



NO Beam

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Conclusions

- RPCs in BaBar deteriorated their performances under the influence of high temperature and high current;
- Big effort has been dedicated to reproduce and understand the problems:
  - Linseed oil seems not cured,
  - under the action of HV, droplets can be created, shorting electrodes,
  - No success, up to now, in trying to cure linseed oil flowing O_2.
- RPCs of new production work well under controlled environmental conditions (low temperature);
- Some problem, still to be better investigated, are evident for RPCs under high background conditions;