Detector Physics of Resistive Plate Chambers

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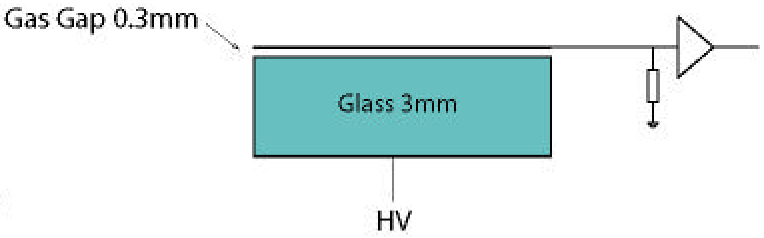
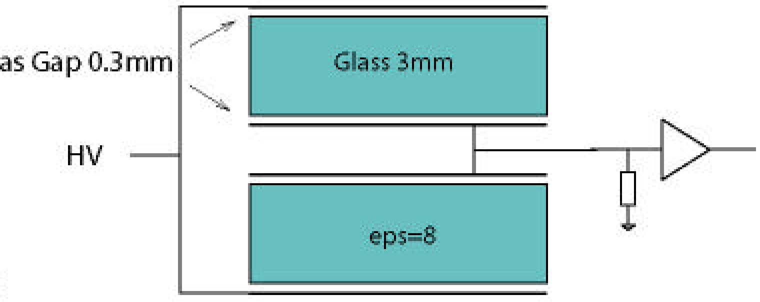
Resistive plate chambers are gaseous parallel plate avalanche detectors with time resolutions down to 50 ps, making them attractive for trigger and time of flight applications.



a)



b)

- **We simulate <u>Timing RPCs</u> in one and four gap configurations as in:**

  P. Fonte et. al., NIM A449 (2000) 295-301

  A. Akindinov, P. Fonte et. al., CERN-EP 99-166

  P. Fonte and V. Peskov, preprint LIP/00-04

- **0.3 mm gap(s); glass resistive plates (e=8, r=2x10^{12} Wcm)**
- **$C_2F_4H_2$ / i-C_4H_{10} / SF_6 (85/5/10)**
- **HV: 3(6)kV, E: 100kV/cm**

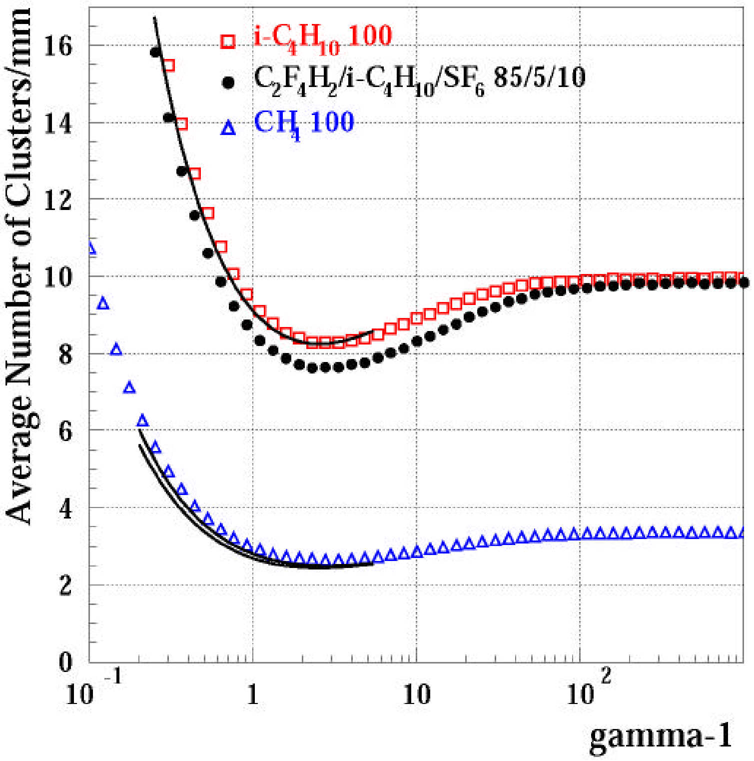
Simulation Input

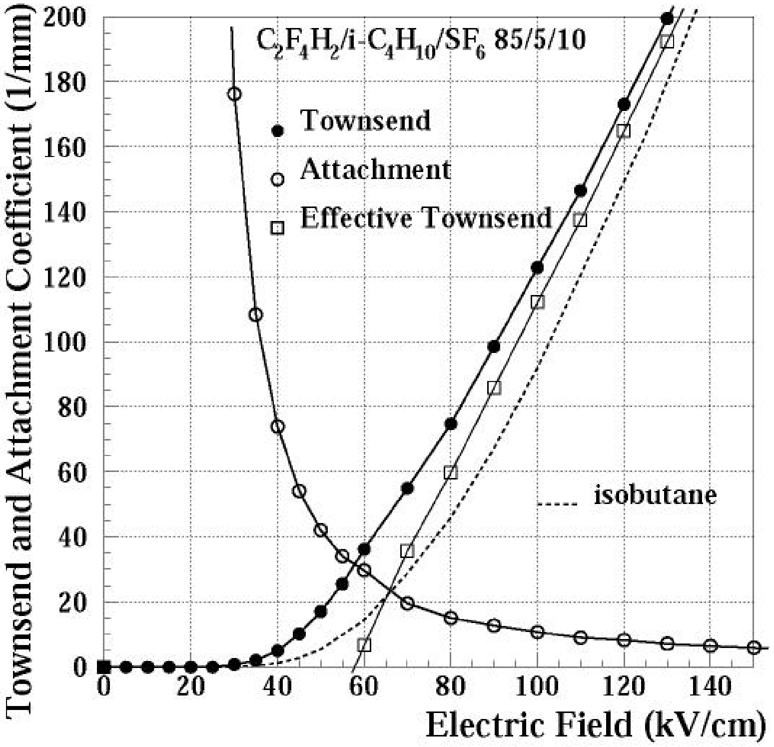
- **Primary ionization:** **HEED** (Igor Smirnov)
- **Townsend, attachment coefficient:** **IMONTE** (Steve Biagi)
- **Diffusion, drift velocity:** **MAGBOLTZ 2** (Steve Biagi)
- **Avalanche fluctuations:** **Werner Legler** (Die Statistik der Elektronenlawinen in elektronegativen Gasen bei hohen Feldstaerken und bei grosser Gasverstaerkung,1960)
- **Space Charge Field:** CERN-OPEN-2001-074, "Static electric fields in an infinite plane condensor with one or three homogeneous layers“

Gas Parameters

- **Primary Ionization: Number of Clusters per mm**
- **p_0=1013mbar, T_0=296.15K**
- **Measurements (lines): F.Rieke et al., Phys.Rev. A6, 1507 (1972)**

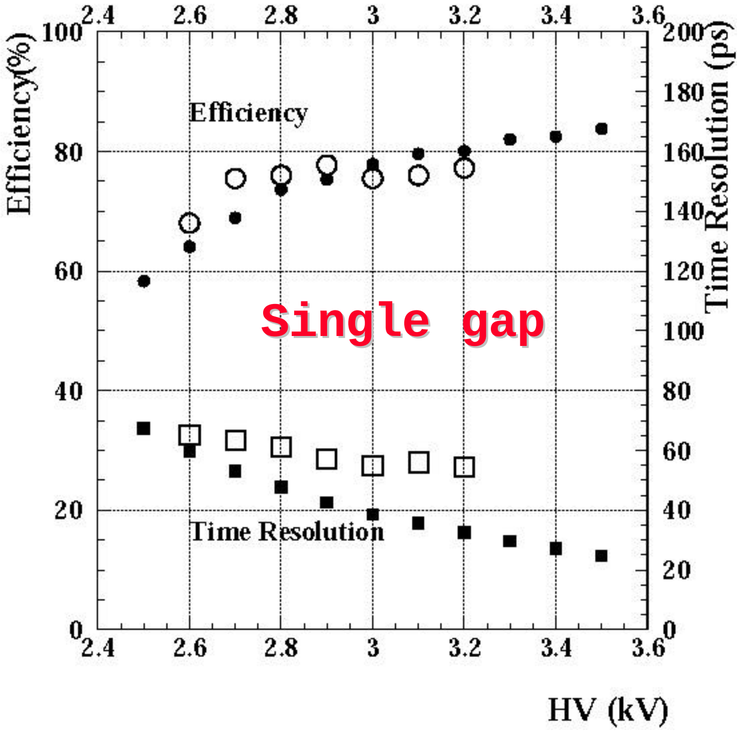
- **Townsend Coefficient**
- **Attachment Coefficient**
- **p_0=1013mbar, T_0=296.15K**

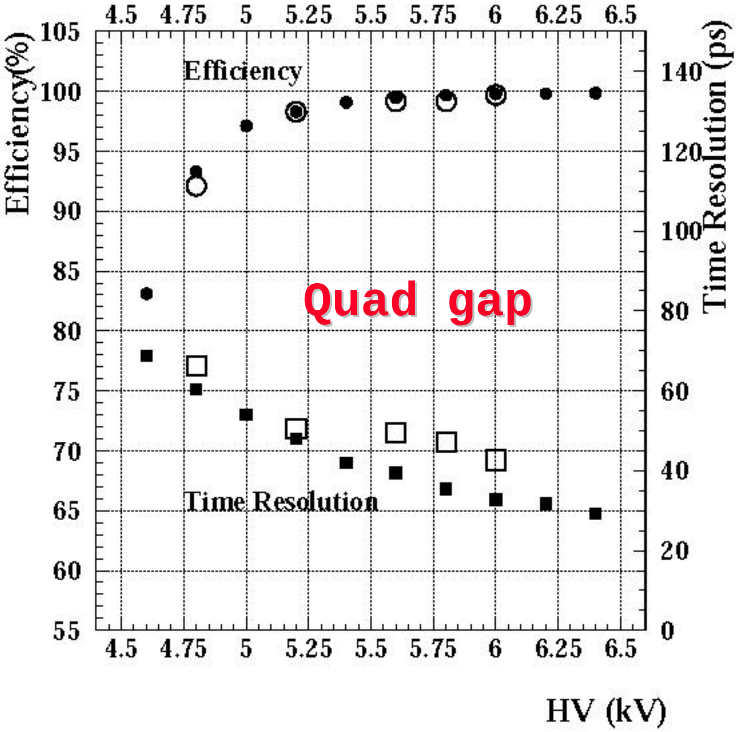




Efficiency and Time Resolution

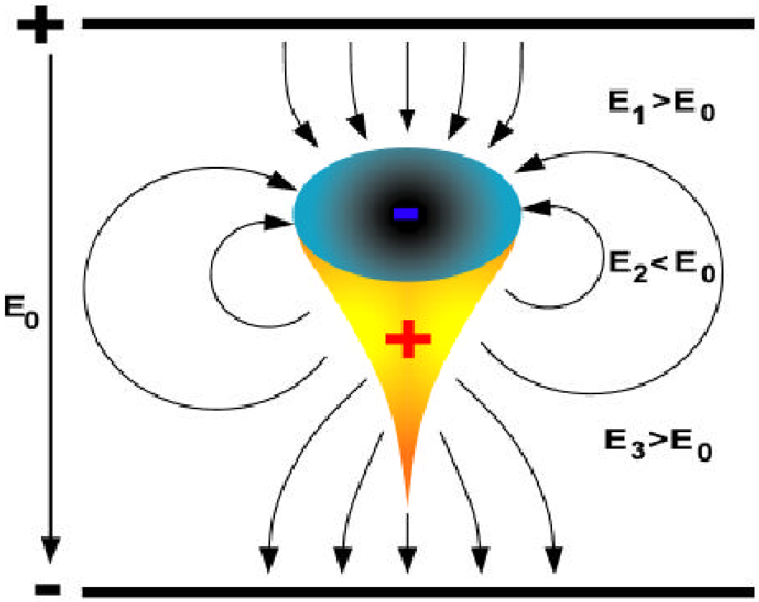
- At threshold crossing: space charge effect has no influence (for very fast amplifiers)
- Measurements: open symbols
- 7GeV pions (9.13 clusters/mm), 20fC threshold, 200ps amplifier peaking time, 1fC noise, T=296.15K and p=970mb

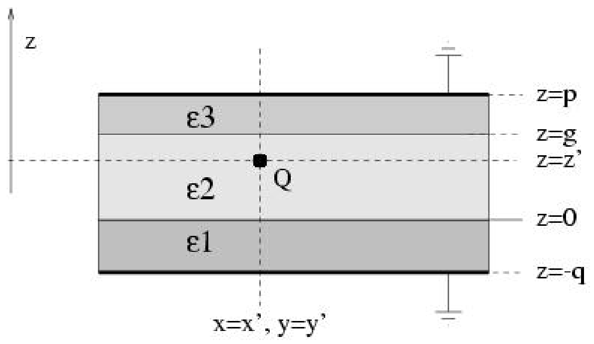




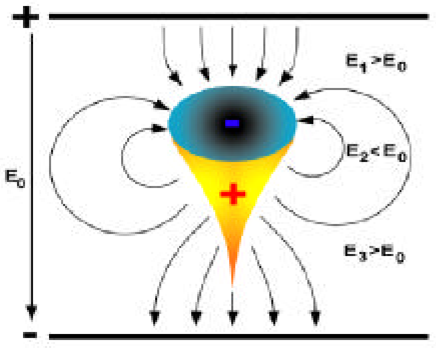
Include Space Charge Effect

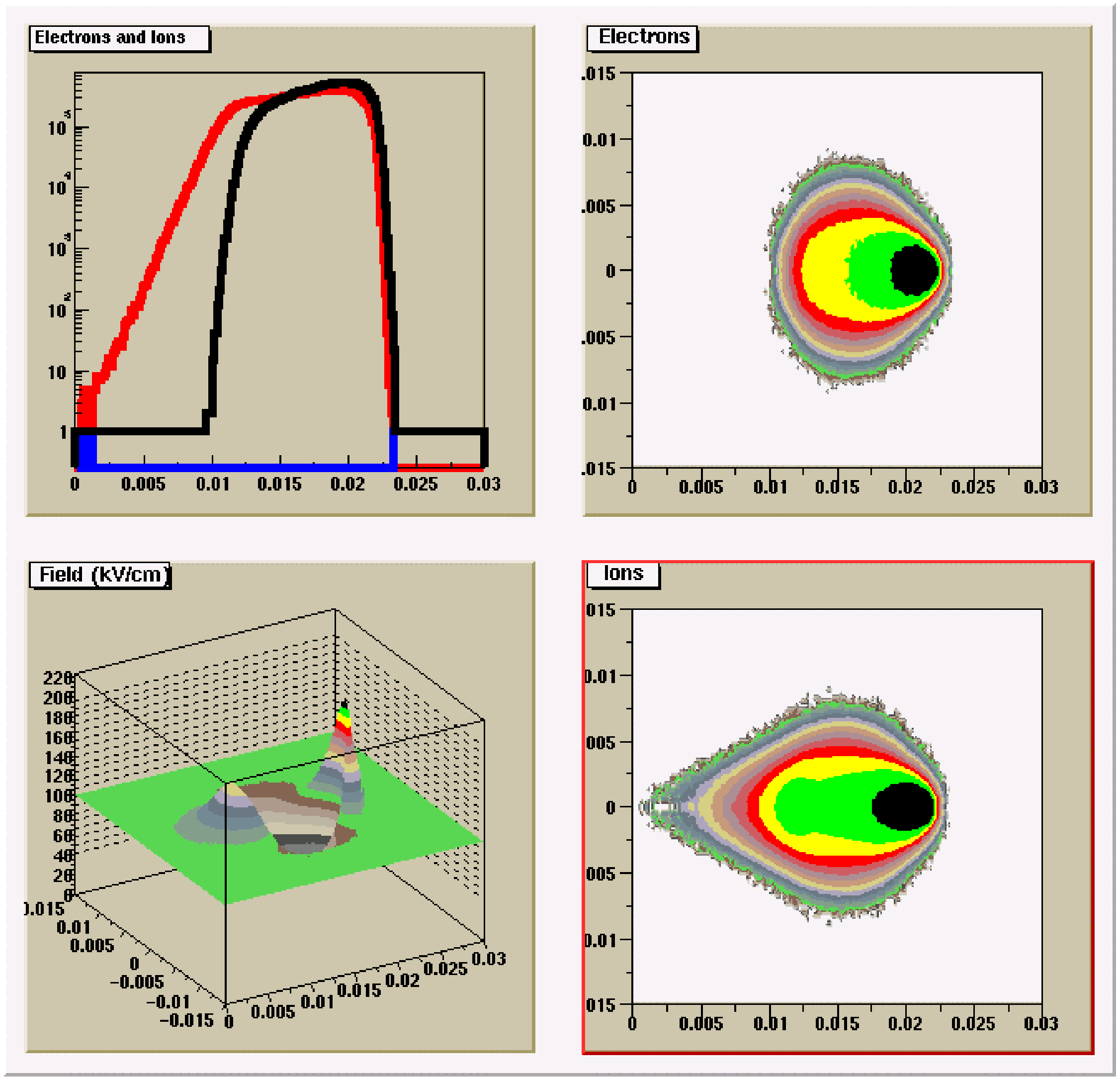
- Divide gas gap into several steps
- Electrons multiply and drift towards the anode
- Calculate dynamically the field E of the space charge at each step where electrons are multiplied
- a(E), h(E), v_D(E)
- Diffusion
- No photons





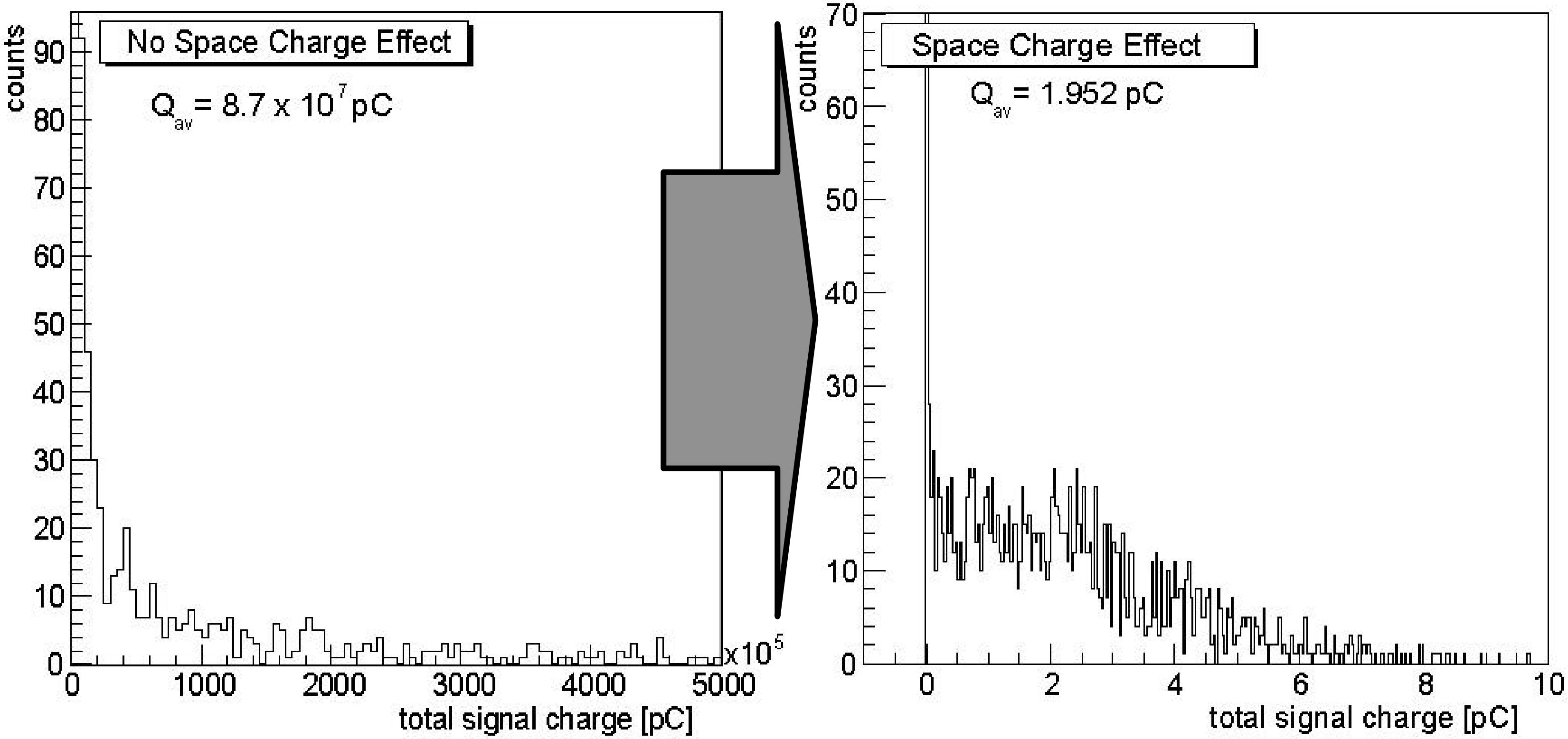
Example Avalanche





Charge Spectra

- **Simulated avalanches at HV=3kV, p=1013mb, single gap RPC**
- **Supression Factor 10^7 !!**



Reminder: Wire Tube/ Wire Chamber

- 1/r field geometry
  - Space charge region very short (<100V)
  - 1.5 orders of magnitude jump to limited streamer region

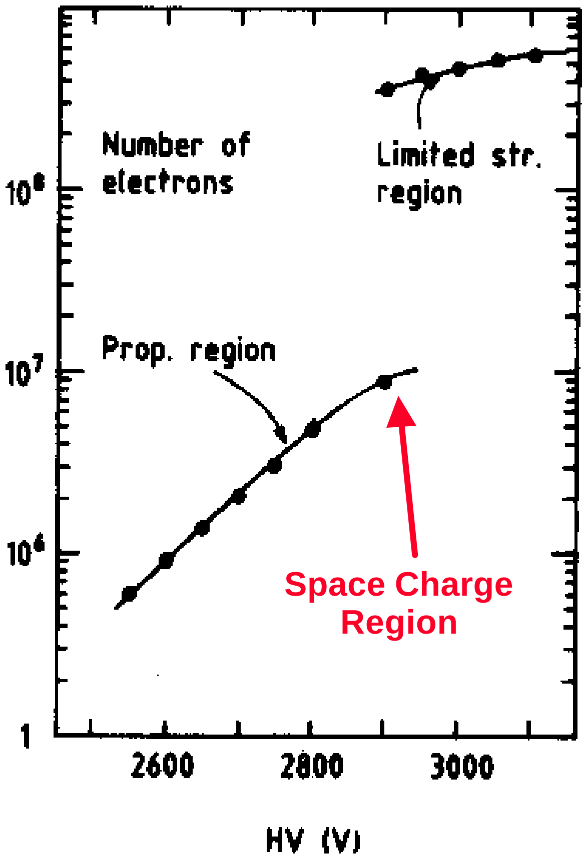
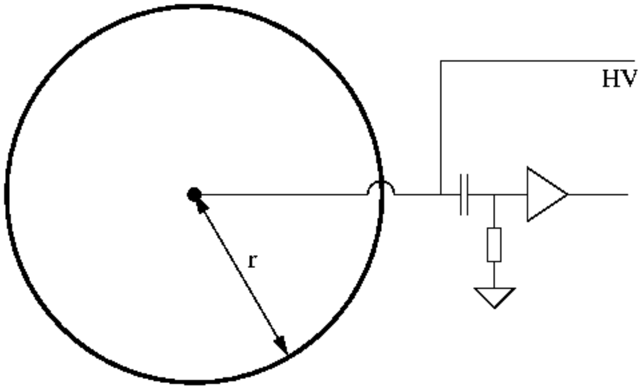


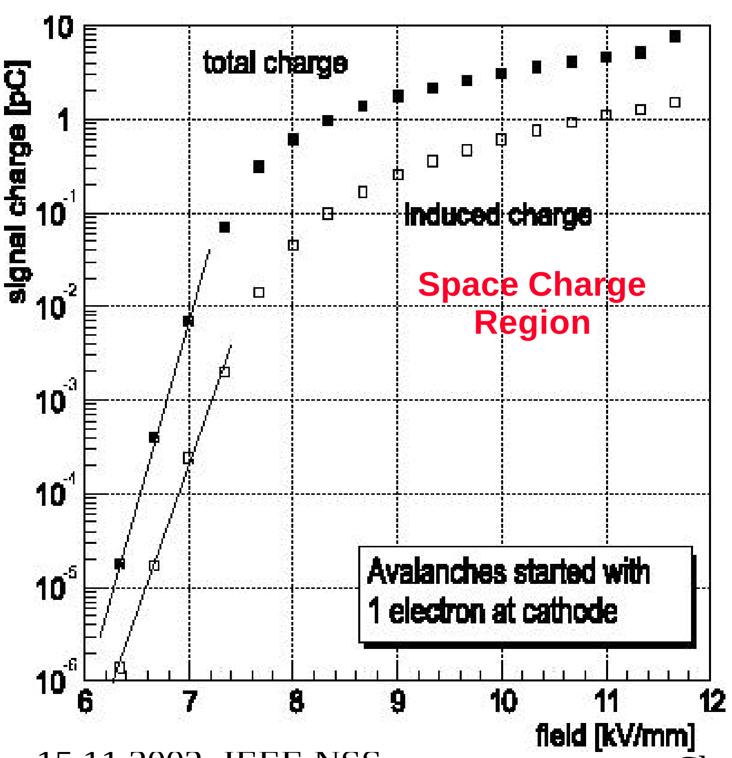
Fig. 4.5. Collected charge as a function of the high voltage, measured by ATAC et al. [ATA 82] on a 100 μm diameter wire in a tube 12 × 12 mm^2, filled with Ar(49.3%) + C_2H_6(49.3%) + CH_3CH_2OH(1.4%)

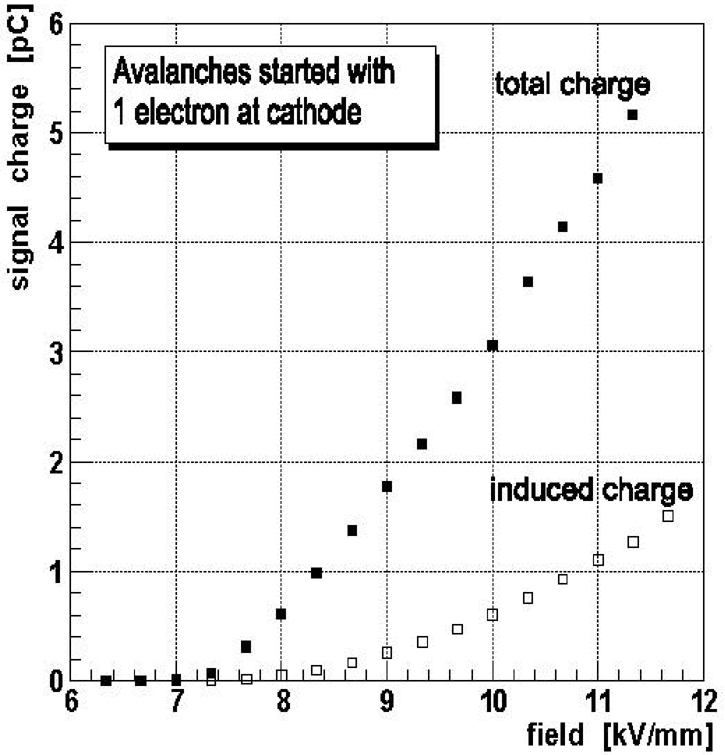
From NIM 200, 345 (1982)



Timing RPC: Long Space Charge Mode

- Homogeneous (applied) electric field
- Proportional Region is below Threshold
- Very long space charge Region (>700V)
- Charge grows first exponentially, then linearly with HV (which is also an experimental fact)



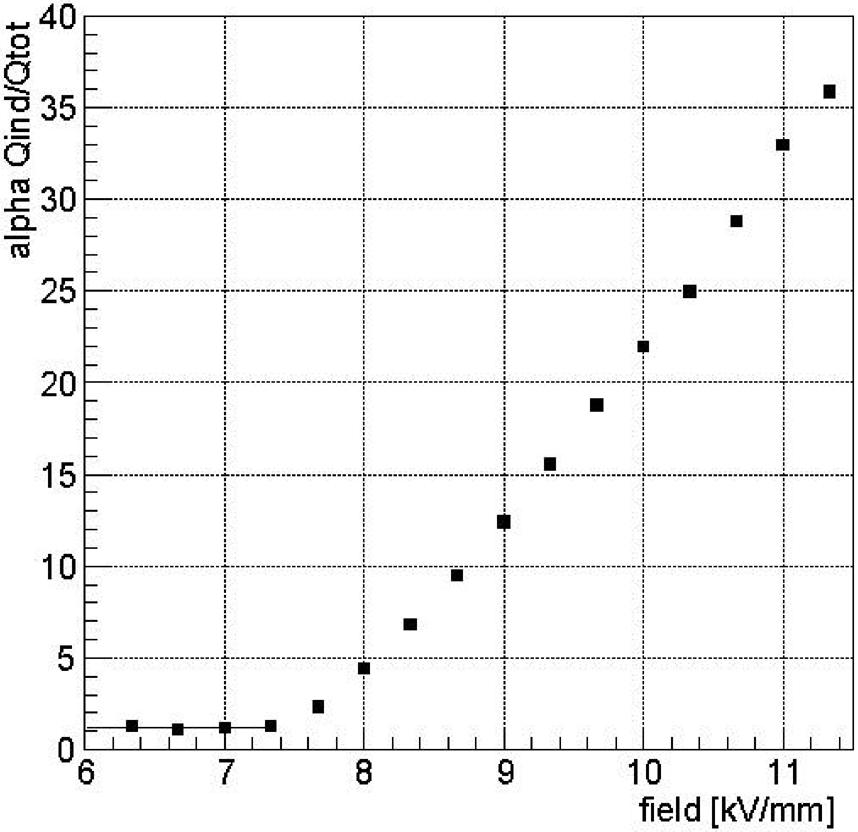


Ratio Q_{ind}/Q_{tot}

- For avalanches where no space charge effect is present we expect:

$$\frac{Q_{ind}}{Q_{tot}} = \frac{E_w}{\alpha}$$

- Indicator for a strong space charge effect present for E > 7.5kV/mm



Conclusion

- We have applied standard detector physics simulations to Timing RPCs and find good agreement with measurements for efficiency, time resolution and charge spectra.

- The operational mode of timing RPCs is strongly influenced by a space charge effect.

- The suppression factor is huge (10^7).

- Details on our work:
  - CERN-EP-2002-024
  - NIM A481(2001) 130-143
  - CERN-EP-2002-046
  - CERN-OPEN-2001-074