RPCs and applications to the Particle Physics

5th Particle Physics Workshop

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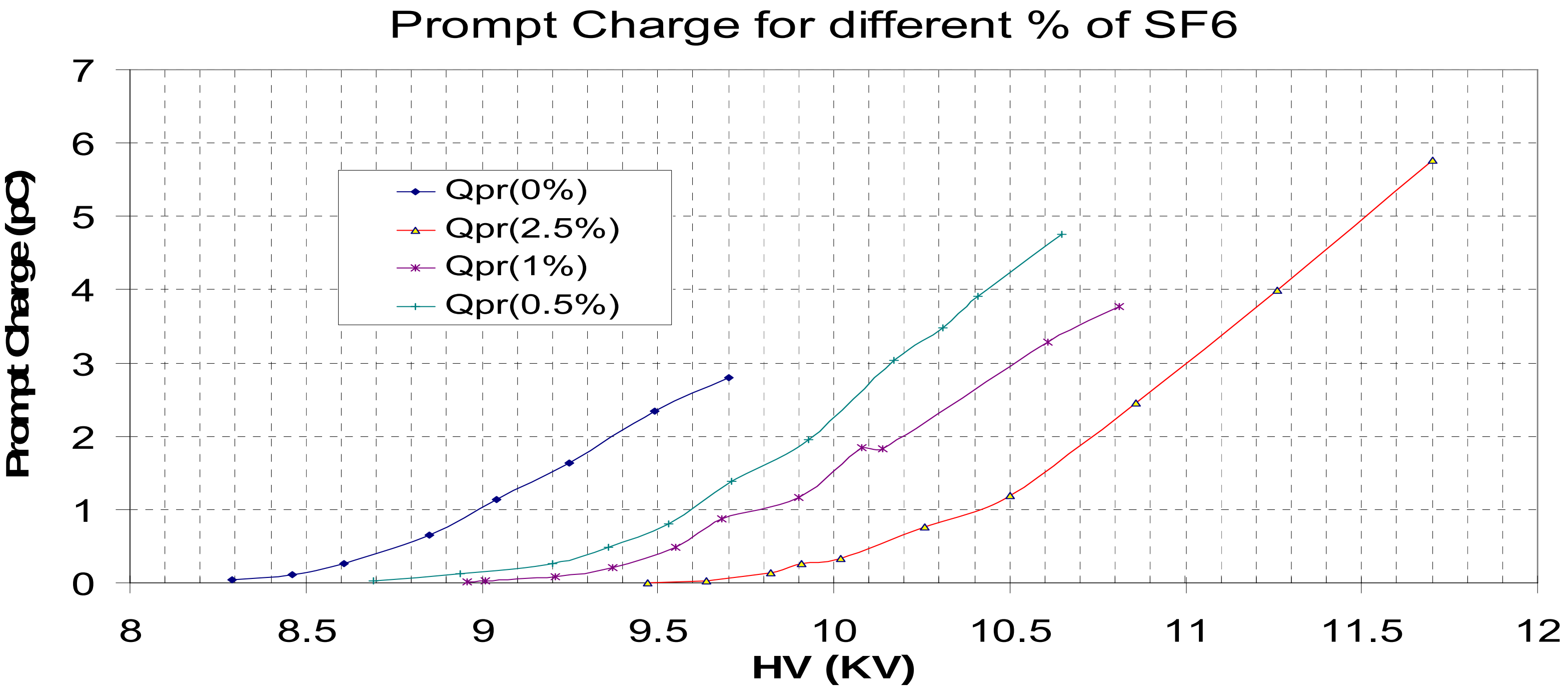
Layout

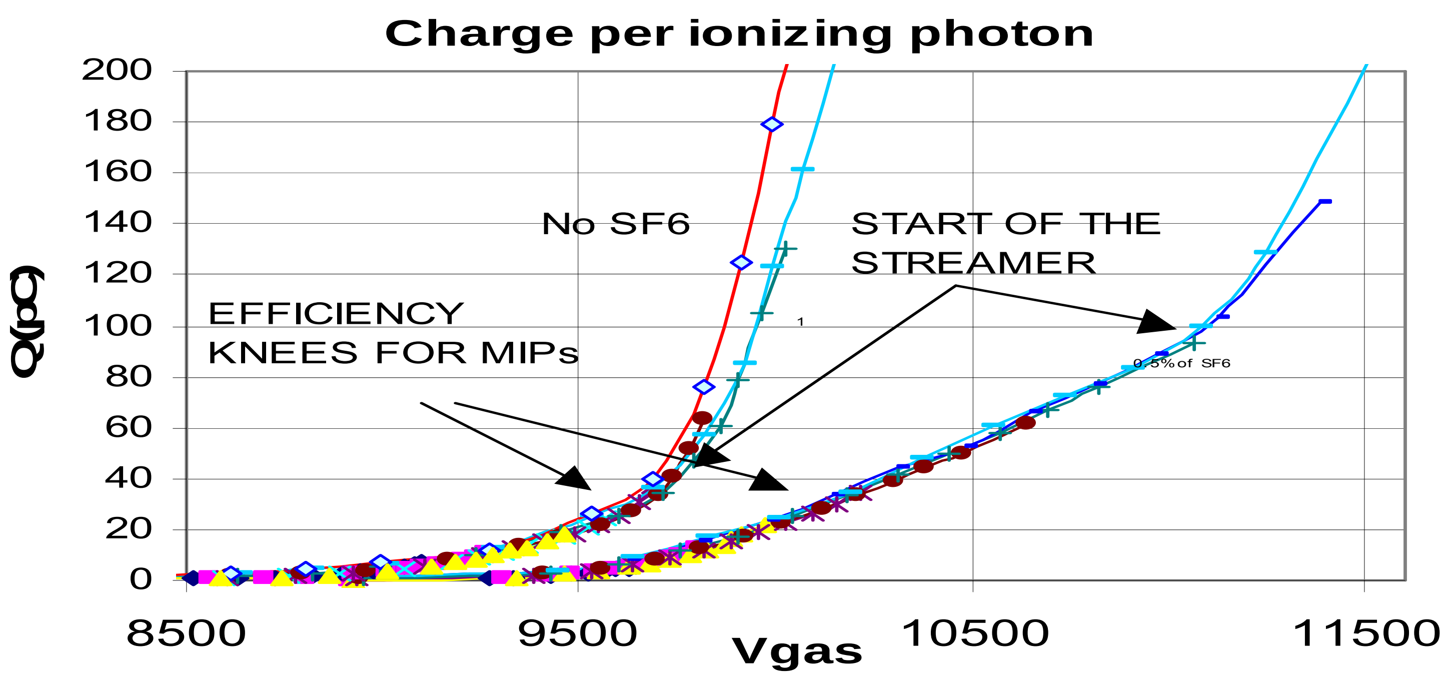
- Avalanche saturation
- Atlas RPC summary
- Applications to neutrino physics: Opera

The saturated avalanche

- There is experimental evidence evidence that the RPCs, in their operating point, work in a saturated avalanche mode:
  - The charge distribution, that is peaked at zero at low voltage, become more gaussian-like well inside the efficiency plateau
  - The prompt and the total charges show an exponential increase at low voltage and a linear increase well inside the efficiency plateau



Prompt Charge for different % of SF6
Prompt Charge (pC)
HV (KV)
Qpr(0%)
Qpr(2.5%)
Qpr(1%)
Qpr(0.5%)
0
1
2
3
4
5
6
7
8
8.5
9
9.5
10
10.5
11
11.5
12



Charge per ionizing photon
Q(pC)
Vgas
No SF6
START OF THE
STREAMER
EFFICIENCY
KNEES FOR MIPs
0.5% of SF6
0
20
40
60
80
100
120
140
160
180
200
8500
9500
10500
11500

The saturated avalanche (2)

- The grow of the avalanche is normally described with the Townsend equation

$$dN/dx = \alpha N$$

- The space charge produced by the avalanche shields the applied field and avoids the exponential divergence. For $\alpha x=20$ the applied field is completely shielded
- The saturation due to the space charge can be explaned by the Townsend equation assuming that the coefficient $\alpha=\alpha(E)$ is field dependent

The logistic equation

- Another possibility is to introduce in the equation a quadratic term $-\beta N^2$ which accounts for the correlation among the avalanche electrons

$$dN/dx = \alpha N - \beta N^2$$

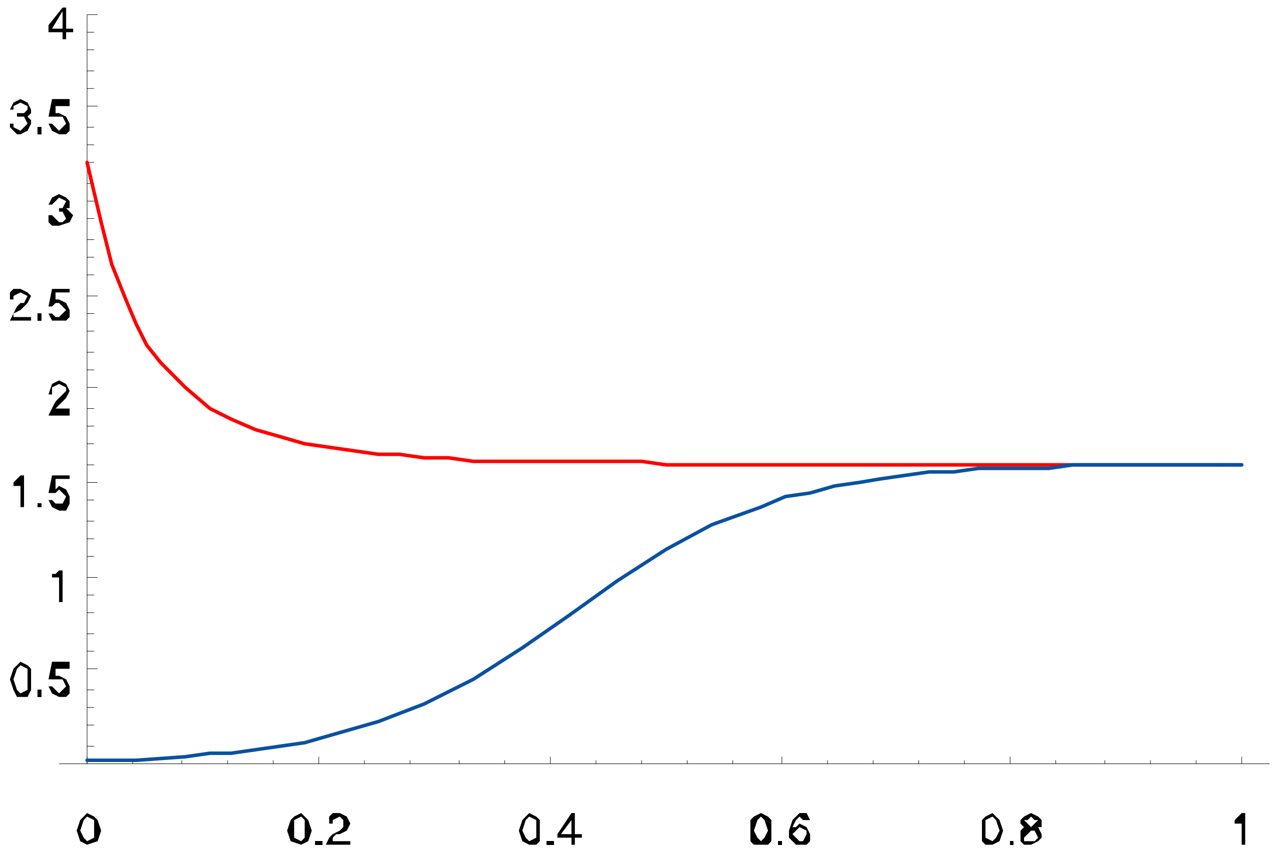
- The solution of this (logistic) equation is

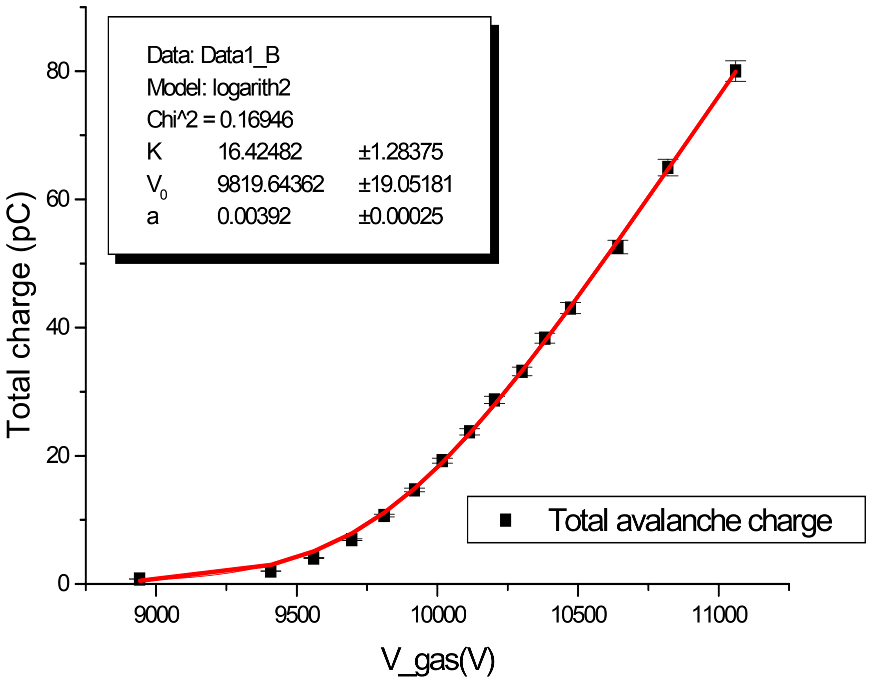
$$N=K/\{1+ (K/N_0 -1)e^{-\alpha x}\}$$

with $K= \alpha/\beta$ and $N_0=N(x=0)$

The logistic equation (2)

- When N approachs K the system saturates and K is the asymptotic number of electrons in the avalanche

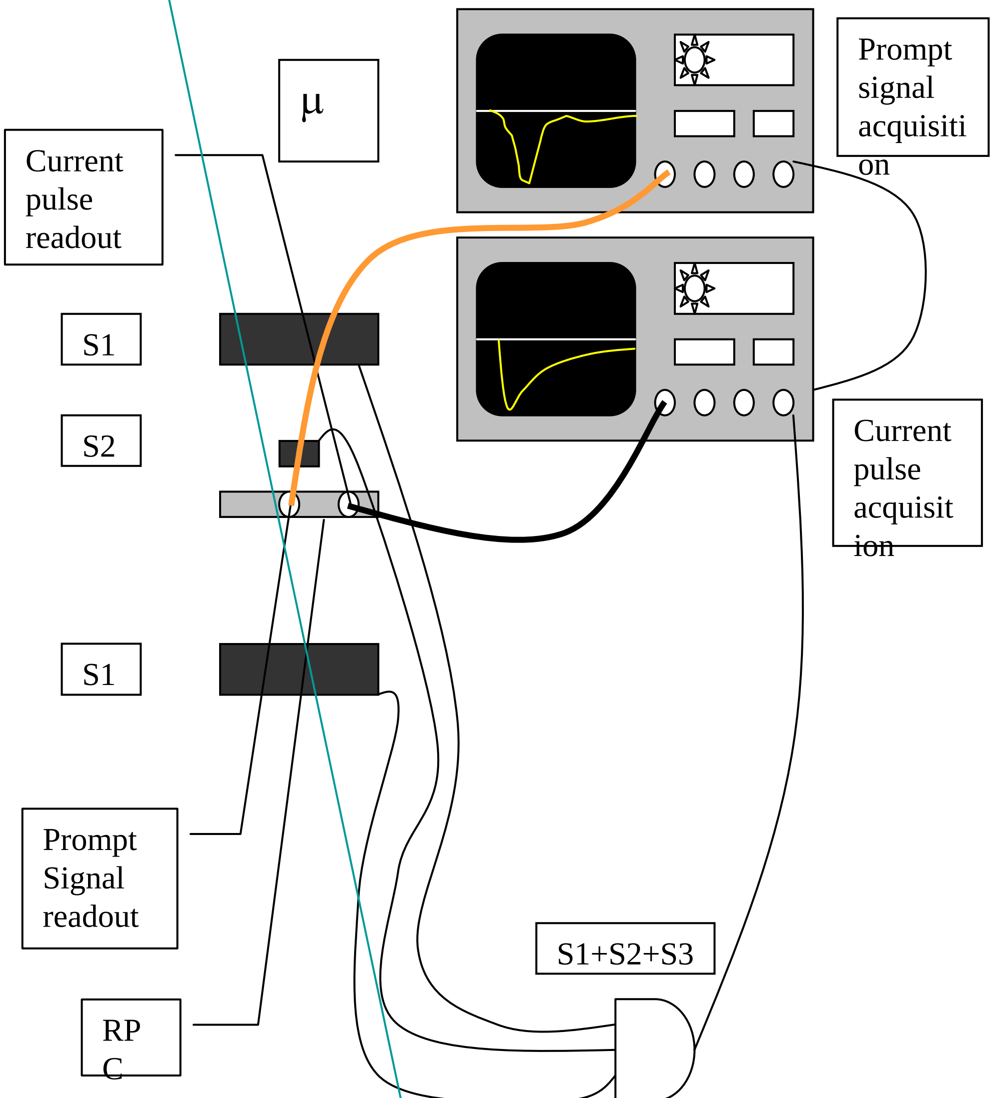




- According to the logistic model the average charge can be fitted with the function:

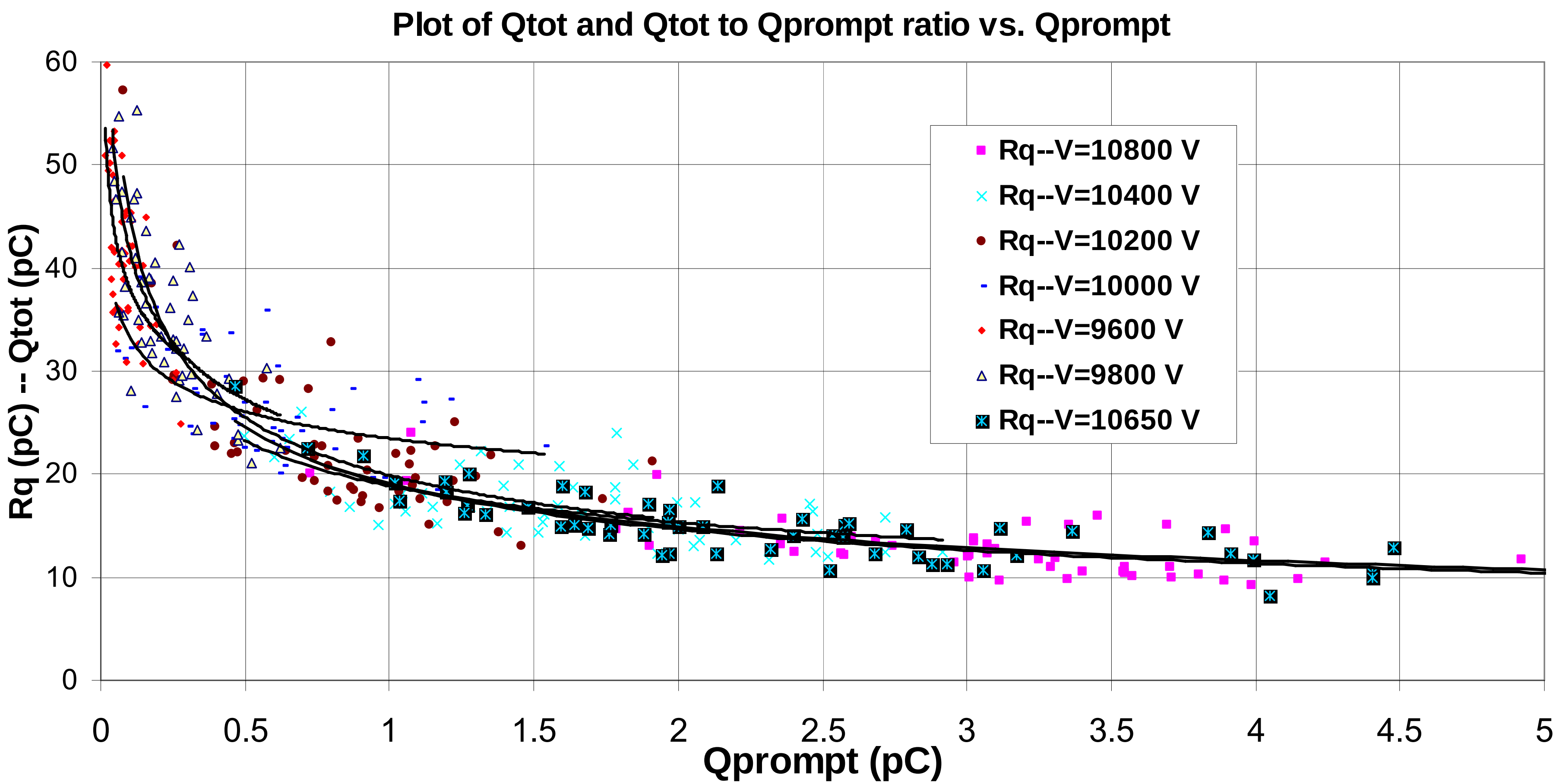
$$\boxed{Q_{tot} = K' \ln[1 + e^{a(V - V_0)}]}$$

Measurement of total to prompt charge ratio



- Simultaneous acquisition for:
  - Prompt charge pulses on the readout strip
  - Total charge on the detector cathode.
- The pulse acquisition is triggered by the scintillator coincidence
- The results refer to different operating voltages

Qtot/Qprompt vs Qprompt scatter plot



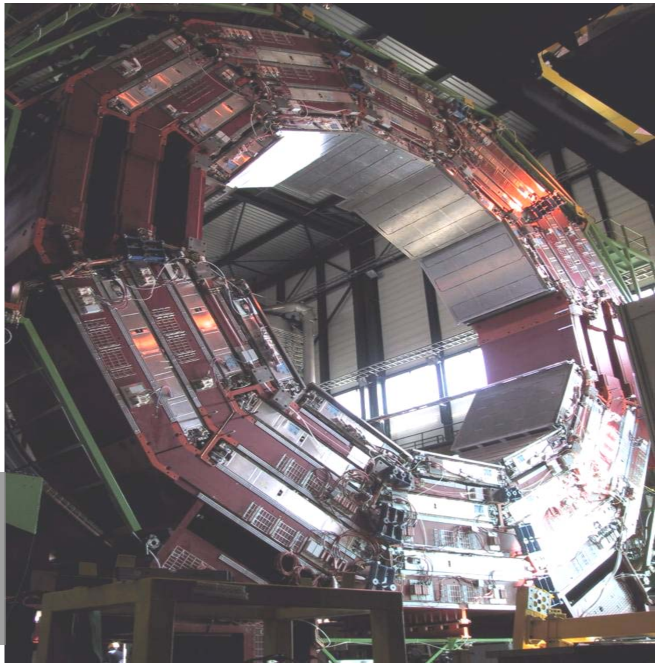
- The logistic equation was introduced to describe the development of a biological population in presence of a finite amount of food resources
- In our case the finite resource is the electrostatic field energy available to sustain the avalanche growth

CMS MUON CHAMBER

RPC-DT coupling

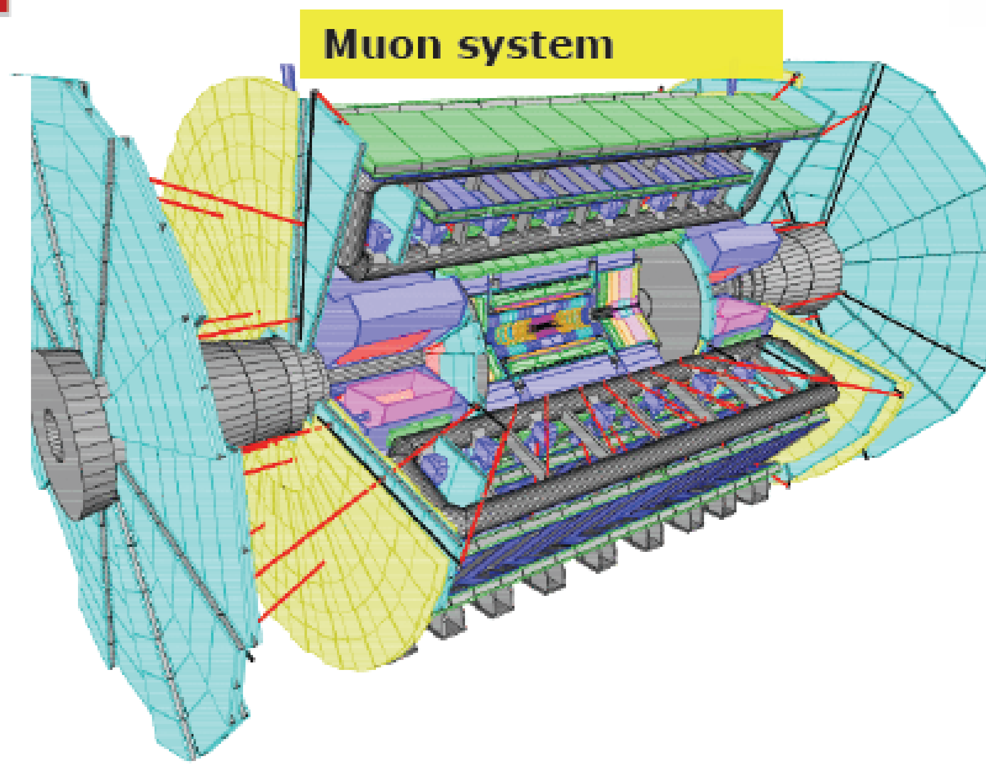
Insertion in the magnet

One CMS wheel



Muon chamber system

- 3 detector stations
  - cylindrical in barrel
  - wheels in end caps
- High-precision tracking chambers
  - MDT at $|\eta| < 2$, CSC at $2 < |\eta| < 2.7$
- Trigger chambers:
  - muon p_t trigger selection
  - bunch-crossing identification
  - second coordinate measurements
    - RPC at $|\eta| < 1.05$,
    - TGC at $1.05 < |\eta| < 2.4$



Type	MDT	CSC	RPC	TGC
N.cham	1172	32	1116	1578
N.chan.	360000	31000	385000	322000
Area	5.500	27	3650	2900

→ A crucial component is the alignment measurement and monitoring system

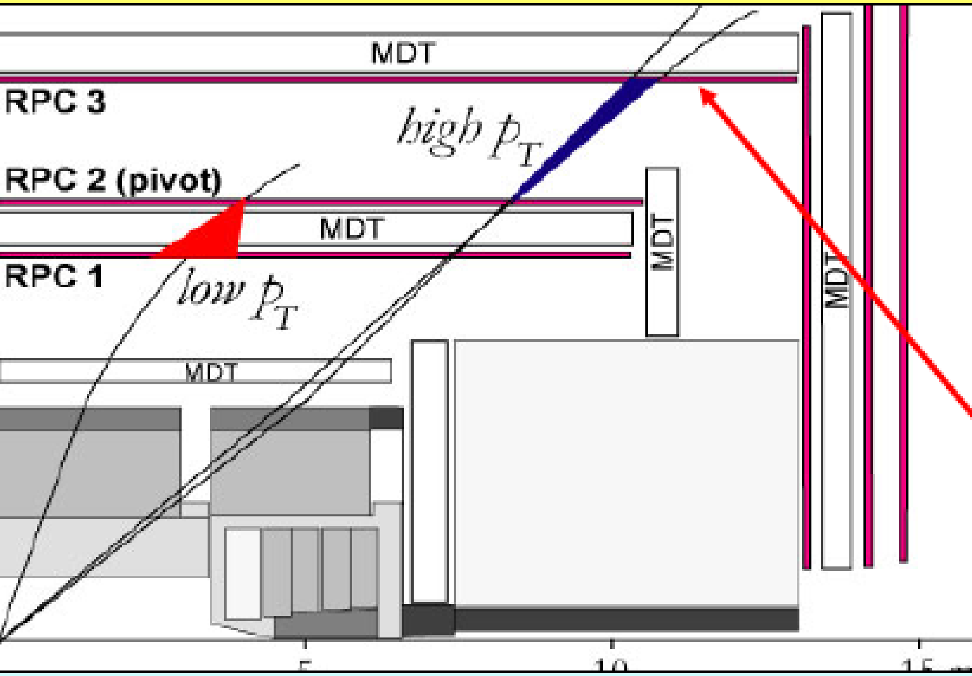
INFN groups (involved in Barrel chamb.)

- MDT (Cs,LNF,Pv,Rm1,Rm3)

ATLAS LVL1 barrel muon trigger scheme

Bunch-crossing rate (40 MHz)
Interaction rate ~ 1GHz at L= 10^{34} $cm^{-2}s^{-1}$

- Level-1 trigger (<100kHz)



RPC operating conditions:

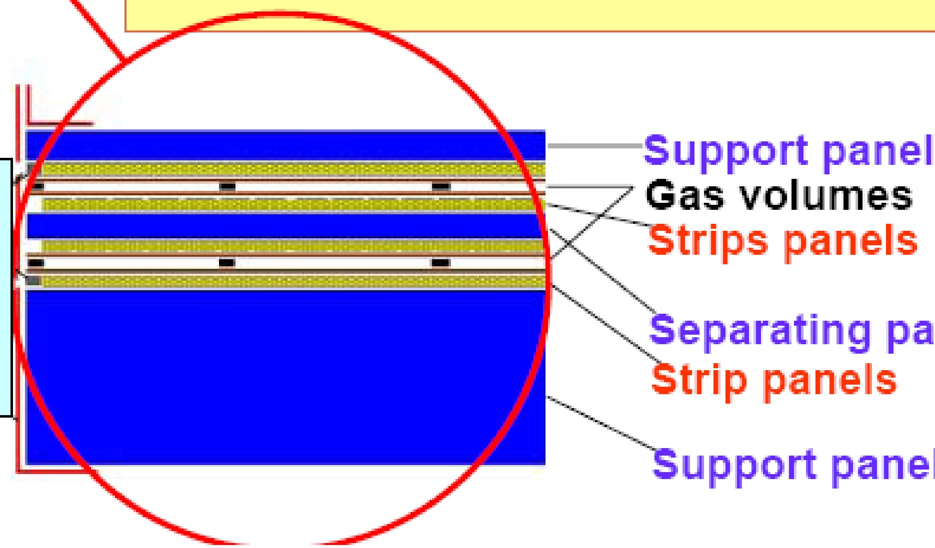
- Gas gap: 2 mm   E ~ 4.8 KV/mm
- Bakelite plates: 2 mm, ρ ~$2x10^{10}$ Ω x cm
- Gas working mode: avalanche
- Gas mixture:
- 94.7%$C_2H_2F_4$+ 5%isoC_4H_{10}+ 0.3%SF_6

Performance:

- Single gap efficiency = 98%
- Time resolution ~ 1.5-2.0 ns
  → b.x. identification

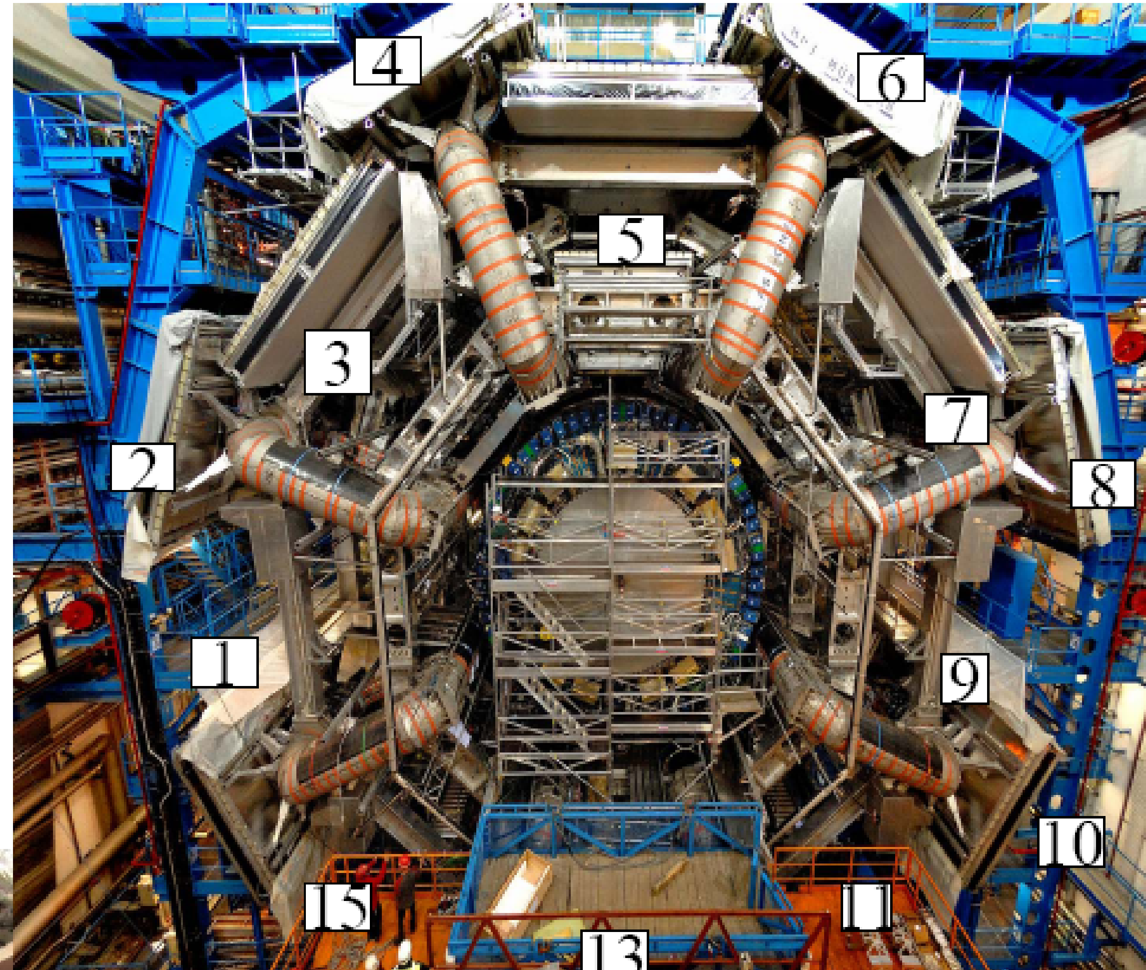
Coincidence:

RPC1 & RPC2 → low pt muons > 6 GeV
low pt & RPC3 → high pt > 20 GeV



Barrel Muon Chambers

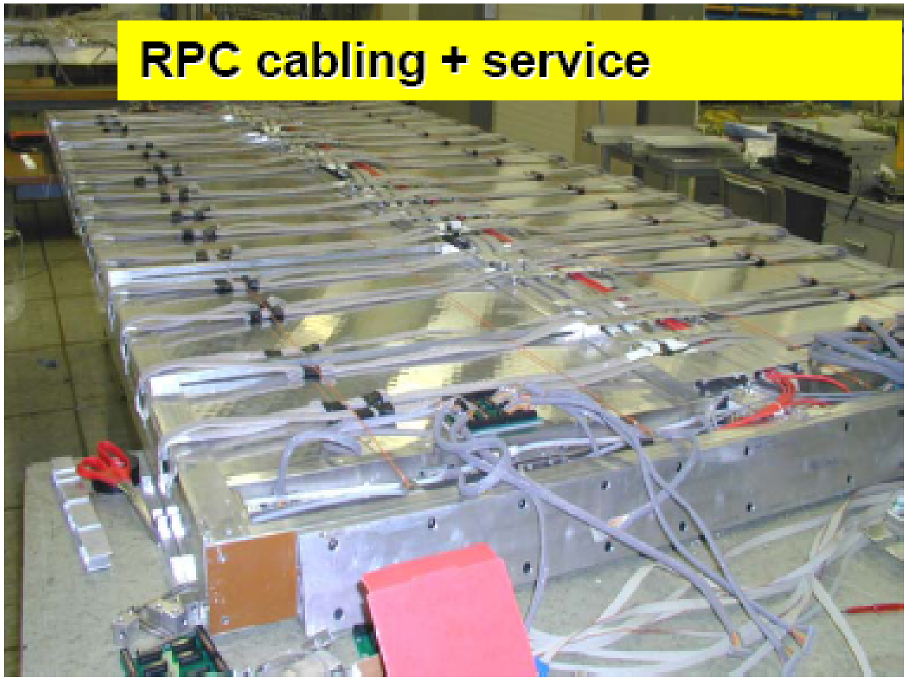
- Muon chambers organized in 16 sectors. Each sector has 3 stations.
  - Inner chambers: BI
  - Middle chambers: BM
  - Outer chambers: BO
  - Chambers in feet region: F (sect 12,14)
- BI are only for tracking
- BM are sandwiched between two RPC (trigger)
- BO chambers contain one RPC

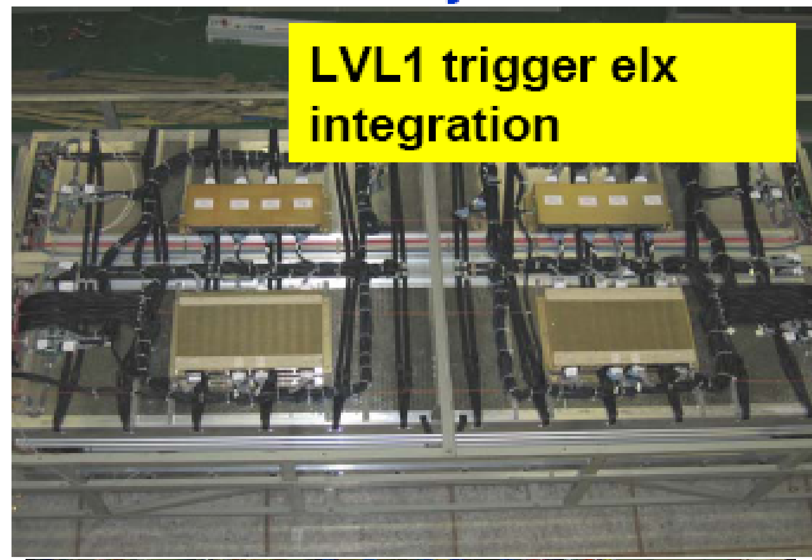


A RPC/MDT muon station

MDT/RPC/LVL1 muon station integration

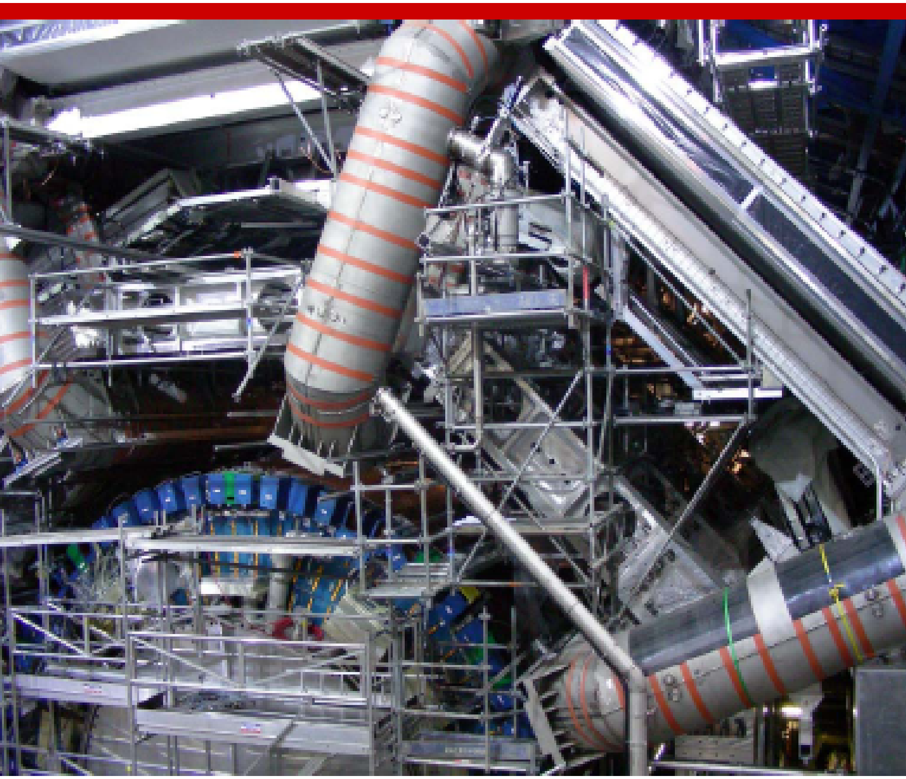
2004-2006 : in BB5 1116 RPCs units have been cabled . 972 integrated with 380 MDT. Integration with LVL1 electronics and test on a cosmic ray test-stand for all units





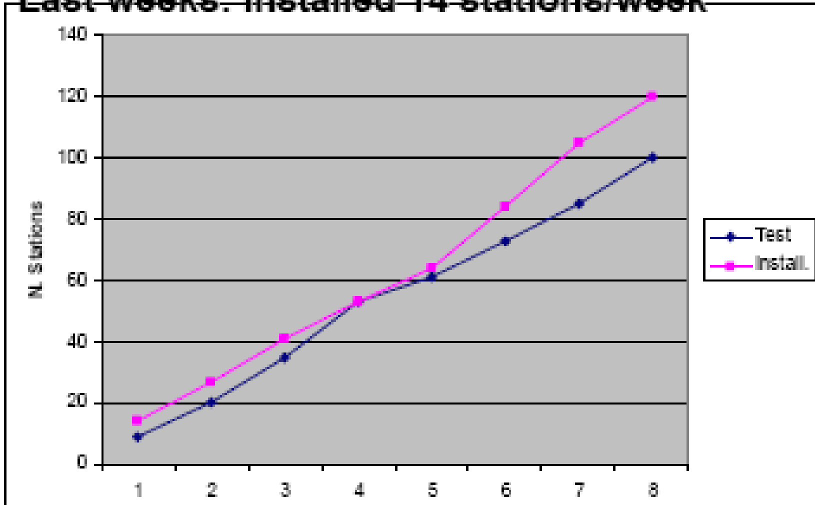
MDT/RPC stations	Total stations	RPC units
BMS/F	84	280
BML	94	298
BOS/F/G	106	202
BOL	96	192
TOTAL	380	972

Barrel Muon chamber installation

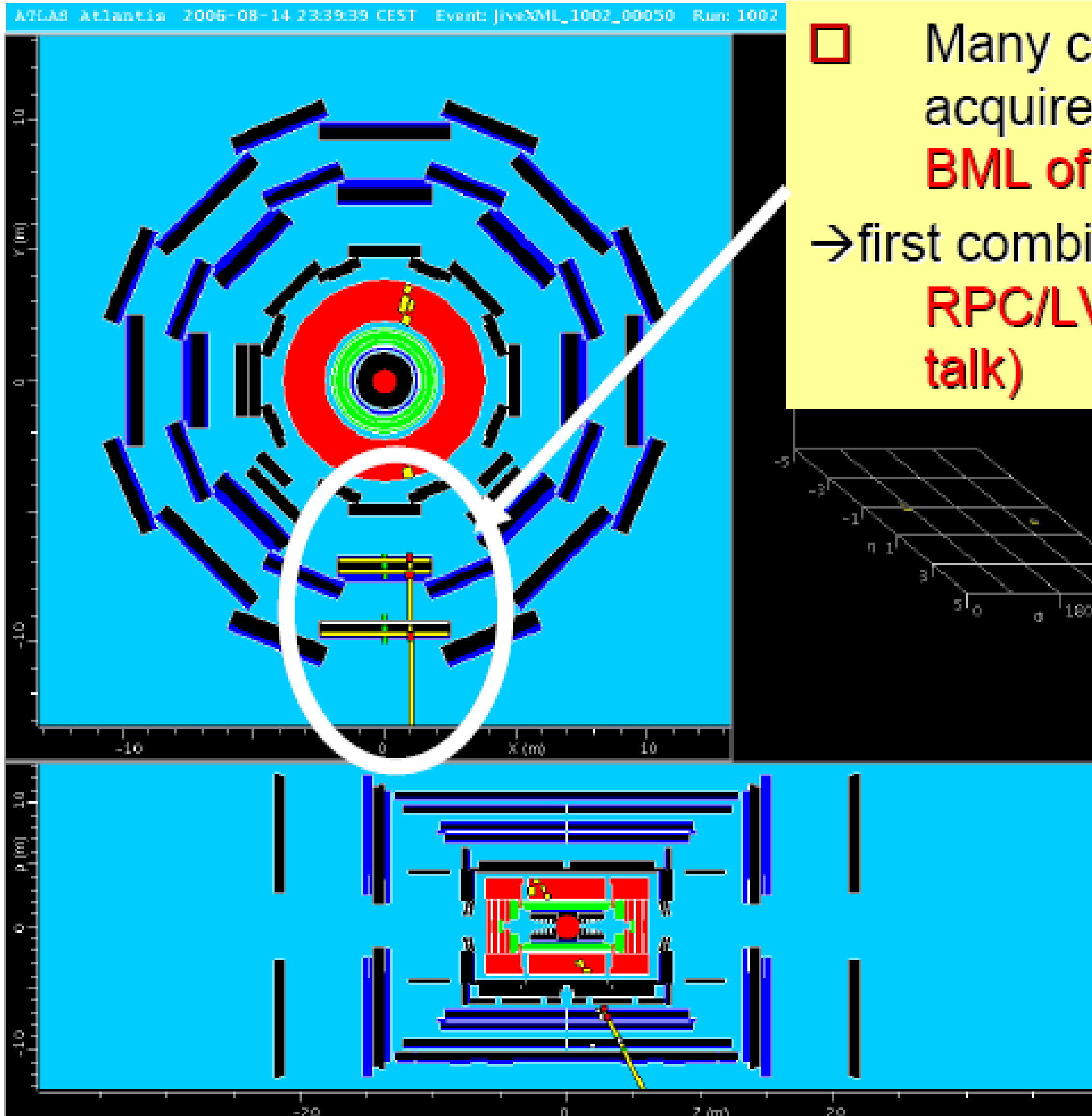


- Started in 2005 in parallel with service installation in the muon spectrometer.
- 594 barrel Muon Stations installed (~85%).
  - All tested in surface at Sx1.
  - 56% in final position
- 72 stations still to be installed in 2006
- 39 in the spring 2007
  - Side C completed, except for sectors 9,11,15, due to interference with movable services for the End-Cap calorimeters
    - to be completed in 2007
  - Side A should be completed before the end of the year

Last weeks: installed 14 stations/week

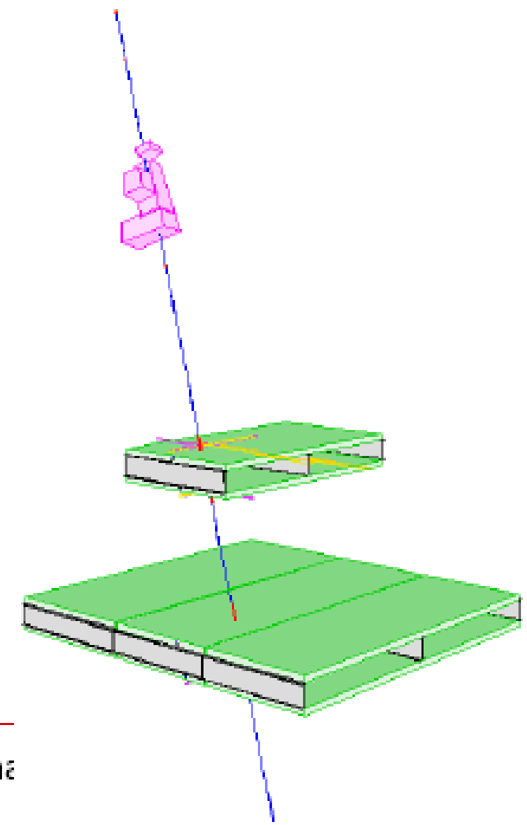


MDT+RPC+LVL1 trigger commissioning



- Many cosmic ray runs successfully acquired in 2006 with 3 BOL + 3 BML of sector 13

→first combined test of MDT and RPC/LVL1 in the pit (G.Gaudio's talk)



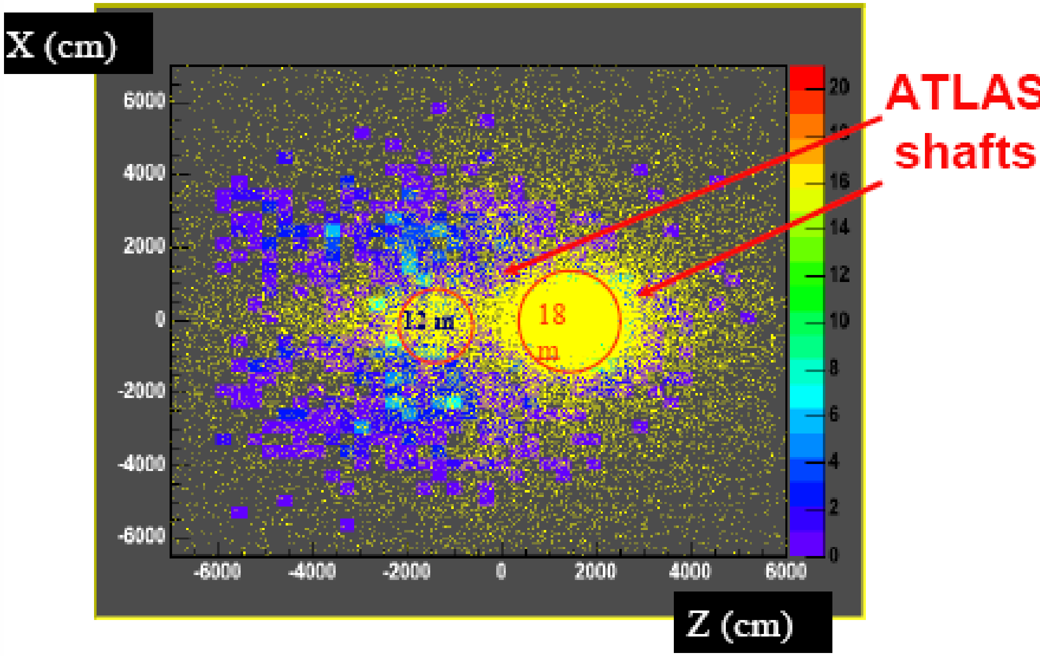
LVL1 muon trigger

→ Tested in August 2006 a full barrel LVL1 muon slice

- Operated with full chain of trigger
  - RPC detectors
  - Splitter / Pad
  - Sector Logic (prototype)
  - MUCTPI (prototype)
  - CTP
  - LTP
  - TTC
  - Detectors

- Checked trigger latency (is within allowed envelope)
- Developing procedure for timing-in the system

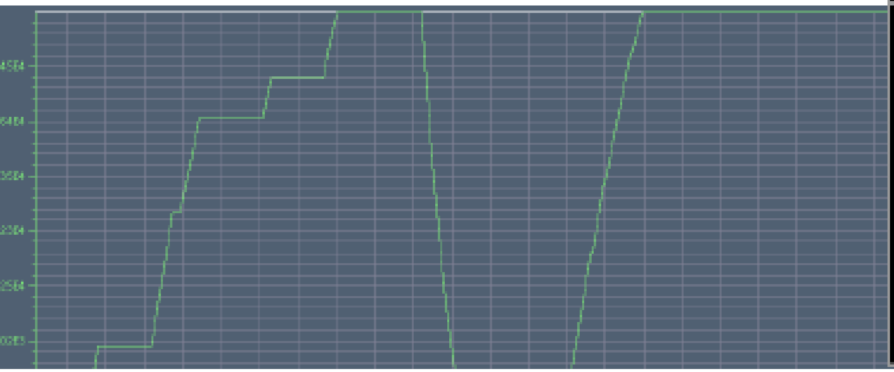
Barrel Trigger Sector 13: Extrapolation of RPC cosmic-ray tracks to ground level

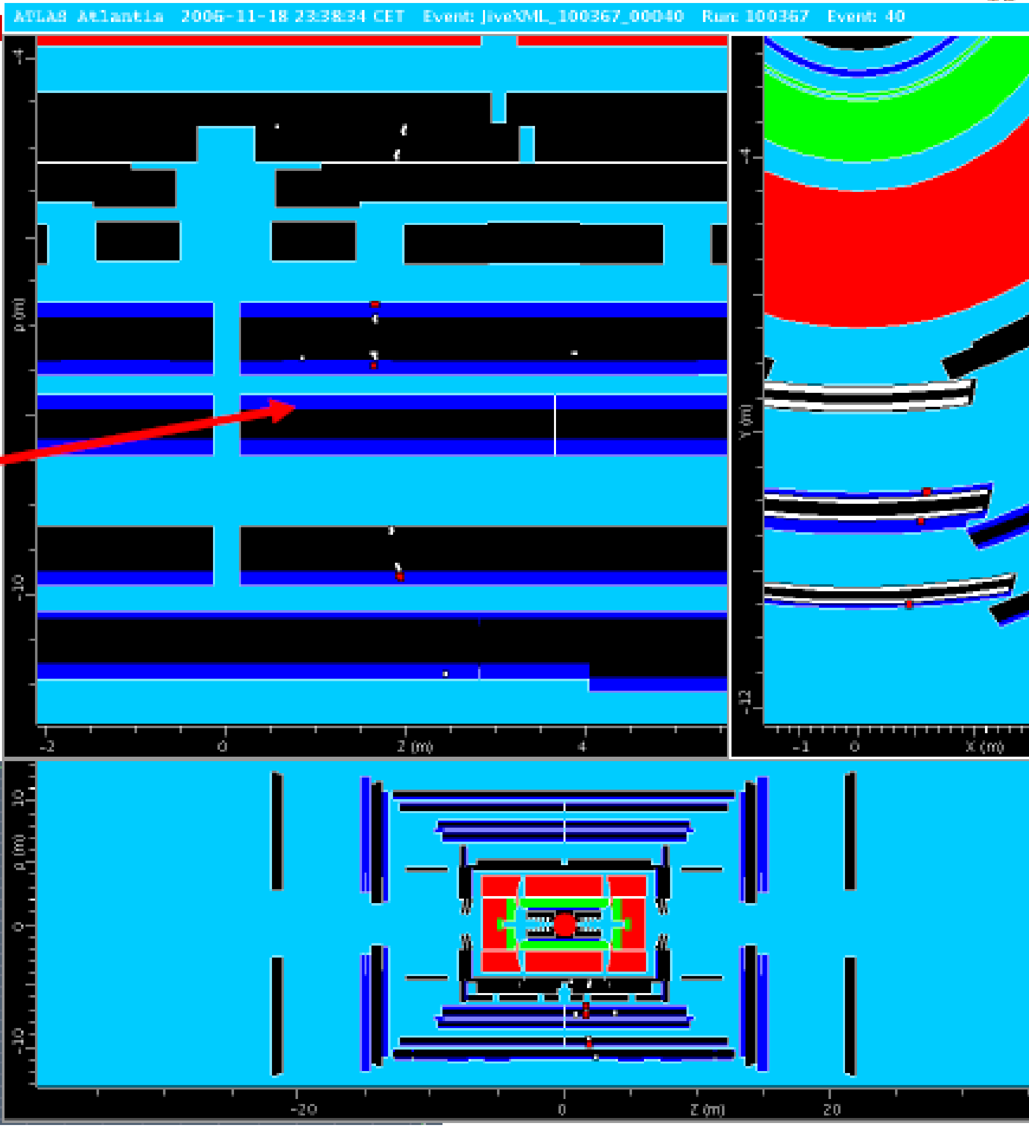


Trigger rate ~40 Hz consistent with simulation of cosmic rays

18-19 November: 24 h test of Toroid Barrel

- >12 h of cosmic ray data taking with the muon chambers (3BIL+ 3BML+ 3BOL) of sect 13 (MDT+RPC+LVL1)
- The first muon track **with magnet on** triggered by the RPCs!!
- A new provoked quench with FD→**All OK again!!**
- No other MAG on test.



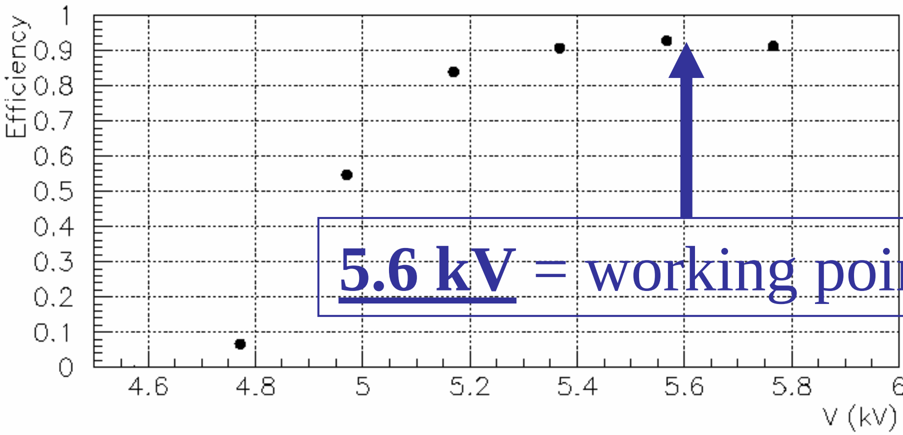


RPC for neutrino physics: test of Opera

- Gas system (preliminary):
  - $Ar/C_2H_2F_4/I\text{-}C_4H_{10}/SF_6 = 75.4/20/4/0.6$
  - Premixed bottles (<4 days autonomy at 5 refills/day)
  - No exhaust, as gas flow (~0.1 m^3/h) << air flow inside Hall C (~10000 m^3/h)

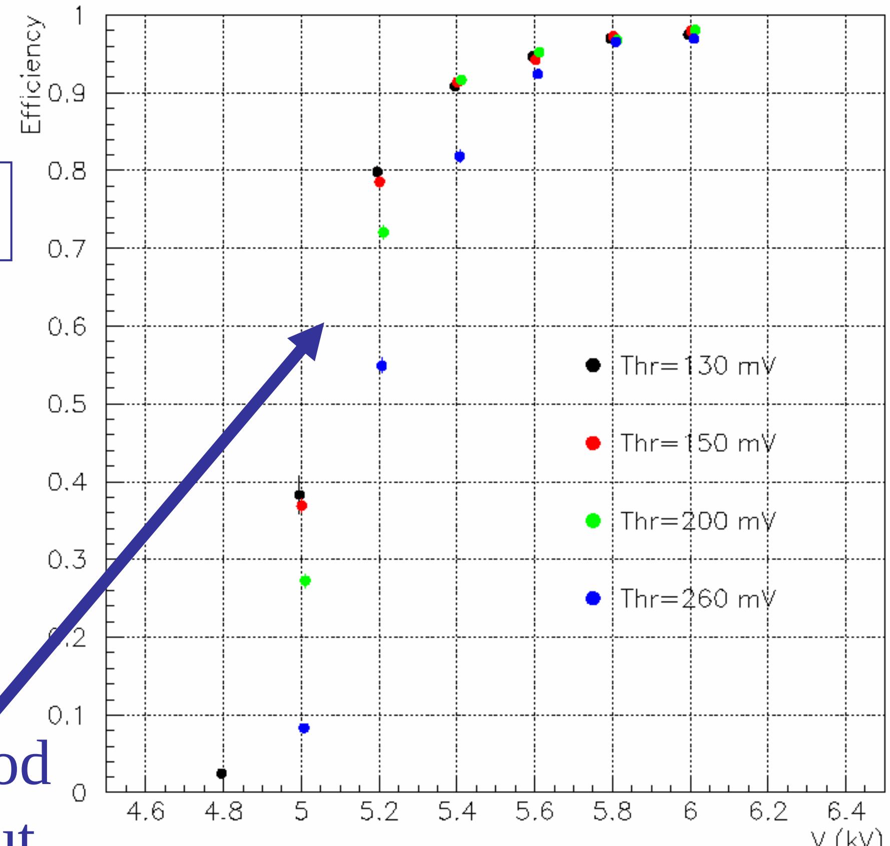
Preliminary tests (I)

Before starting underground let's fix the **working voltage** and **thresholds** with cosmic rays at **external GS lab**……



5.6 kV = working point

Horizontal FE boards

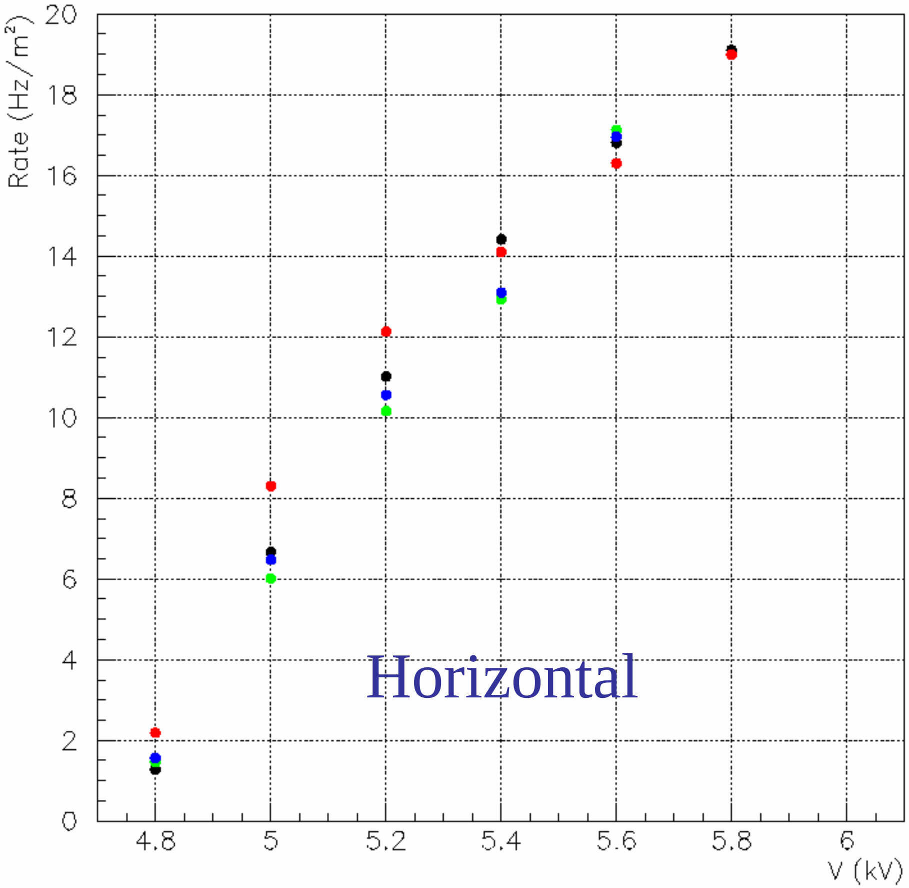


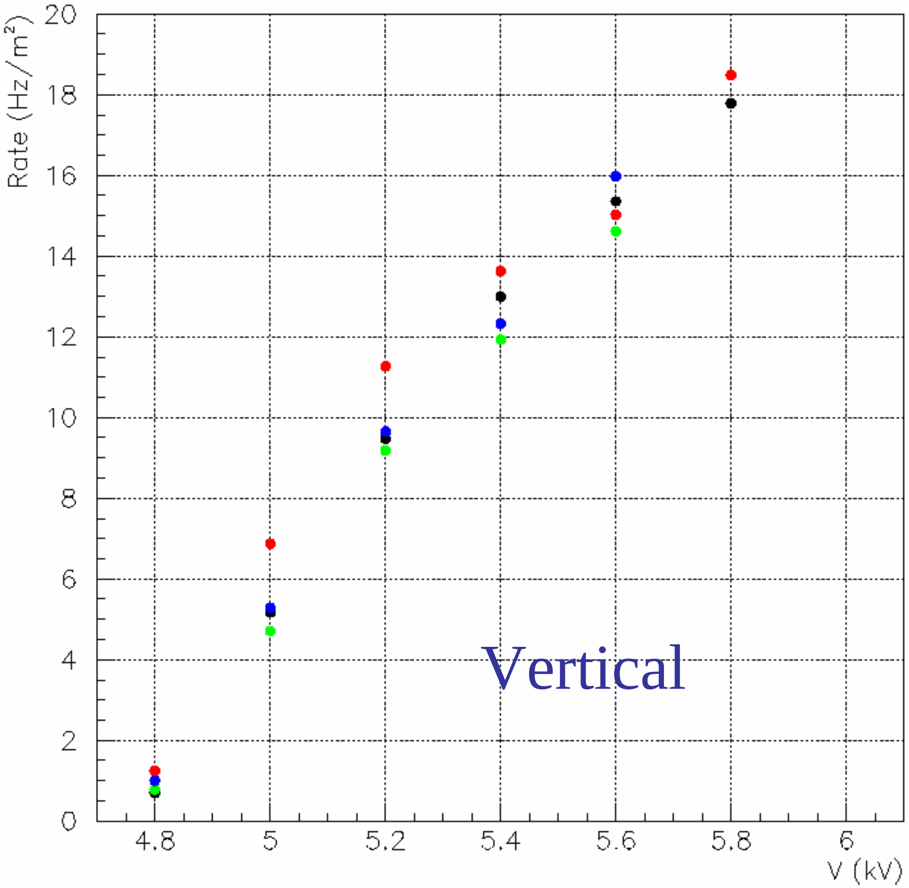
Threshold:

1. Not too low → noise
2. Not too high → low efficiency

150 mV on preamp output seems a good choice for horizontal FE boards, but….

Counting rates (I)



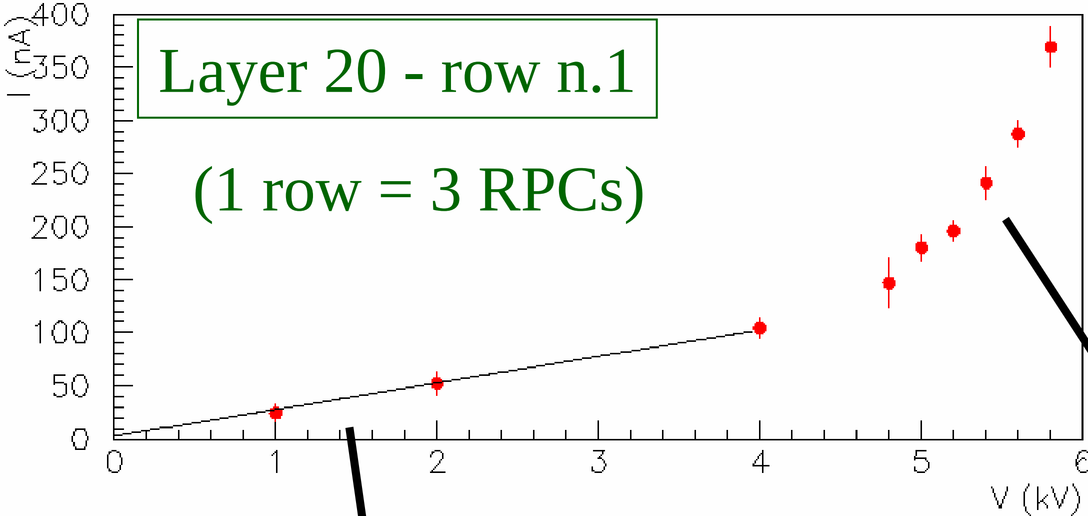


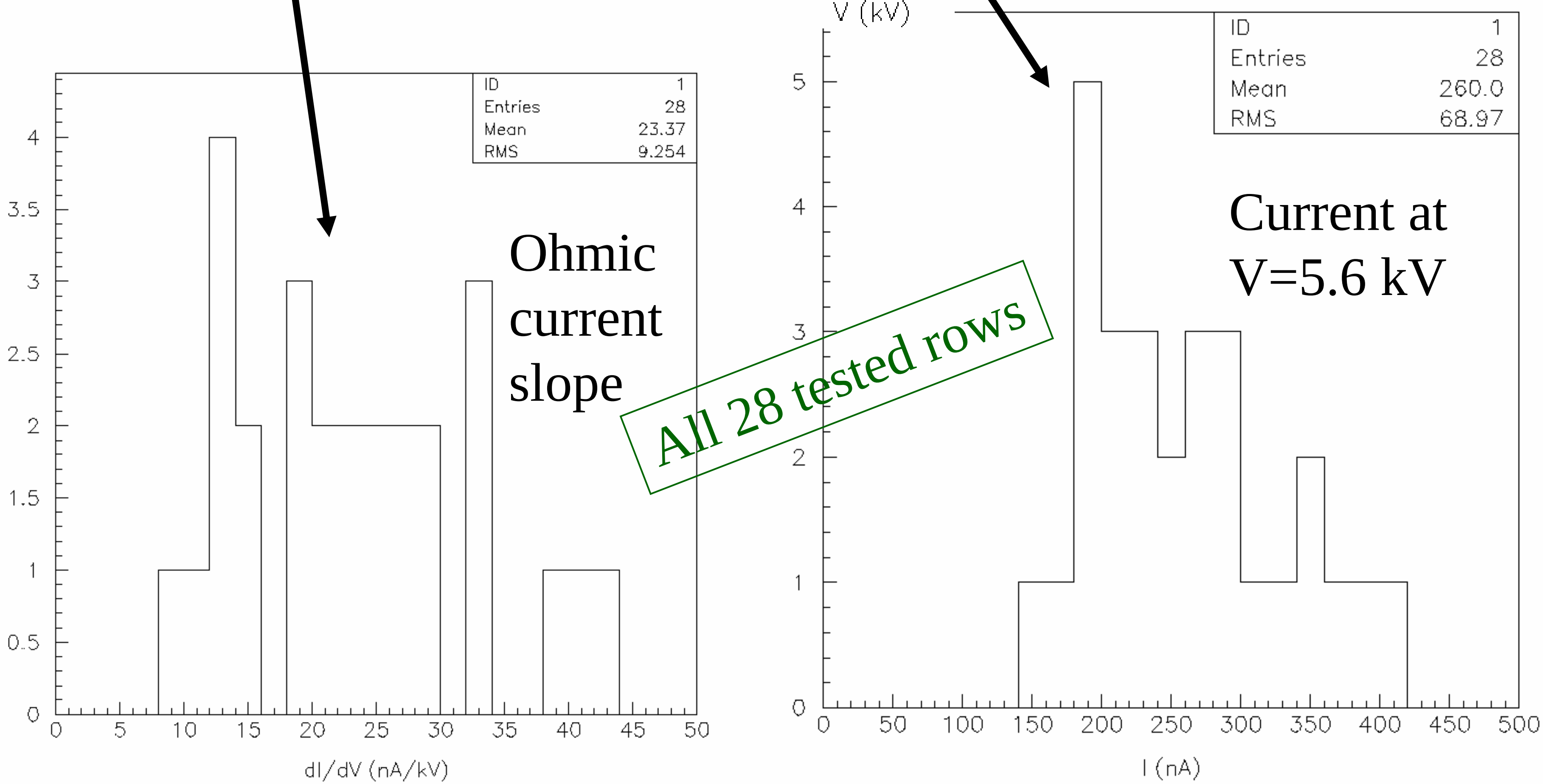
Counting rates:

- at 5.6 kV are about 17 Hz/m^2 (1.2 kHz/layer)
- Slightly lower for vertical strip planes
- Good uniformity among different layers

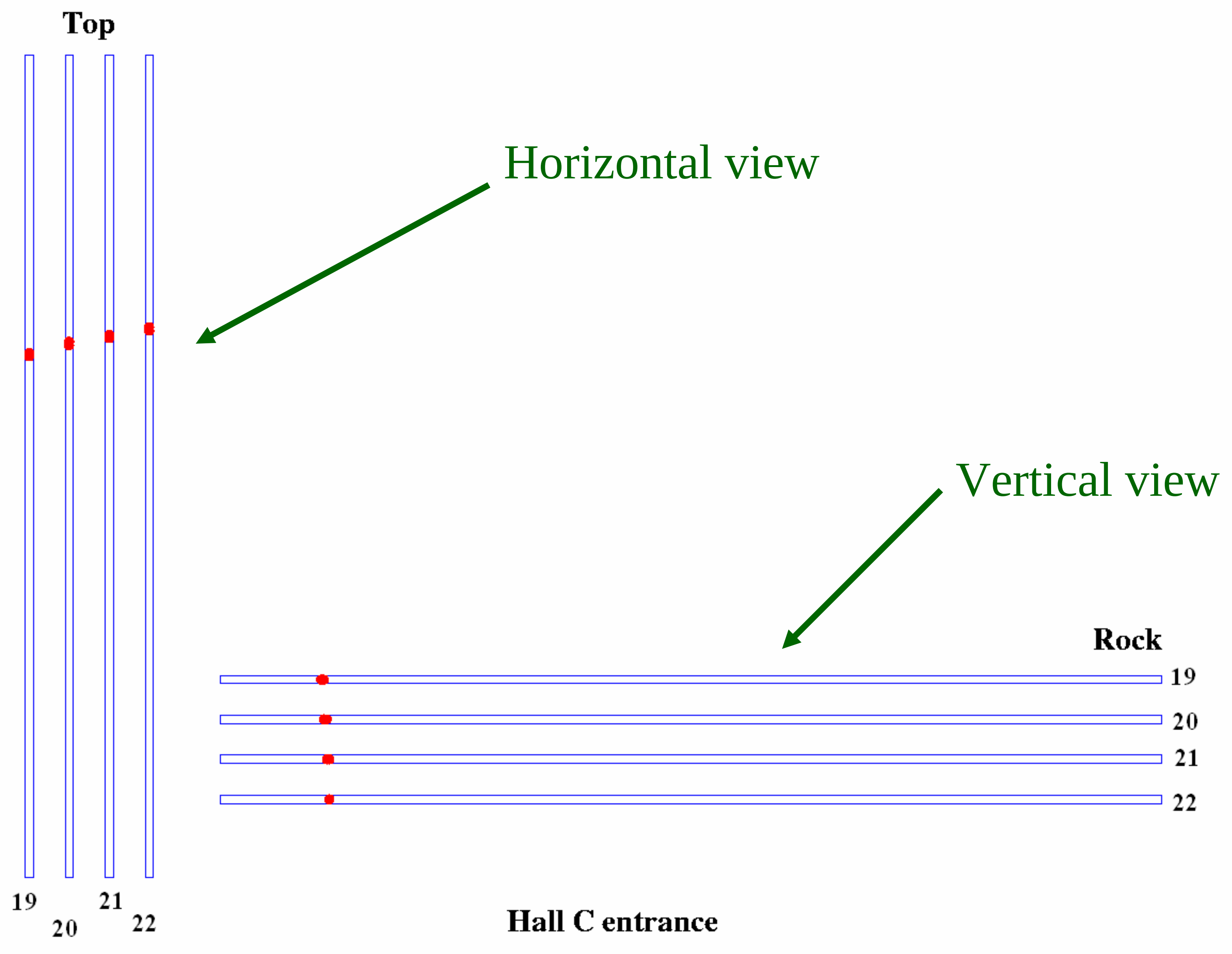
Currents

Very low currents,
also at low voltage

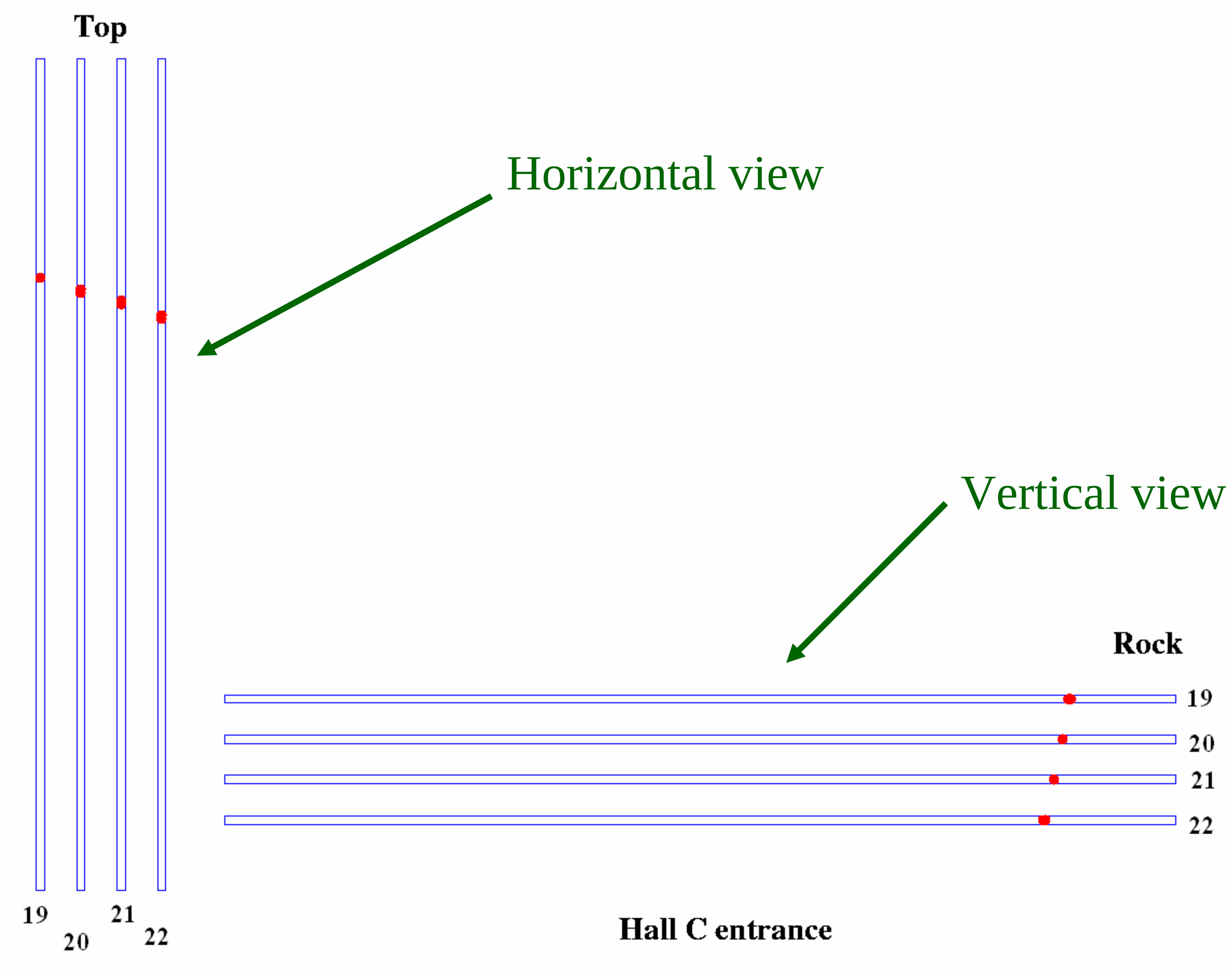




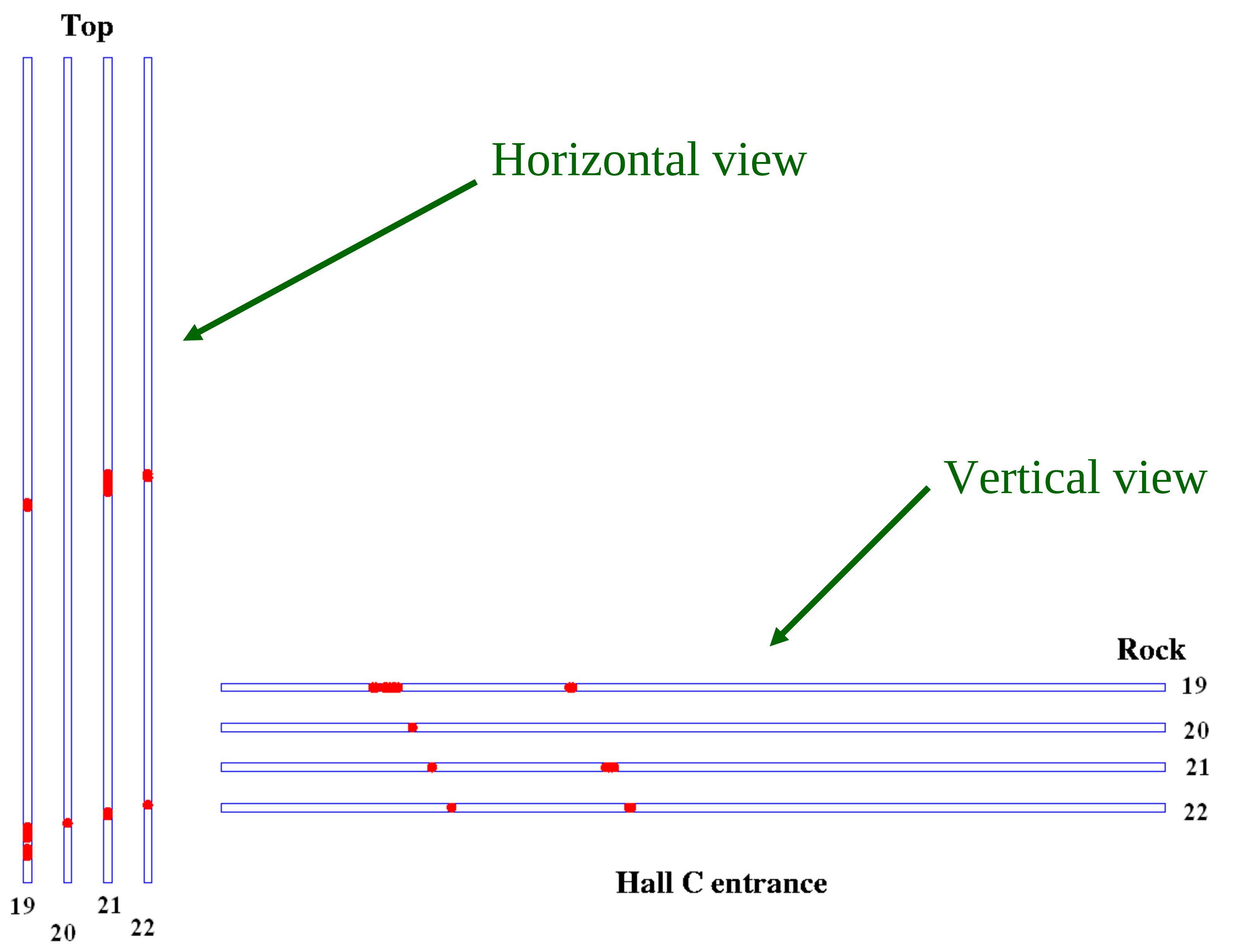
Selected events: single muon



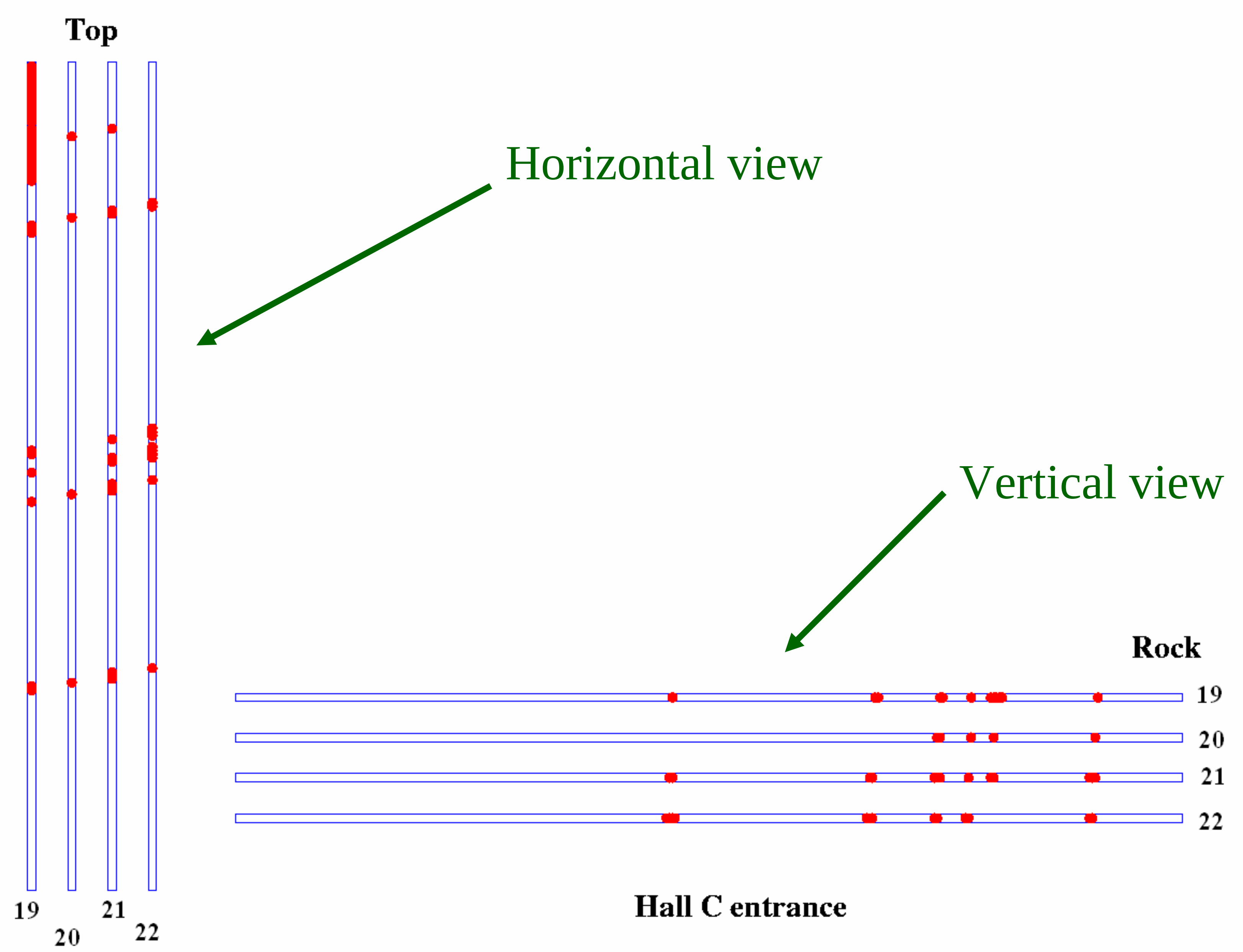
Selected events: single muon



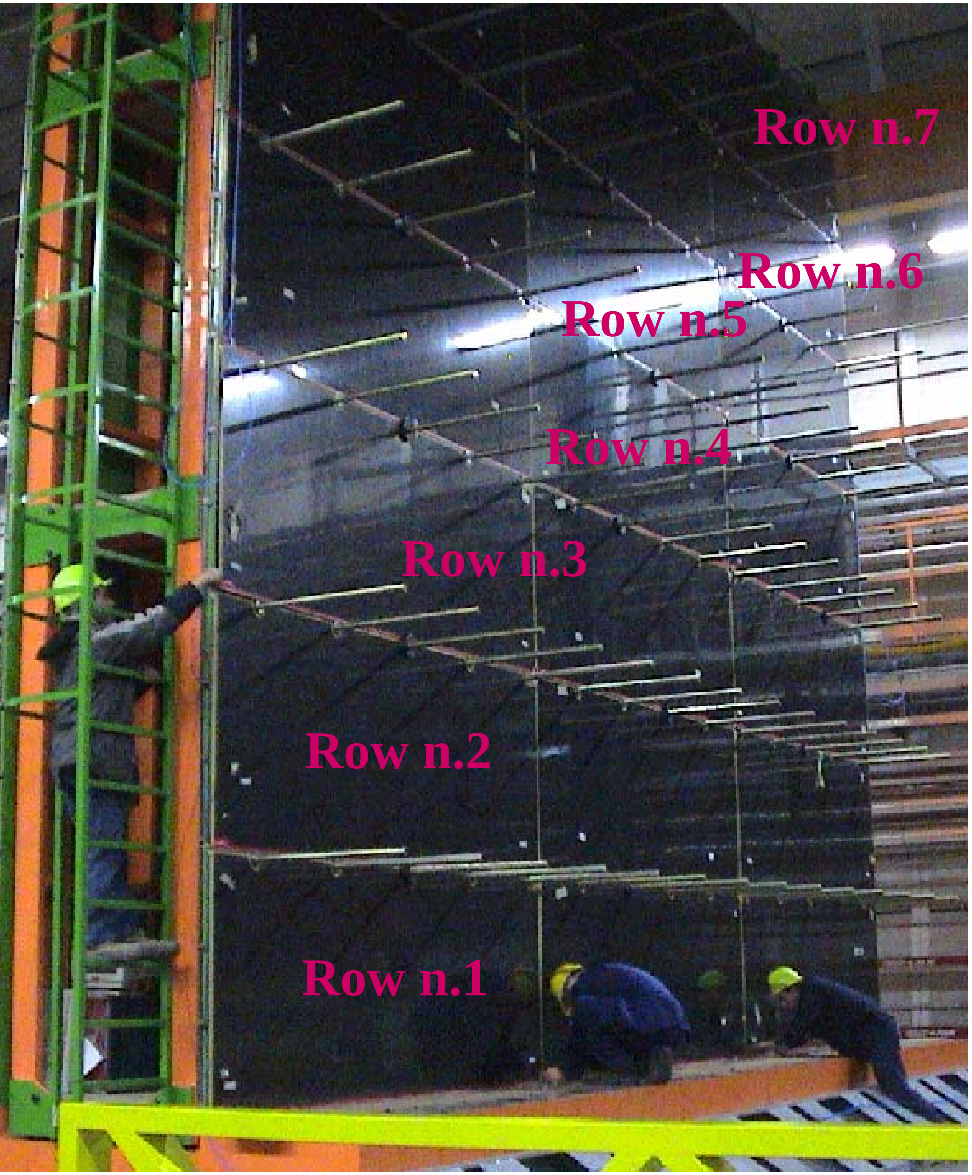
Selected events: dimuon



Selected events: muon bundle



Test set-up (additional)



Each layer is composed by 7*3 RPCs:

1 row = 3 RPCs
1 layer = 7 rows = 21 RPCs
4 layers = 28 rows = 84 RPCs