Comments on the gas system

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- Issues of scale
- What gas mix?
- Summary

NuMI Off-axis Experiment Detector Workshop
SLAC, Jan 24-26, 2003

The Scale – crude assumptions

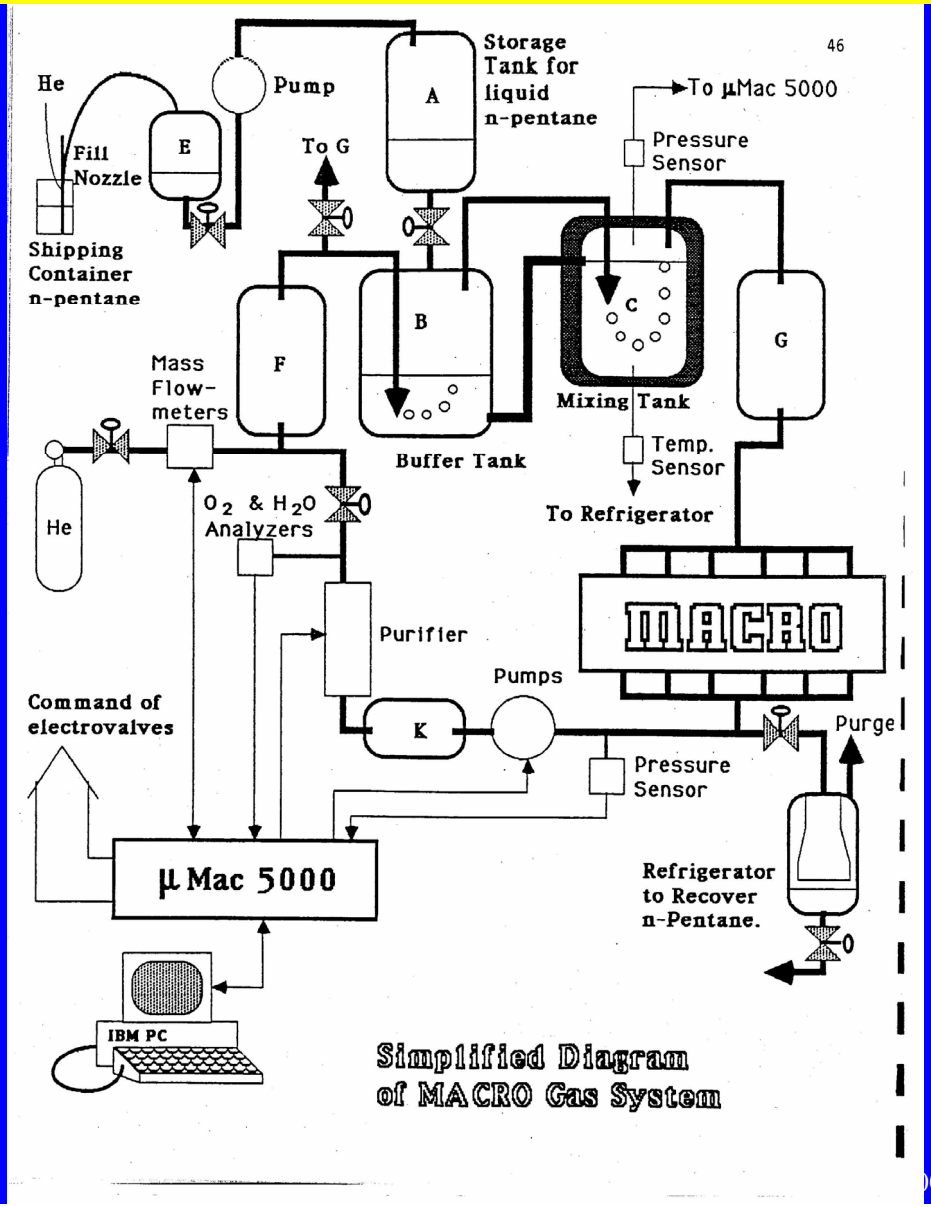
- 20 x 20 m^2
- 2 mm gap → 0.8 m^3" 1 m^3 / plane
- 500-plane detector → 500m^3 total
  - 200,000 m^2 (40 acres)
  - (1A-type cylinder of Ar contains ~8 m^3 of gas)
  - Need ~60 gas cylinders to fill the detector
- 2 x 2 m^2 chambers →
  - 100 chambers / plane
  - 50,000 chambers
  - 1 cm Aq overpressure → F = 400 N
- >> 50,000 Swagelock (?) fittings
  - ($1.8 / piece in brass)
- For LSTs it would be 5-10 (?) times larger volume

Main issues for a large gas system

- **Safety**
- **Gas mixing and supply**
- **Gas distribution and flow control**
- **Hermeticity and purity of the system**
- **Gas circulation and purification (or exhaust)**
- **Gas system monitoring**
- **Long term reliability**

Assure all (or most ?) of the above inexpensively !!

Large gas system of the past



MACRO

- ~ 500 m^3
- 1 volume exchange in 5 days
- He – n-pentane mix

Soudan-2

- ~600 m^3
- Ar-CO2
- ~8.5 m^3 / week leak
- $30-40k / year

Safety

- **Safety of personnel –**
  - » non-flammable
  - » non-toxic
  - » standard (easy) handling
- **Safety of the detector**
  - » chemically non-aggressive mix
  - » benign radicals (plasma chemistry!)
  - » avoid mechanical (pressure) stresses
- **Safety of the environment**
  - » environmentally friendly

Gas mixing and supply

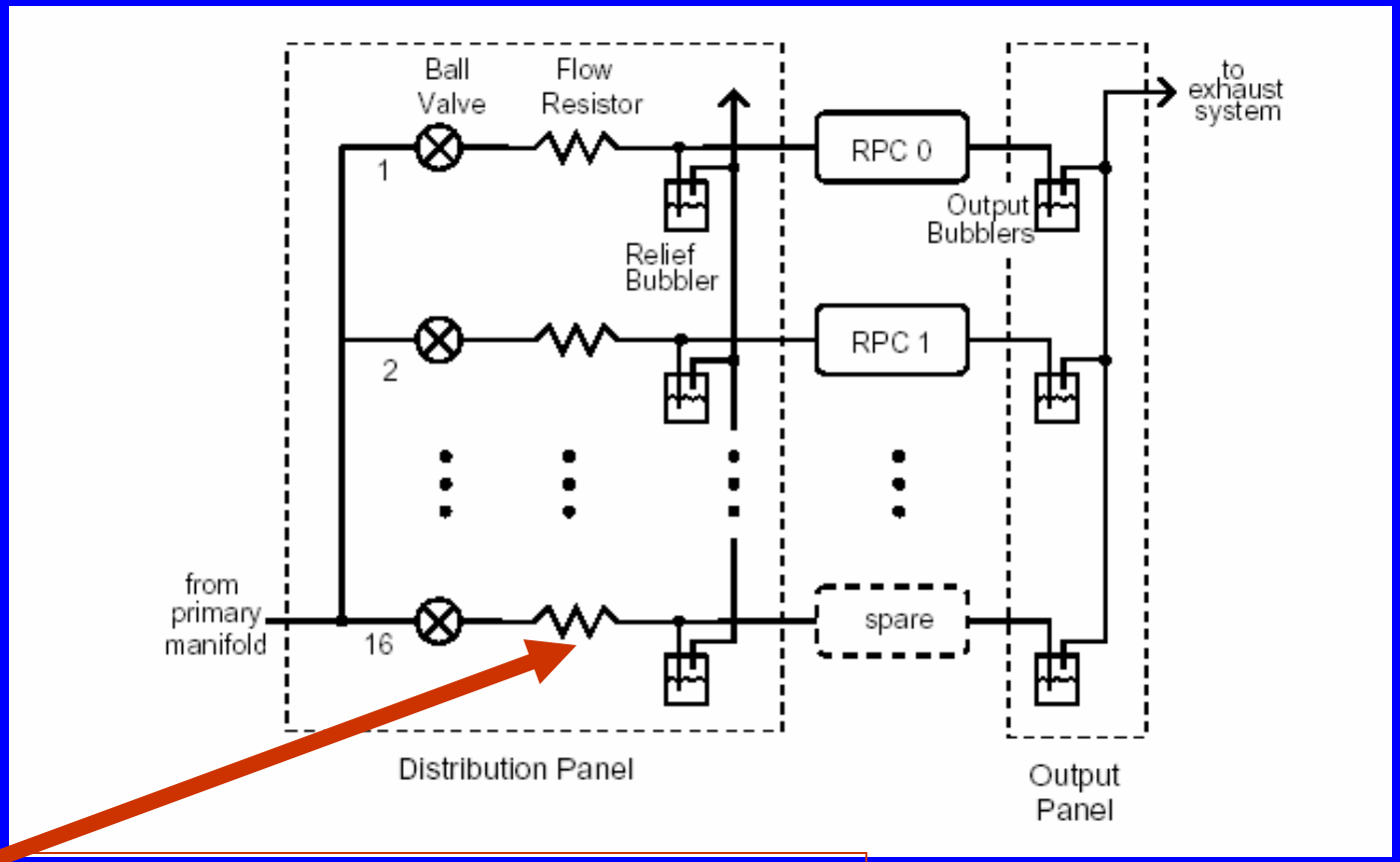
- Precision of the mix
  - Ambient T, p, humidity factors
- Automatic control and monitoring of the mix
- Cylinder exchange

Gas distribution and flow control

- Balance flow to all chambers
- Flow monitoring (electronic and/or visual)
- Overpressure protection
- Modularity (chamber/units replacement ?)
- Computerized gas flow control
- What flow rate ?
- Purging (high rate?) flow

Gas distribution – e.g., Belle

Functional schematics from Belle
(courtesy of D. Marlow)



Important! (also implemented in Soudan-2)

Hermeticity and gas purity

- Avoid porous components
  - avoid O_2
  - avoid H_20
  - perhaps other constraints
- Sieves, scrubbing
- Test points for monitors
- "Offline" performance: chromatography / mass spectroscopy
- "Online performance" – radioactive sources / CR

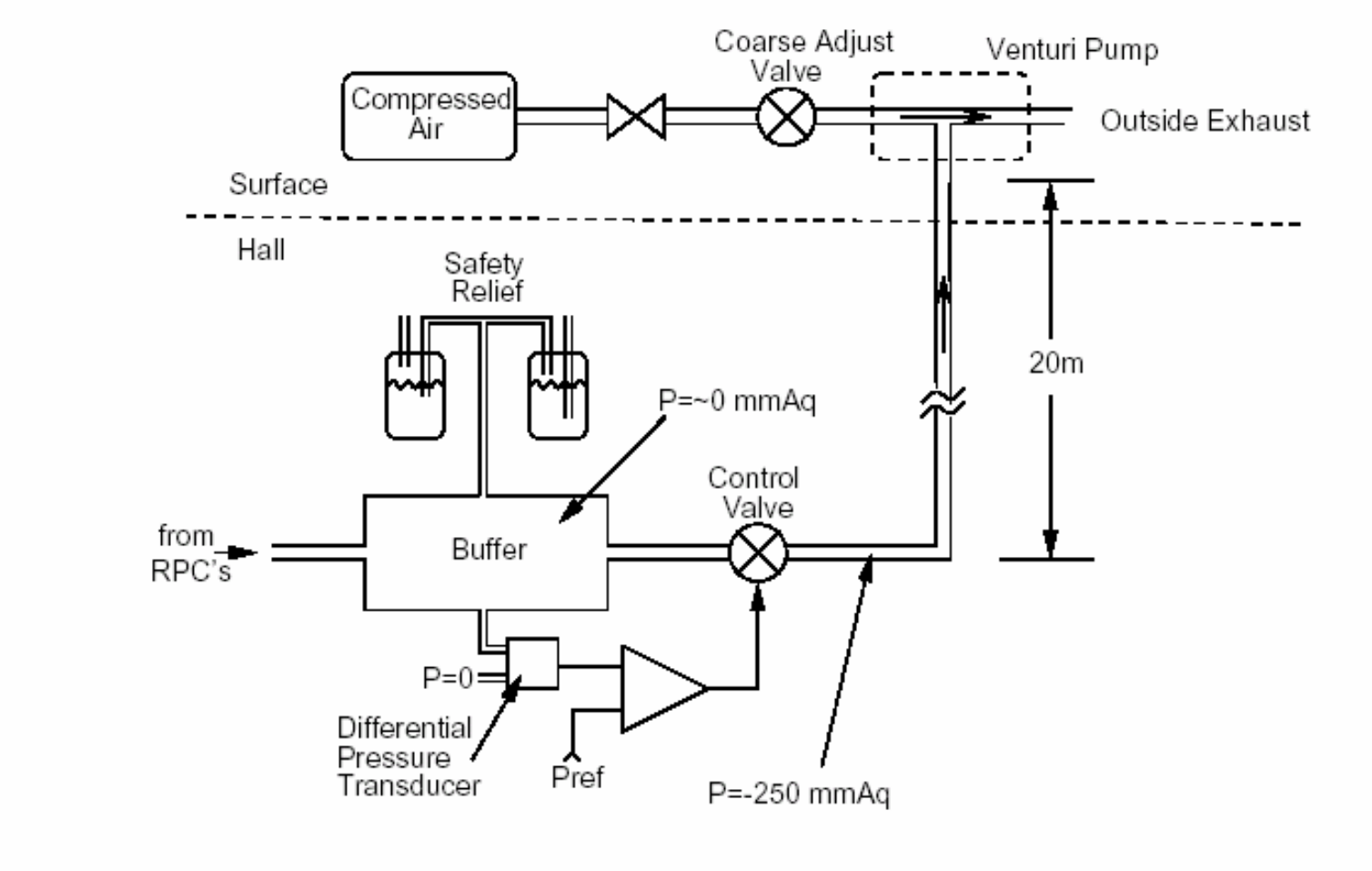
(→ monitoring)

Gas recirculation and purification (or exhaust)

- Cannot afford not to circulate ?!
  - Cost of operation with exhaust
  - Cost of recirculating system and its maintenance
- What flow rates ?
- Variable flow rates ?
- How non-hermetic (contaminated system)
- Watch back pressure (w/ redundancy)

Gas exhaust example - Belle

(courtesy of D. Marlow)



Gas system monitoring and control

Monitor "everything"

gas mixing
gas flow
bubblers
actual gas mix

circulation
chamber performance

chamber currents

Long term reliability

- Constant gas mix
- Robust monitoring / controlling
- Cylinder exchange
- Replacements of sieves and manifolds
- Purification
- Circulation

What gas mix? – personal view

- **RPC gas mix:**
  - **Quenching of the streamer / avalanche**
    - **Electron-ion pairs** **e.g., Ar**
    - **Electron quenching** **e.g., SF6, HFC-134a, HFC-13B1**
    - **Photon quenching** **e.g., iC_4H_{10}**
  - **Signal size ~10-1000 pC**
- **RPC gas problems:**
    - **Aggressive radicals: HF_x**
    - **Water**
- **Plasma chemistry**
    - **Not enough known!**
    - **Monte carlo programs: Magboltz, Imonte, Heed,.. - how helpful?**
- **Conclusions:**
  - **avoid HF**
  - **Freonless mixes**

RPC gas mix examples

- **BaBar RPCs**
  - **Ar – iC_4H_{10}-Freon 13B1 (TDR)**
    59% - 37% - 4%
  - **Study of non-flammable, freonless mixes**
- **Belle RPCs**
  - **Ar – iC_4H_{10}- HFC 134A**
    30% - 8% - 62%
  - **Study of non-flammable, freonless mixes**
- **ARGO-YBJ**
  - **Ar – iC_4H_{10}-$C_2H_2F_4$**
    45% - 45% - 10%
    60% - 27% - 13%
    75% - 15% - 10%
  - **Study of non-flammable, freonless mixes**

Belle studies – freonless mix

Freonless gas mixtures for glass RPC operated in streamer mode

Y. Hoshi [b], Y. Mikami [a], T. Nagamine [a], K. Watanabe [a], A. Yamaguchi [a,1], Y. Yusa [a]

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[b] *Tohoku-Gakuin University, Tagajo 985-8537, Japan*

2 May 2002

Table 1
Composition of the gas mixtures used in this test.

$HFC-134a$	C_4H_{10}/Ar	$C_4H_{10}=8$	$C_4H_{10}/O_2=6/5$	$C_4H_{10}/O_2=4/10$
$134a/C_4H_{10}/Ar$	C_4H_{10}/Ar	$C_4H_{10}/Ar/CO_2$	$C_4H_{10}/O_2/Ar/CO_2$	$C_4H_{10}/O_2/Ar/CO_2$
8/30/62	70/30	8/30/62	6/5/30/59	4/10/30/56
	50/50	8/20/72	6/5/20/69	4/10/20/66
	30/70	8/10/82	6/5/10/79	4/10/10/76
		8/ 5/87	6/5/ 5/84	4/10/ 5/81

Belle studies

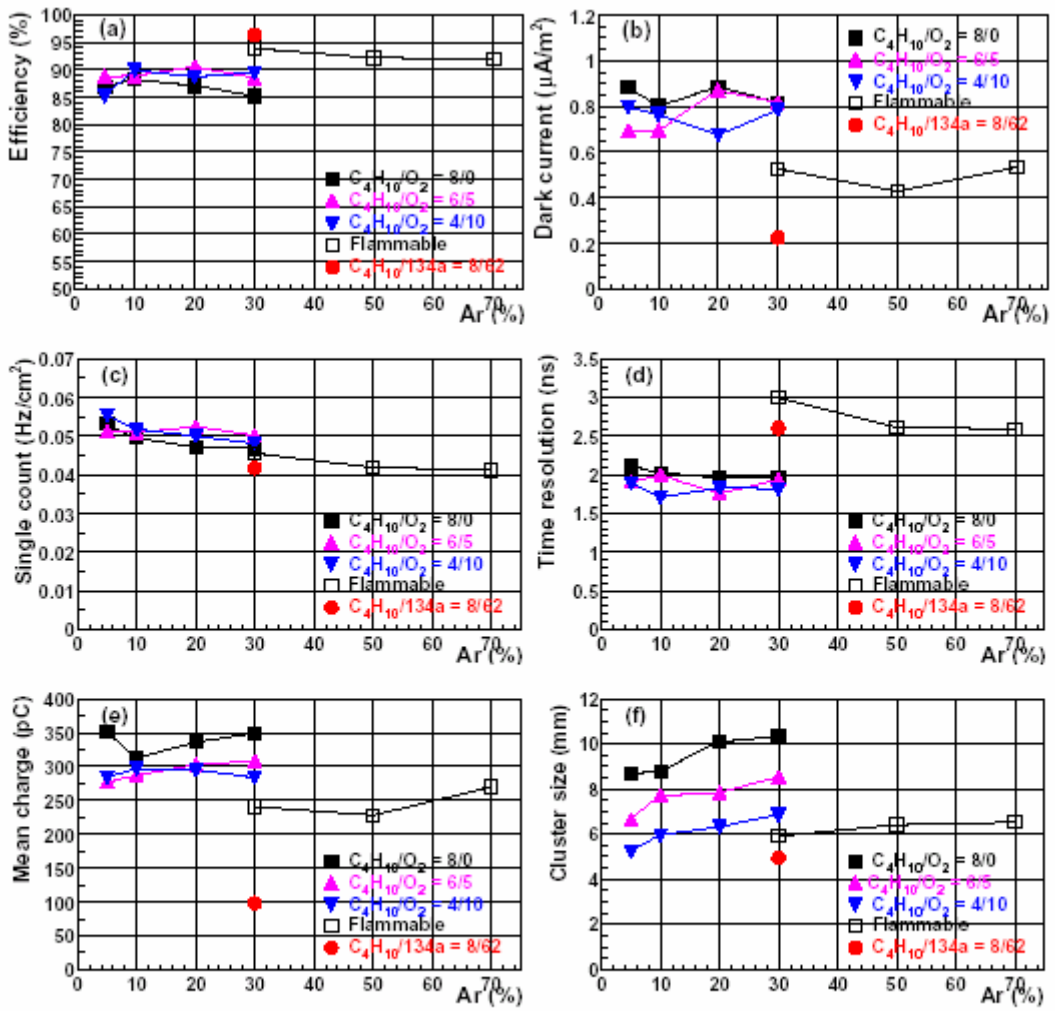
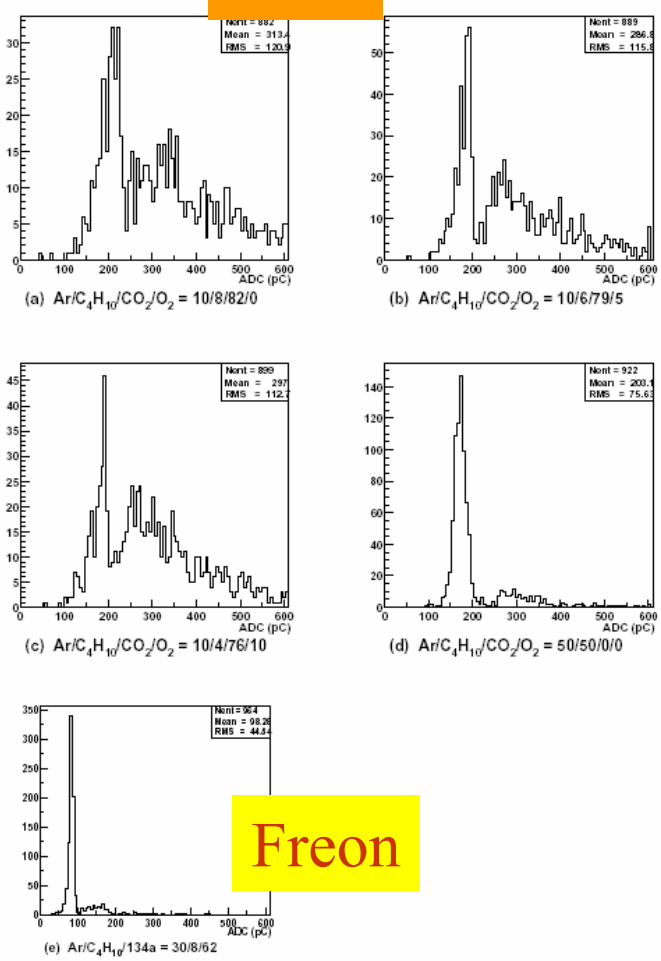


Fig. 4. *Performances at plateau HV;(a) efficiency, (b) dark current, (c) single count rate, (d) time resolution, (e) mean charge, and (f) cluster size.*

Belle

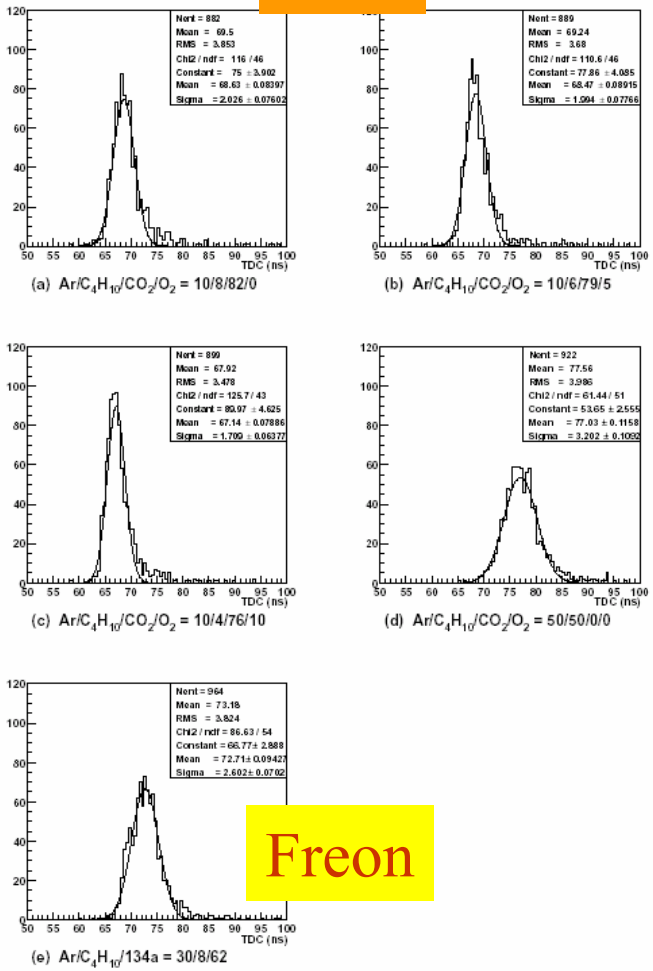
ADC



Freon

Fig. 5. *ADC distributions at the plateau HV for (a)-(c) freonless (10% Ar), (d) frammable, and (e) 62% HFC-134a gas mixture.*

TDC



Freon

Fig. 6. *TDC distributions at the plateau HV for (a)-(c) freonless (10% Ar), (d) frammable, and (e) 62% HFC-134a gas mixture. Solid curves are Gaussian fits to the distributuins.*

ARGO-YBJ

Study of RPC gas mixtures for the ARGO-YBJ experiment

B. Bartoli, R. Buonomo, E. Calloni, S. Catalanotti,
B. D'Ettorre Piazzoli, G. Di Sciascio, M. Iacovacci

INFN and Dipartimento di Fisica dell'Università di Napoli, Italy

Abstract

The ARGO-YBJ experiment consists of a RPC carpet to be operated at the Yangbajing laboratory (Tibet, P.R. China), 4300 m a.s.l., and devoted to the detection of showers initiated by photon primaries in the energy range 100 GeV - 20 TeV. The measurement technique, namely the timing on the shower front with a few tens of particles, requires RPC operation with 1 ns time resolution, low strip multiplicity, high efficiency and low single counting rate. We have tested RPCs with many gas mixtures, at sea level, in order to optimize these parameters. The results of this study are reported.

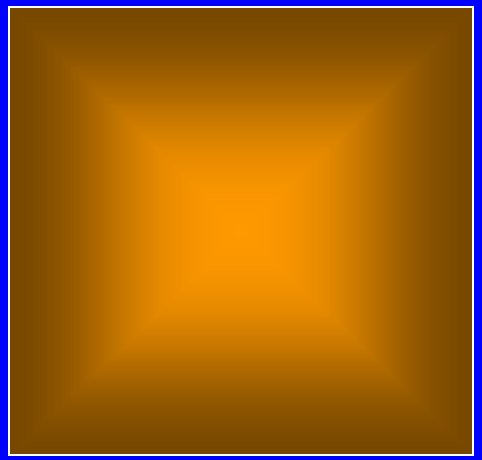
Summary

- Large volume gas systems (i.e., similar to off-axis detector)
  have been operated in the past !

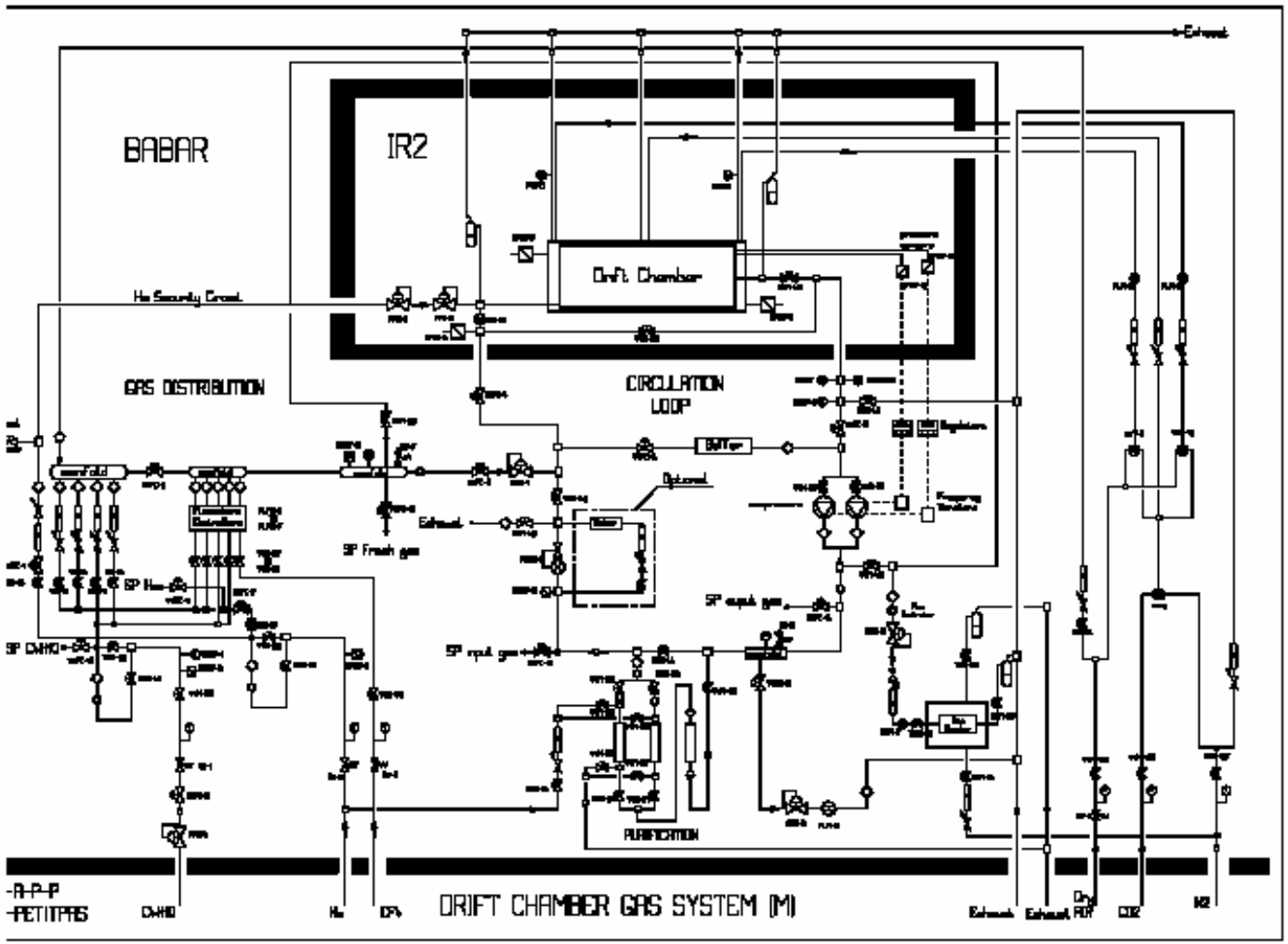
- For a large off-axis RPC system more touchy issues revolve around
  - uniform distribution of flow
  - avoidance of over-pressure
  - remote control and monitoring (of "everything")

- Likely need of circulation/purification system

- Need some R&D:
  - Find acceptable safe freonless mix.
  - Study signals (size, after-pulsing, x-talk…) → readout.
  - How dirty can the gas be (contamination, purification)?
  - What is the minimal flow rate?



Another gas system example – BaBar DCH



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN–EP/2002–046
20 June 2002

Detector Physics and Simulation of Resistive Plate Chambers

W. Riegler[1)], C. Lippmann[1)], R. Veenhof[1)]

Abstract

We present a simulation model suited to study efficiency, timing and pulse-height spectra of Resistive Plate Chambers. After discussing the details of primary ionisation, avalanche multiplication, signal induction and frontend electronics, we apply the model to timing RPCs with time resolutions down to 50 ps and trigger RPCs with time resolutions of about 1 ns.

4 Avalanche Multiplication

Each electron will start an avalanche which will grow until it hits the resistive plate or metal electrode. Avalanche multiplication for electro-negative gases at high fields is described in detail in [19]. In case the probability that an electron multiplies is independent of the previous position of multiplication, the avalanche development is characterised by the Townsend coefficient α and attachment coefficient η. Fig. 4 shows these parameters as calculated with Imonte [8]. For the trigger RPCs with E=50 kV/cm we expect an effective Townsend coefficient of around 10/mm while for the timing RPCs with E=100 kV/cm we expect a value around 100/mm. If the avalanche contains n electrons at position x the probability that it contains $n+1$

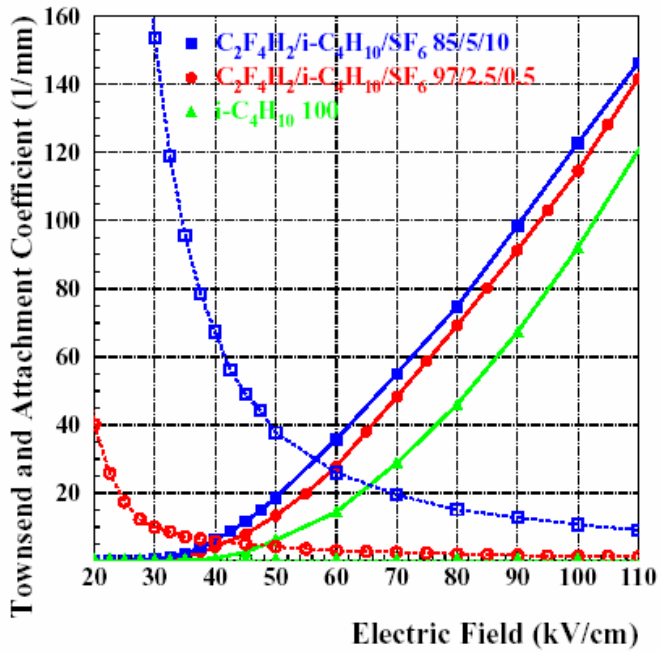


Figure 4: Townsend and attachment coefficient as calculated by IMONTE [8].

at $x+\mathrm{d}x$ is given by $n\alpha\mathrm{d}x$. Following the same arguments the probability that for an avalanche of size n, one electron gets attached (forming a negative ion) over distance $\mathrm{d}x$ is $n\eta\,\mathrm{d}x$. For the average number of electrons $\overline{n}$ and positive ions $\overline{p}$ we therefore have the relations

$$\frac{\mathrm{d}\overline{n}}{\mathrm{d}x} = (\alpha - \eta)\overline{n} \qquad \frac{\mathrm{d}\overline{p}}{\mathrm{d}x} = \alpha\overline{n} \tag{3}$$

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haracterised by the average number of clusters per unit of length
n for the number of electrons per cluster. The numbers are calculated using Heed [6]. The average number of clusters/mm versus $(\gamma - 1)$ of the particle is shown in Fig. 3a). For the RPC gas we find an average of 7.5 clusters/mm for a minimum ionising particle. The predicted numbers of isobutane and methane are shown as a reference since measurements for the gases are available [16]. The prediction from Heed matches the experimental results quite well, it should however be mentioned that the experimental numbers vary significantly in the literature. For a 10 GeV pion we find on average 9.5 clusters/mm, so the average distance between clusters is $\lambda = 105\ \mu m$. The cluster size distribution for two gases is shown in Fig. 3b. The distance between the clusters is exponentially distributed, so the proba-

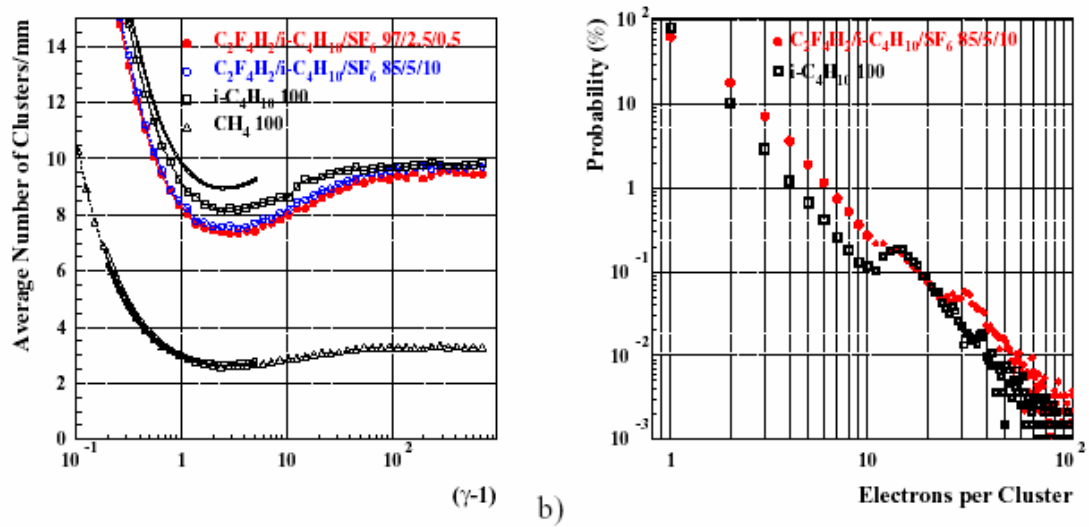

Figure 3: (a) Average number of clusters/mm for different gases predicted by Heed [6]. The 'solid bands' show measurements for methane and isobutane from [16]. (b) Cluster size distribution for a pion energy of 10 GeV as simulated by Heed. Cutting at 500 electrons the average number of electrons/cluster is 2.45 for the RPC gas.

ARGO-YBJ

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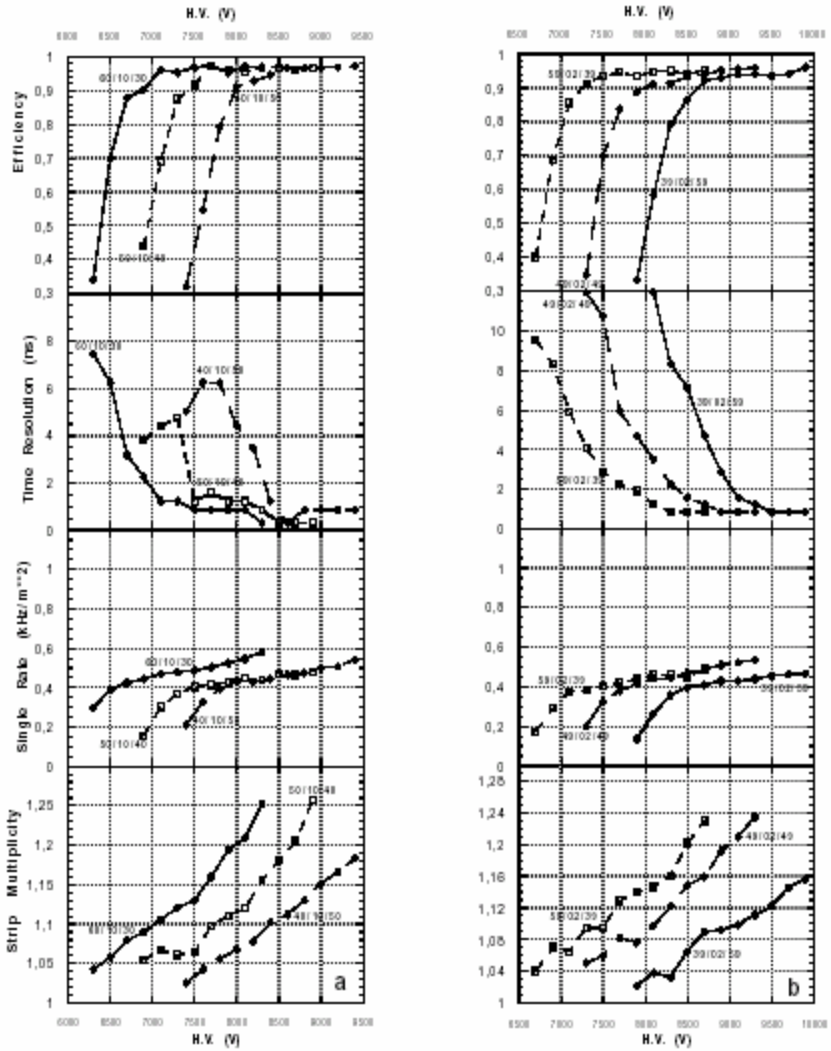
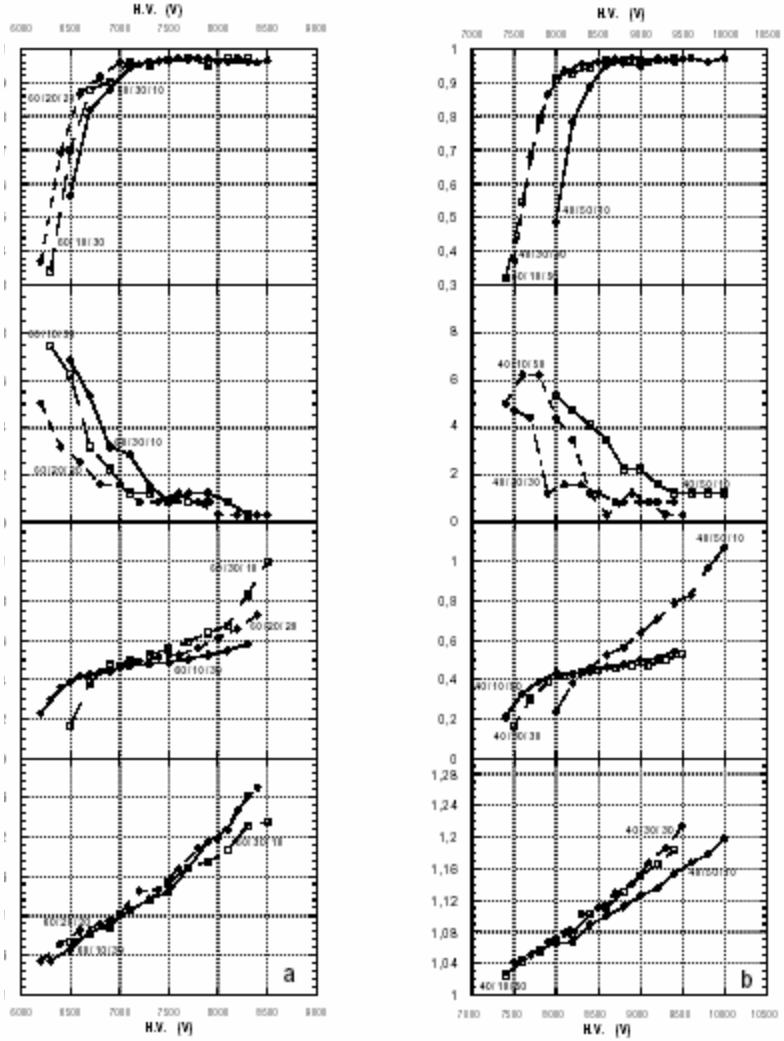


Fig. 2. Efficiency, time resolution, single rate and mean strip multiplicity for gas mixtures with a) 10% of i-But; b) 2% of i-But.



Efficiency, time resolution, single rate and mean strip multiplicity for gas mixtures 60% of Ar; b) 40% of Ar.

ARGO-YBJ

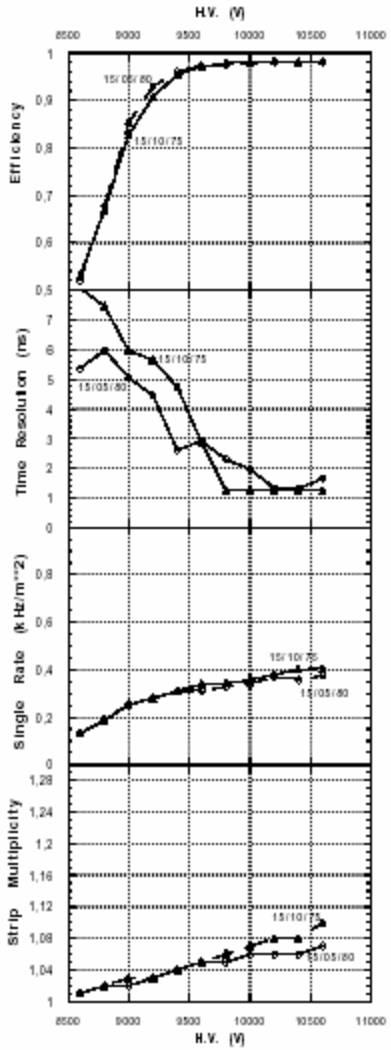
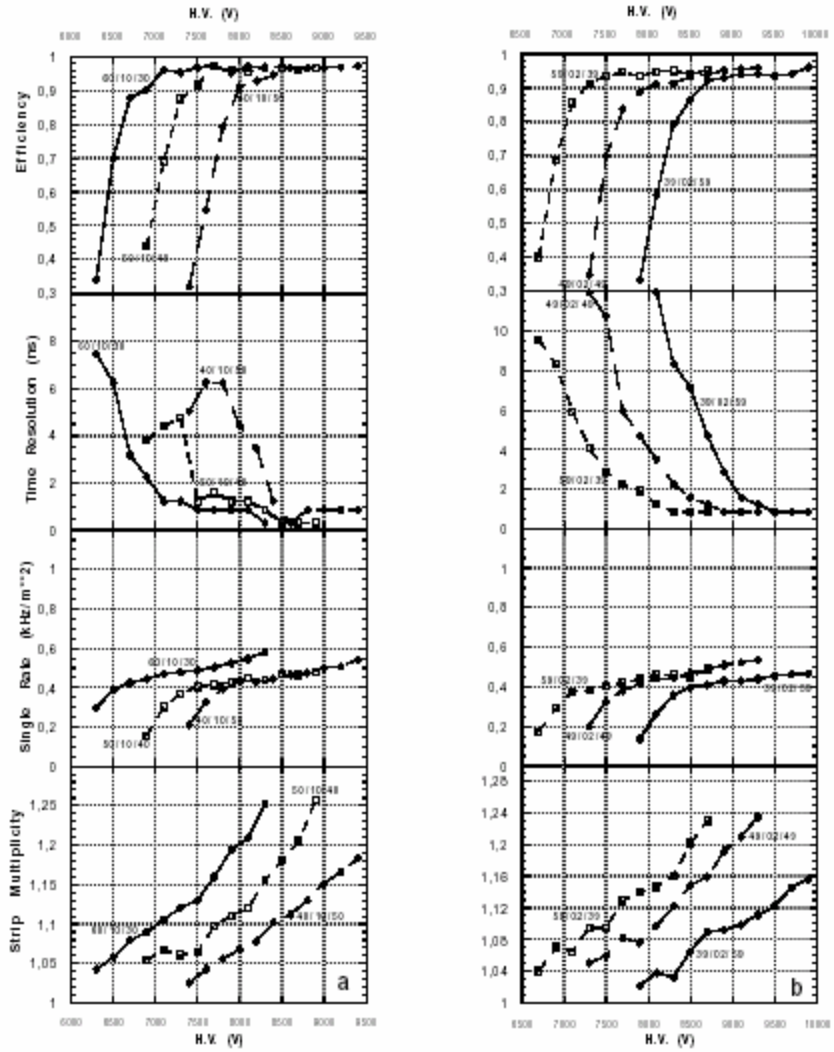


Fig. 3. Efficiency, time resolution, single rate and mean strip multiplicity for the gas mixtures Ar/i-But/TFE = 15/10/75 and Ar/i-But/TFE = 15/5/80.



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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Test of freonless operation of resistive plate chambers with glass electrodes—1 mm gas gap vs 2 mm gas gap

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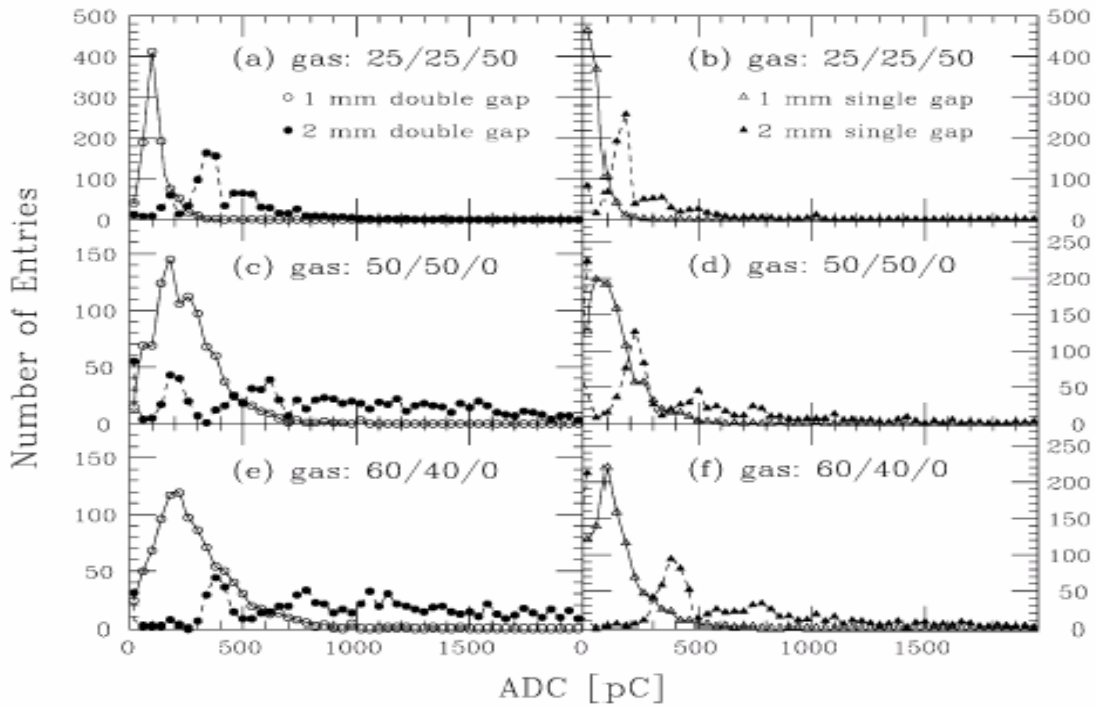

Fig. 6. Signal charge distributions. (a) and (b) freon mixture: Ar/iso-C_4H_{10}/$C_2H_2F_4$ = 25/25/50, (c) and (d) non-freon mixture: Ar/iso-C_4H_{10} = 50/50, and (e) and (f) non-freon mixture: Ar/iso-C_4H_{10} = 60/40. (a), (c) and (e) double-gap mode: circles, and (b), (d) and (f) single-gap mode (RPC A): triangles. The open symbols with solid curve show the 1 mm gap RPCs and the closed symbols with dash curve show the 2 mm gap RPC.