

Theoretical and experimental studies of Resistive Plate Chamber (RPC) detector

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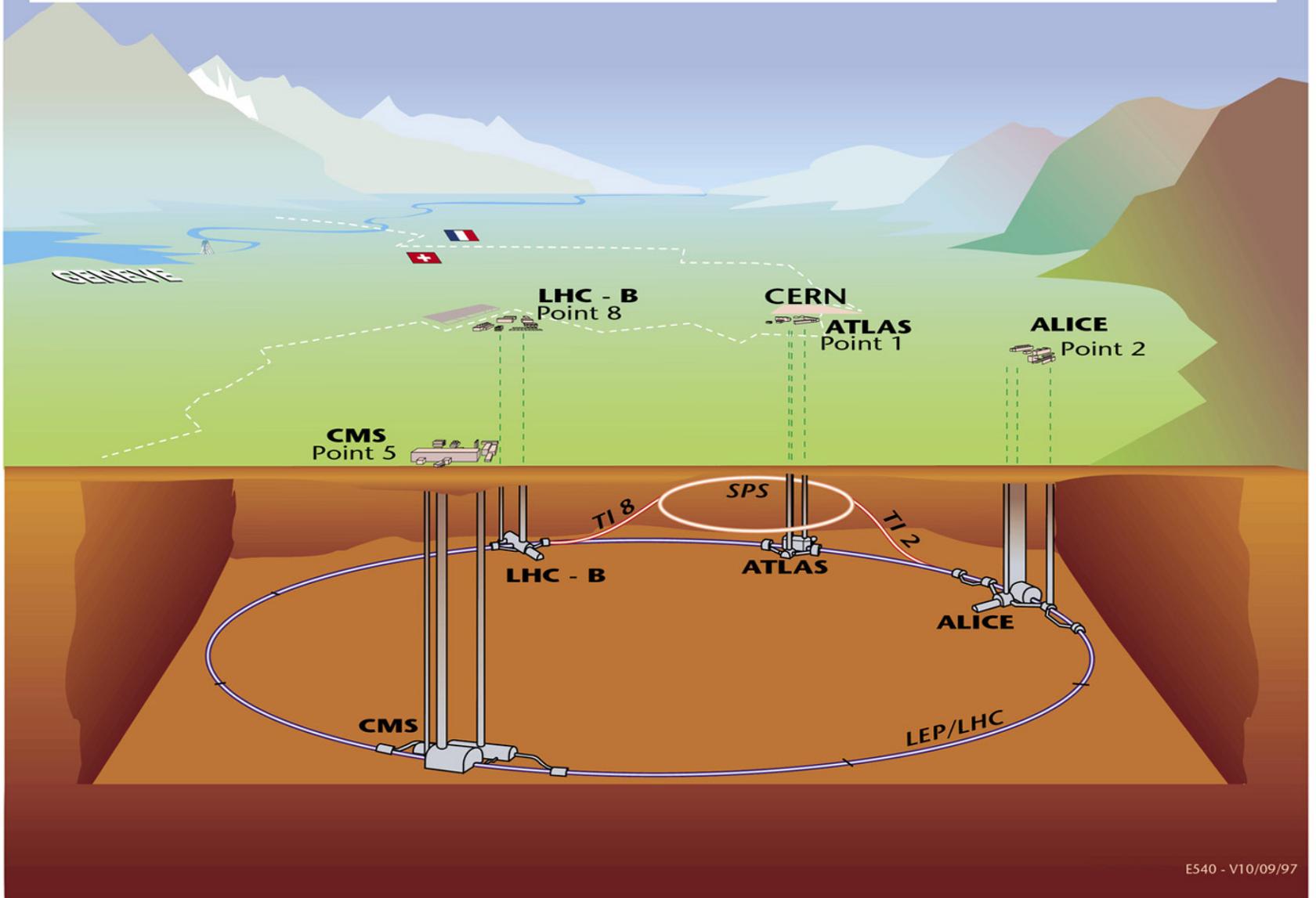
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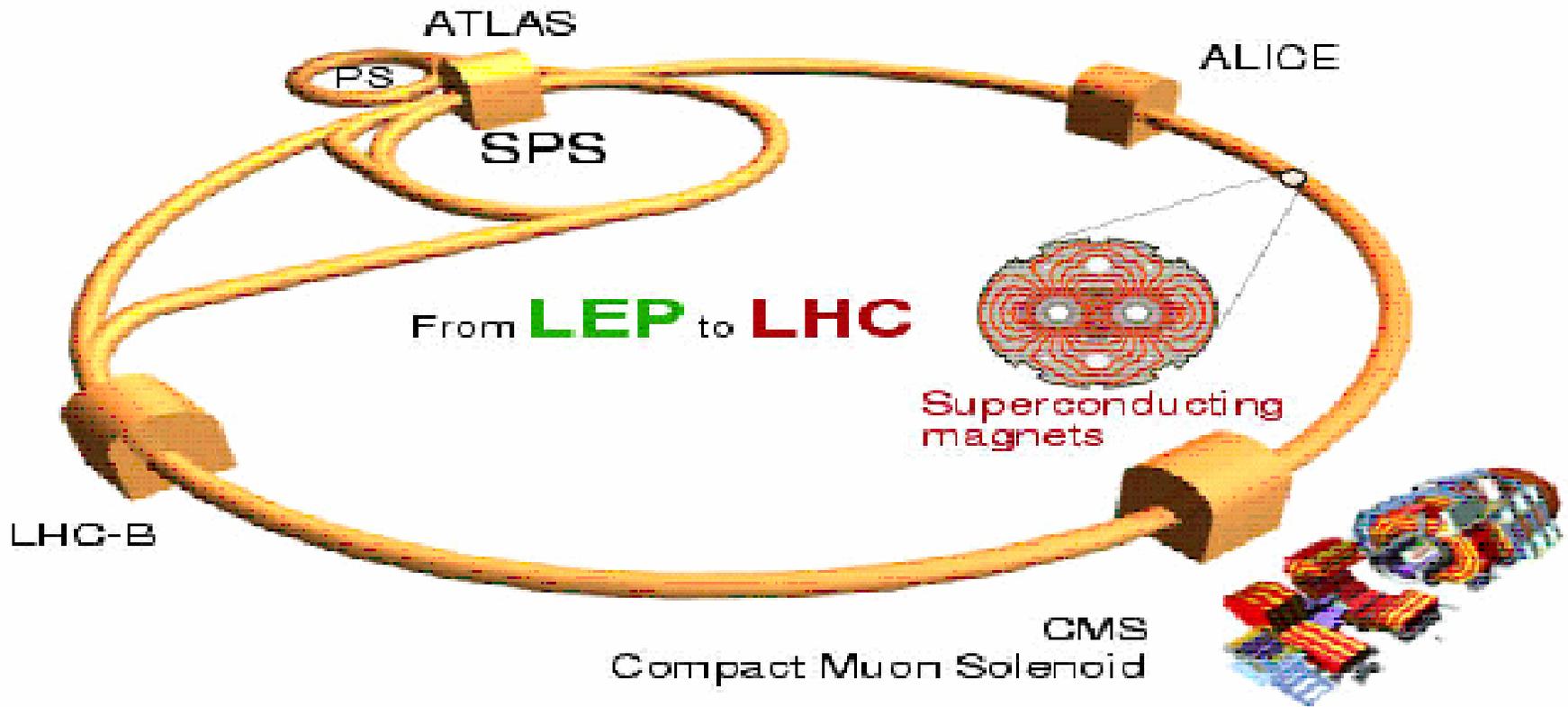
LHC project at CERN



Overall view of the LHC experiments.



The Large Hadron Collider (LHC)



	Beams	Energy	Luminosity
LEP	e+ e-	200 GeV	$10^{32} \text{ cm}^{-2}\text{s}^{-1}$
LHC	p p	14 TeV	10^{34}
	Pb Pb	1312 TeV	10^{27}

CMS: Compact Muon Solenoid

CMS Collaboration

36 Nations, 160 Institutions, 2008 Scientists and Engineers (November 2003)

TRIGGER & DATA ACQUISITION

Austria, CERN, Finland, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Switzerland, UK, USA

TRACKER

Austria, Belgium, CERN, Finland, France, New Zealand, Germany, Italy, Japan*, Switzerland, UK, USA

CRYSTAL ECAL

Belarus, CERN, China, Croatia, Cyprus, France, Ireland, Italy, Japan*, Portugal, Russia, Serbia, Switzerland, UK, USA

PRESHOWER

Armenia, Belarus, CERN, Greece, India, Russia, Taipei, Uzbekistan

RETURN YOKE

Barrel: Czech Rep., Estonia, Germany, Greece, Russia
Endcap: Japan*, USA, Brazil

SUPERCONDUCTING MAGNET

All countries in CMS contribute to Magnet financing in particular:
Finland, France, Italy, Japan*, Korea, Switzerland, USA

FEET

Pakistan, China

FORWARD CALORIMETER

Hungary, Iran, Russia, Turkey, USA

HCAL

Barrel: Bulgaria, India, Spain*, USA
Endcap: Belarus, Bulgaria, Russia, Ukraine
HO: India

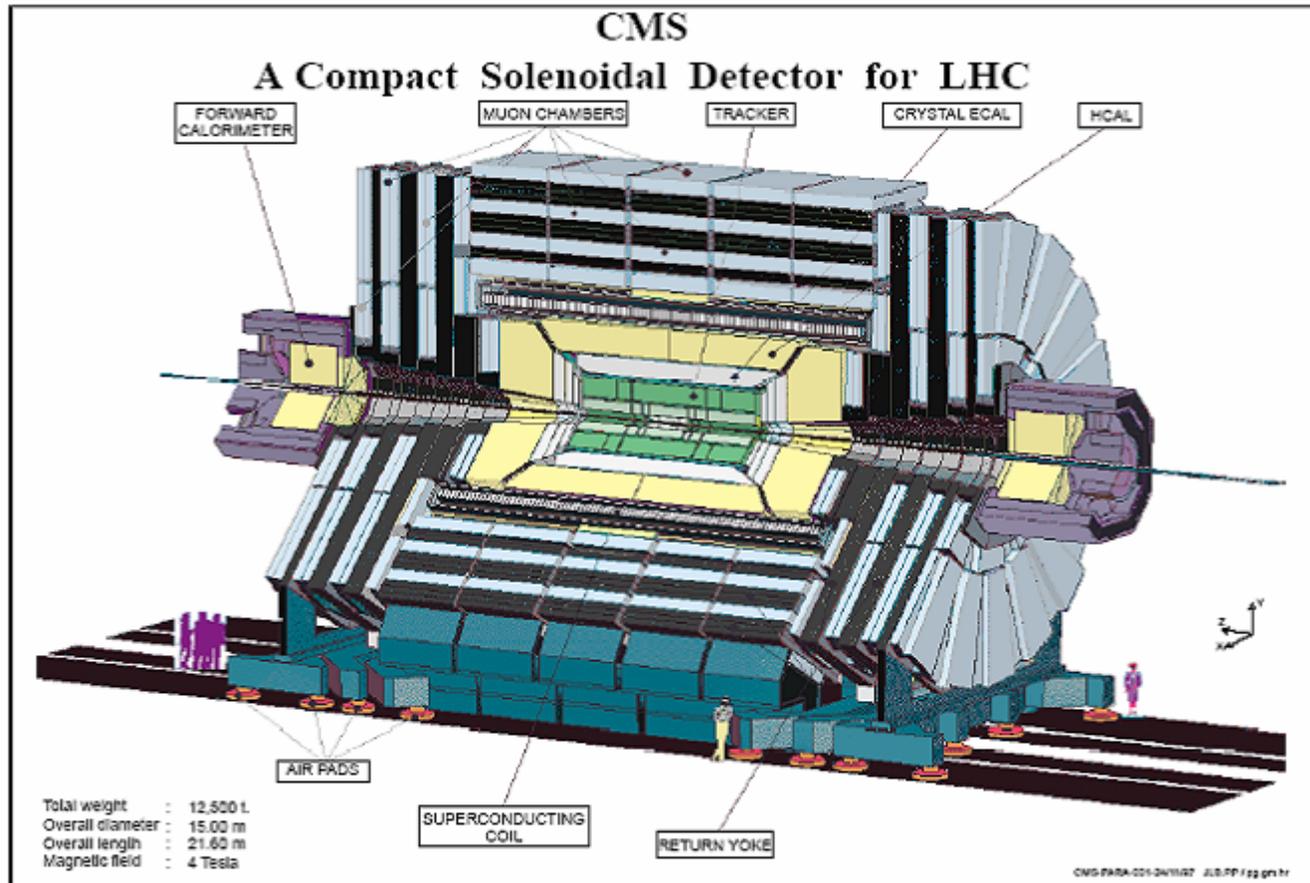
MUON CHAMBERS

Barrel: Austria, Bulgaria, CERN, China, Germany, Hungary, Italy, Spain,
Endcap: Belarus, Bulgaria, China, Korea, Pakistan, Russia, USA

Total weight : 12500 T
Overall diameter : 15.0 m
Overall length : 21.5 m
Magnetic field : 4 Tesla

* Only through industrial contracts

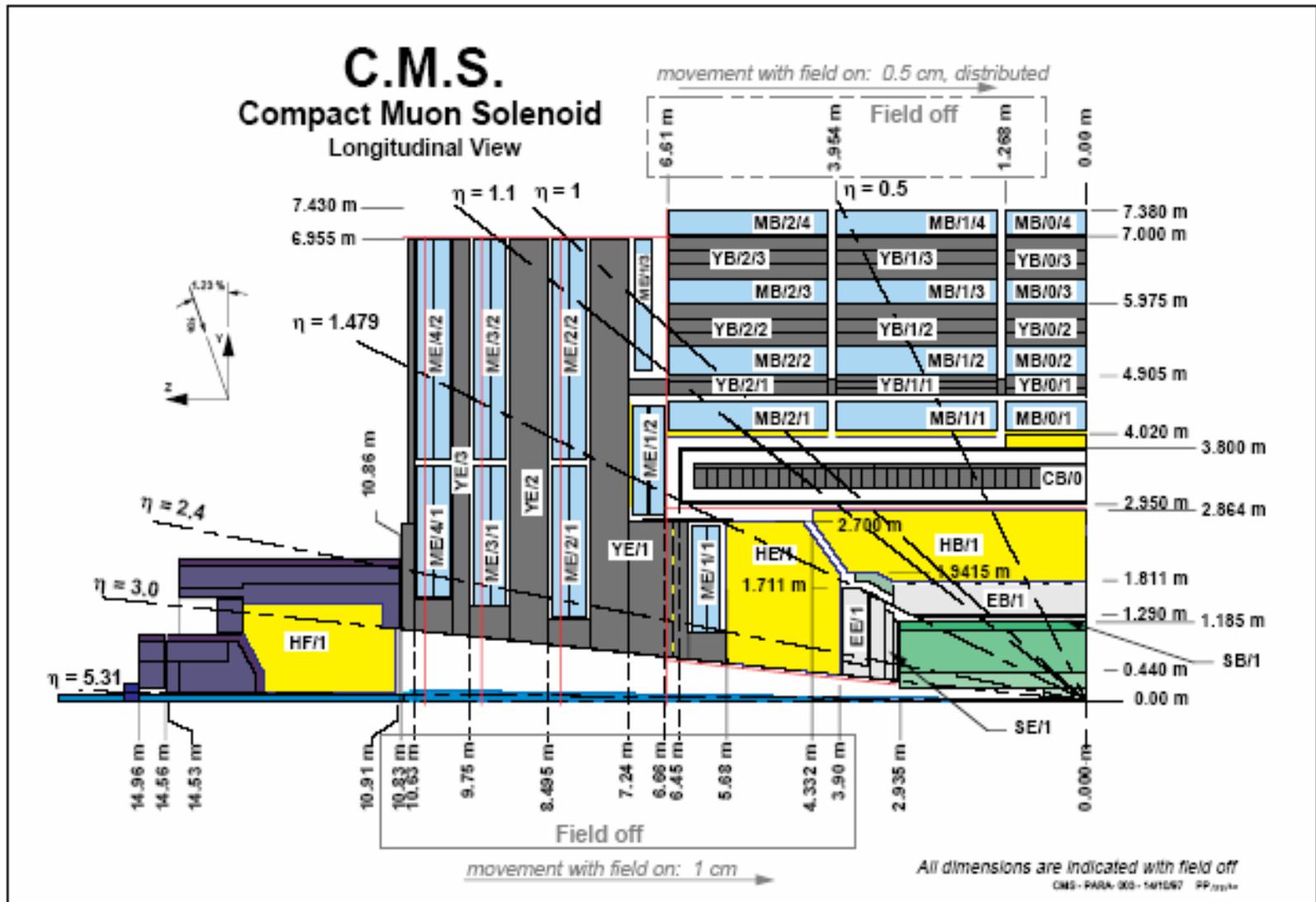
CMS Muon system



The CMS Muon detector is made of 3 different sub-detectors:

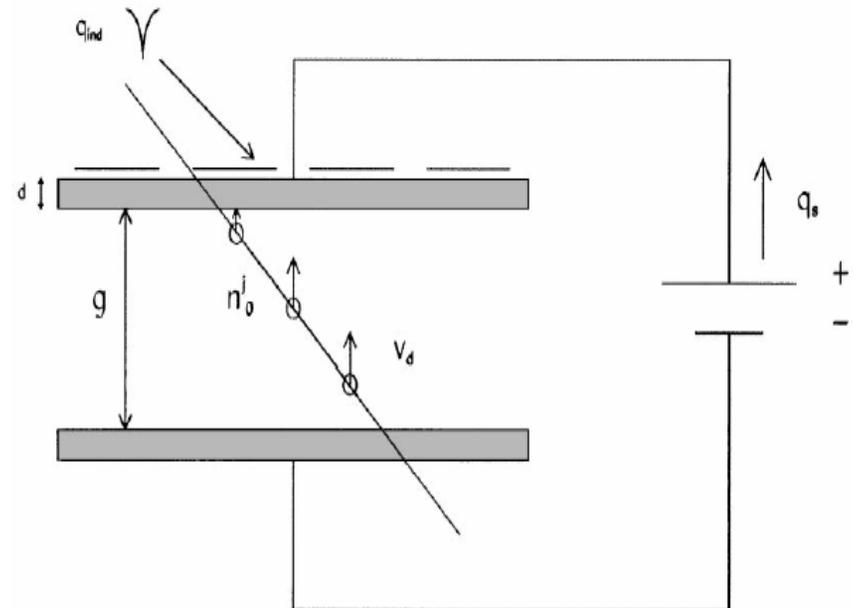
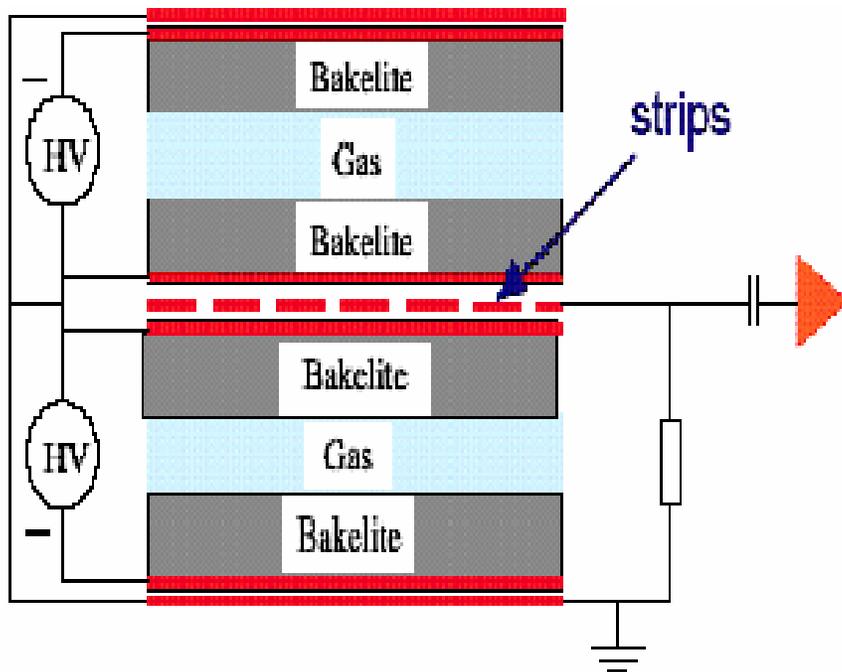
- Drift Tubes (DT) in the barrel region.
- Cathode Strip Chambers (CSC) in the endcap region
- Resistive Plate Chambers (RPC) as trigger detectors in both the barrel and the endcap.

CMS MUON SYSTEM: Barrel & Endcap



RPC detector; principles and applications

- two resistive ($2\text{-}5 \times 10^{10}$ ohm.cm) parallel plates.
- 2 mm length gas gap.
- high voltage and ground electrodes.
- Readout strips



RPC detector; principles and applications

Modes of operation:

1. Streamer
2. Avalanche

- RPCs originally conceived to work on streamer mode (up to ~ 100 Hz/cm²).
- In LHC experiments : a large neutron and gamma-ray background, producing high hit rate up to ~ 1000 Hz/cm² .
- To overcome this difficulty, RPCs will be operated in avalanche mode, Using lower electric field.
- Transferring part of amplification from gas to front-end electronic.

RPC detector; principles and applications

Nowadays RPCs are used in many fields :

- **LHC at CERN: ALICE, ATLAS, CMS**
- **Extensive Air Shower (EAS) physics**
- **X-ray imaging, UV imaging, Positron Emission Tomography (PET), ...**
- **As a part of other instruments: like BESIII spectrometer, ...**

Theoretical simulation of RPC

- Monte carlo procedure (Fortran programming)
- gas mixtures :
 - C₂F₄H₂/i-C₄H₁₀/SF₆ (96.7/3/0.3)
 - Ar/CO₂ (50/50)
 - Ar/i-C₄H₁₀ (50/50)
- 120 GeV Muon and 50 kV/cm electric field.

Theoretical simulation of RPC (cont.)

Simulation procedures:

1. Cluster creation

- Average number of clusters per unit length.
- Number of electrons per cluster.

$$P(x) = \frac{1}{\lambda} e^{-x/\lambda}$$

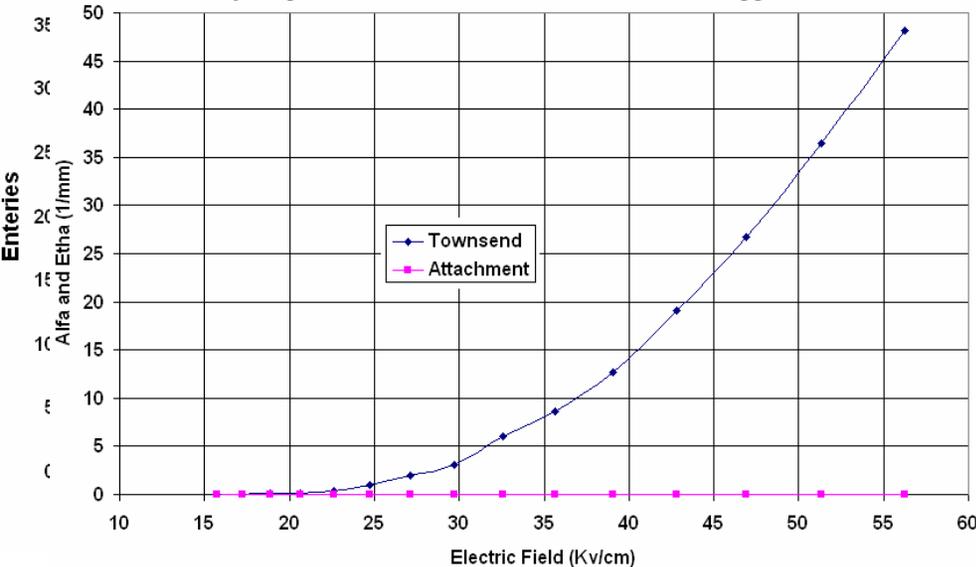
2. Calculation of the avalanche constants of gas mixture

- **“Heed”** program developed at CERN.
- Townsend and attachment coefficients.

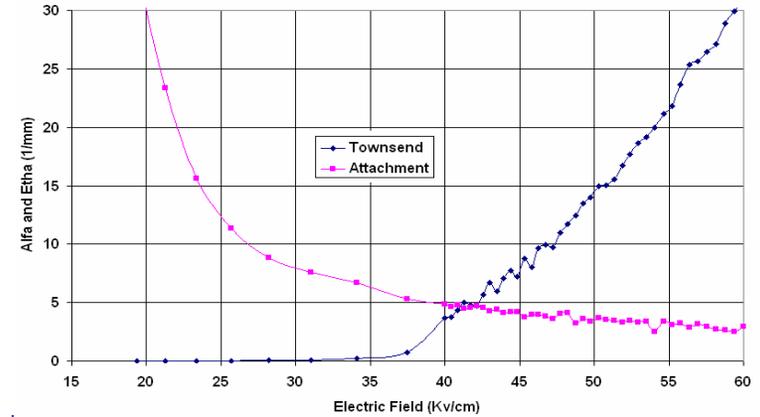
calculated using **“Magboltz”** program developed at CERN.

Number of cluster per cm for 120 GeV Muon mean = 41.70, rms=6.67

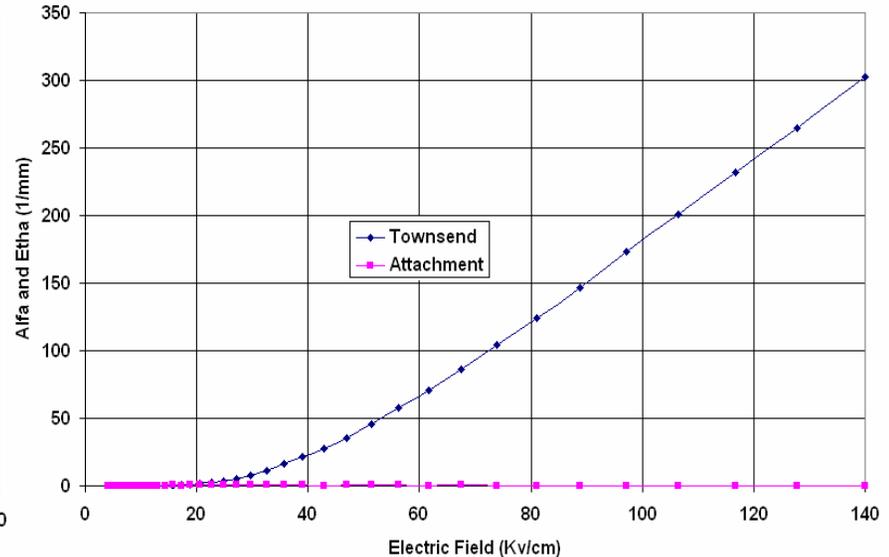
Townsend and attachment coefficient for argon and isobutane as calculated by Magboltz for T=296.15 K and P=760 torr for trigger RPC.



Townsend and attachment coefficient for C2F4H2/i-C4H10/SF6 as calculated by Magboltz for T=296.15 K and P=760 torr for trigger RPC.



Townsend and attachment coefficient for argon and CO2 as calculated by Magboltz for T=296.15 K and P=760 torr for trigger RPC.



Theoretical simulation of RPC (cont.)

Simulation procedures:

3. Avalanche development, calculated by means of Reigler formula (NIM,500(2003) 144-162).

$$P(n, x) = \begin{cases} k \frac{\bar{n}(x)-1}{\bar{n}(x)-k}, & n = 0 \\ \bar{n}(x) \left(\frac{1-k}{\bar{n}(x)-k}\right)^2 \left(\frac{\bar{n}(x)-1}{\bar{n}(x)-k}\right)^{n-1}, & n > 0 \end{cases}$$

where

$$\bar{n}(x) = e^{(\alpha-\eta)x}, \quad k = \frac{\eta}{\alpha}$$

4. Using central limit theorem for high $N(t)$.

5. Finally a comparison between $N(t)$ and $N_{\text{sat}} (5 \times 10^7)$

simulates space charge effect.

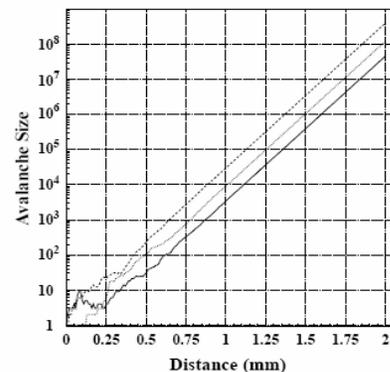
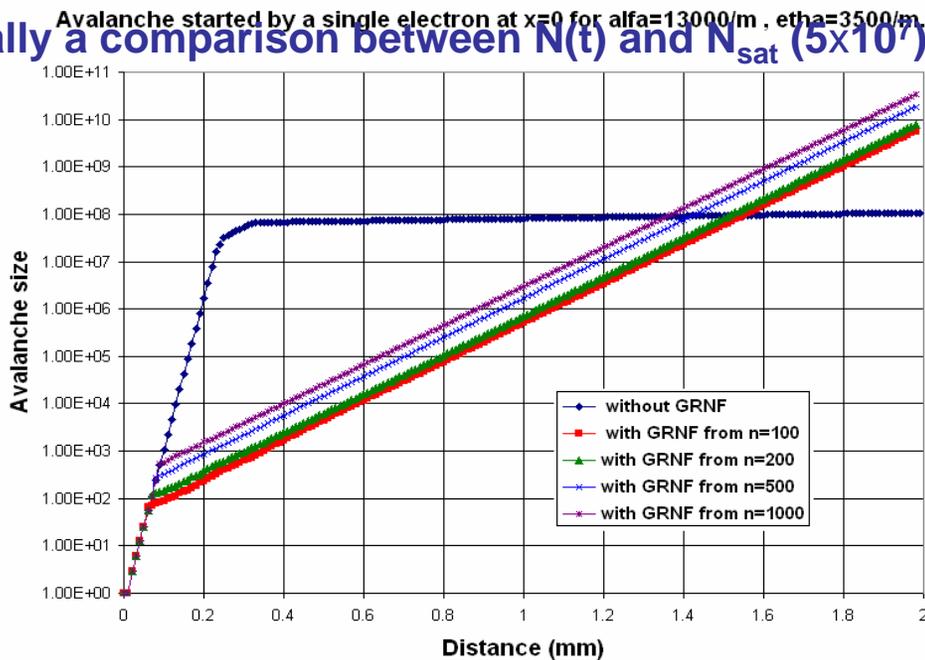


Fig. 6. Avalanches started by a single electron at $x = 0$ for $\alpha = 13/\text{mm}$, $\eta = 3.5/\text{mm}$. We see that the very beginning of the avalanche decides on the final avalanche size. Once the number of electrons is sufficiently large the avalanche grows like $e^{(\alpha-\eta)x}$.

Theoretical simulation of RPC (cont.)

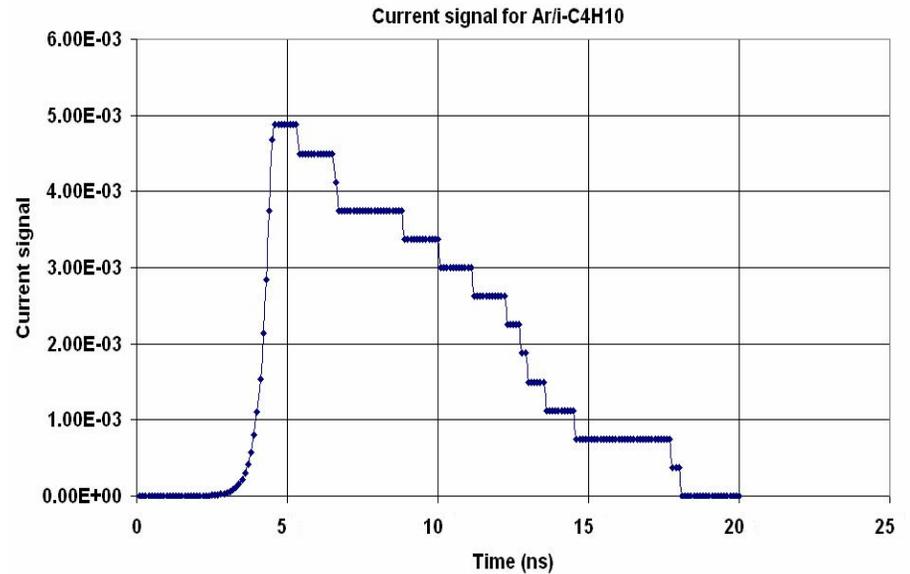
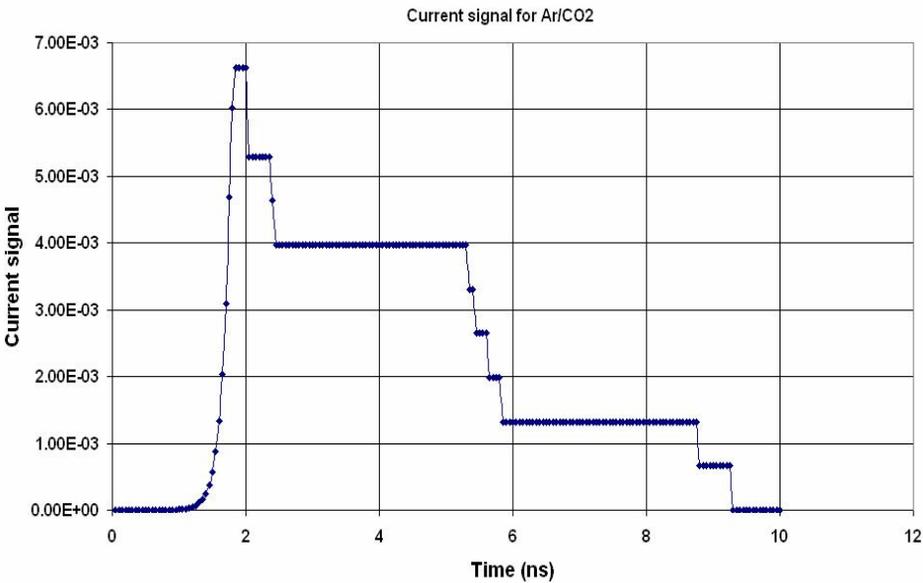
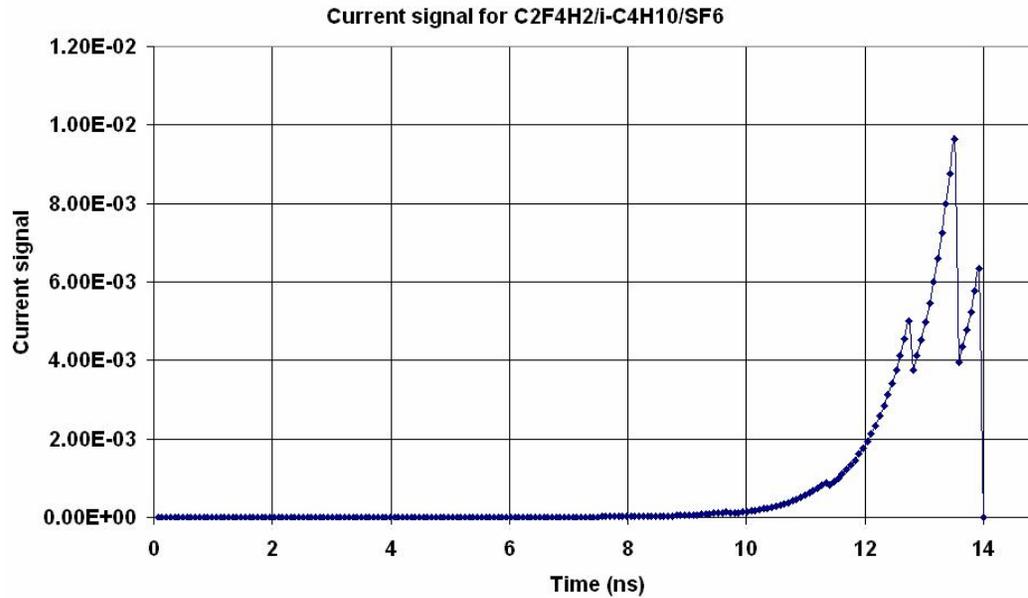
5. Induced signals

- Calculation of induced signal by means of “Ramo theorem” and “weighting field”:

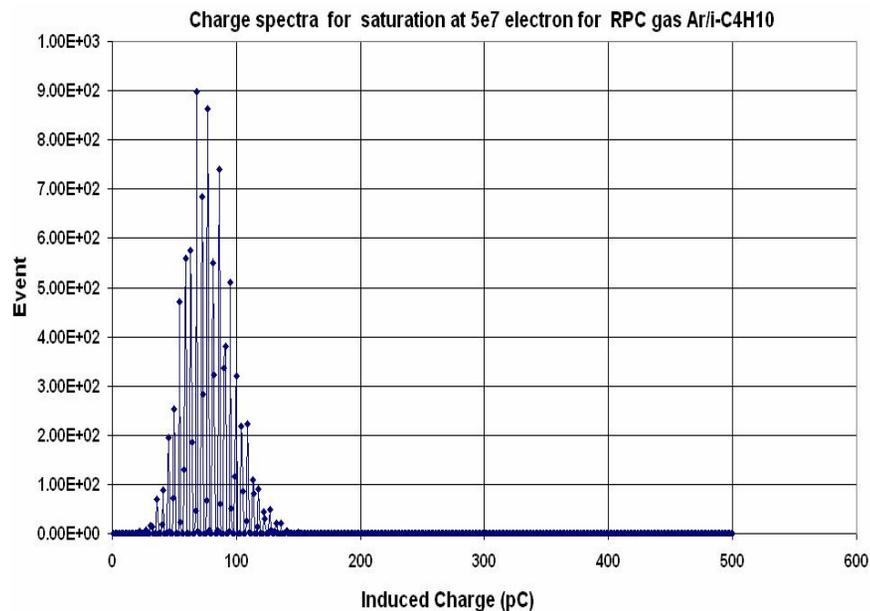
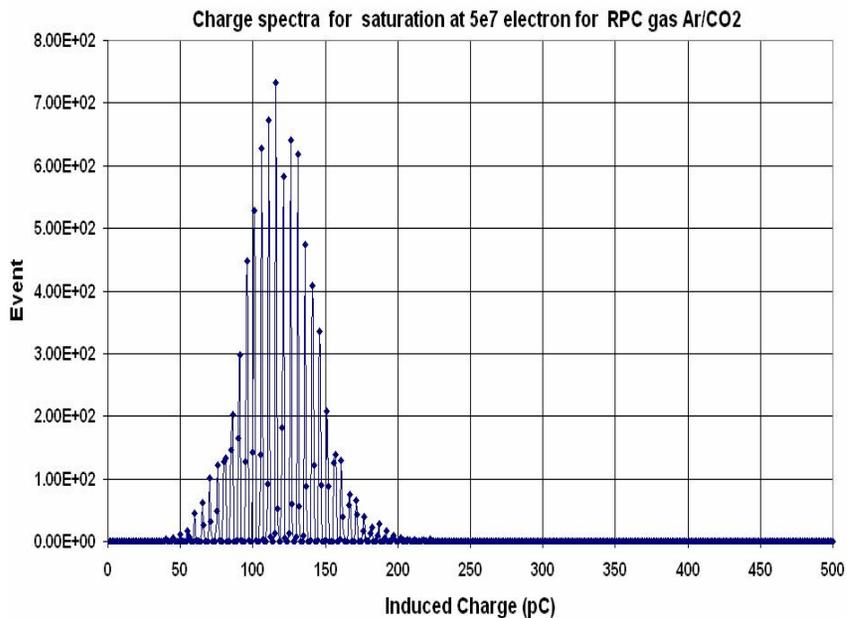
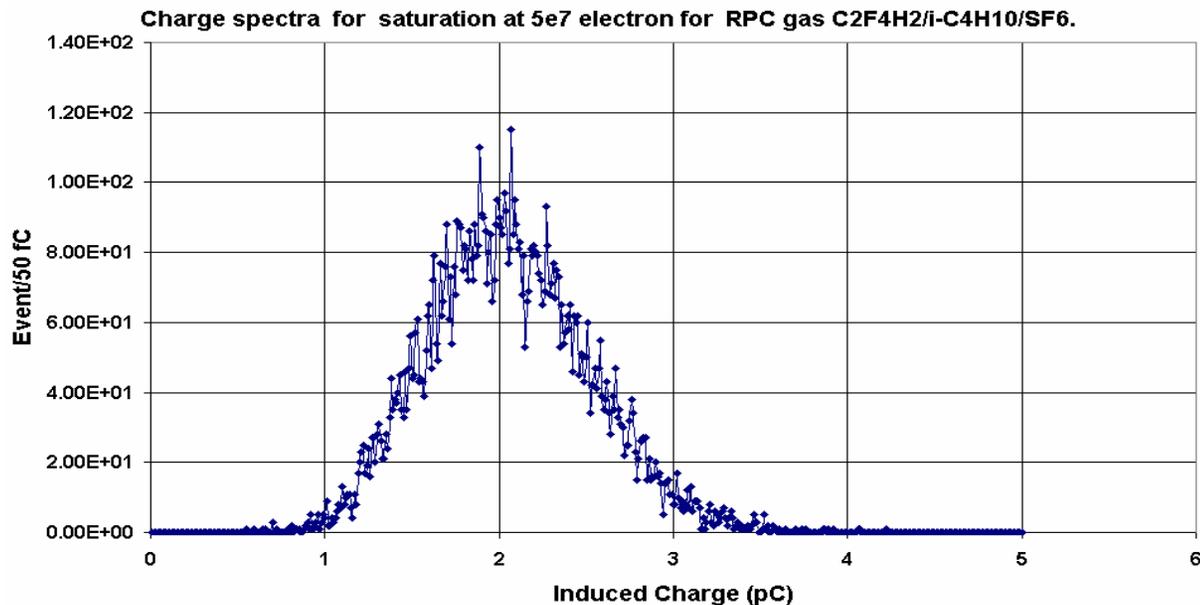
$$i(t) = \frac{E_w \cdot v}{V_w} e_0 N(t) \qquad \frac{E_w}{V_w} = \frac{\epsilon_r}{2b + d\epsilon_r}$$

- The induced charge is calculated by integrating induced current through the gap.

Theoretical simulation of RPC (cont.)



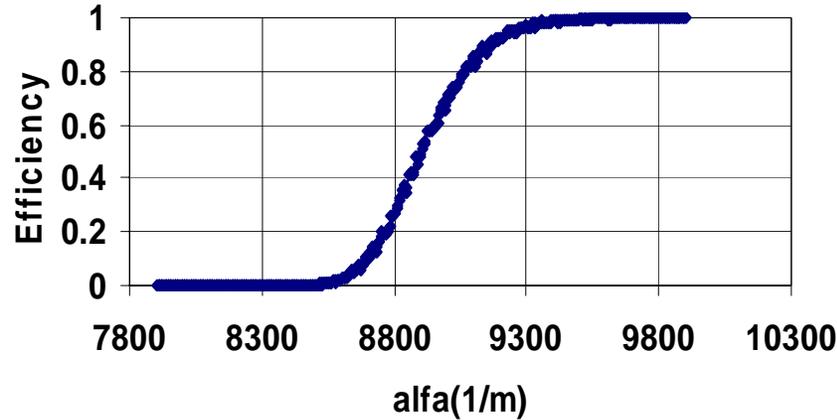
Theoretical simulation of RPC (cont.)



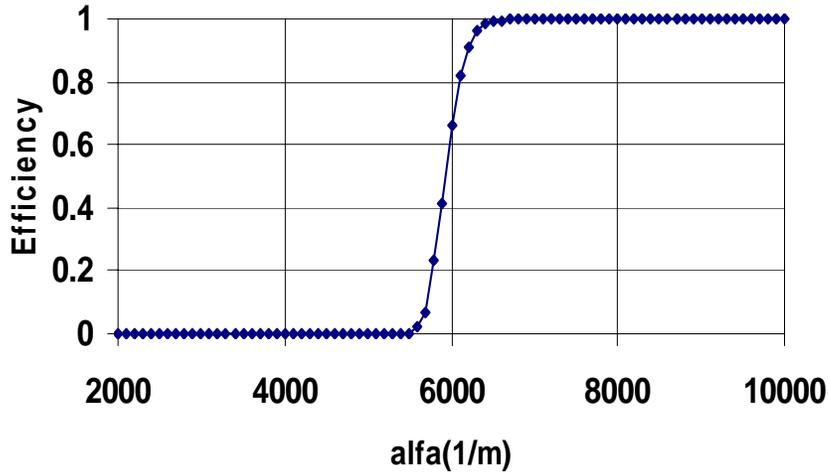
efficiency

- A certain electronic threshold q_{thr} (80 fC) .

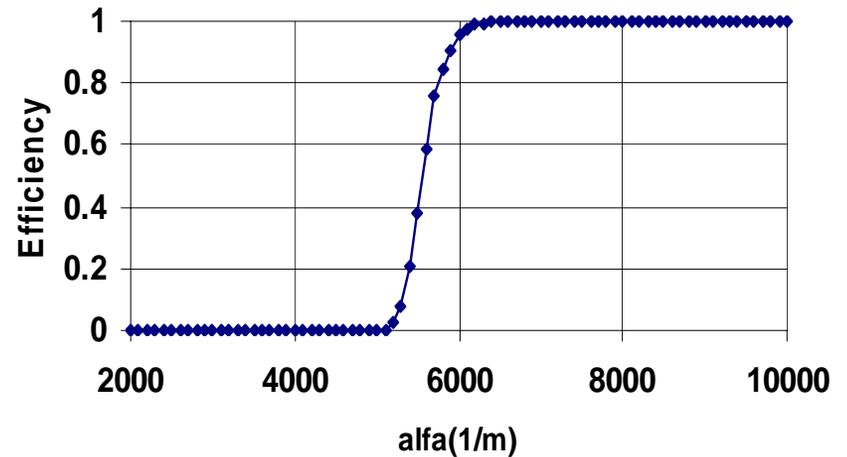
Efficiency plot for C2F4H10/i-Buthane/SF6



Efficiency plot for Ar/Co2



Efficiency plot for Ar/i-C4H10



Conclusions

- The RPC group activities during last year were reported.
- Experimental part; gas leakage test and High voltage test has been performed.
- Efficiency test is in progress.
- Theoretical simulation (SM): (for three gas mixtures)
- Induced signal strongly depends on the type of gas mixture.
- Streamer characteristic of argon based gas mixtures.
- Development of SM by space charge effect is in progress.

