RPCs detectors in running and future experiments

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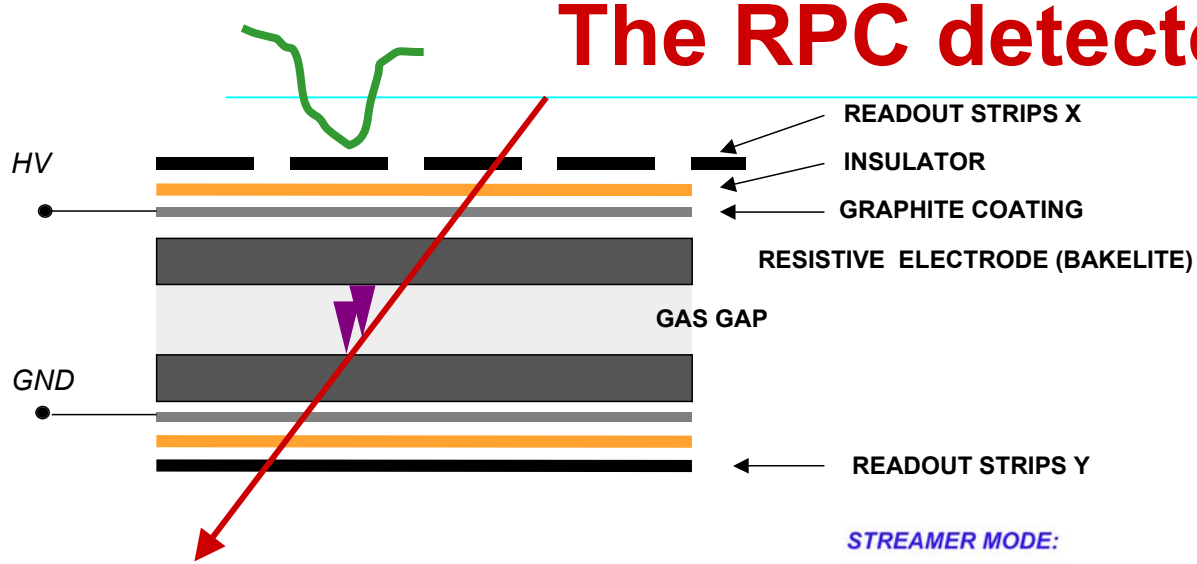
Outline

- The Resistive Plate Chamber
- Trigger RPCs in running experiments: BaBar and Belle
- Trigger RPCs at future LHC experiments
- TOF RPCs: STAR and ALICE
- Conclusions

The RPC detector

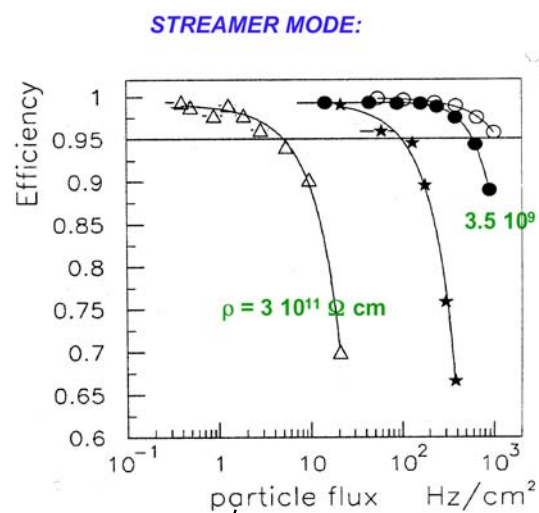


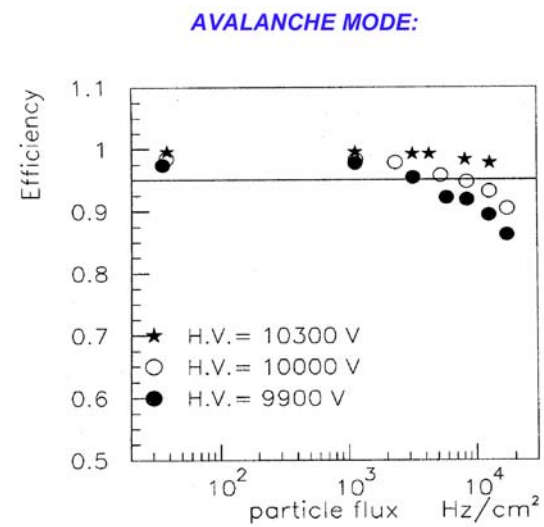
- time resolution ~ 1 ns
- space resolution ~ 1 cm
- rate capability ~ 10 Hz/cm^2
- cheap
- shapeable detectors and readout electrodes

Trigger RPC: BaBar, BELLE, Argo, ALICE, ATLAS, CMS

main issue is rate capability

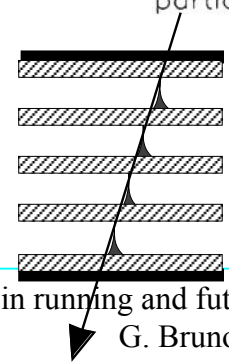
- mode of operation (streamer / avalanche)
- electrode resistivity





Time Of Flight RPC: STAR, ALICE

Multigap technology development

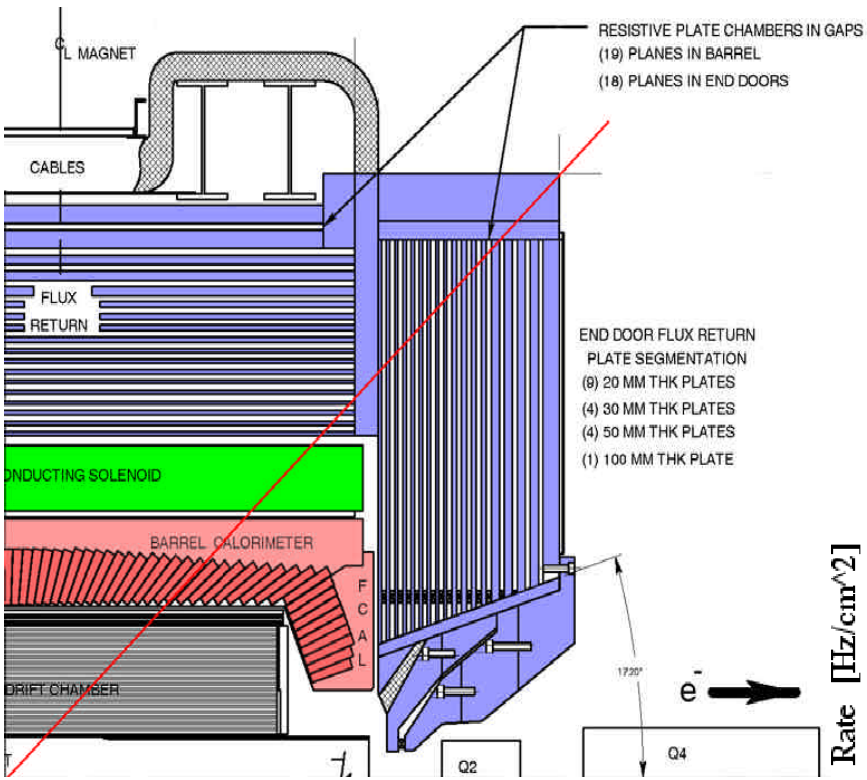


} <1 mm

time res ~ 100 ps

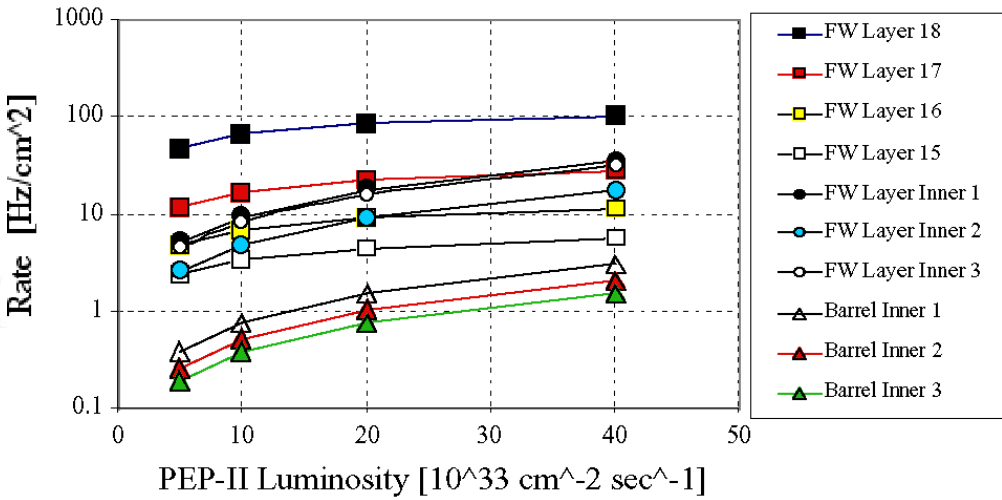
rate capability ~ 1 kHz/cm^2

The BaBar IFR (Instrumented Flux Return)



The RPC-based system:

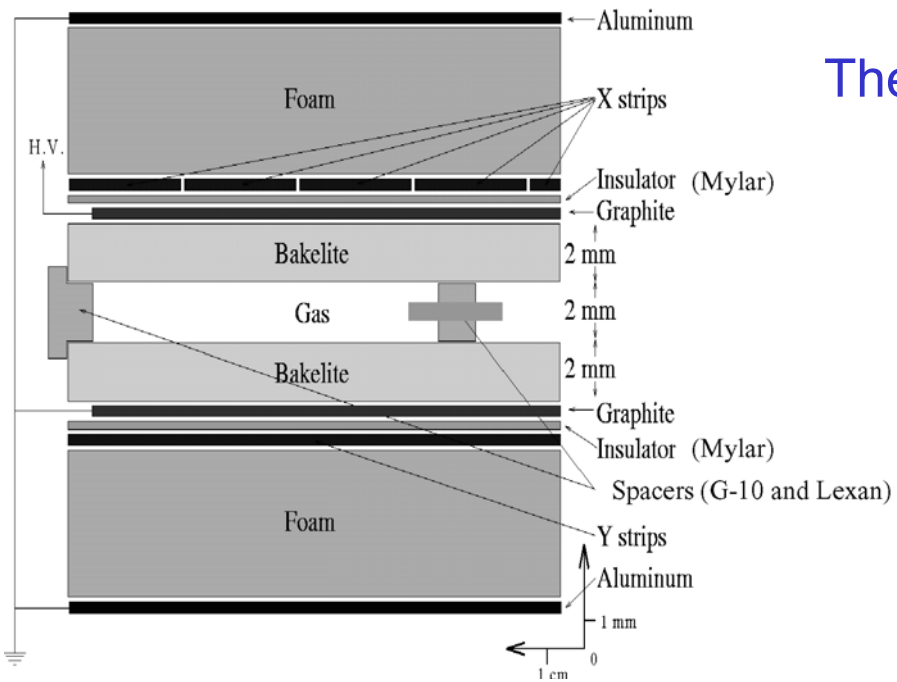
- Muon and neutral hadron identification, cosmic veto trigger
- Instrumented iron Flux Return (IFR) with 19(B) 18(E) detecting layers (one per slot)
- 774 RPCs in total: 342 barrel + 432 endcaps (2300 m^2)



Pattern recognition:

- Cluster building
- Association of extrapolated charged tracks in the drift chamber to the IFR clusters
- Cluster identified as neutral if not associated
- μ/π discrimination through a cut on the iron penetration dependent on p and θ

BaBar RPCs

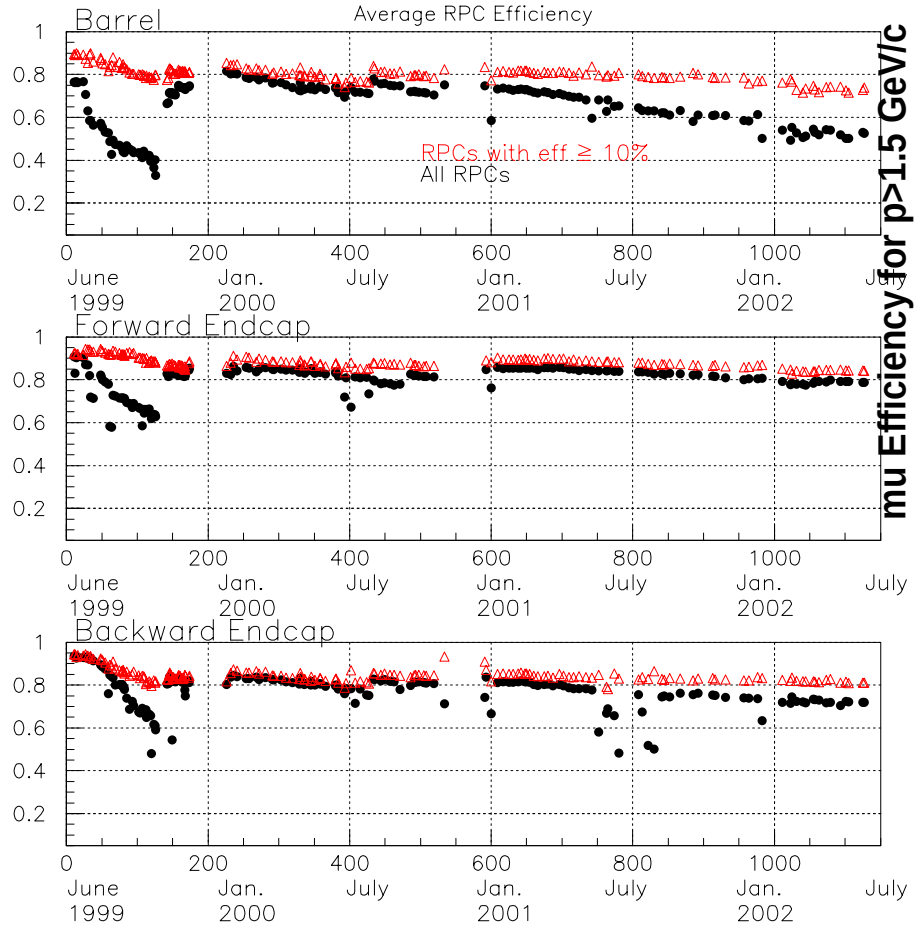


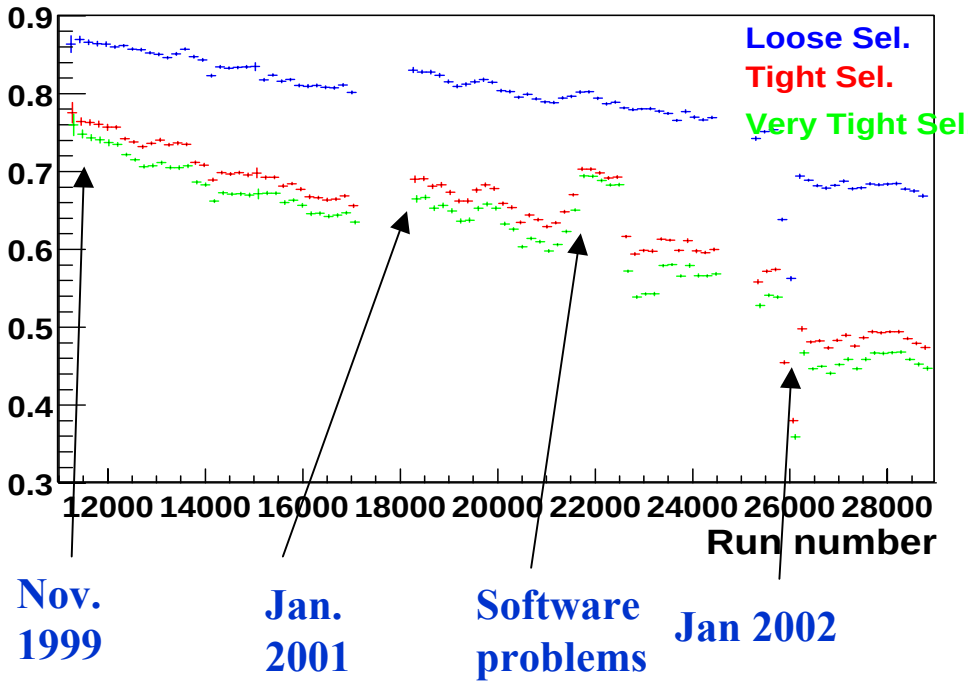
The detectors:

- Single gap (2 mm)
- Streamer mode
- Gas: 60% Ar + 35% $C_2H_2F_4$ + 5% C_4H_{10}
- High resistivity oiled bakelite ($10^{11} \div 10^{12}$ Ωcm)
- Two dimensional strip readout

- **July 1999: Original chambers showed large dark currents and sharp efficiency drops following heating at temperatures of 30^0-35^0. Efficiency keeps on declining to date. Problems related to excess of linseed oil.**
- **Nov 2000: replacement of 24/216 forward RPCs with new chambers with a single cured oil coat. The RPCs in the outermost layers showed dramatic ageing effects after 140 days of operation (500 C/m^2). The others show decreasing efficiency, but at a lower rate than the original ones.**
- **Dec 2002: replacement of the remaining old forward RPC with new ones: better quality control. So far good behaviour.**

BaBar RPC performance



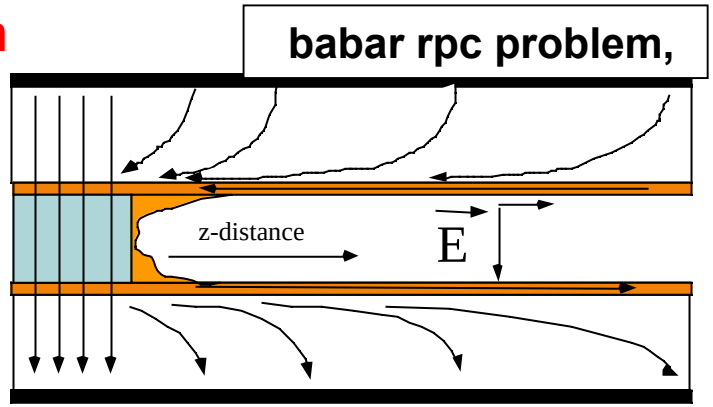


The gradual decrease in efficiency since first operation in ’99 obviously affects the muon identification efficiency.

Issue: aging

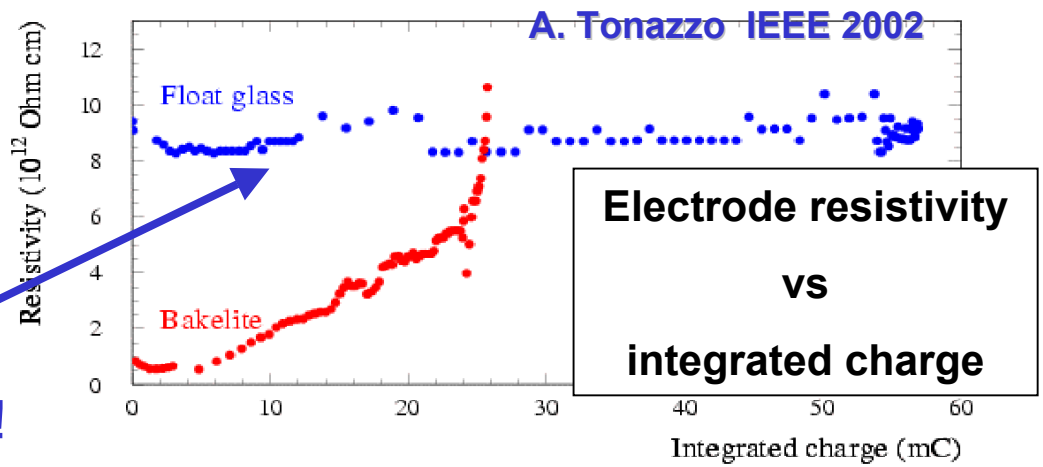
No final exhaustive answer to all BaBar RPC problems, but it has been put in evidence :

- Dependence of bakelite volume resistivity on
  - temperature
  - integrated current
  - presence of water

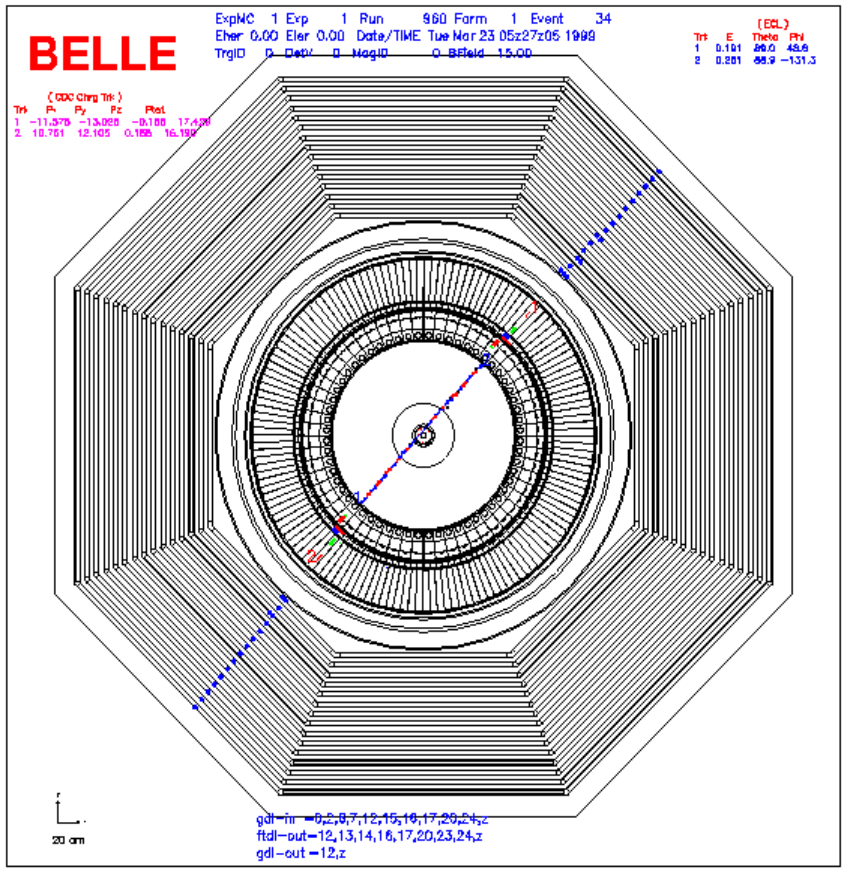


- Dependence of oil volume and surface resistivity and change in chemical properties
  - temperature
  - presence of water
  - integrated current
  - presence of HF

Glass resistivity more stable!



The BELLE K_L/μ detector



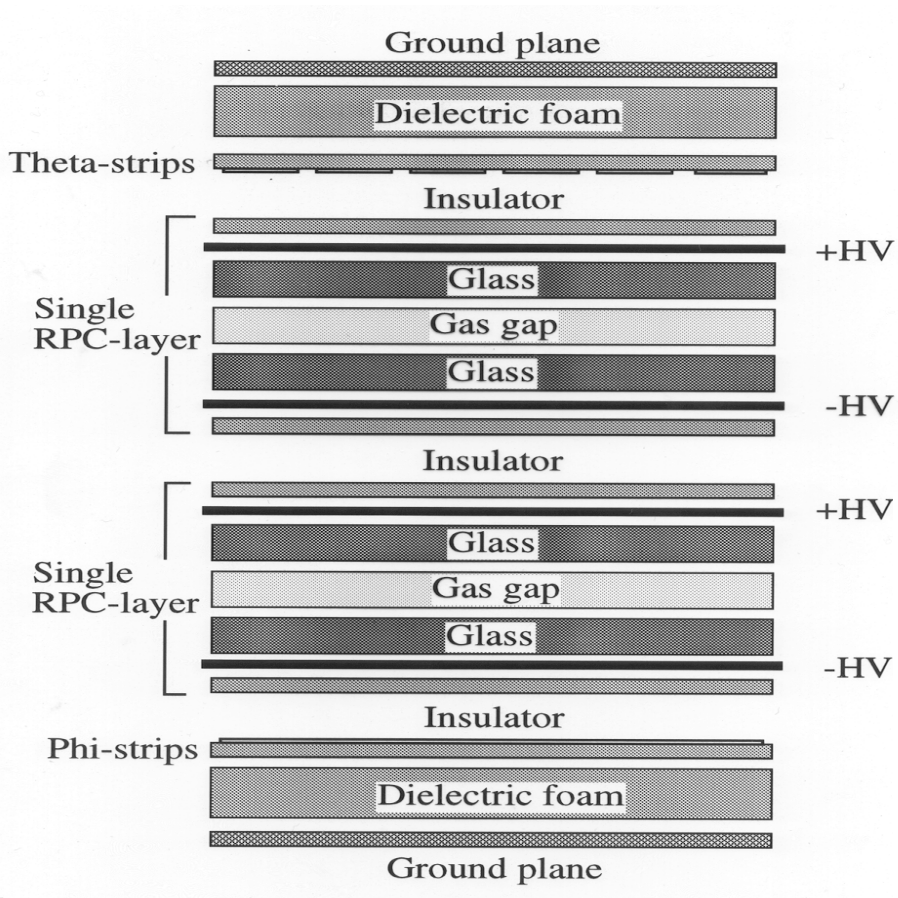
The RPC-based system:

- Muon and K_L identification
- Instrumented iron flux return with 15 (14) detecting layers in the barrel (end caps)
- 2200 m^2 of RPCs in total.

Pattern recognition:

- Cluster building
- Association of extrapolated charged tracks in the drift chamber to the clusters
- Cluster identified as K_L if not associated
- Computation of muon likelihood based on iron penetration and deviation of the measured hits

Belle RPCs

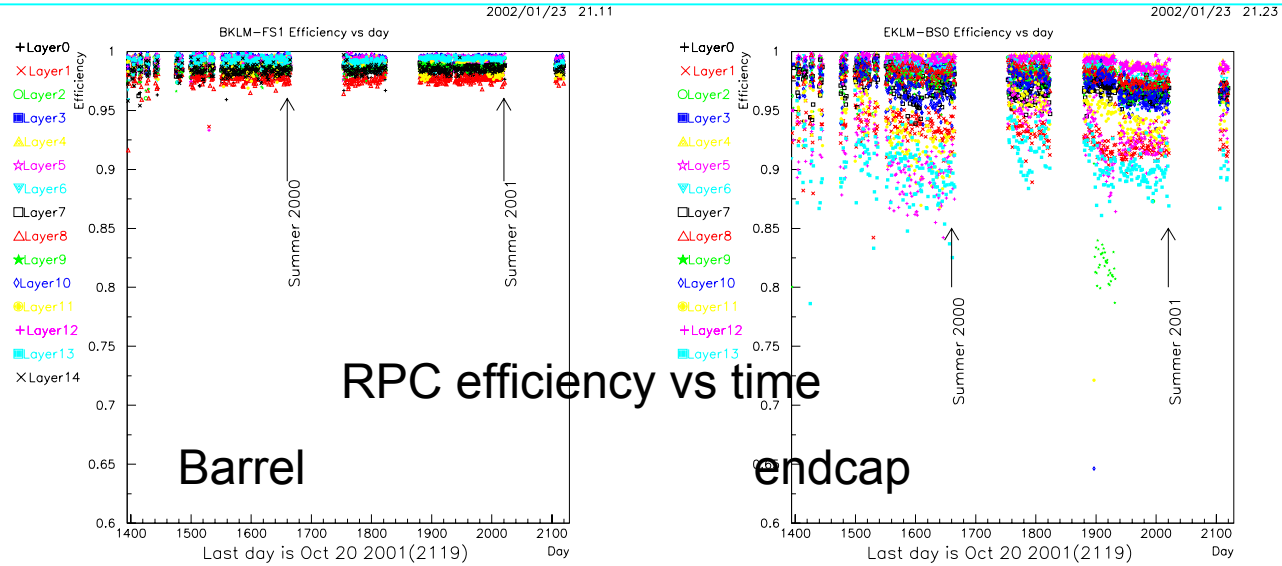


The detectors:

- Double gap (2 mm). Non-overlapping spacers
- Streamer mode
- Gas: 30% Ar + 62% $C_2H_2F_4$ + 8% C_4H_{10}
- Float glass non-oiled electrodes ($10^{12} \div 10^{13}$ Ωcm)
- Two dimensional strip readout

- **June 1998: soon after installation observation of increase in dark current and efficiency drop. Operation of the detectors was immediately halted. Water vapor had permeated the long polyethylene tubing (HF production).**
- **March 1999: after having replaced tubing and dried the detectors, the dark currents were back to initial values and efficiencies almost restored.**
- **Overall, the detectors have behaved well so far**

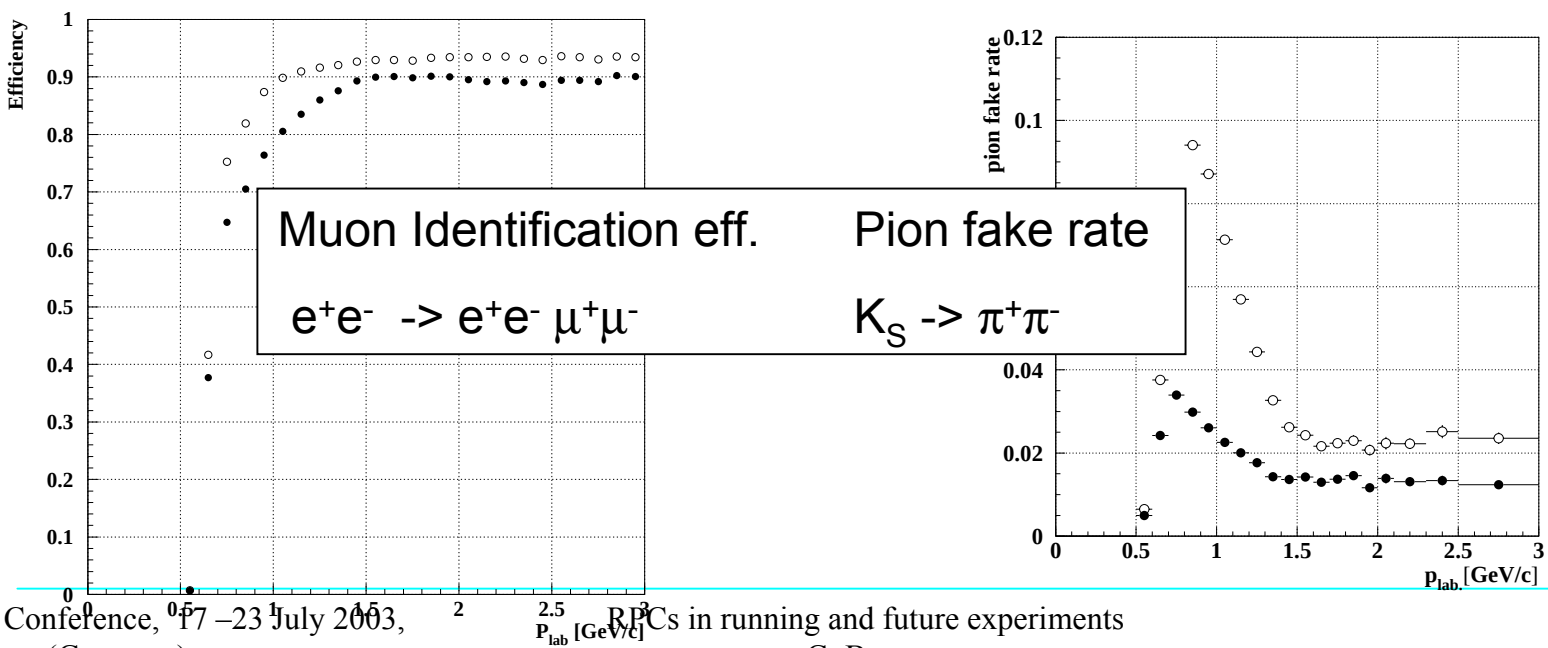
BELLE RPC performance



RPC efficiency vs time

Barrel

endcap



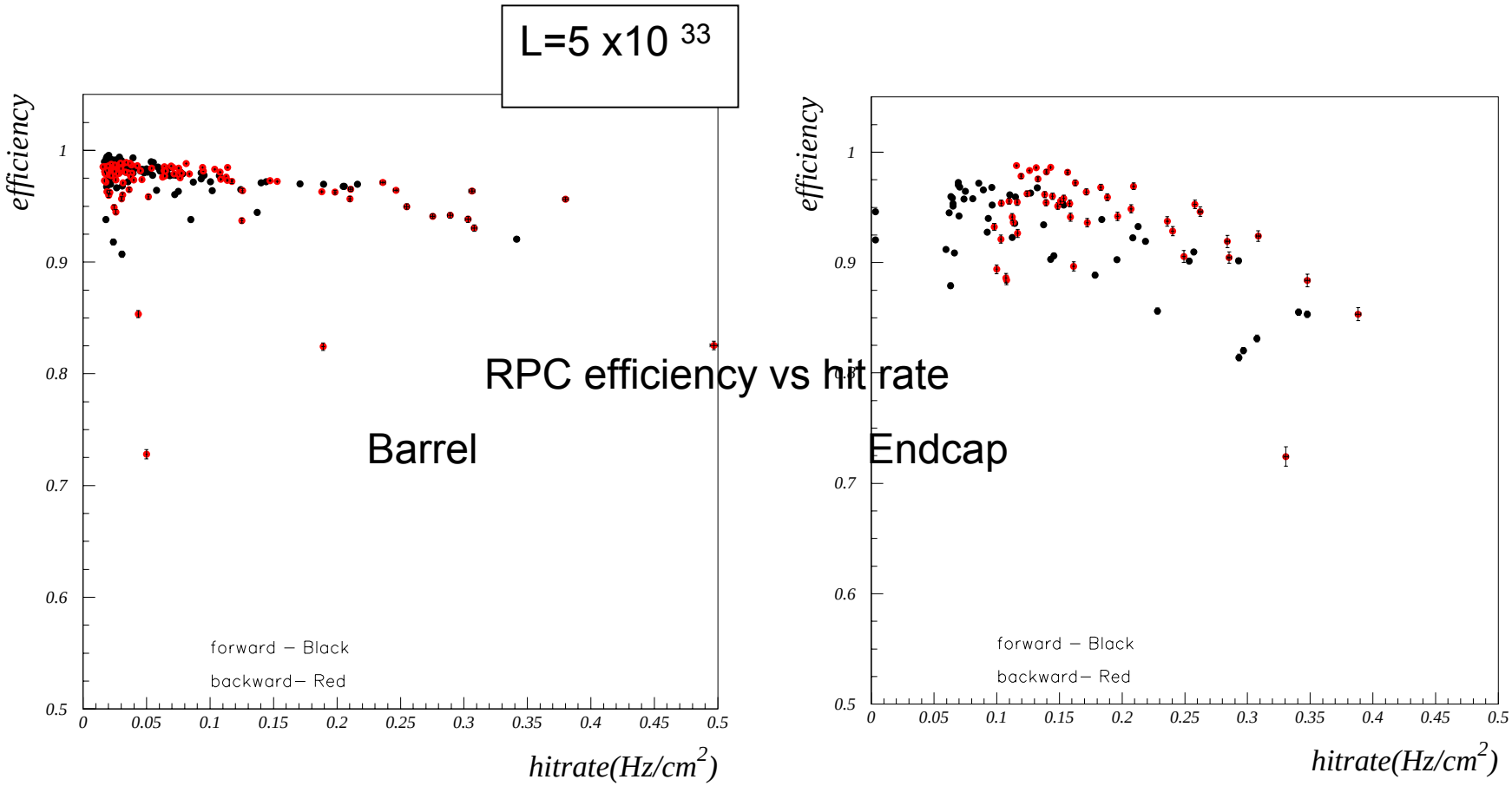
Muon Identification eff.

$e^+e^- \rightarrow e^+e^- \mu^+\mu^-$

Pion fake rate

$K_S \rightarrow \pi^+\pi^-$

Issue: rate capability



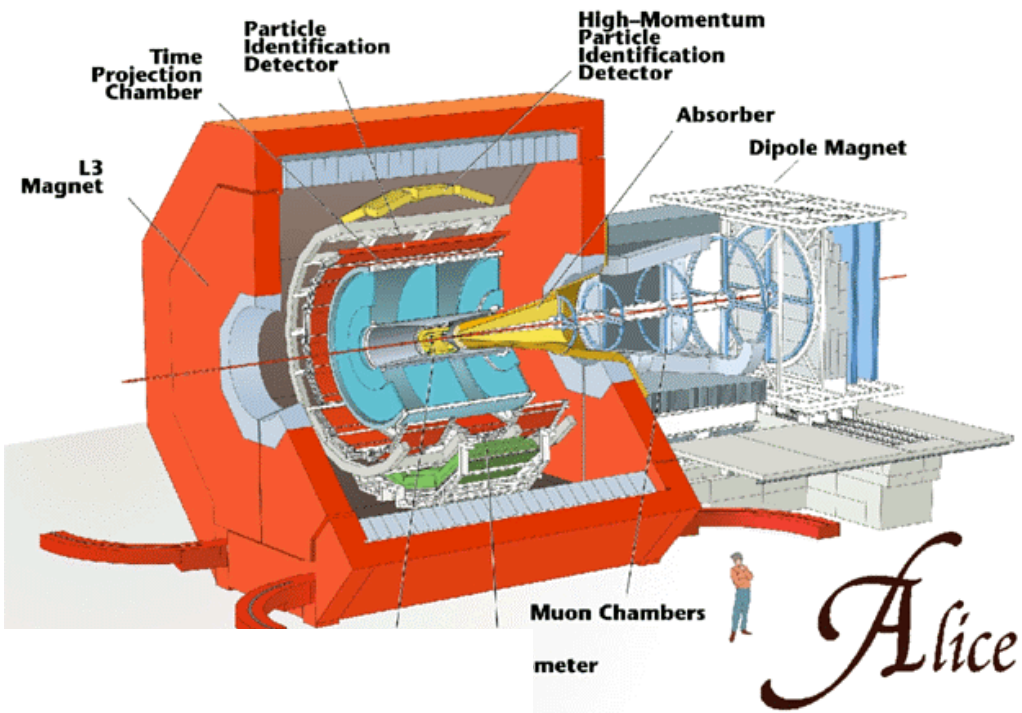
RPC efficiency vs hit rate

In view of the progressive increase in luminosity of KEKB, BELLE is thinking of alternatives to glass RPCs for better rate capability.

ALICE Trigger RPC

ALICE:

- 4 stations , 50 m2 , rates<100Hz/cm2, very easy access to the detectors.
- streamer mode
- single gap, oiled bakelite. res.:$3x10^9$ Ωcm,
- gas:49% Ar + 40% $C_2H_2F_4$ + 7% C_4H_{10} + 1% SF_6

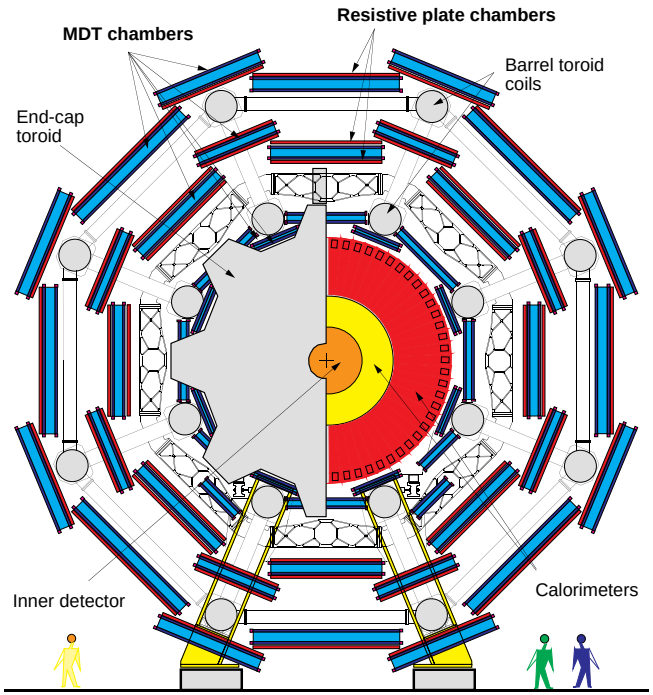


SF_6 electronegative gas.

It allows to reduce the average signal charge and

- in streamer mode: operate the detector at lower voltage in streamer mode (**G. Aielli et al. NIM A 478**)
- in avalanche mode: larger streamer free efficiency plateau (**P. Camarri et al. NIM A 414**)

ATLAS RPCs

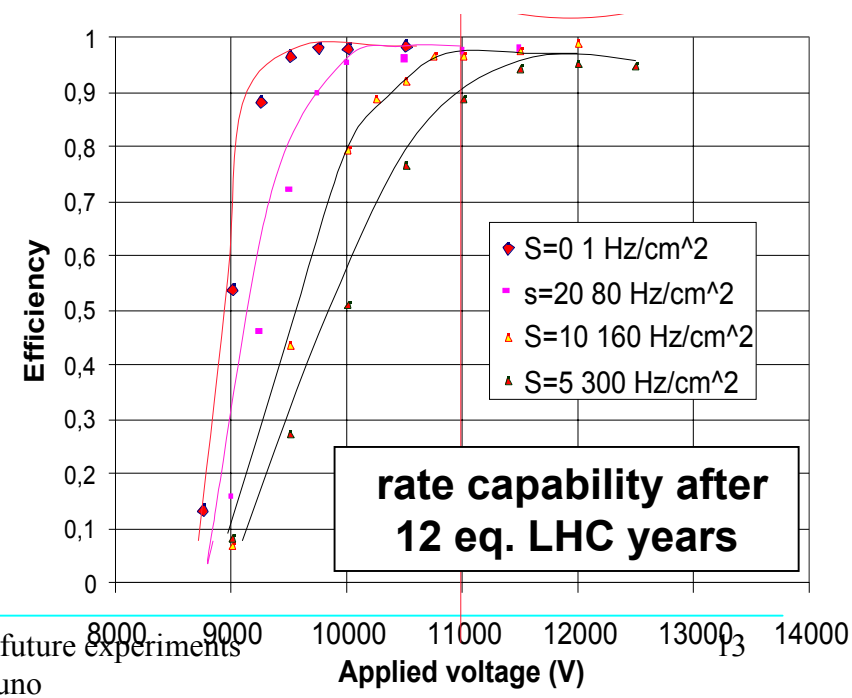


Sole Barrel L1 Muon Trigger. Based on hit coincidences (3/4 low pt, 4/6 high pt):

- 6 layers in 3 stations , 7000 m2 , rates:~10 Hz/cm2
- avalanche mode
- single gap, 96.7% $C_2H_2F_4$ + 3% C_4H_{10} + 0.3% SF_6
- oiled bakelite ~10^{10} Ωcm
- two dimensional strip readout

Aging tests on a prototype have shown that after 10 LHC years the total detector resistance increased by 1 order of magnitude. Part of it can be recovered with new graphite coat.

G. Aielli et al. NIM A 478

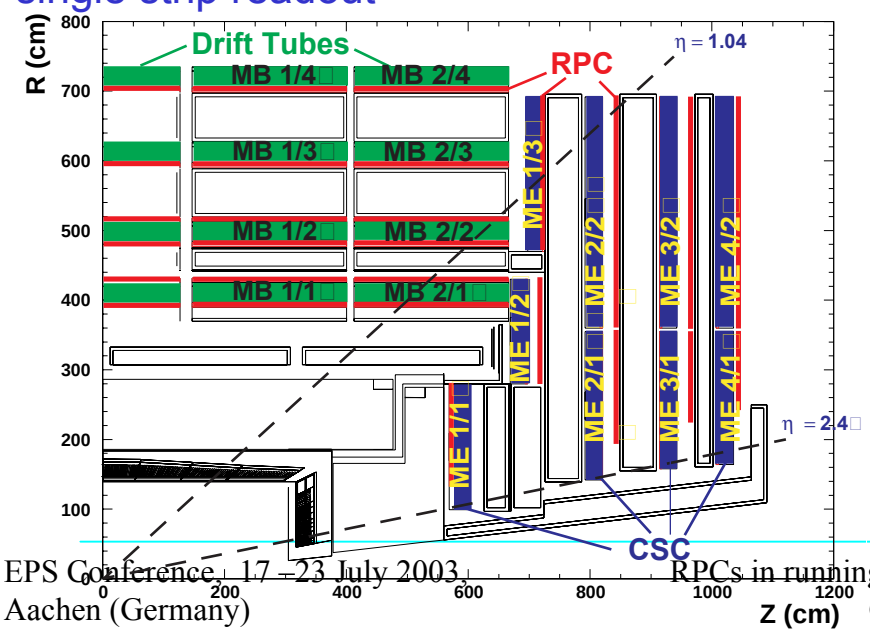


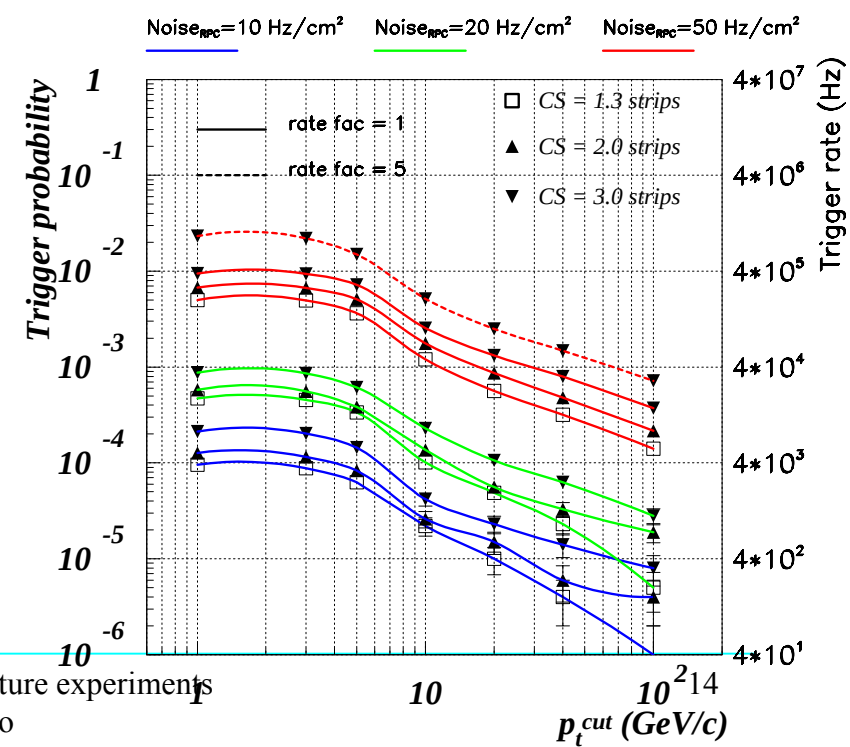
CMS RPC

One of the two Level 1 trigger systems. Based on 3/4 (4/6 where possible) plane coincidences

- 6000 m^2 , rates:1 (barrel)÷300 (endcap)Hz/cm^2
- avalanche mode
- double gap, 96% $C_2H_2F_4$ + 3.5% C_4H_{10} + 0.5% SF_6
- bakelite ~10^{10} Ωcm. Oiled up to |η|<1.6. Non oiled in 1.6<|η|<2.1
- single strip readout

CMS had started with non-oiled RPCs everywhere. Too high noise rates have obliged the collaboration to decide for oiling chambers up to |η|<1.6





STAR and ALICE TOFs

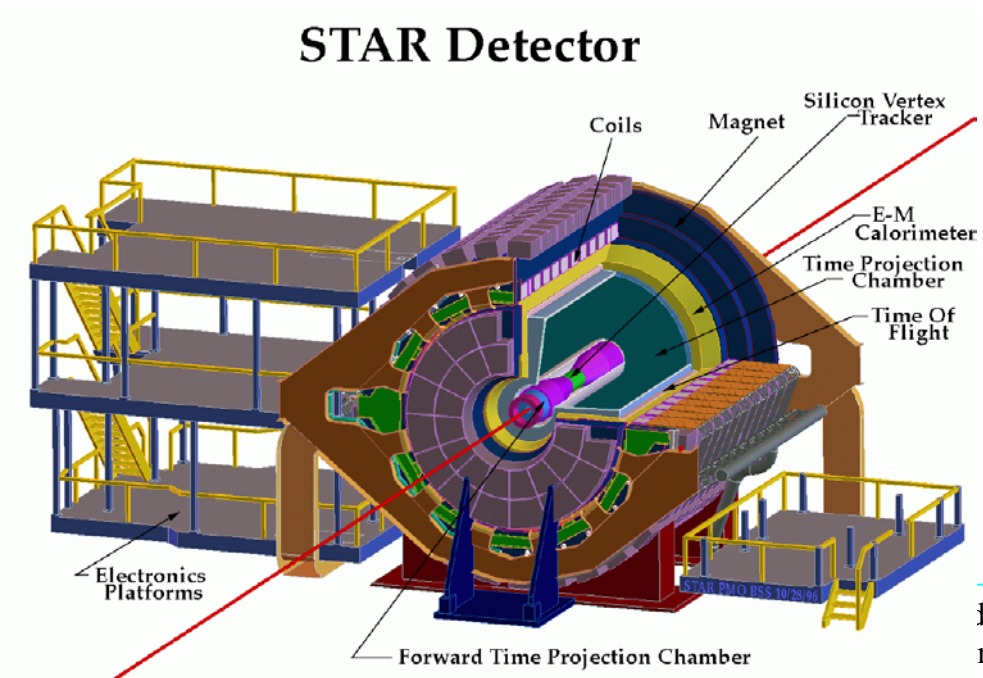
Time Of Flight system for the identification of e, π, K, p up to ~2.5 GeV. requirements:

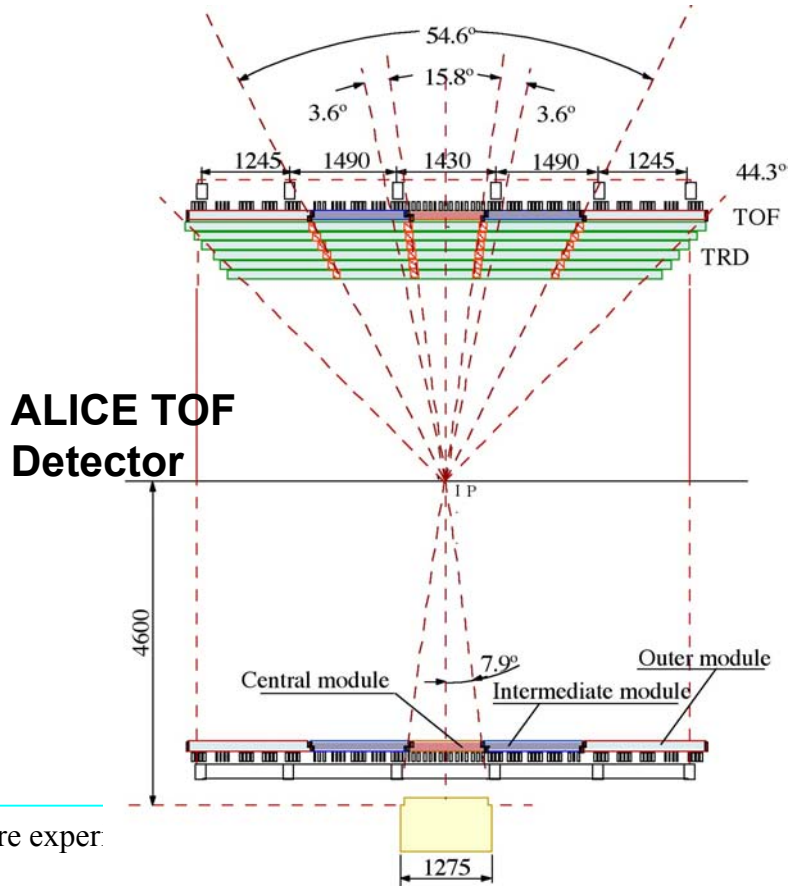
- occupancy 10%-15%
- rate capability up to 200 Hz/cm2
- time resolution better than 80 ps
- operation in a 0.5(S) 0.2(A) T magnetic field

The RPC-based proposed system:

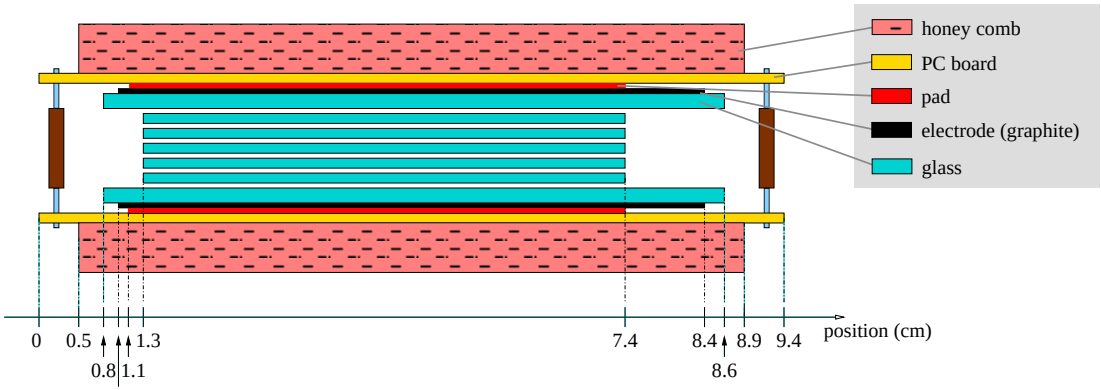
STAR: coverage up to |η|<1 , 50 m^2 of MRPCs in total.

ALICE: coverage up to |η|<0.9 , 160 m^2 of MRPCs in total.



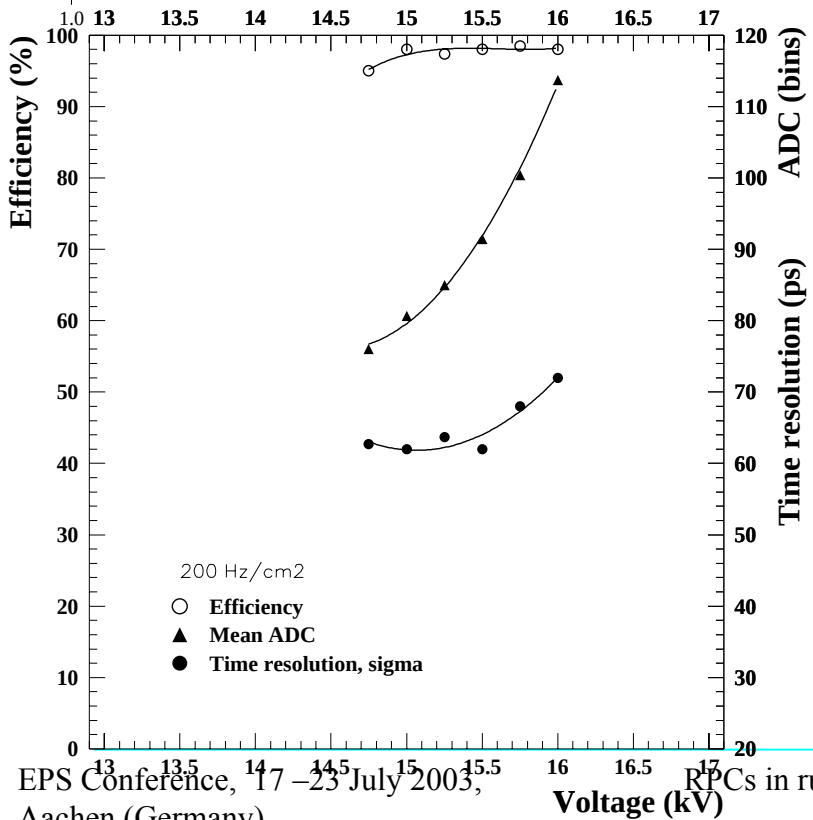


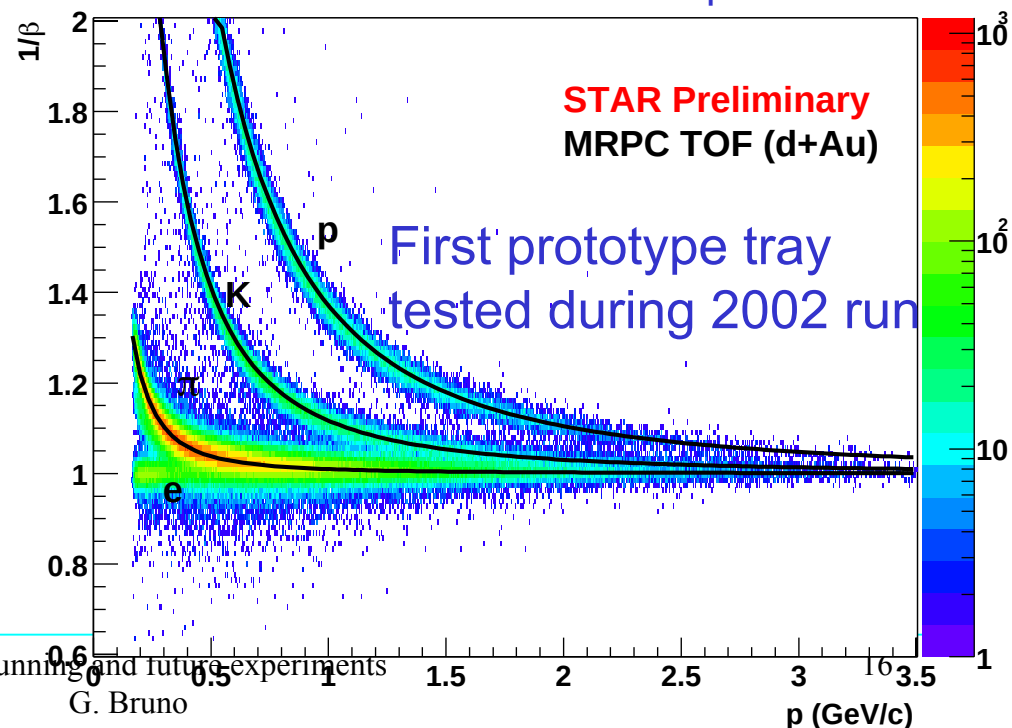
STAR MRPC performance



The detectors:

- 5-gaps MRPC.
- gap width = 220 μm
- Proportional mode
- Gas: 90% $C_2H_2F_4$ + 5% C_4H_{10}
- Glass electrodes ~500 μm thick (~10^{13} Ωcm)
- Readout: 3.1 x 6.5 cm^2 pads





First prototype tray tested during 2002 run

Summary and conclusions

- BaBar oiled bakelite RPCs behavior has raised serious aging issues, some of which are not yet fully understood to date
  - Major concern for the LHC experiments
- Belle glass RPCs have been behaving relatively well, but inadequate for detecting rates >> 1 Hz/cm^2
- LHC experiments need more R&D, although the present performance seems to be acceptable
- Multi Gap RPCs is the emerging technology for large Time Of Flight systems
  - Preliminary results on experiment runs are promising