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

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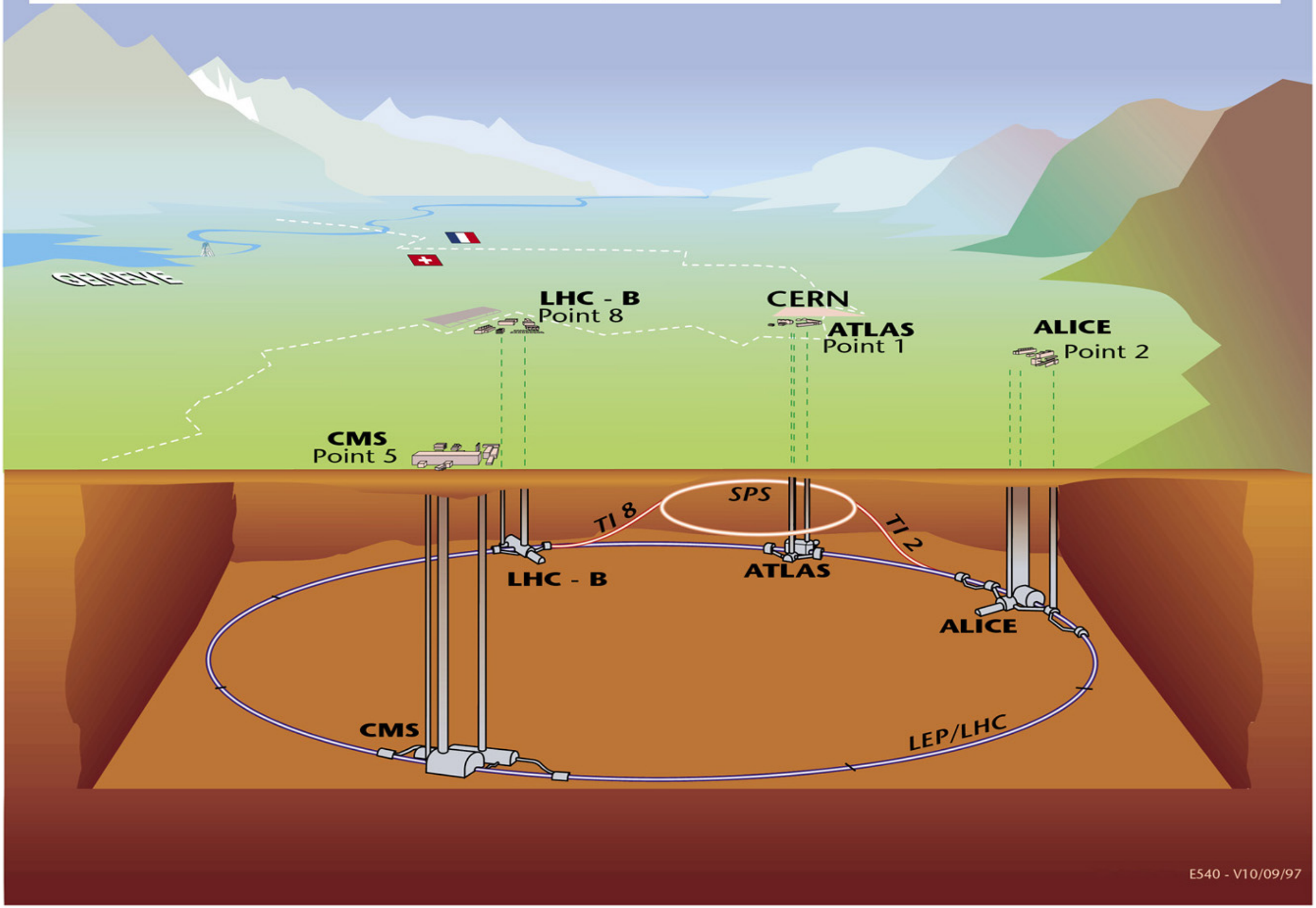
Contents :

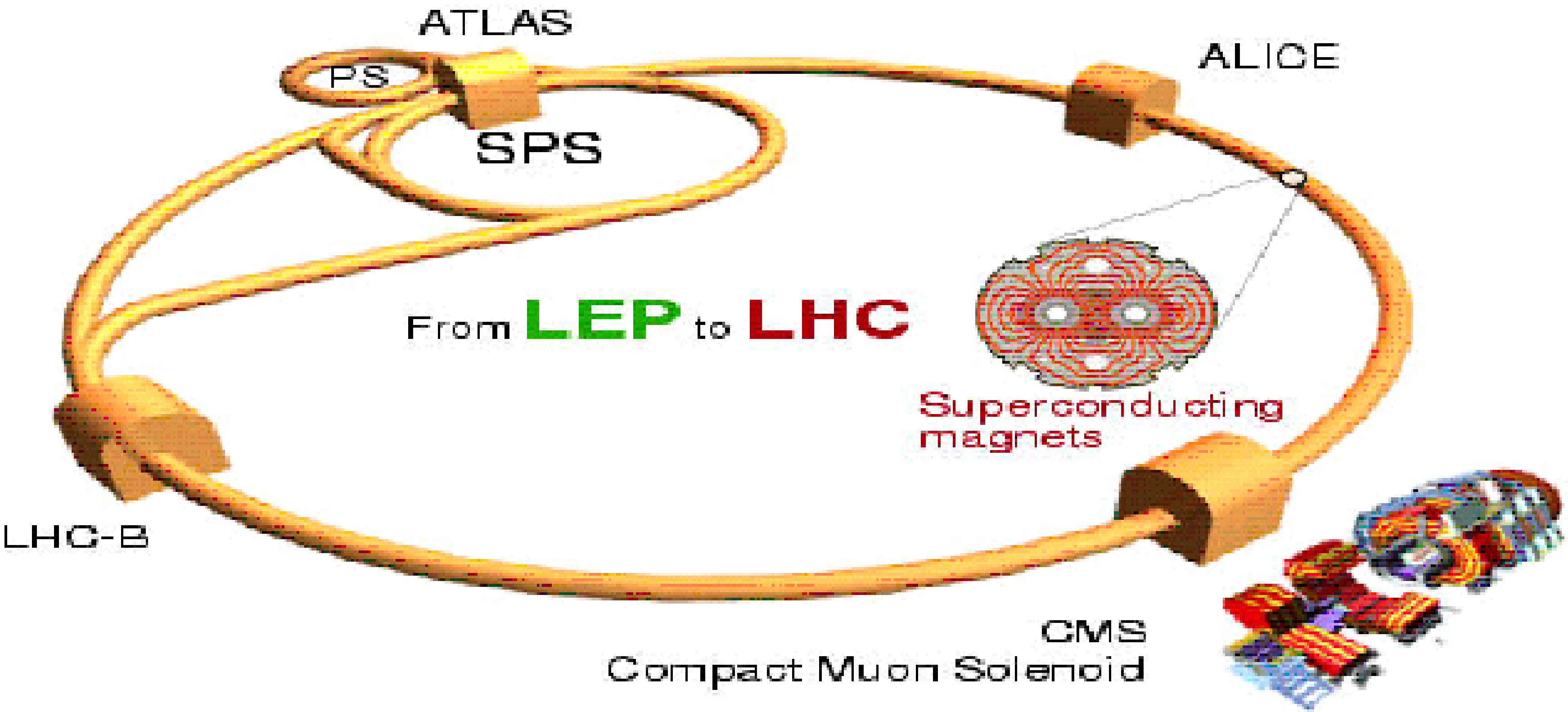
- LHC project and CMS experiment
- CMS Muon system and RPC project
- RPC detector; principles and applications
- RPC experimental studies
- Theoretical simulation of RPC
- Conclusion

LHC project at CERN

Overall view of the LHC experiments.



The Large Hadron Collider (LHC)

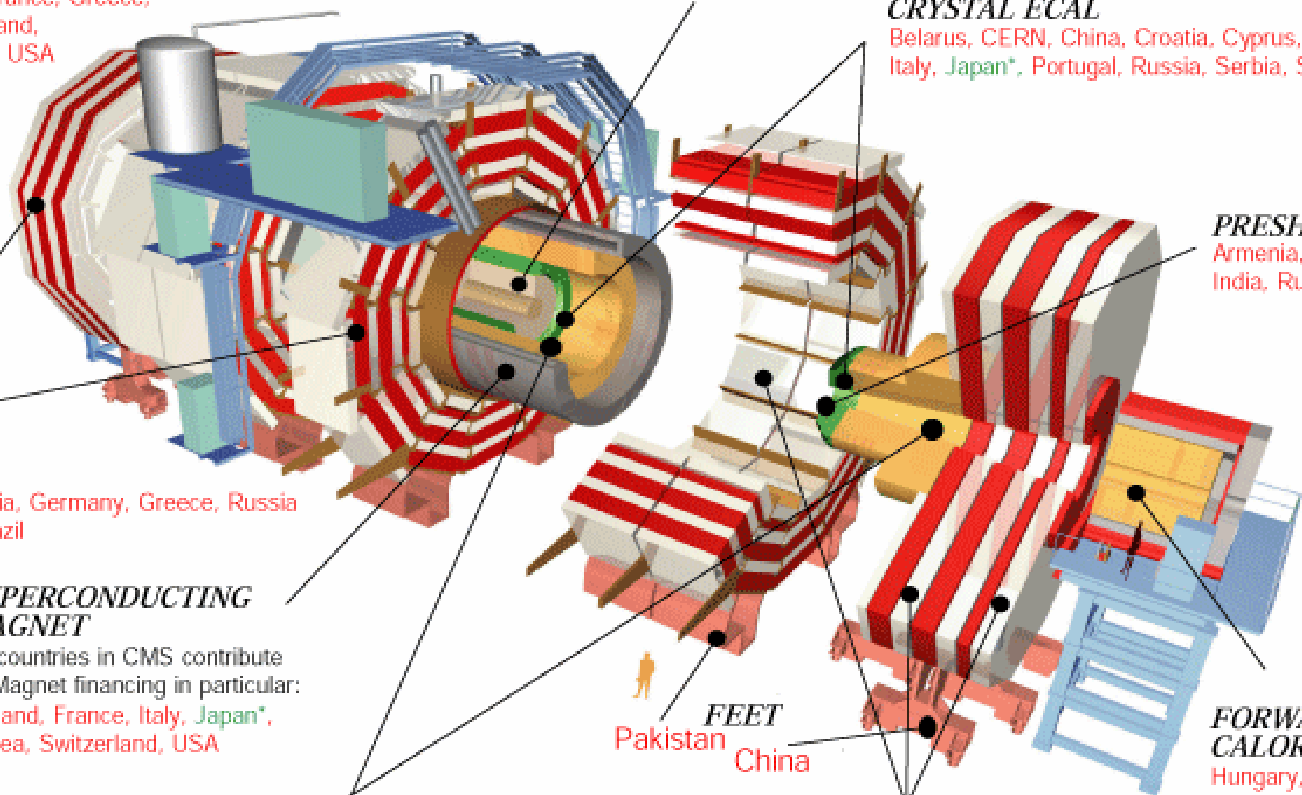


	Beams	Energy		Luminosity
LEP	e+ e-	200	GeV	10^{32} cm^{-2}s^{-1}
LHC	p p	14	TeV	10^{34}
	Pb Pb	1312	TeV	10^{27}

CMS: Compact Muon Solenoid

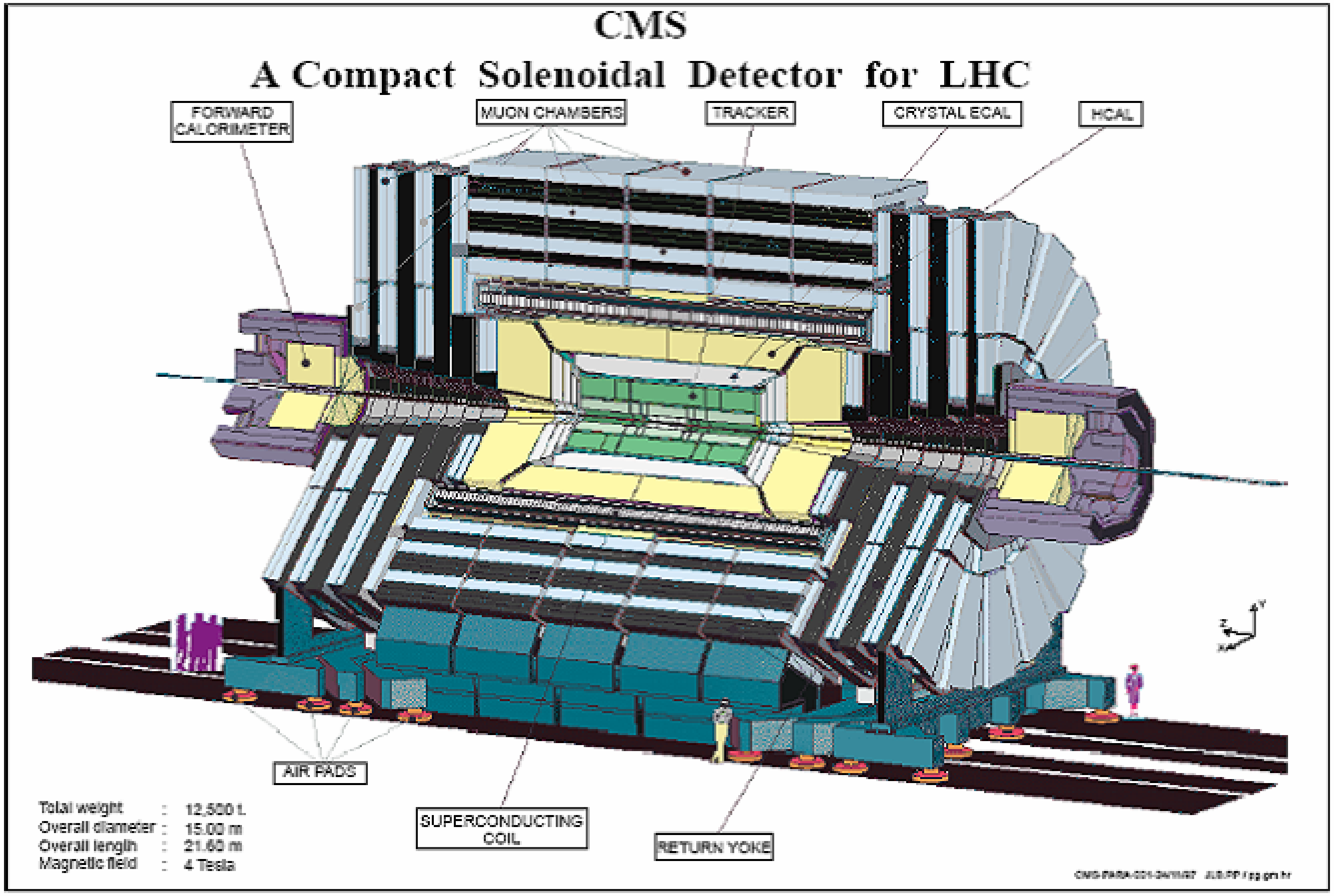
CMS Collaboration

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



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

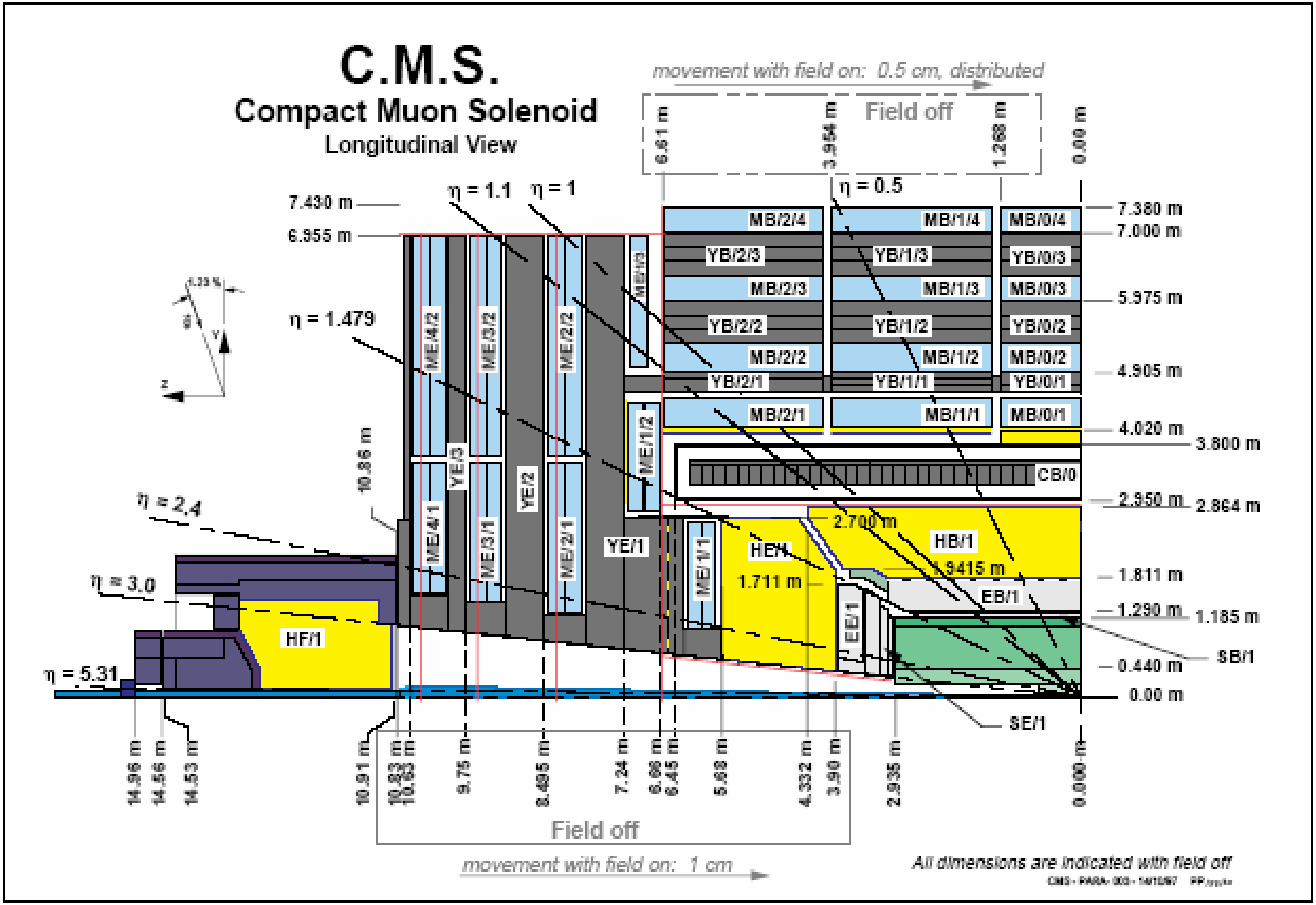
CMS Muon system



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

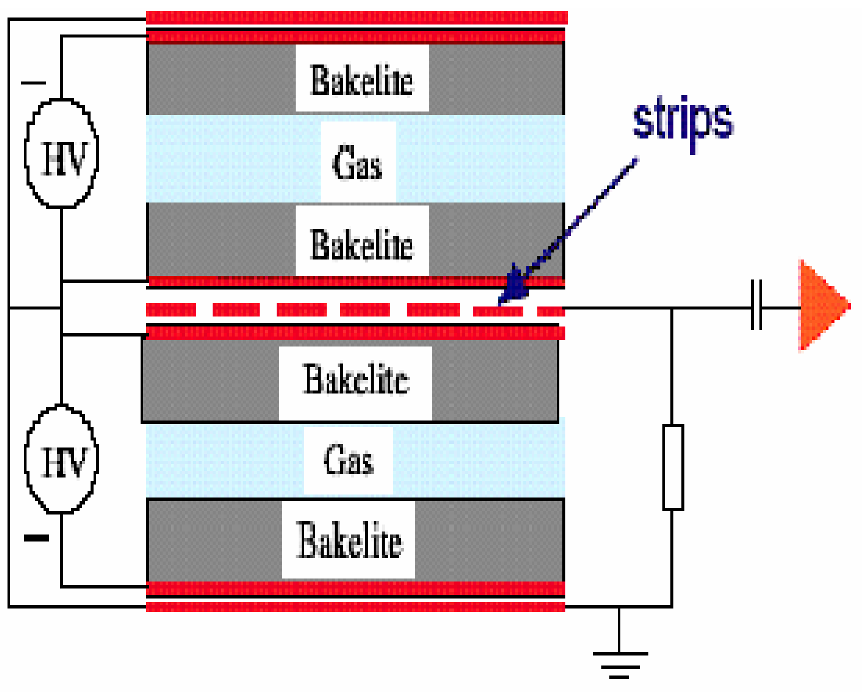
- **Drift Tubes (DT) in the barrel region.**
- **Cathode Strip Chambers (CSC) in the endcap region**
- **Resistive Plate Chambers (RPC) as trigger detectors in both the barrel and the endcap.**

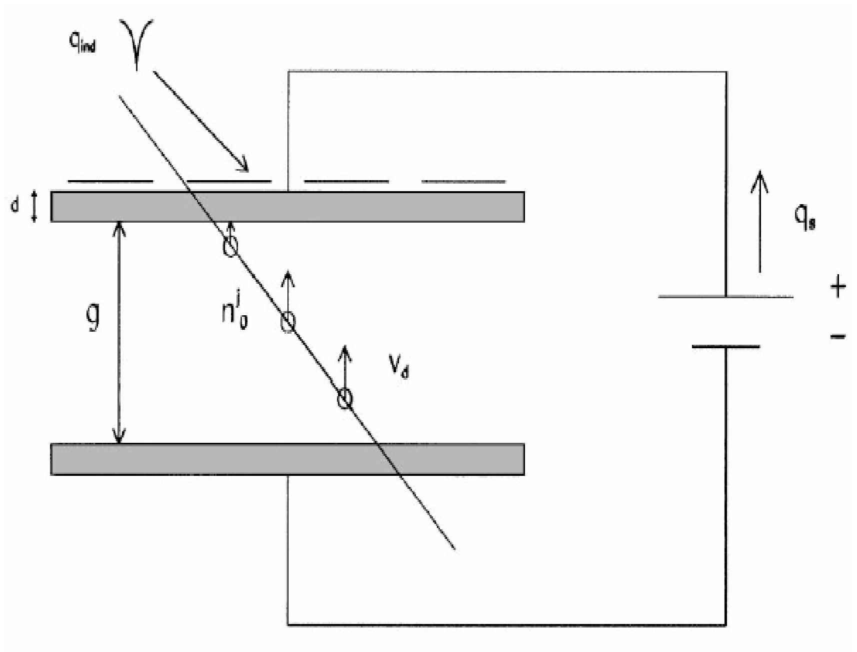
CMS MUON SYSTEM: Barrel & Endcap



RPC detector; principles and applications

- two resistive (2-5x10^{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/cm^2).
- In LHC experiments : a large neutron and gamma-ray background, producing high hit rate up to ~1000 Hz/cm^2 .
- 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.

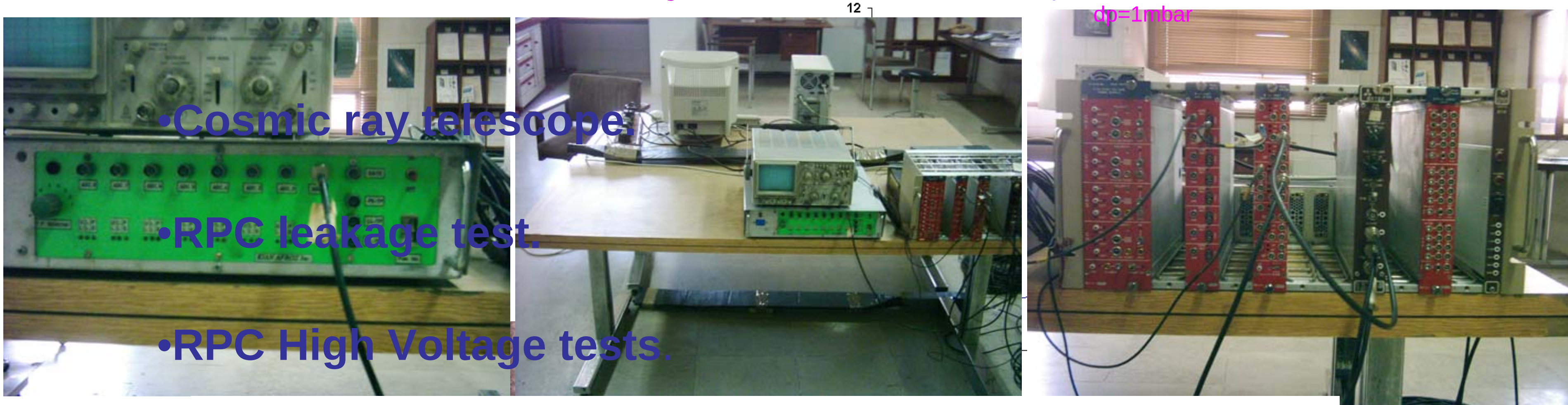
RPC detector; principles and applications

Nowadays RPCs are used in many fields :

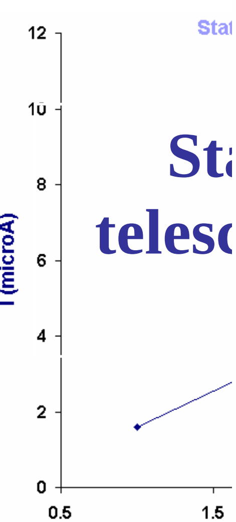
- **LHC at CERN: ALICE, ATLAS, CMS**
- **Extensive Air Shower (EAS) physics**
- **X-ray imaging, UV imaging, Positron Emission Tomography (PET), …**
- **As a part of other instruments: like BESIII spectrometer, …**

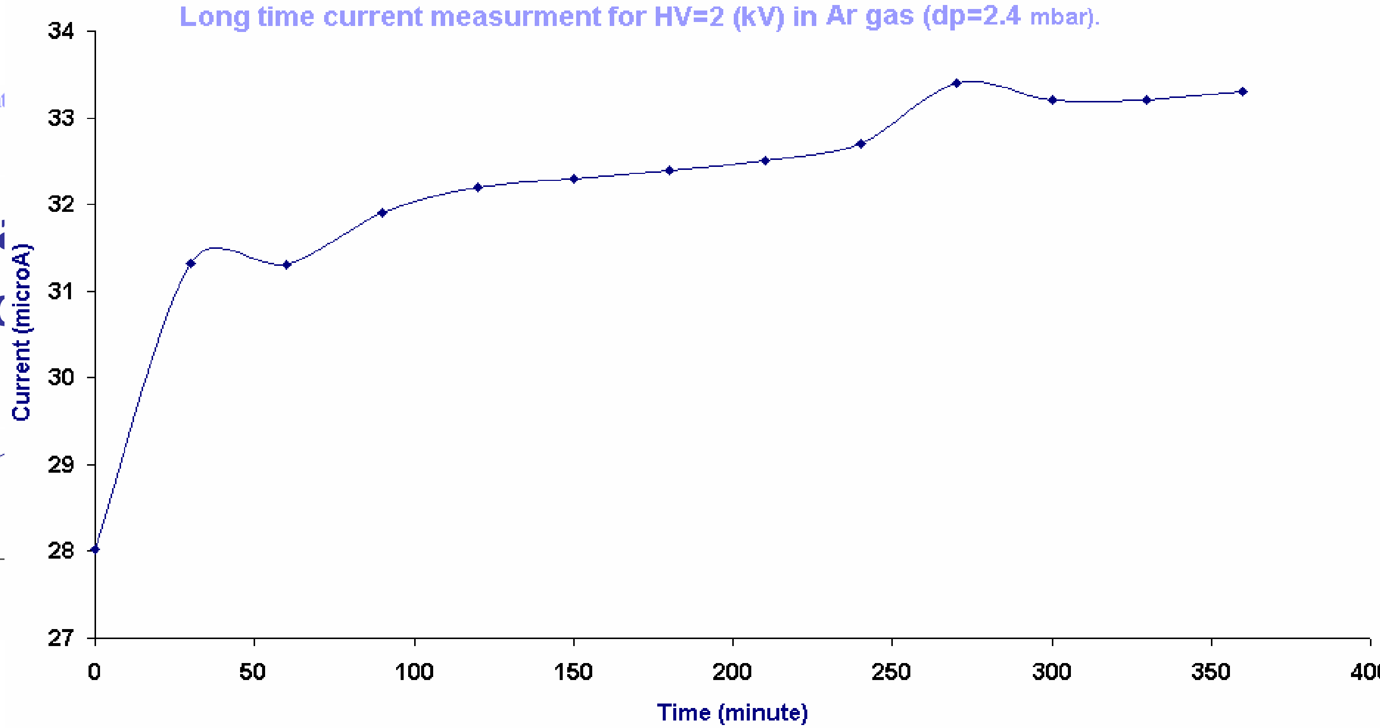
RPC experimental studies

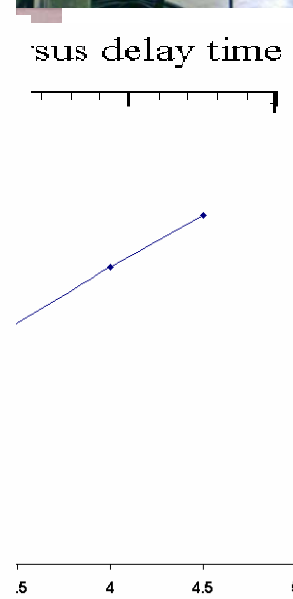
Cosmic ray telescope ,Preliminary activities.



- •Cosmic ray telescope.
- •RPC leakage test.
- •RPC High Voltage tests.







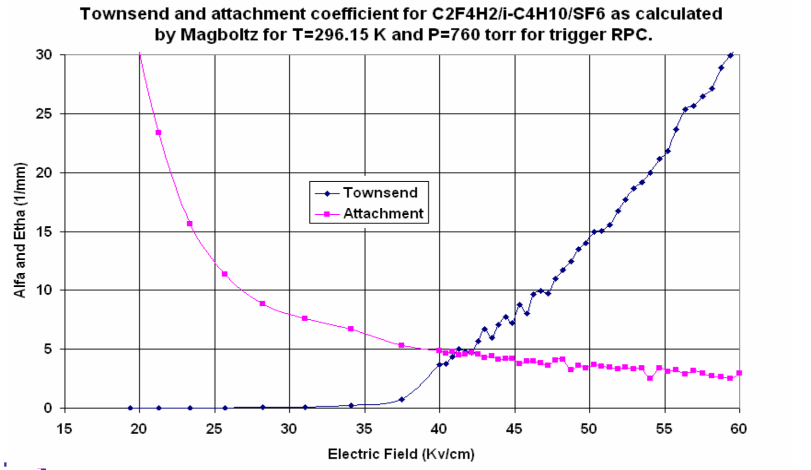
Theoretical simulation of RPC

- Monte carlo procedure (Fortran programming)
- gas mixtures :

> - $C_2F_4H_2$/i-C_4H_{10}/SF_6 (96.7/3/0.3)
> - Ar/CO_2 (50/50)
> - Ar/i-C_4H_{10} (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.**

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

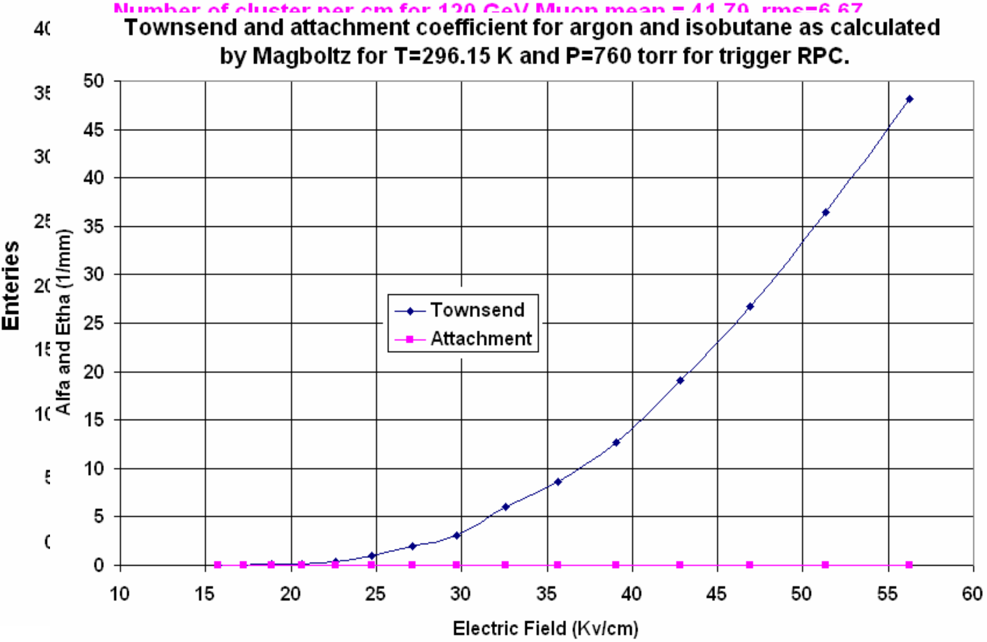
❖ Lambda is property of gas mixture evaluated using "Heed" program developed at CERN.

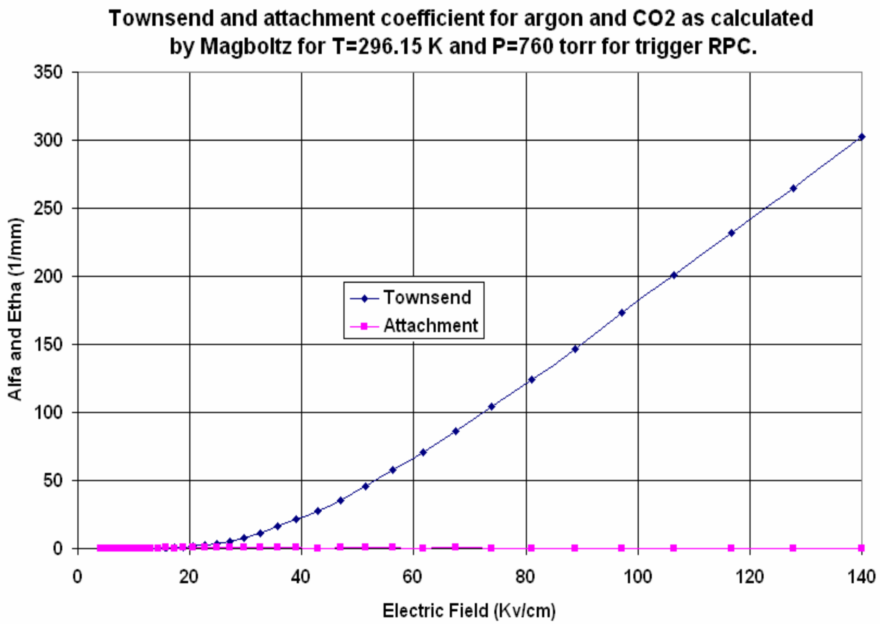
2. Calculation of the avalanche constants of gas mixture

- ➢ **Townsend and attachment coefficients.**

calculated using "Magboltz" program developed at CERN.

Number of cluster per cm for 120 GeV Muon mean = 41.79, rms=6.67





Theoretical simulation of RPC (cont.)

Simulation procedures:

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

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

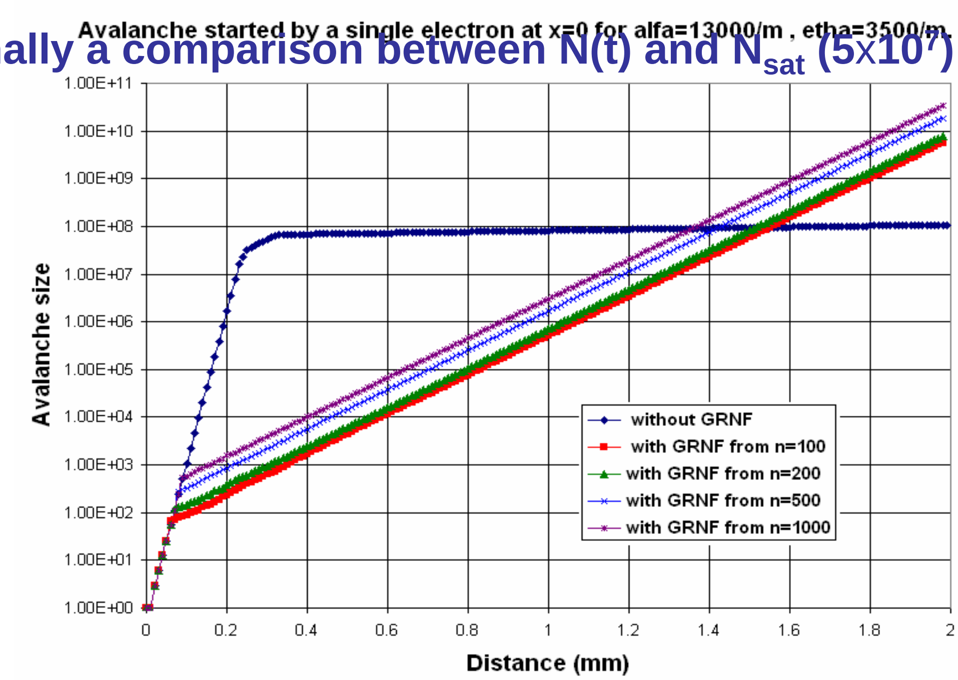
where

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

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

$$\mu = n_i\bar{n}(\Delta x), \qquad \sigma_\mu = \sqrt{n_i}\sigma(\Delta x)$$

5. **Finally a comparison between N(t) and N_{sat} (5×10^7) simulates space charge effect.**



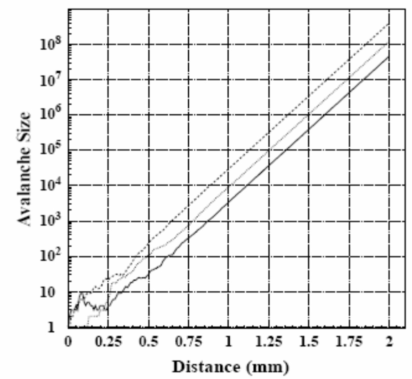


Fig. 6. Avalanches started by a single electron at $x = 0$ for $\alpha = 13/\text{mm}$, $\eta = 3.5/\text{mm}$. We see that the very beginning of the avalanche decides on the final avalanche size. Once the number of electrons is sufficiently large the avalanche grows like $e^{(\alpha-\eta)x}$.

Theoretical simulation of RPC (cont.)

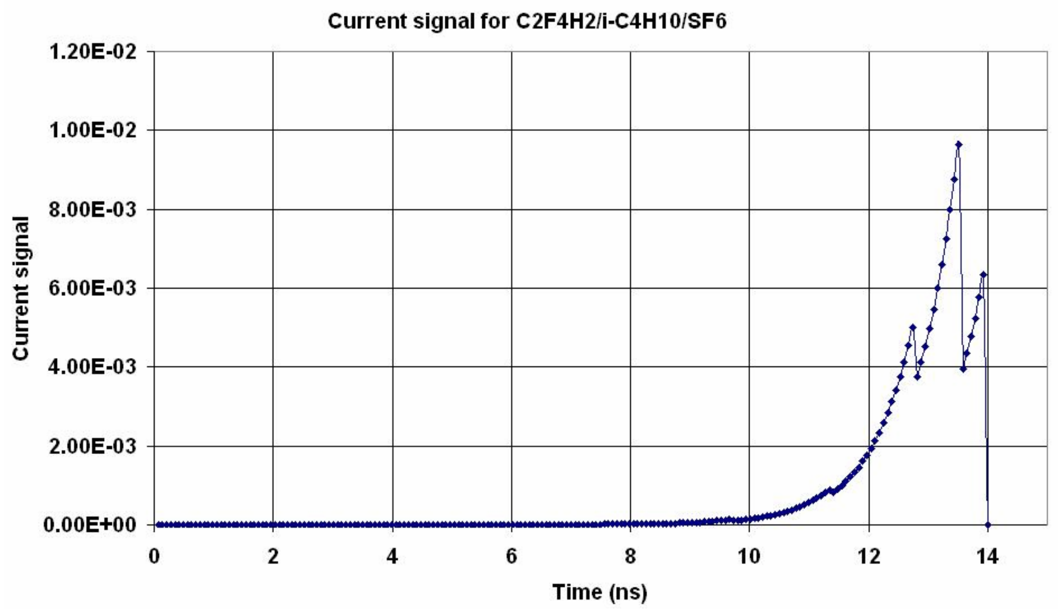
5. Induced signals

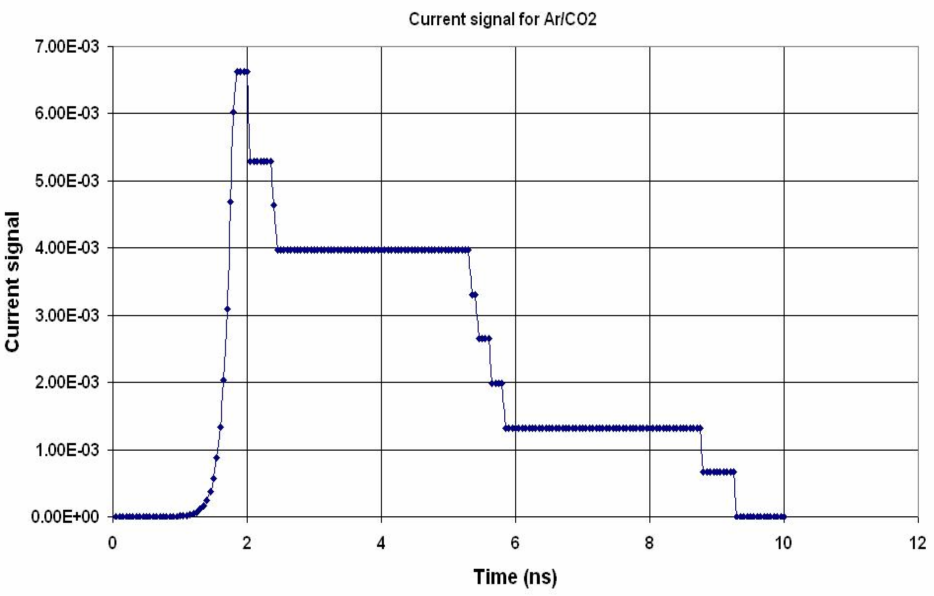
- **Calculation of induced signal by means of "Ramo theorem" and "weighting field":**

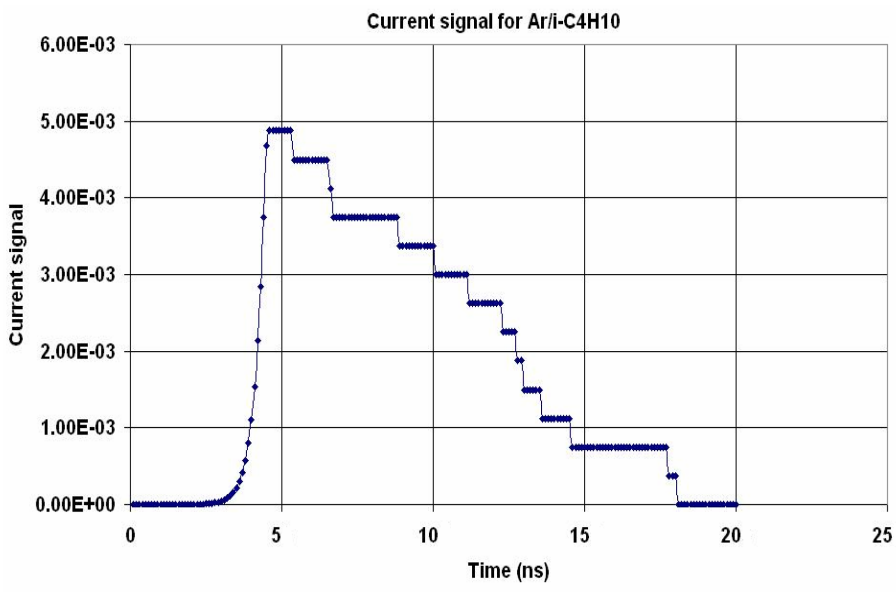
$$i(t) = \frac{E_w \cdot v}{V_w} e_0 N(t) \qquad \frac{E_w}{V_w} = \frac{\varepsilon_r}{2b + d\varepsilon_r}$$

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

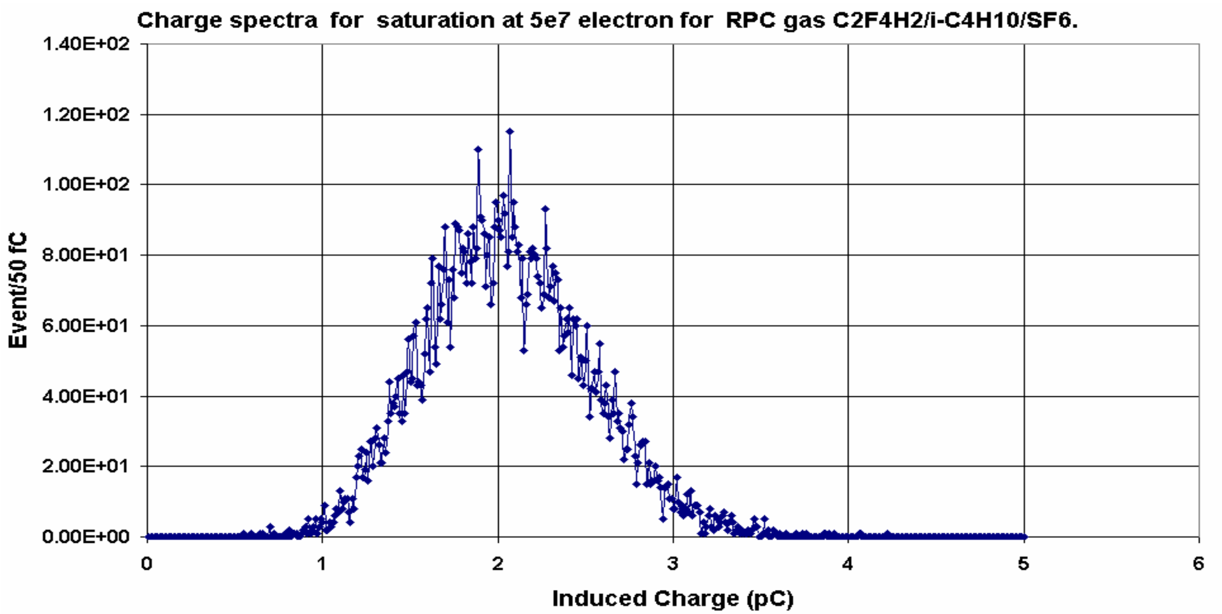
Theoretical simulation of RPC (cont.)

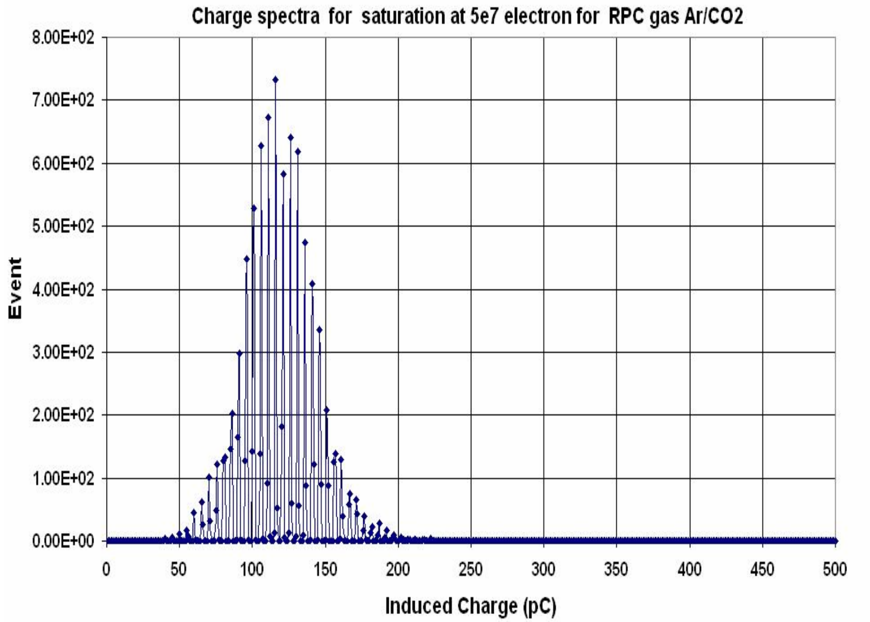


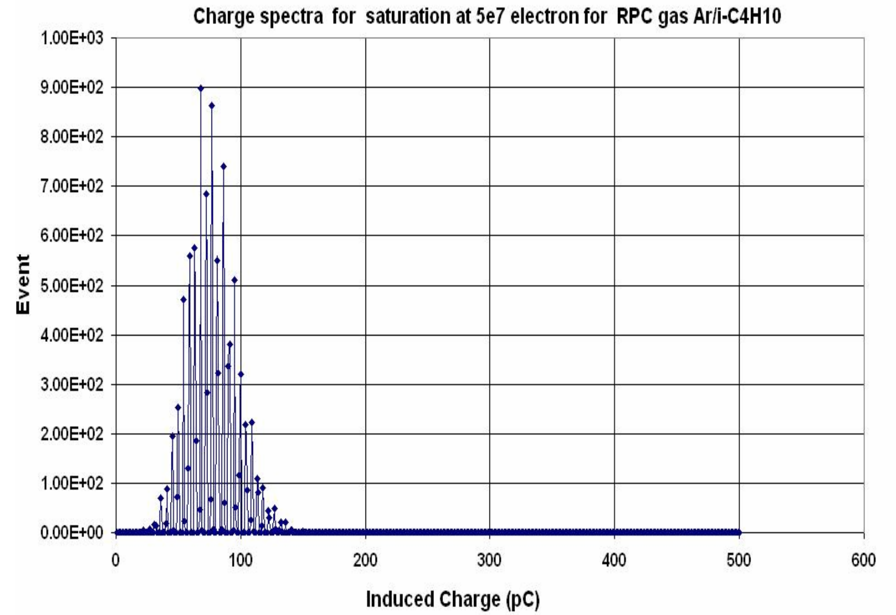




Theoretical simulation of RPC (cont.)

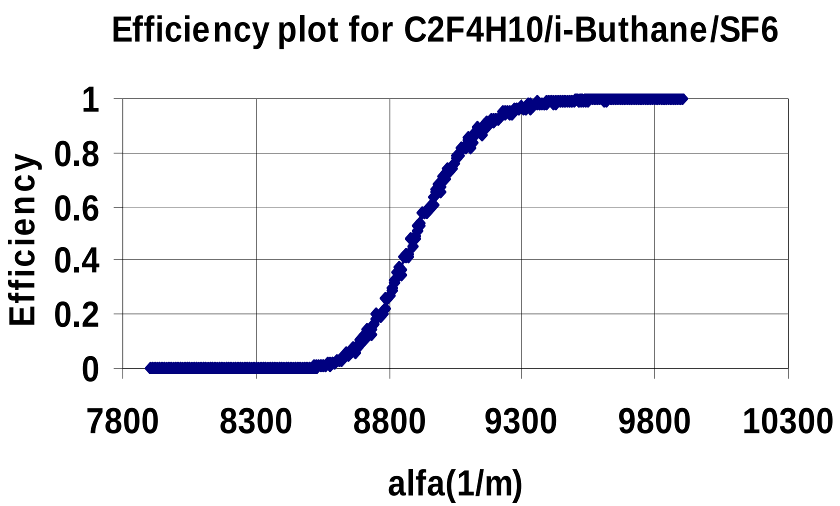


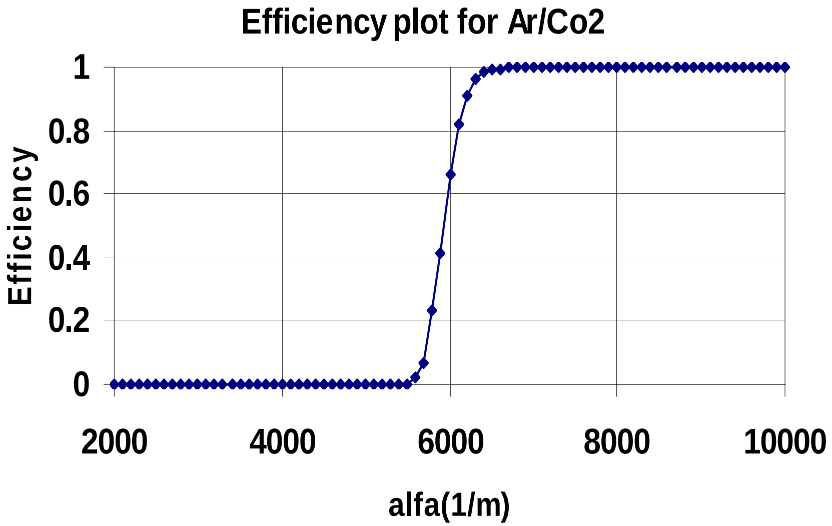


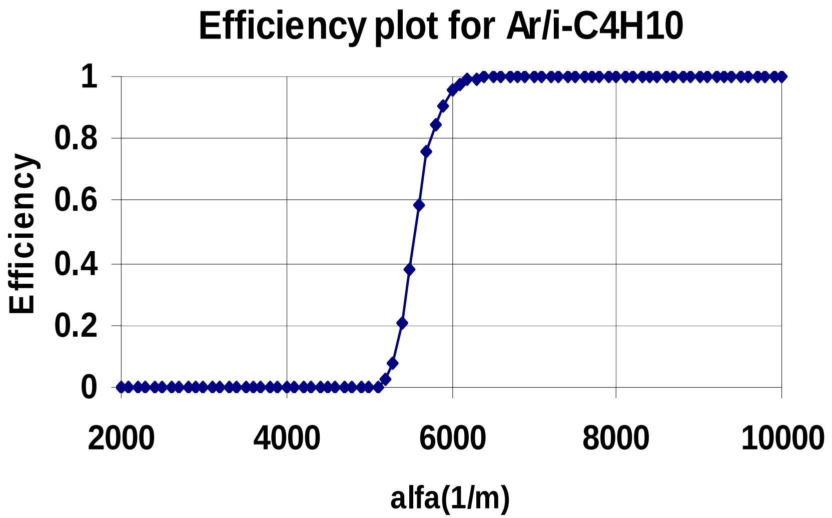


efficiency

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







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.