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 m²) 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
    \( \rho_v = 3 \pm 5 \times 10^{12} \, \Omega \text{cm} @ 25 ^\circ \text{C} \)

- 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 m²/day
  - Controllable and reproducible surface resistivity

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 $1\div10^{10}$ $e^-$/pulse
Setup at the BTF

$E_{e^-} = 500 \text{ MeV}$

Focused beam

- $\sigma_x \sim 2 \text{ mm}$
- $\sigma_y \sim 2 \text{ mm}$

Defocused beam

- $\sigma_x \sim 20 \text{ mm}$
- $\sigma_y \sim 2 \text{ mm}$

RPC with 8 mm strip pitch
Efficiency Plateau

Ar/C_2H_2F_4/i-C_4H_10 = 48/48/4

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

Defocused beam:
- 2 Hz & 1 e^-/spill
- \( \sigma_x \approx 20 \text{ mm} \)

Focused beam:
- 2 Hz 1 & e^-/spill
- \( \sigma_x \approx 2 \text{ mm} \)
Efficiency vs Rate I

\[ \varepsilon = \frac{\varepsilon_0}{1 + \varepsilon_0 \phi \Sigma \tau_d} \]

\( \varepsilon_0 \) = intrinsic eff.

\( \phi \) = particle flux

\( \Sigma \) = spark dim.

\( \tau_d \) = dead time

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

volume resistivity

Ar/C\textsubscript{2}H\textsubscript{2}F\textsubscript{4}/i-C\textsubscript{4}H\textsubscript{10} = 48/48/4

90% efficiency

T=19 C

HV=7800 V

T=25 C

HV=7800 V

\( \Sigma \tau \text{ (cm}^2\text{s}) \)

- 0.62 +/- 0.07
- 0.64 +/- 0.06

\( \Sigma \tau \text{ (cm}^2\text{s}) \)

- 0.21 +/- 0.04
- 0.26 +/- 0.04
- 0.26 +/- 0.05
- 0.25 +/- 0.05
90% efficiency in streamer mode at 0.5 Hz/cm²

- 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 cm²
      - hits within 2 cm from fitted muon track
      - e > 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)
  - $\text{H}_2\text{O}$ 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

Large amount of F on the glass surface (50 atomic layers)

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

1. $\text{NH}_3$ (25%) + Ar (20 vol.)
2. $\text{NH}_3$ (25%) + standard gas mix.
   (24vol./48h) 24 h with dry gas
3. $\text{NH}_3$ (25%) + standard gas mix.
   (12vol./24h) 48 h with dry gas

Run start: 2003 Sep 22, 16:23:05; HV=7.8 kV; Ar/Freon/Iso 46/46/3

Efficiency to cosmic rays
A basic solution

- Stainless steel/copper tubing
  - dry gas (H₂O<50 ppm)
- More quenched gas mix (Ar/C₂H₂F₄/i-C₄H₁₀=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

\[ \varepsilon \approx 94\% \]
\[ \varepsilon \approx 79\% \]

Singles rate ≈ 0.15 Hz/cm²

(≈ 0.05 Hz/cm² expected from cosmic rays and radioactivity)
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

3 mm size hexagonal cell
2 mm gap
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/cm² 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?