R&D for RPC detectors

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Outline

- RPC with glass electrodes
- The R&D programme of the CaPiRe experiment
  - Large area glass RPC prototypes
  - Rate capability measurements
  - Long term stability studies
- Conclusions and outlook

RPC with glass electrodes

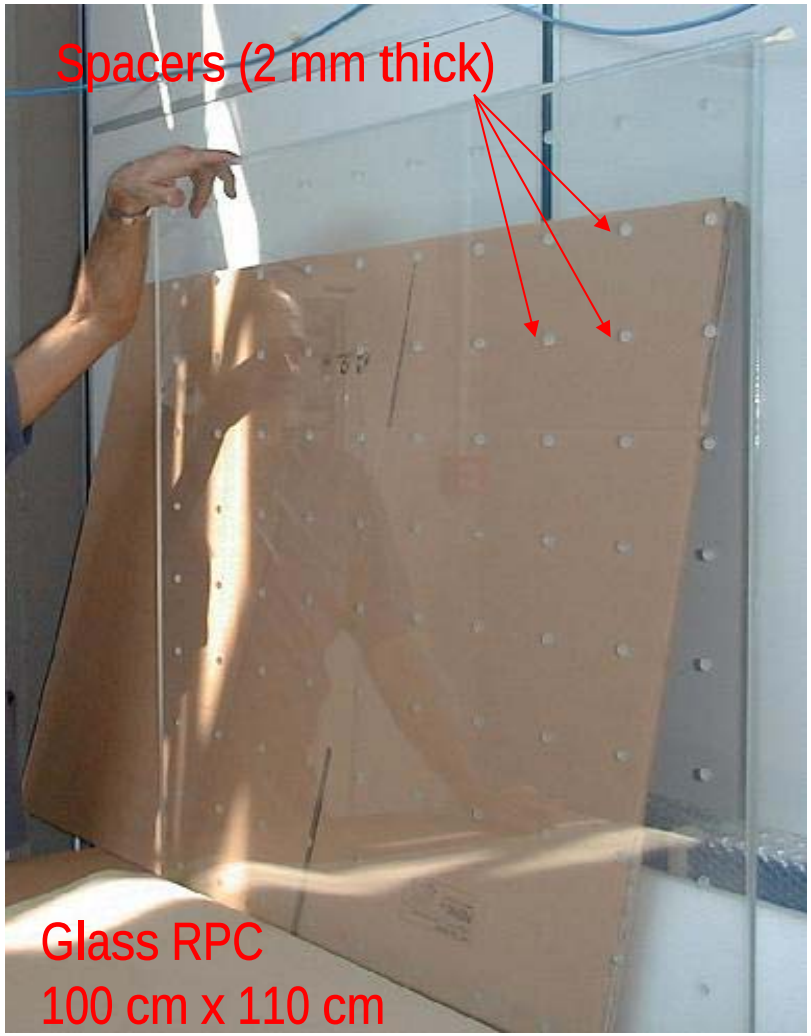
- Advantages of glass electrodes
  - high electrode planarity (*float* glass)
  - high stability of the electrode resistivity
  - Relatively inexpensive and commercially available
  - One successful application on large scale (~2000 m^2) at colliders (BELLE experiment)
- Disadvantages
  - high volume resistivity (limited rate capability)
  - absence of industrial standards for mass production

Motivations for CaPiRe

CaPiRe R&D programme

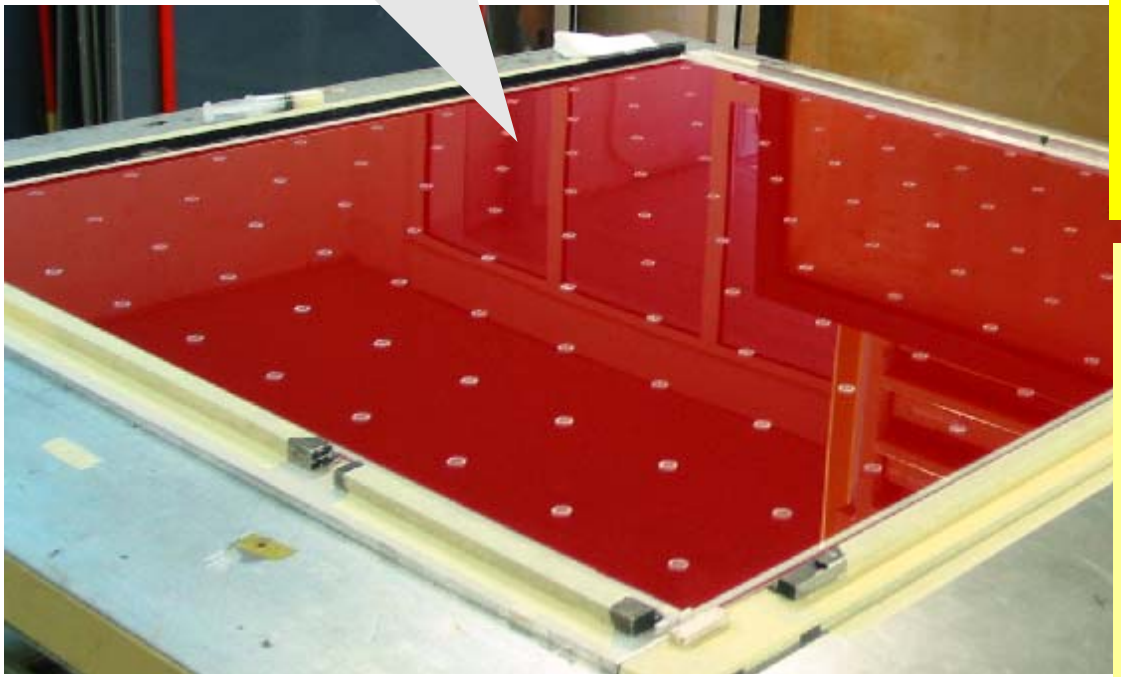
- Design and engineering of large area glass RPC prototypes suited for mass production
  - Test industrial procedures for detector assembly
  - Adoption of techniques derived from glass industry
  - Test prototypes performance and reproducibility
- Search for electrode materials and/or working conditions to overcome the rate capability limitations of glass RPC

Glass RPC prototypes



- RPC prototypes produced in collaboration with General Tecnica:
  - 100 cm x 110 cm surface
  - 2 mm gap
  - 2 mm glass
    (ρ_v=3÷5 x 10^{12} Ωcm @ 25 ºC)
- Assembly procedure and materials for spacers, supports and gas connectors identical to bakelite RPC produced by GT

Silk Screen Printing



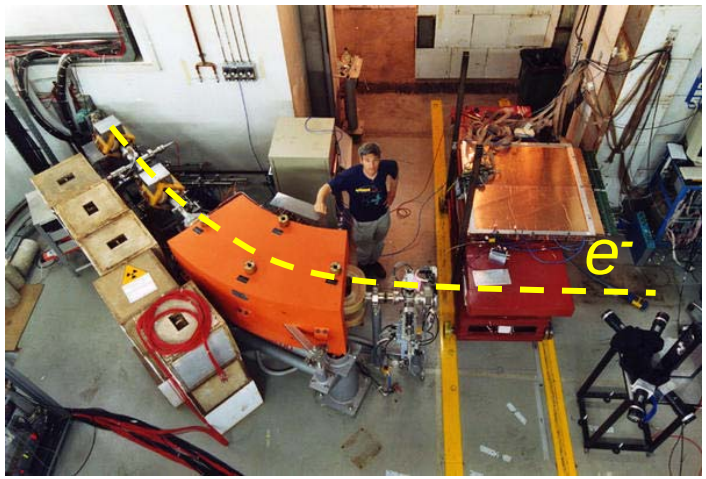
Resistive acrylic paint for electrical contacts deposited with silk screen printing technique

- Fast and reliable:
  - Up to 1000 m^2/day
  - Controllable and reproducible surface resistivity

G.C. Trinchero, A. Giuliano, P.Picchi, Nucl. Instr. and Meth. A 508 (2003) 102
M.Ambrosio et al. Nucl. Instr. and Meth. A 508 (2003) 98.

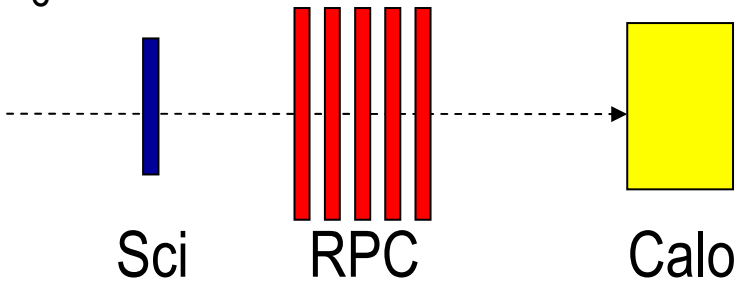
Rate capability studies

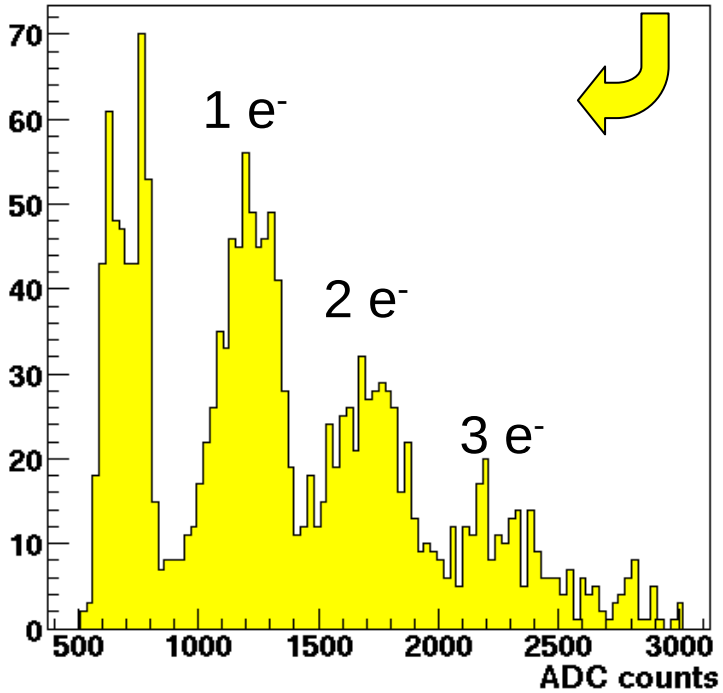
- Test Beam Facility @ LNF ideal bench for:
  - detector efficiency vs particle flux (rate capability)
  - aging maps
- BTF parameters:
  - e^- energy 50÷750 MeV
  - Repetition rate up to 49 Hz
  - Pulse duration 10 ns
  - Intensity $1 \div 10^{10}$ e^-/pulse



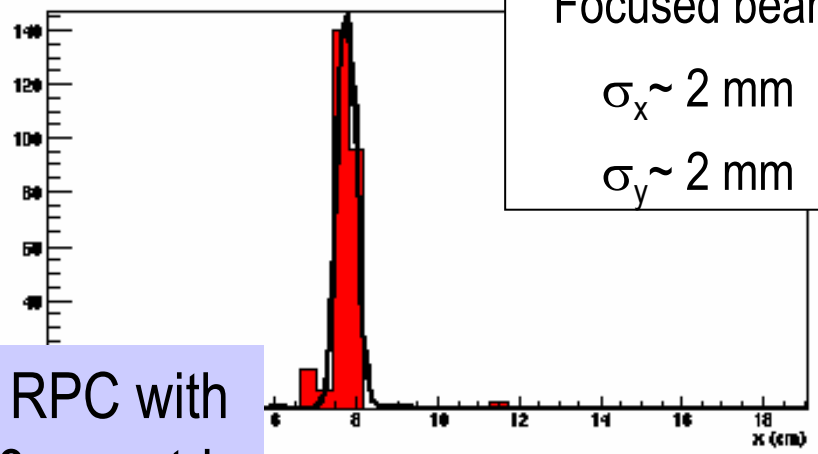
Setup at the BTF

E_{e-} = 500 MeV





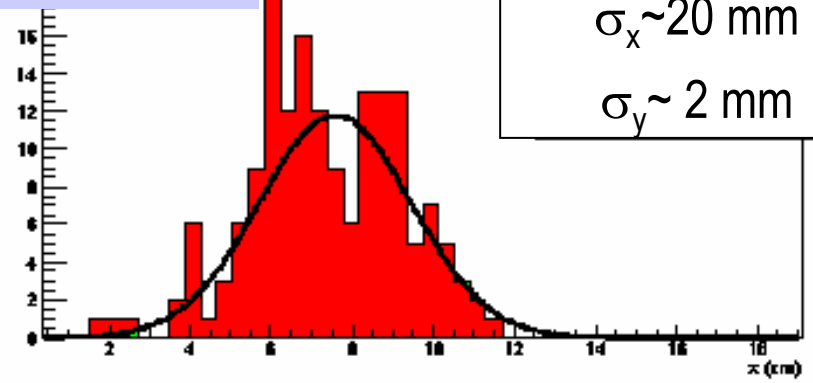
RPC with 8 mm strip pitch



Focused beam

σ_x~ 2 mm

σ_y~ 2 mm



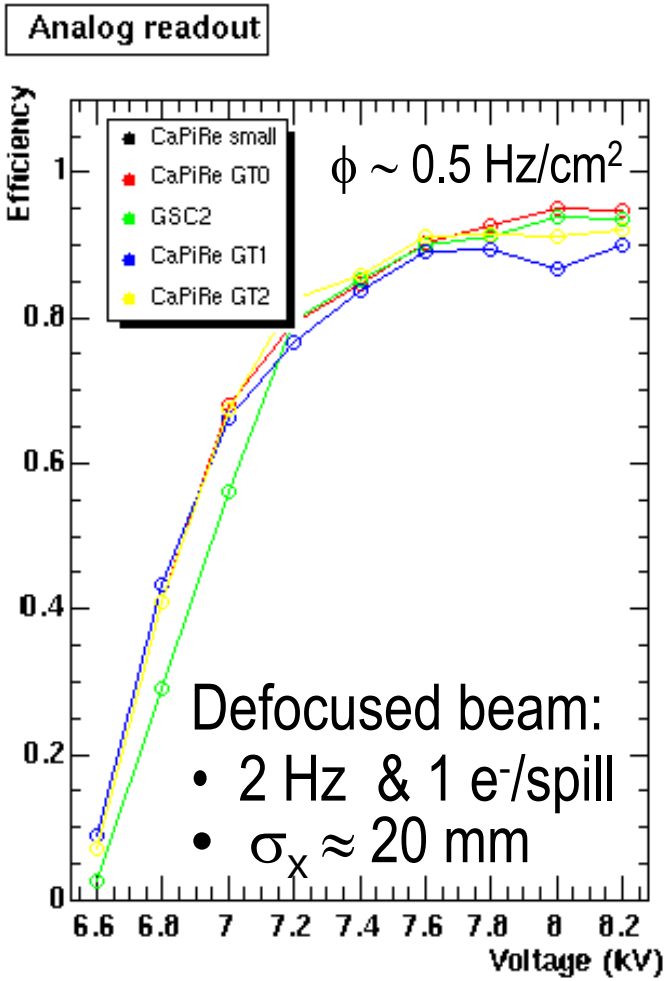
Defocused beam

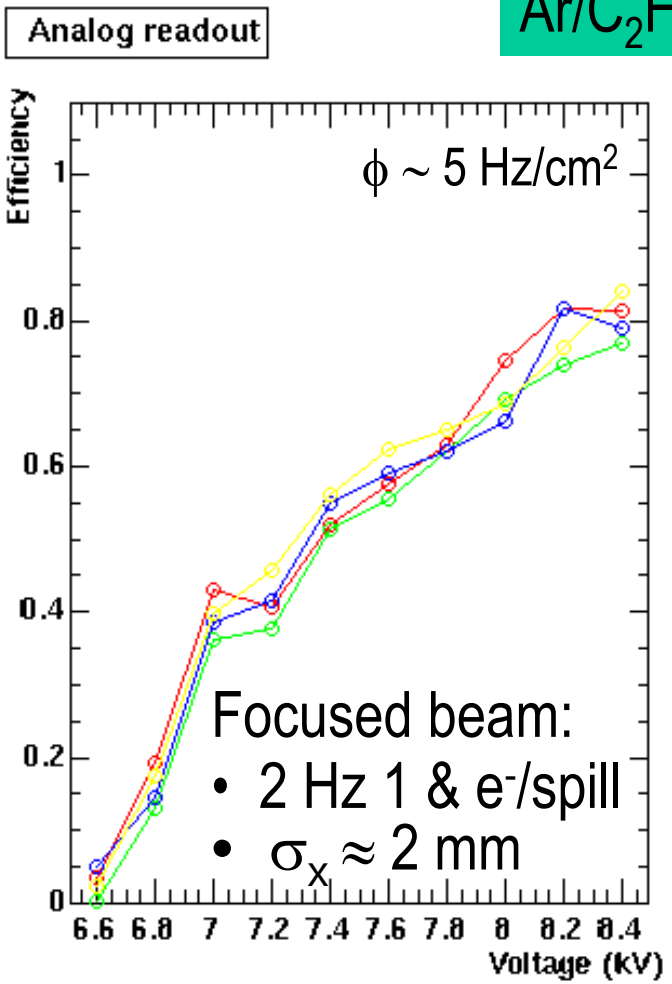
σ_x~20 mm

σ_y~ 2 mm

Efficiency Plateau

$Ar/C_2H_2F_4/i\text{-}C_4H_{10}=48/48/4$



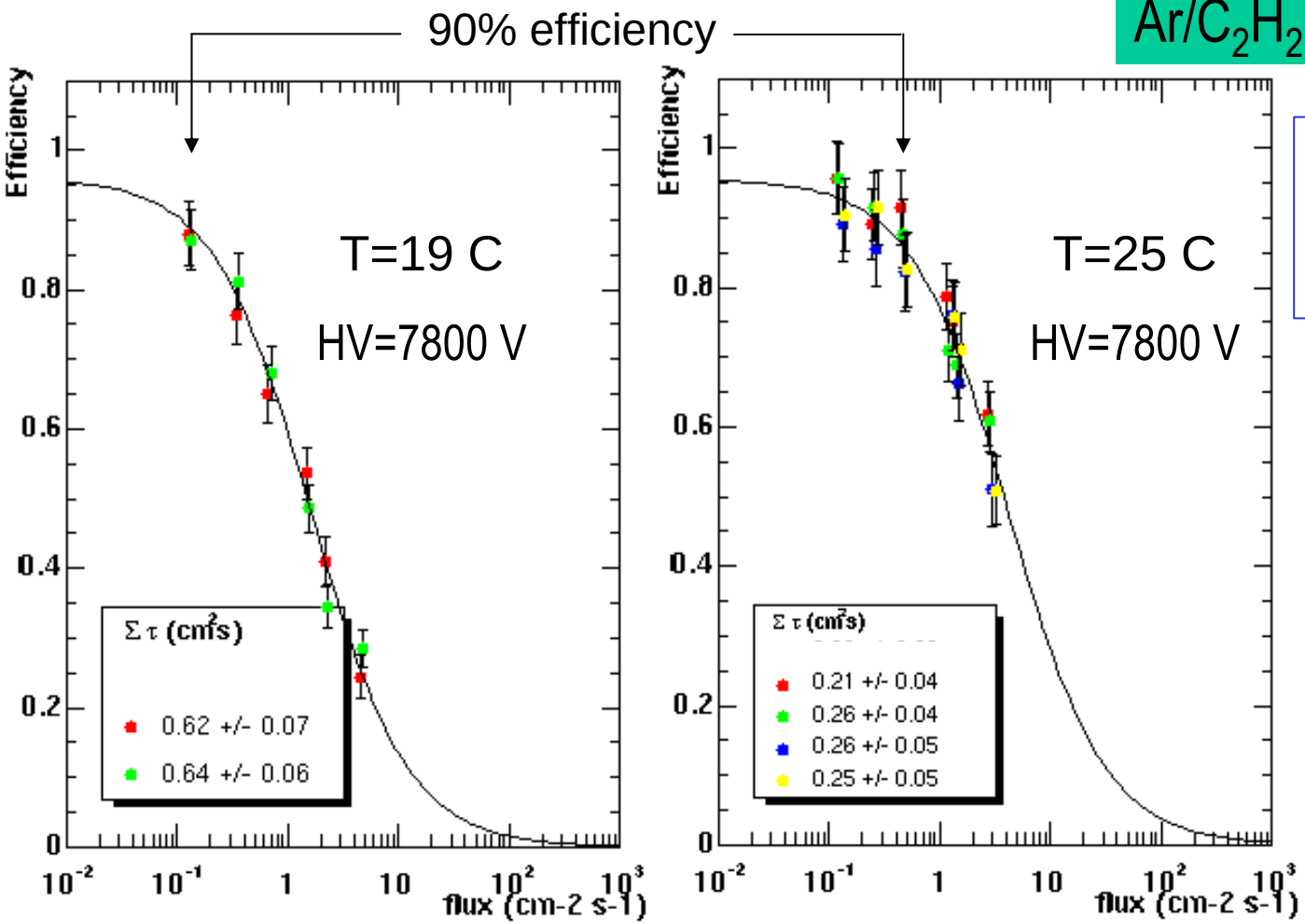


$$\tau_d = -\tau \ln\left(1 - \frac{V_{thresh}}{V_0}\right)$$

GT1 and GT2 just out of the factory and with HV on since one day!

Efficiency vs Rate I

$Ar/C_2H_2F_4/i\text{-}C_4H_{10}=48/48/4$



$$\varepsilon = \frac{\varepsilon_0}{1+\varepsilon_0 \phi \, \Sigma \tau}$$

ε_o = intrinsic eff.

ϕ = particle flux

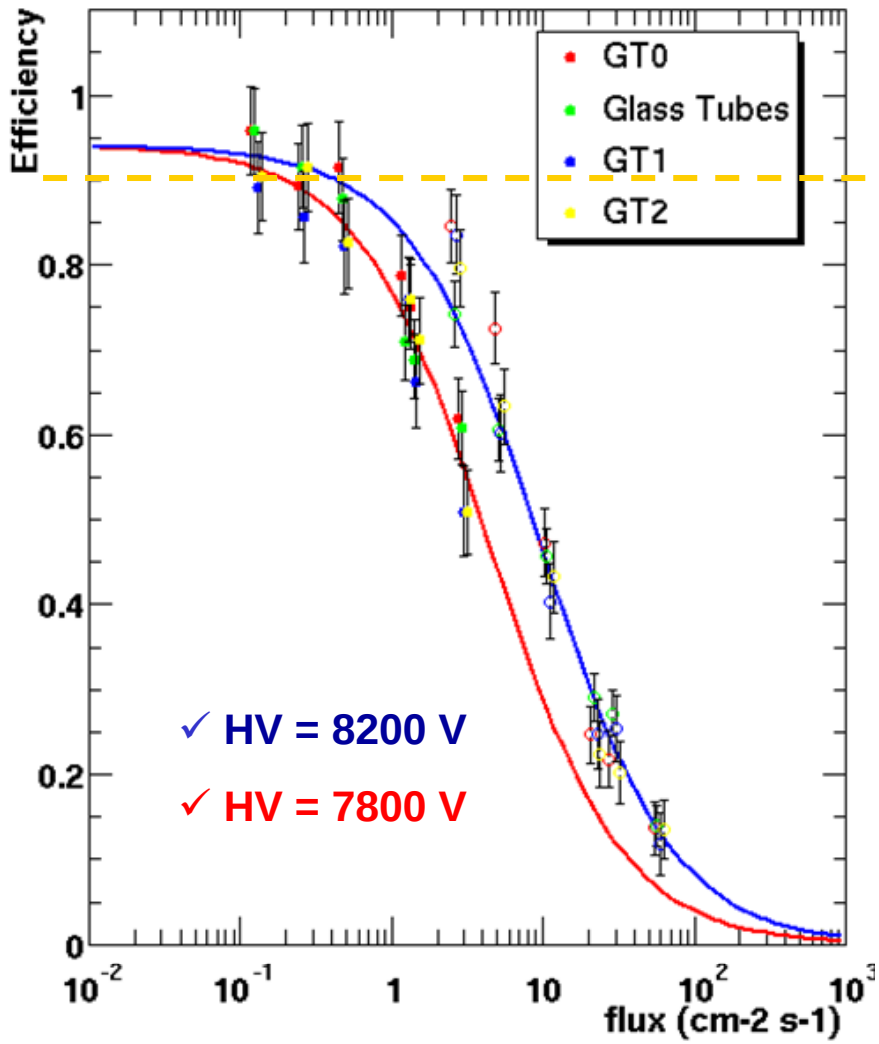
Σ = spark dim.

τ_d = dead time

$$\div \rho(T_0) e^{-0.11\Delta T}$$

volume resistivity

Efficiency vs Rate II

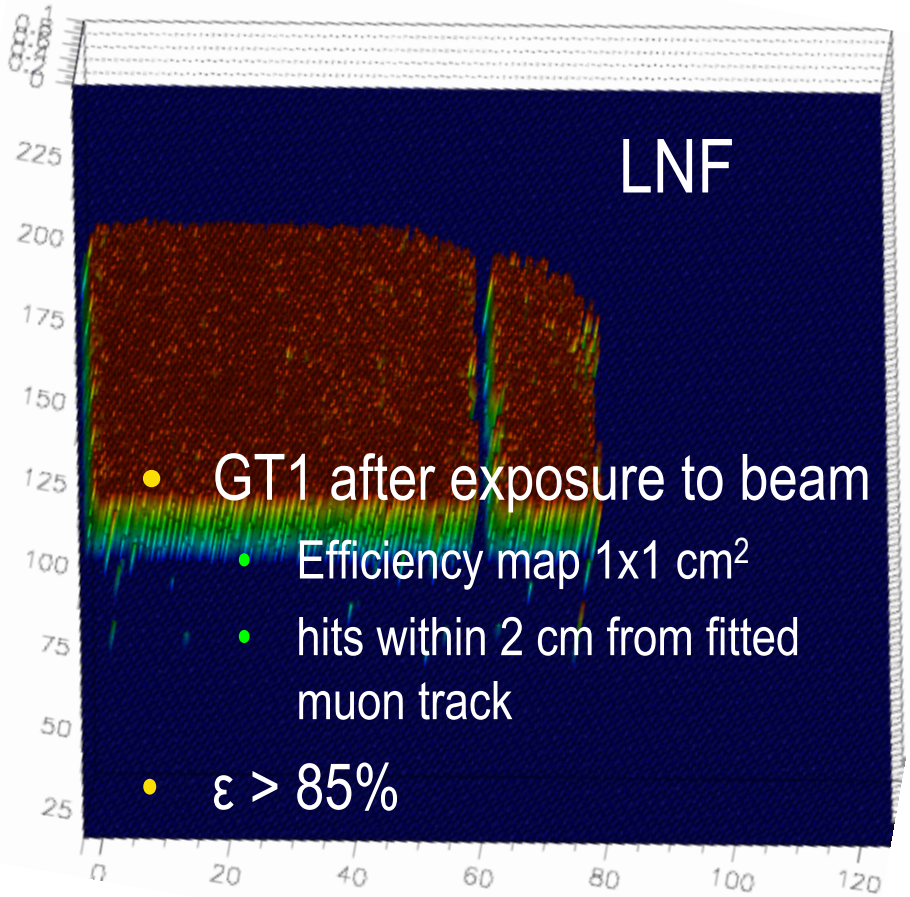


$Ar/C_2H_2F_4/i\text{-}C_4H_{10}=48/48/4$

- 90% efficiency in streamer mode at 0.5 Hz/cm^2
  - Just about right for a muon detector at the Linear Collider
  - Higher voltages/temperatures increase the rate capability
- To further extend the rate capability:
  - Avalanche mode (gas gain reduction by ~100)
  - Low resistivity glass

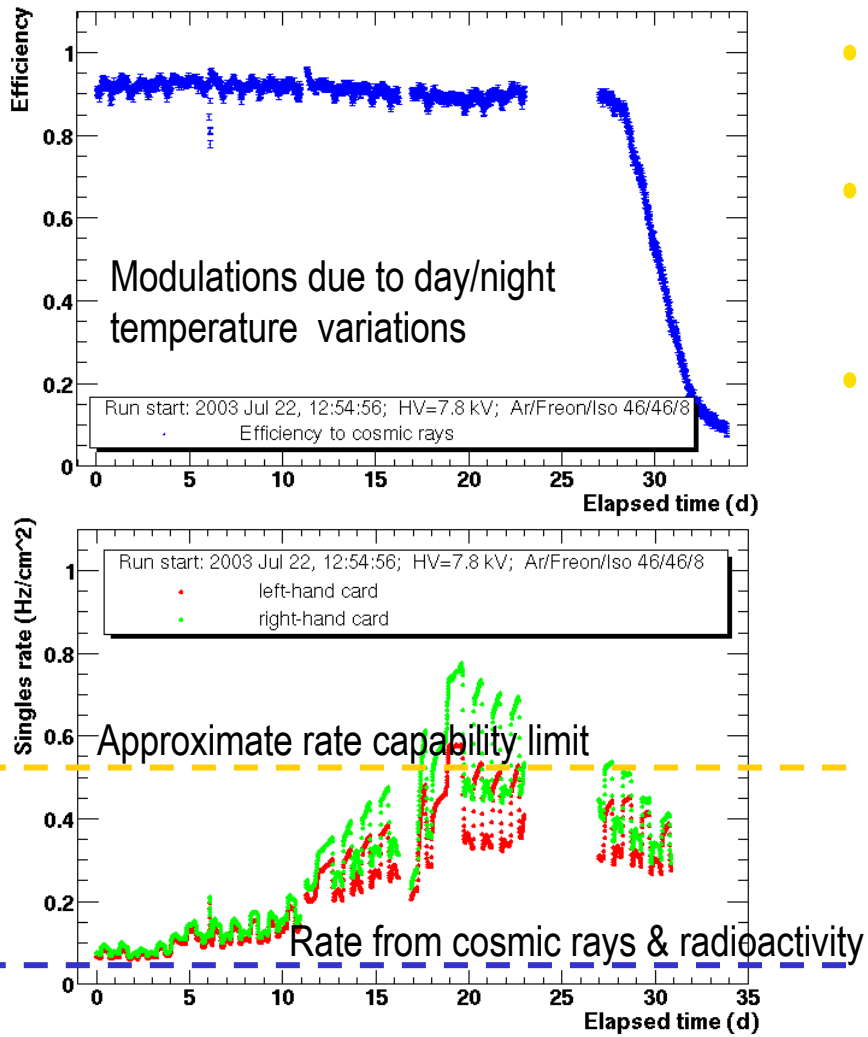
Long term (in)stability

- Continuous monitoring with cosmic rays
  - RPC arrays at LNF and Milano Bicocca
    - Efficiency and chamber noise (singles) maps
- All the chambers tested in 2003 have shown a significant efficiency drop



- GT1 after exposure to beam
  - Efficiency map 1x1 cm^2
  - hits within 2 cm from fitted muon track
- $\varepsilon > 85\%$

An example

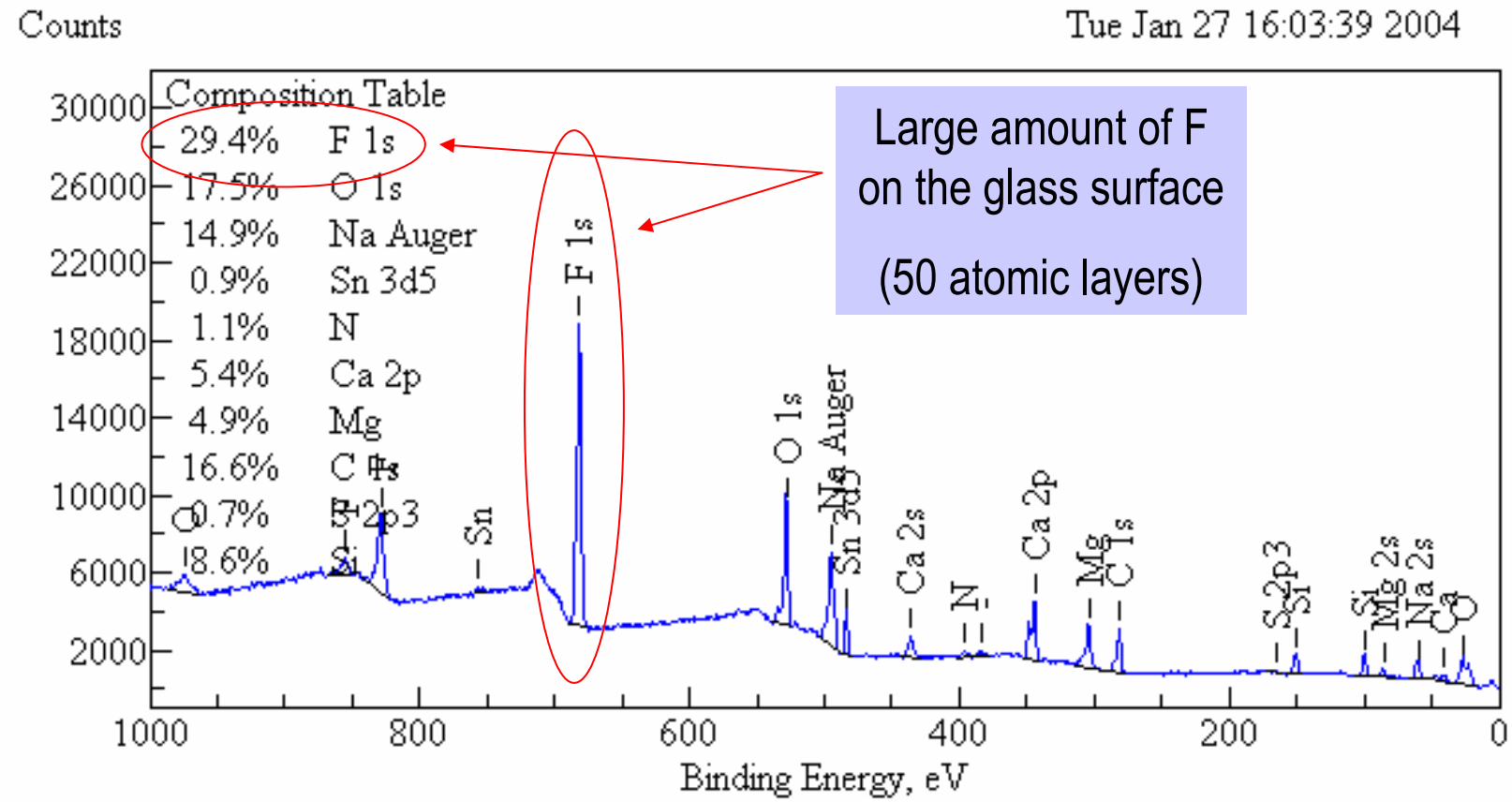


- Fast efficiency drop after a few weeks of operation
- Steady increase of the singles rate and of the RPC dark current
- Possible interpretation
  - Wet gas problem like in BELLE (overlooked)
    - sparks + Freon → HF (chemical attack of the glass surface)
    - H_2O modifies the surface conductivity
  - Water content > 200-300 ppm measured in both the set-up (permeability of plastic tubes)

Preliminary ESCA analysis of damaged electrodes

Courtesy of C.Bianchi & F.Ragaini,
Dipartimento di Chimica, Università di Milano

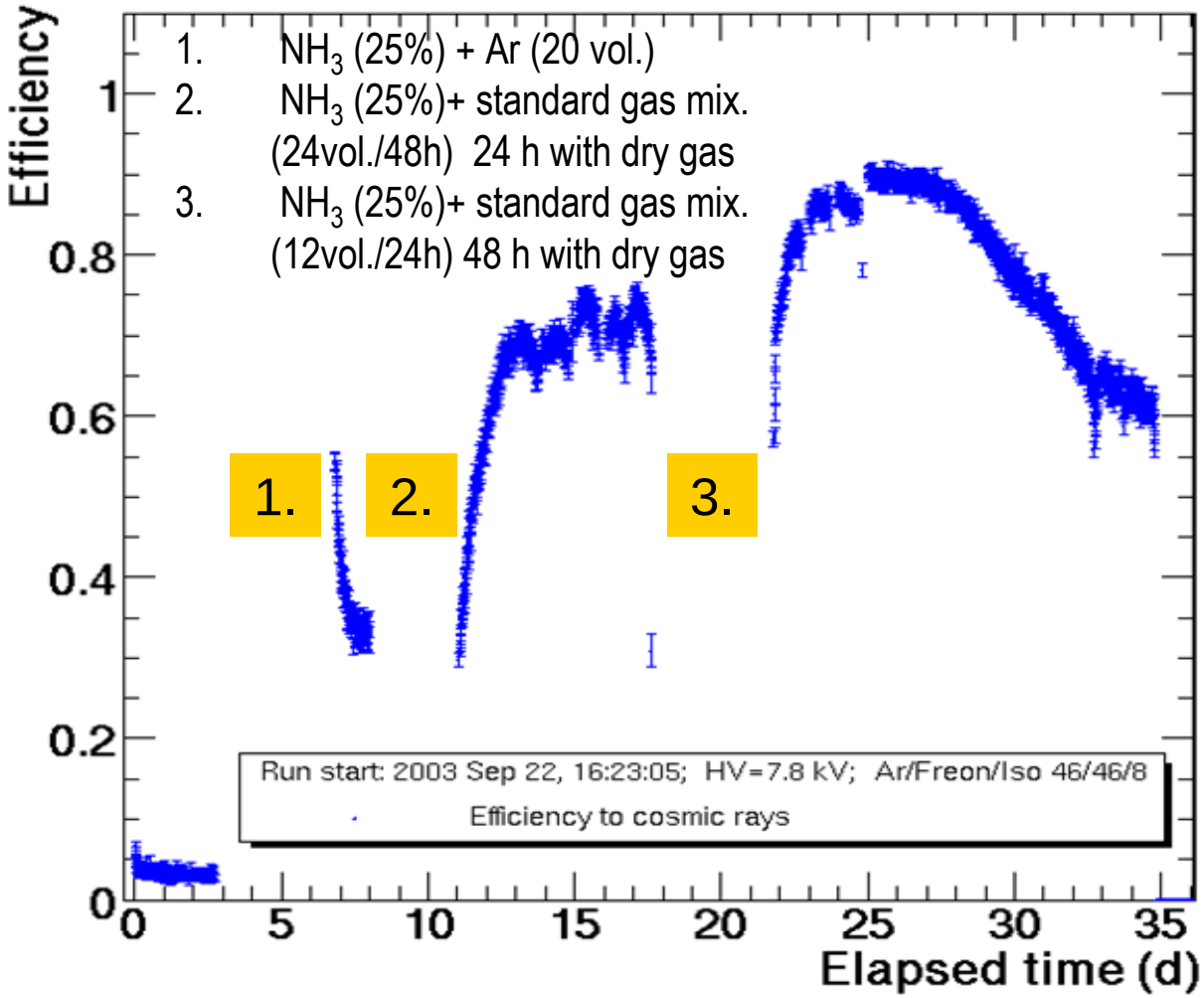
System Name: XI ASCII
Pass Energy: 156.51 eV
Charge Bias: 5.0 eV
Tue Jan 27 16:03:39 2004



Large amount of F on the glass surface

(50 atomic layers)

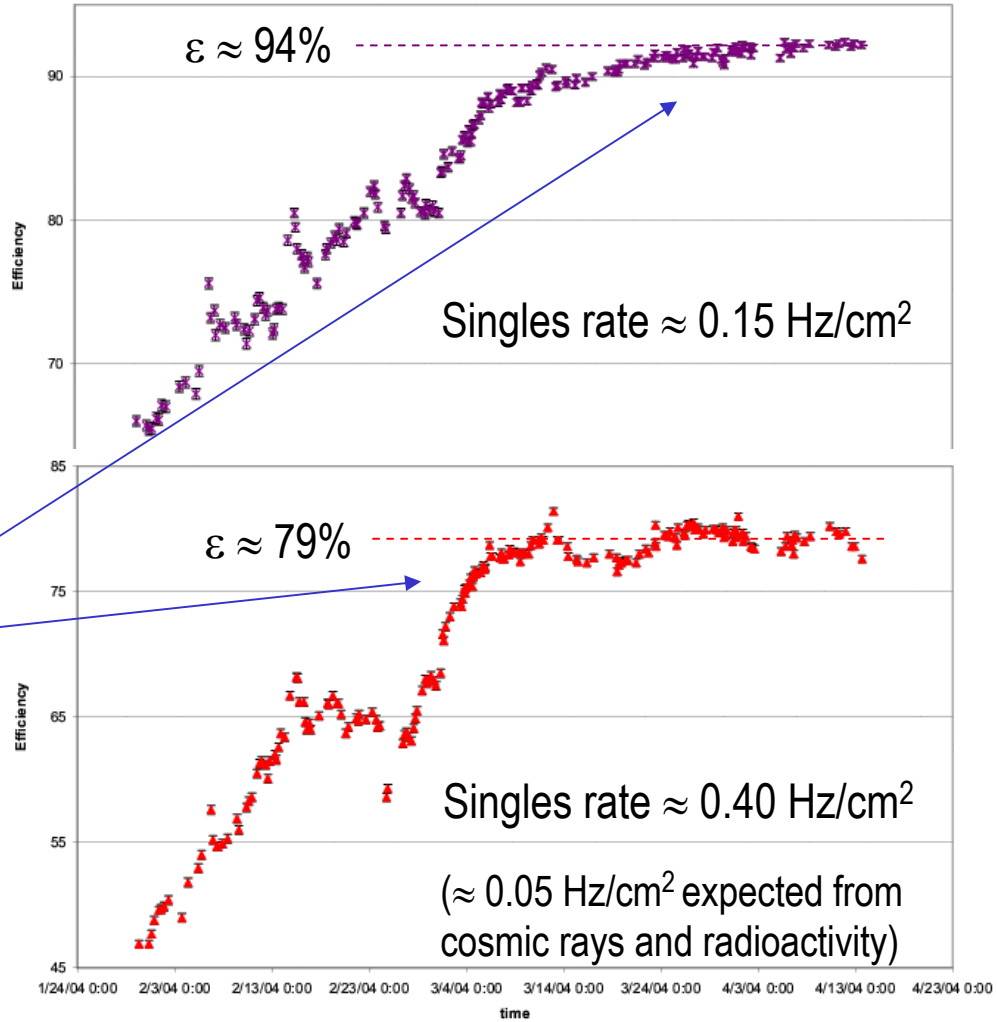
Alchemy (bubbling through ammonia)



- Suggested procedure to recover loosely damaged chambers
  - H.Sakai et al. NIM A484,153
  - C.Gustavino et al, RPC 2003 Conference
- Successful temporary recovery of a “dead” camber
- Need further tests
- Not for stable running

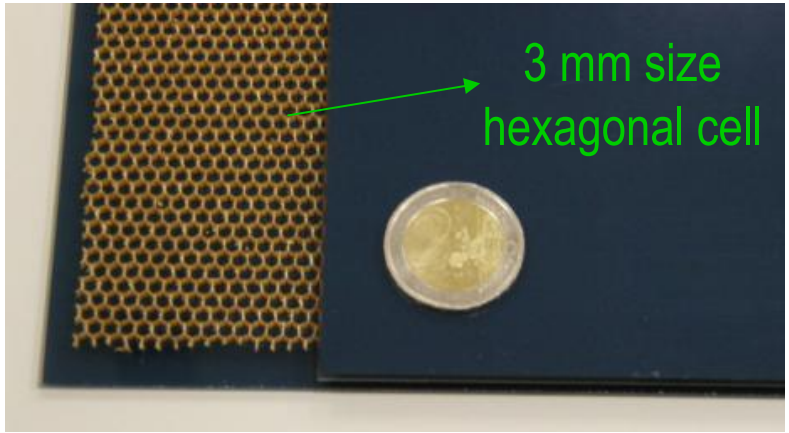
A basic solution

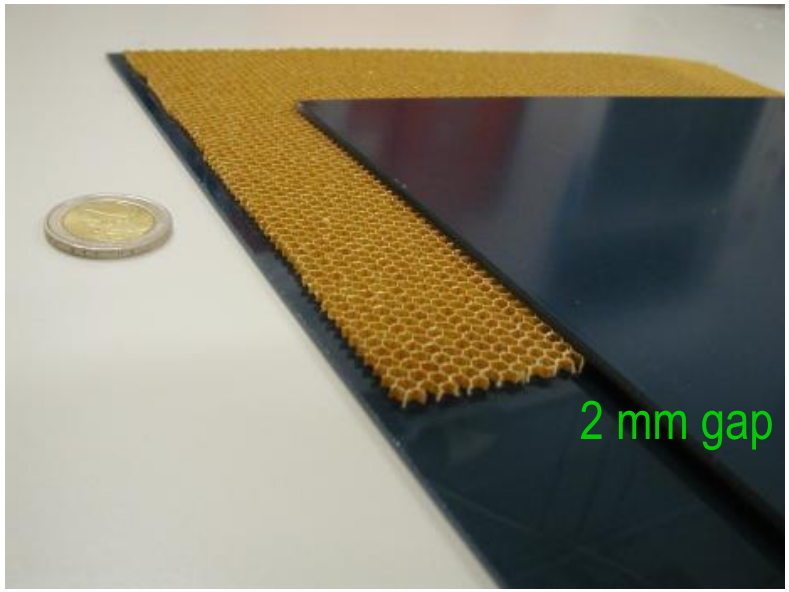
- Stainless steel/copper tubing
  - dry gas (H_2O<50 ppm)
- More quenched gas mix ($Ar/C_2H_2F_4/i\text{-}C_4H_{10}$=27/64/9)
  - lower charge in the spark (catalyst of HF formation)
- (Partial) recovery of damaged chambers
- New chambers under study
  - → Test the chamber lifetime



Another way out?

- Mechanical quenching
  - Honeycomb spacer blind to visible and UV photons and to electrons
  - Use of freon-less gas mixes
  - Spark dimensions determined by the cell size
    - Rate capability tuneable only through the electrode resistivity
  - Under study





Conclusions and outlook

- Large area glass RPC prototypes have been produced in collaboration with industry
  - Good efficiency (when new)
  - Somewhat noisy
- Maximum rate capability in streamer mode around 0.5 Hz/cm^2 with commercial float glass
  - Just about right for muon detectors at the Linear Collider
  - Further studies are planned to extend the rate capability (avalanche mode and conductive glasses)
- Instability problems related to water contamination
  - Running with dry gas (chamber lifetime?)
  - Recovery procedures?
  - Mechanically quenched RPC?