Commissioning with cosmic rays of the ALICE Muon Trigger System

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Journées de Rencontre Jeunes Chercheurs 2009

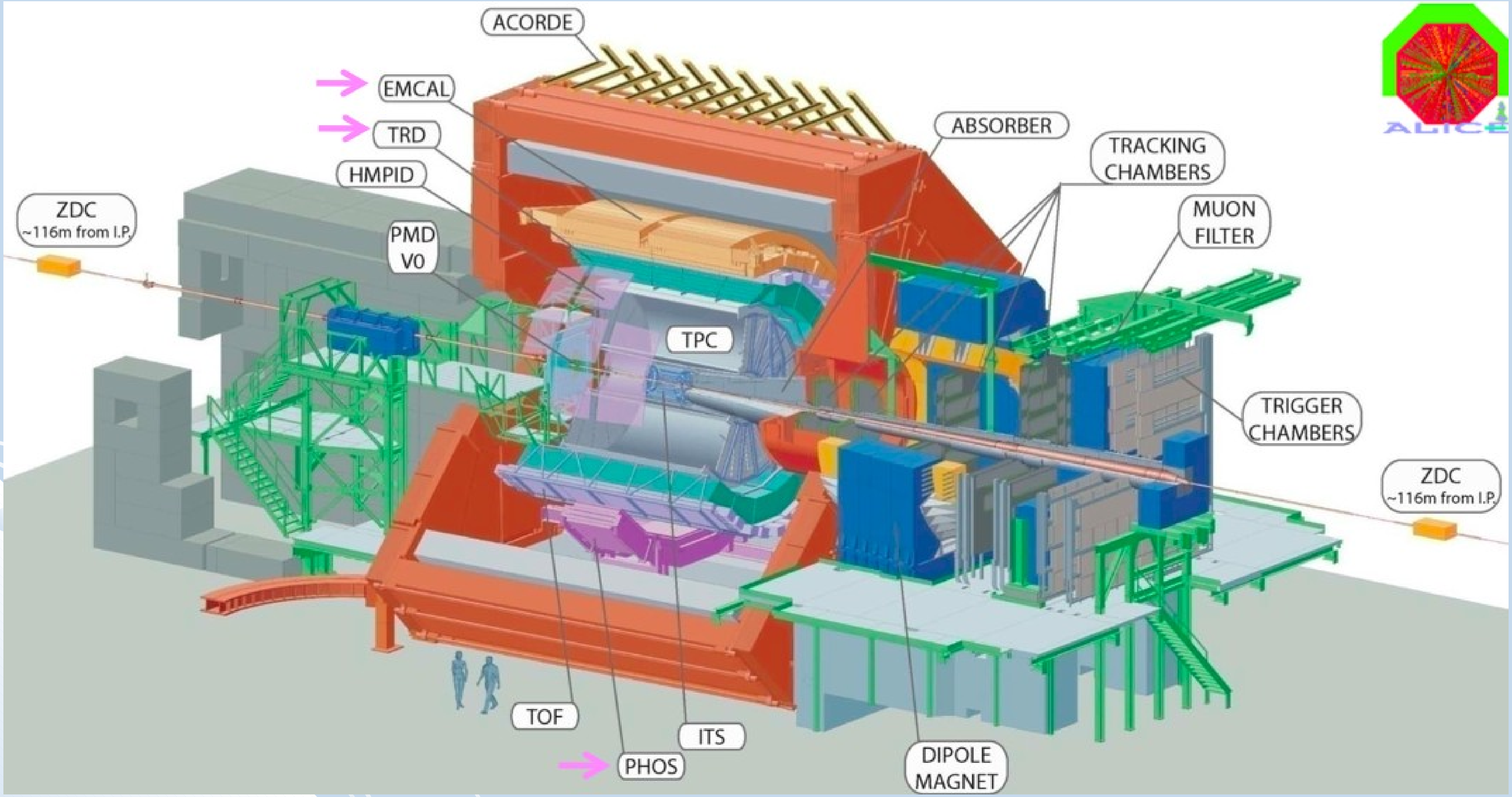
OUTLINE:

1) **Overview of the trigger system of the ALICE Muon Spectrometer.**

2) **Commissioning measurements and results.**

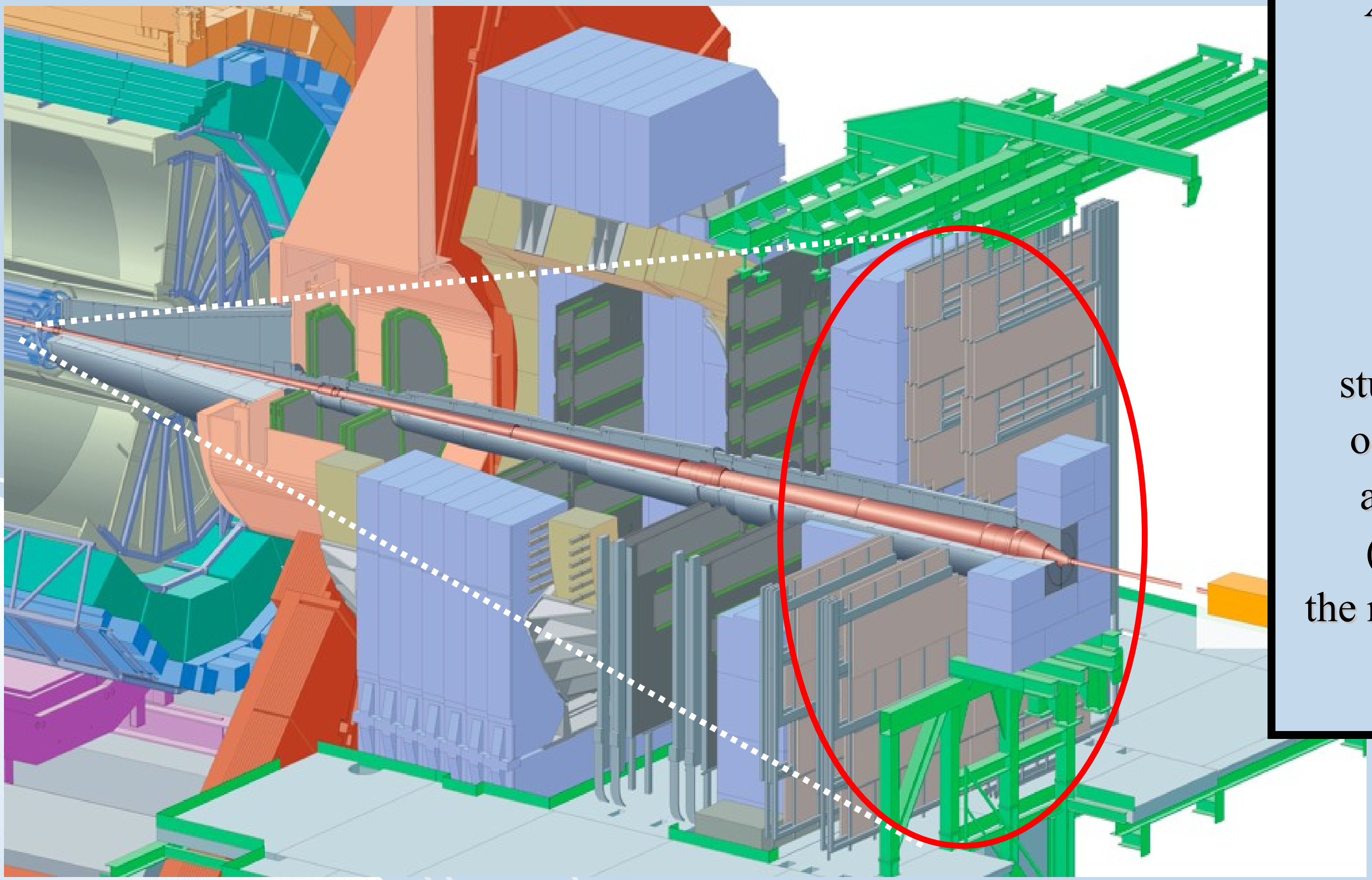
Alice experiment

A Large Ion Collider Experiment



ALICE experiment @LHC is specifically dedicated to ultra-relativistic heavy-ion collisions

The Muon Spectrometer (I)



Forward muon spectrometer

Angular acceptance

$2^0 < \theta < 9^0$

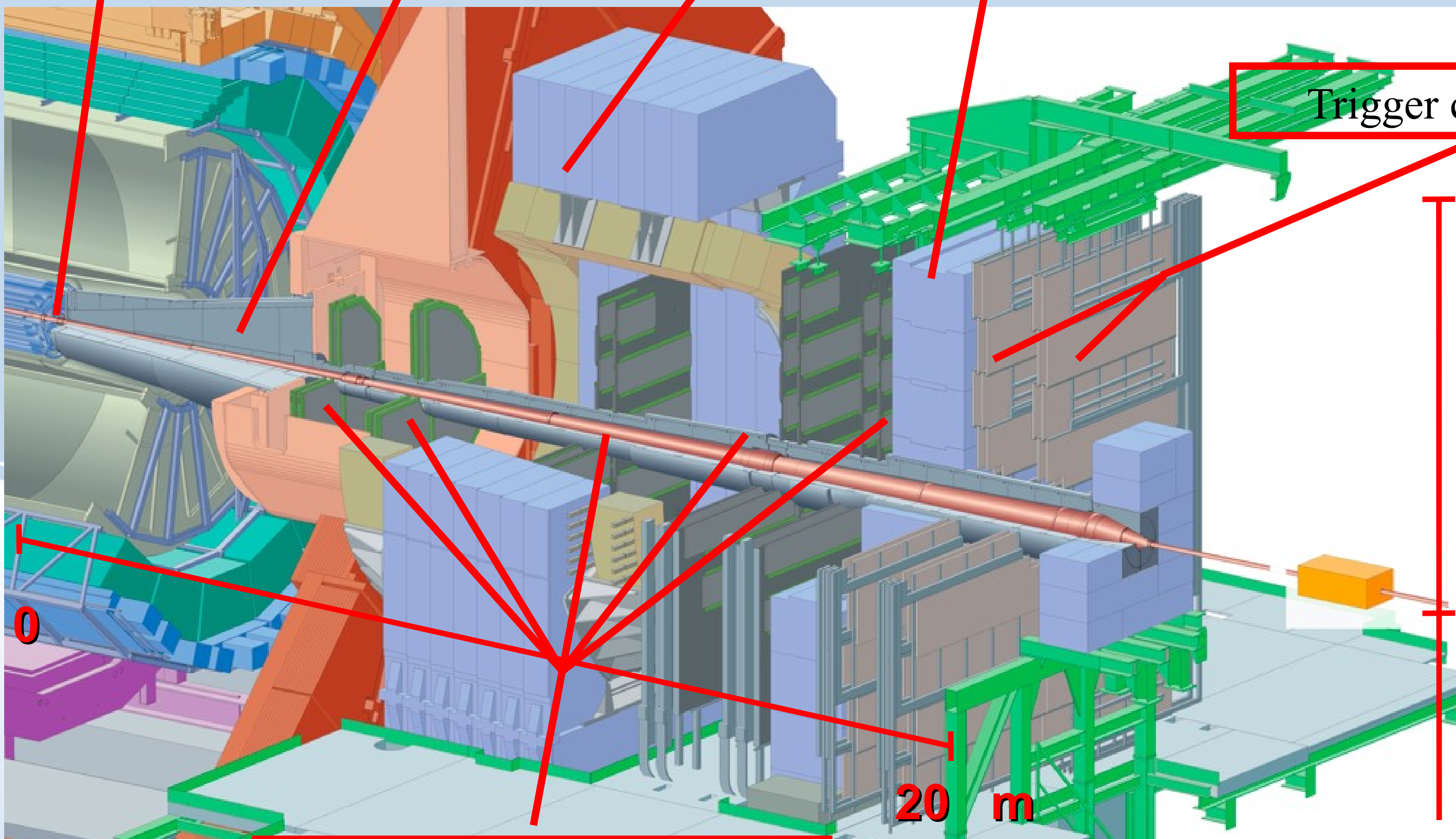
Pseudorapidity

$-4 < \eta < -2.5$

study of the production of open heavy flavour and heavy quarkonia (J/Ψ and Υ) through the muon (μ) decay channel

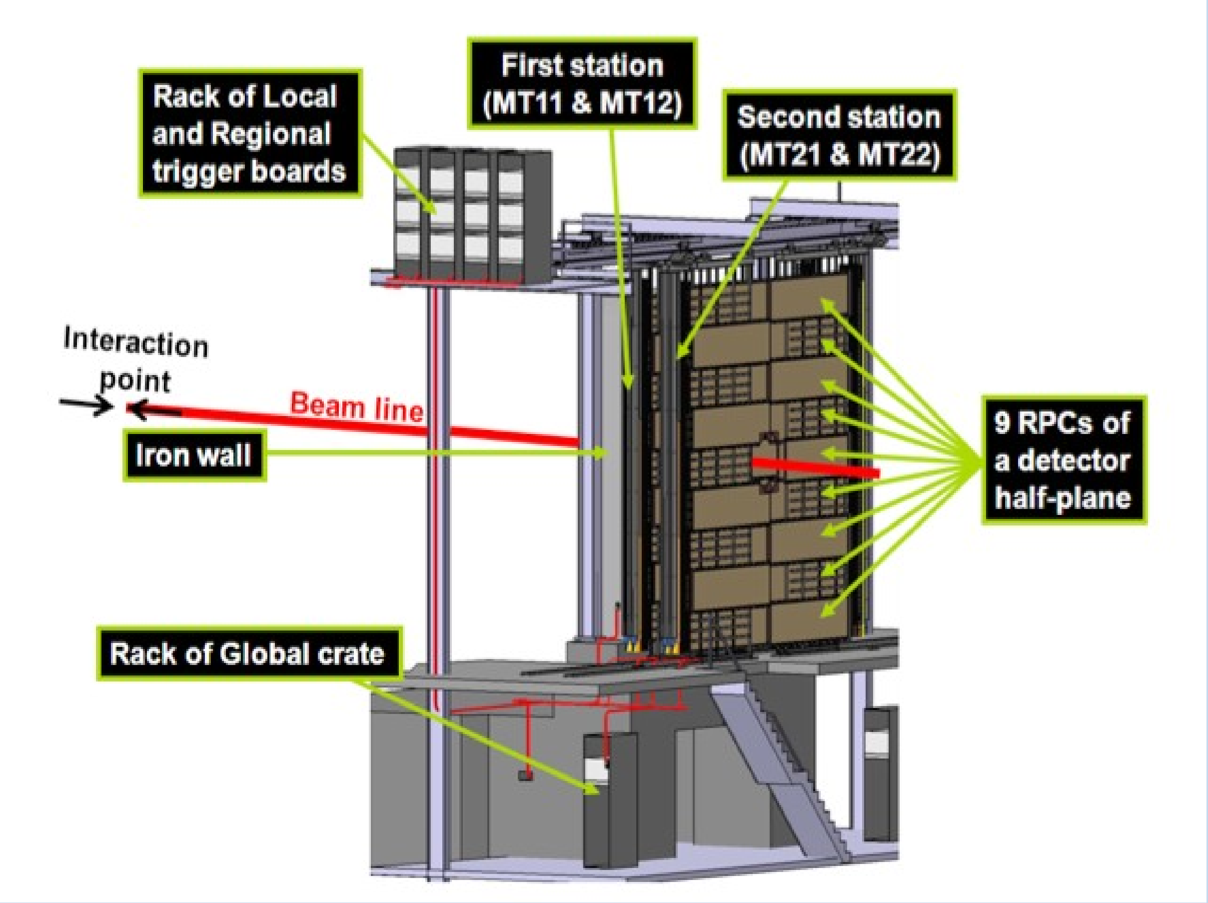
The Muon Spectrometer (II)

the *components*



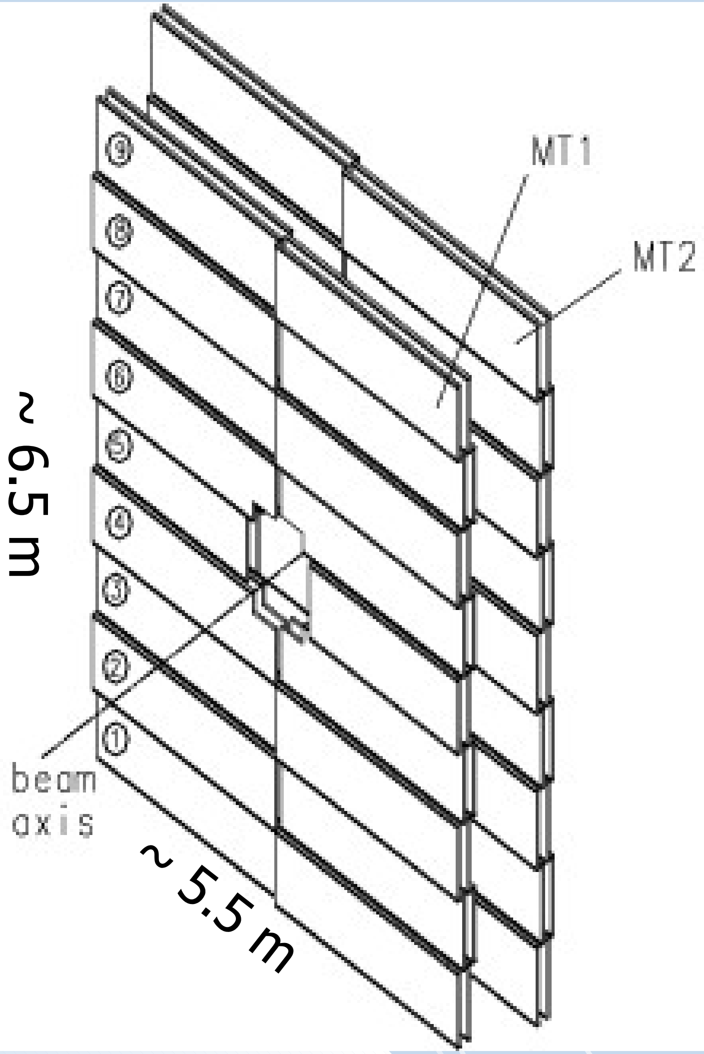
The trigger system: Muon Trigger Chambers

2 trigger stations (**MT1** and **MT2**) located at about 16 m from the IP and 1 m apart from each other placed behind an iron muon filter



Layout of the trigger stations and the iron wall installed in the Alice cavern.

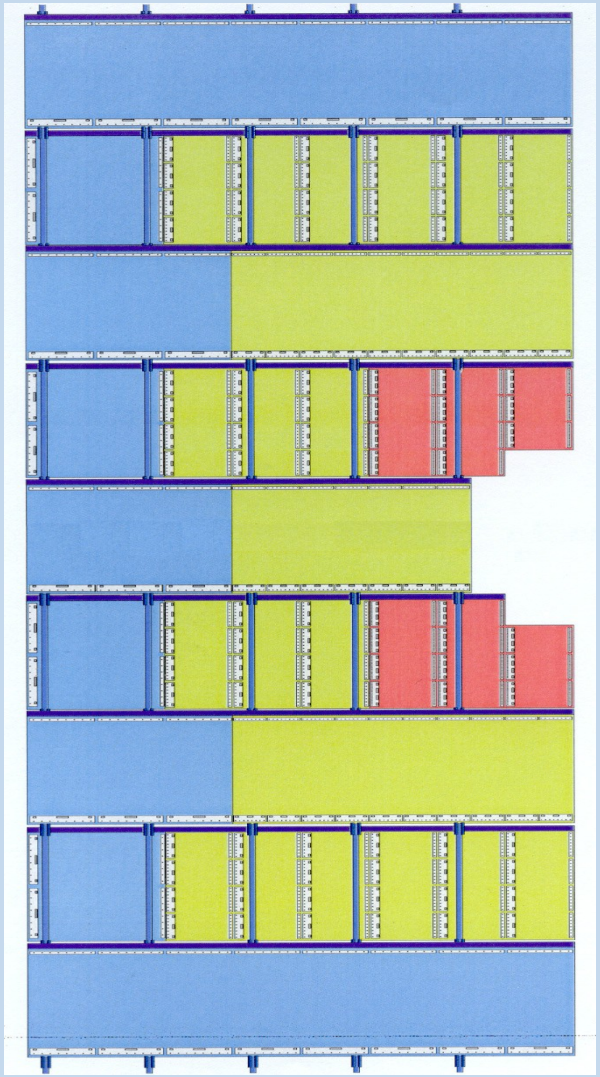
The trigger system: Muon Trigger Chambers



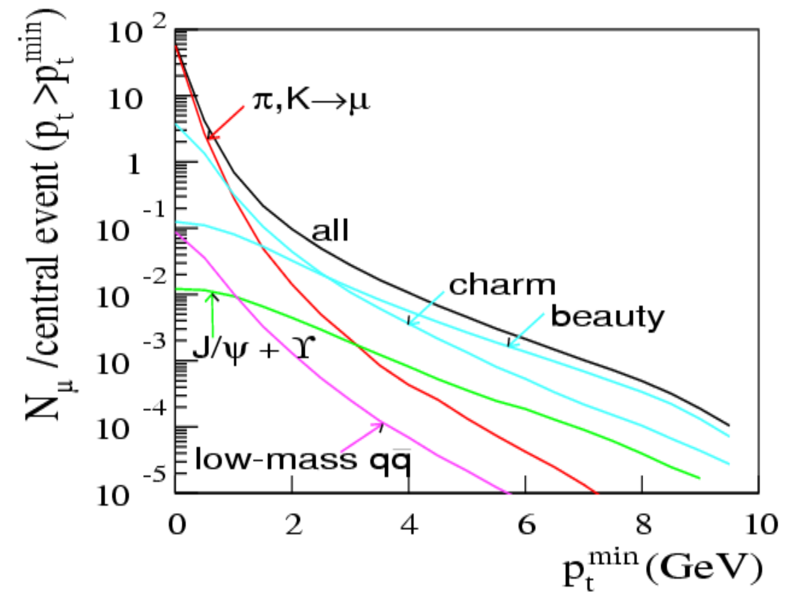
2 stations, of two planes each
total area: ~ 140 m^2

72 RPCs of 3 different shapes
and dimensions :
~1.6 m^2 ÷ 2.1 m^2

20992 strips and front-end channels
strip pitch:
10-45 mm(~1/2/4 cm)
strip length:
170÷720 mm



The principle of the trigger (I)



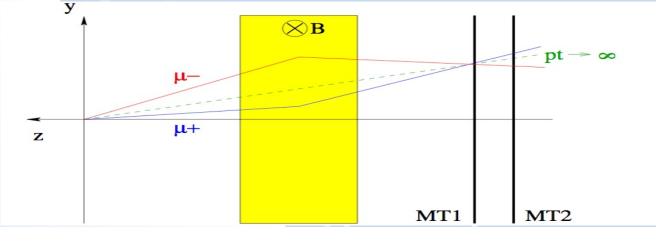
GOAL:

- Selection of (muon) tracks pointing to I.P. with p_t above 2 thresholds:

  low $p_{t\ cut}$ = 1 GeV/c

  high $p_{t\ cut}$ = 2 GeV/c

- Trigger signals for single μ, like-sign and unlike-sign μ pairs

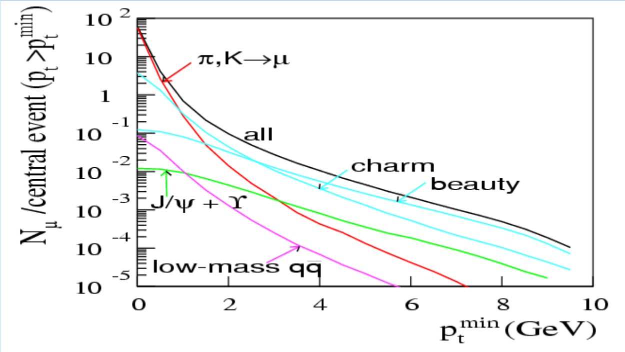


PRINCIPLE:

- *cut on p_t ⇔ cut on deviation between MT1and MT2*

→ *select tracks in a road of a given width*

The principle of the trigger (II)



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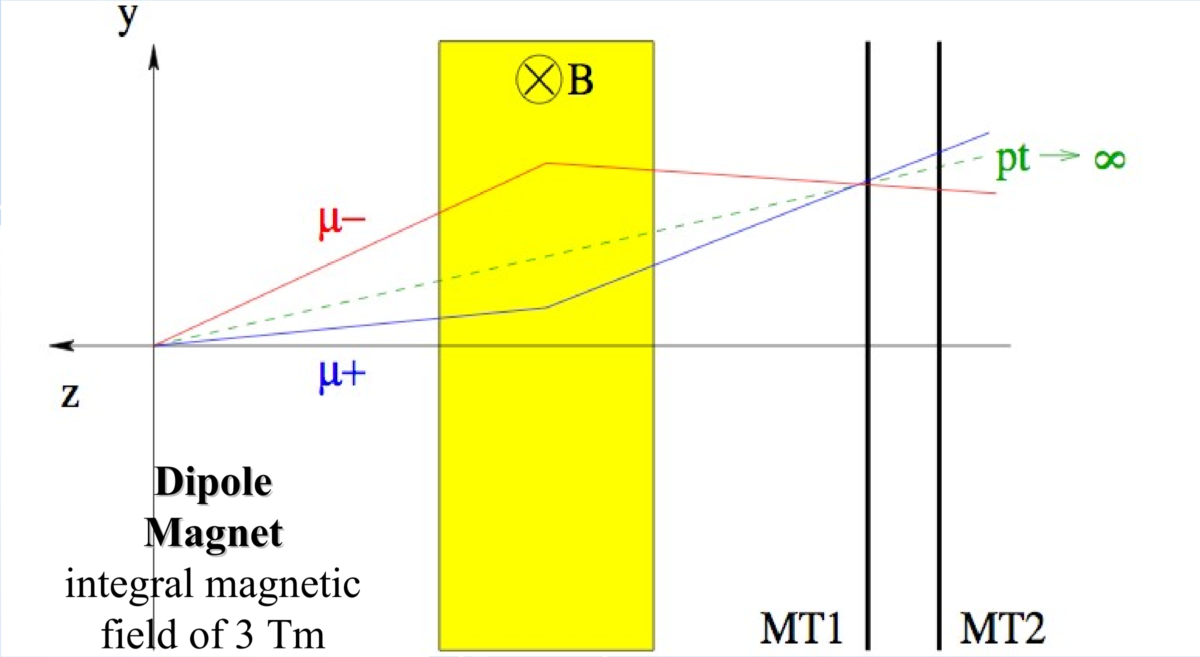
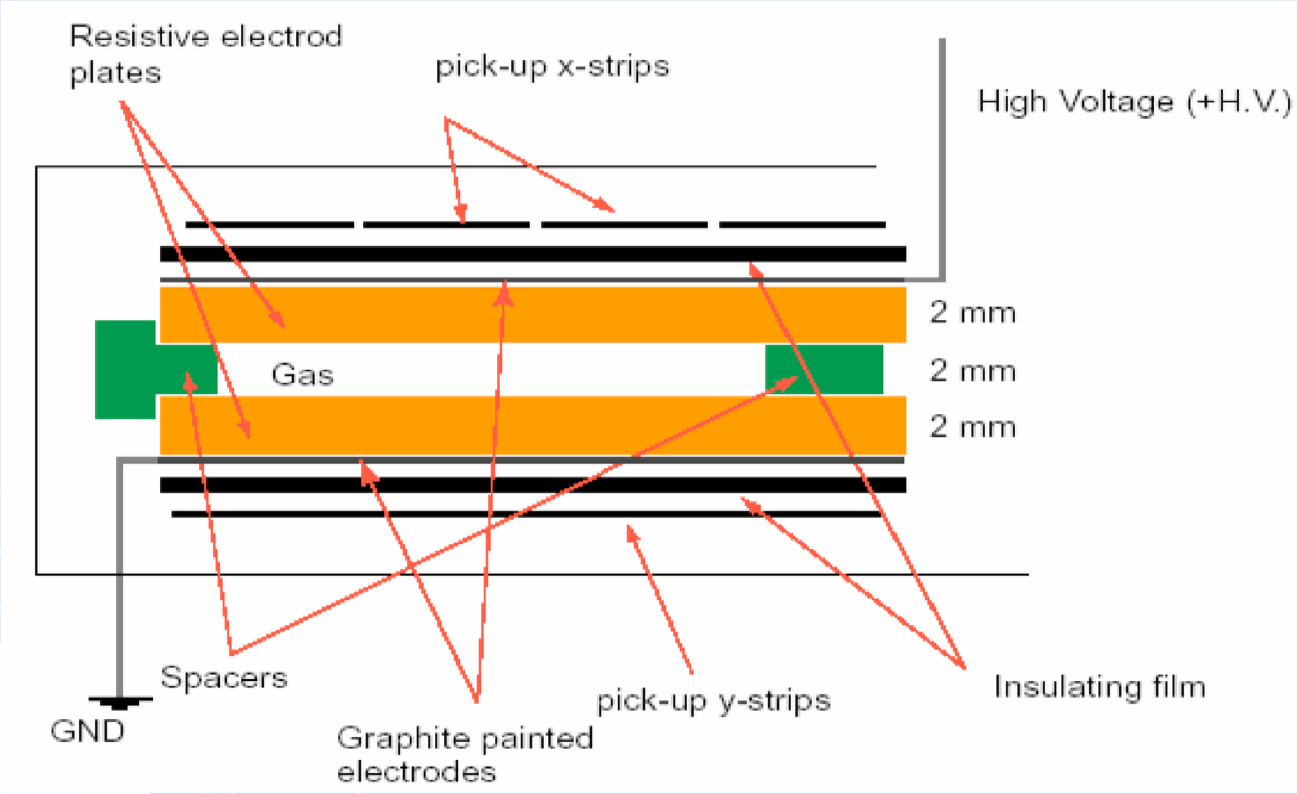


PRINCIPLE:

- cut on p_t ⇔ cut on deviation between MT1and MT2
  → select tracks in a road of a given width

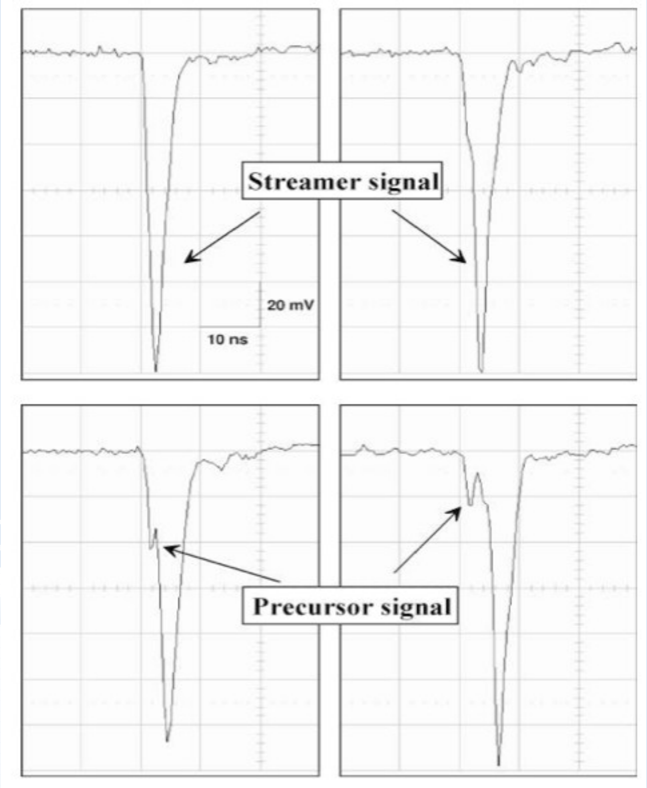
Resistive Plate Chambers (I)

A **Resistive Plate Chamber** (RPC) is a planar geometry gaseous detector



Resistive Plate Chambers (II)

Gas mixtures: avalanche vs streamer



The **difference** between the streamer and avalanche modes lies in the **gas mixture (quenchers)** and **HV** applied between the two electrodes.

Main advantages of streamer and avalanche RPC operation

Operation mode	**Advantages**
Streamer	*Spatial resolution*
	No amplification needed
	Lower noise rate
Avalanche	*Time resolution*
	Rate capability
	Slower ageing

ALICE MuonTrigger RPCs

→Typical avalanche operation voltages ~ 10 kV

→ Typical streamer operation voltages ~ 8 kV

Resistive Plate Chambers (III)

ALICE : both *A-A* and *p-p* data-taking

Requirements for A-A data taking:

- *Spatial resolution* ~ 1 cm
- *Occupancy* as low as possible (few % Pb-Pb) and *cluster-size* as close as possible to 1
- *Rate capability* ~3 Hz/cm^2 (Pb-Pb) and ~25 Hz/cm^2 (Ar-Ar)
- *Time resolution* ~ 2 ns

Requirements for p-p data taking:

- Expected *muon trigger rate* much lower than in A-A collisions
- *Rate capability* ~100 Hz/cm^2
- Goal: *detector lifetime*

Resistive Plate Chambers (IV)

RPC performances

Rate capability up to ~100 Hz/cm^2 (p-p) → **Low resistivity bakelite:** **ρ = 2÷8 10^9 Ωcm**

Time resolution ~ 2 ns → **Dual threshold** **Front End Electronics** **10 mV - 80 mV**

Resistive Plate Chambers (IV)

RPC performances

Rate capability up to ~100 Hz/cm^2 (p-p) → **Low resistivity bakelite: ρ = 2÷8 10^9 Ωcm**

Time resolution ~ 2 ns → **Dual threshold Front End Electronics 10 mV - 80 mV**

Requirements for A-A data taking:

Spatial resolution ~ 1 cm

Occupancy as low as possible (< % Pb-Pb) and *cluster-size* as close as possible to 1

↓

Streamer mode

Resistive Plate Chambers (IV)

RPC performances

Rate capability up to ~100 Hz/cm^2 (p-p) → **Low resistivity bakelite: ρ = 2÷8 10^9 Ωcm**

Time resolution ~ 2 ns → **Dual threshold Front End Electronics 10 mV - 80 mV**

Requirements for A-A data taking:

Spatial resolution ~ 1 cm

Occupancy as low as possible (< % Pb-Pb) and *cluster-size* as close as possible to 1

↓

Streamer mode

Requirements for p-p data taking:

Expected *muon trigger rate* much lower than in A-A collisions

Goal: *detector lifetime*

↓

"Highly saturated" avalanche mode

Resistive Plate Chambers (V)

The two gas mixtures in detail.....

The gas mixture used will be different for A-A and p-p collisions.

A-A collisions (a wet, low-gain streamer mixture will be used)

50.5% Ar **41.3%** $C_2H_2F_4$ **7.2%** C_4H_{10} **1%** SF_6

p-p collisions (a wet, highly-saturated avalanche mixture will be used)

89.7% $C_2H_2F_4$ **10%** C_4H_{10} **0.3%** SF_6

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1) Overview of the trigger system of the ALICE Muon Spectrometer

2) Commissioning measurements and results

Muon Spectrometer commissioning with cosmic rays: goals

- **Global test of the Muon Spectrometer**

Muon Spectrometer commissioning with cosmic rays: goals

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- **Test of the Trigger Chambers and of the Tracking Chambers separately**

Muon Trigger commissioning with cosmic rays: goals

- Global test of the Muon Spectrometer
- Test of the **Trigger Chambers** and of the Tracking Chambers separately

Detectors

Dark current and rate measurements

RPCs working point

Electronics

test of Front-End and trigger electronics

DAQ, DCS

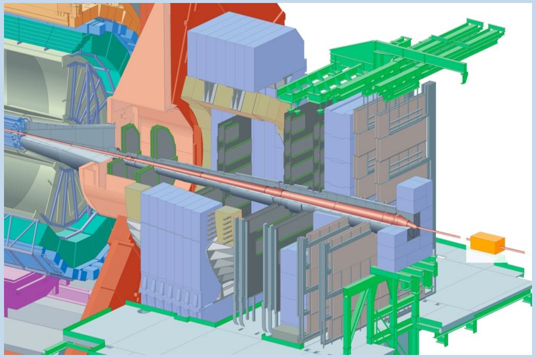
Muon Trigger commissioning with cosmic rays: goals

- Global test of the Muon Spectrometer
- Test of the **Trigger Chambers** and of the Tracking Chambers separately

Detectors	**Electronics**
Dark current and rate measurements	*test of Front-End and trigger electronics*
RPCs working point	*DAQ, DCS*

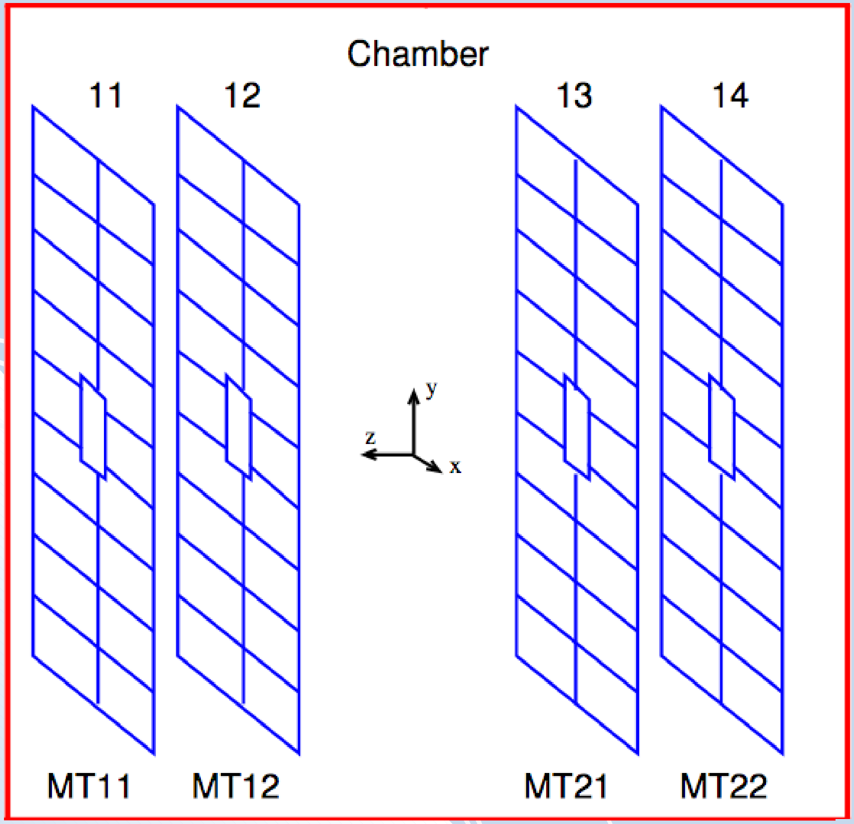
RPC working point in streamer

RPC working point in avalanche



Trigger chamber efficiency (I)

Due to : *geometrical acceptance* and *projective geometry trigger* (the tracks triggered have to come from the Interaction Point IP)

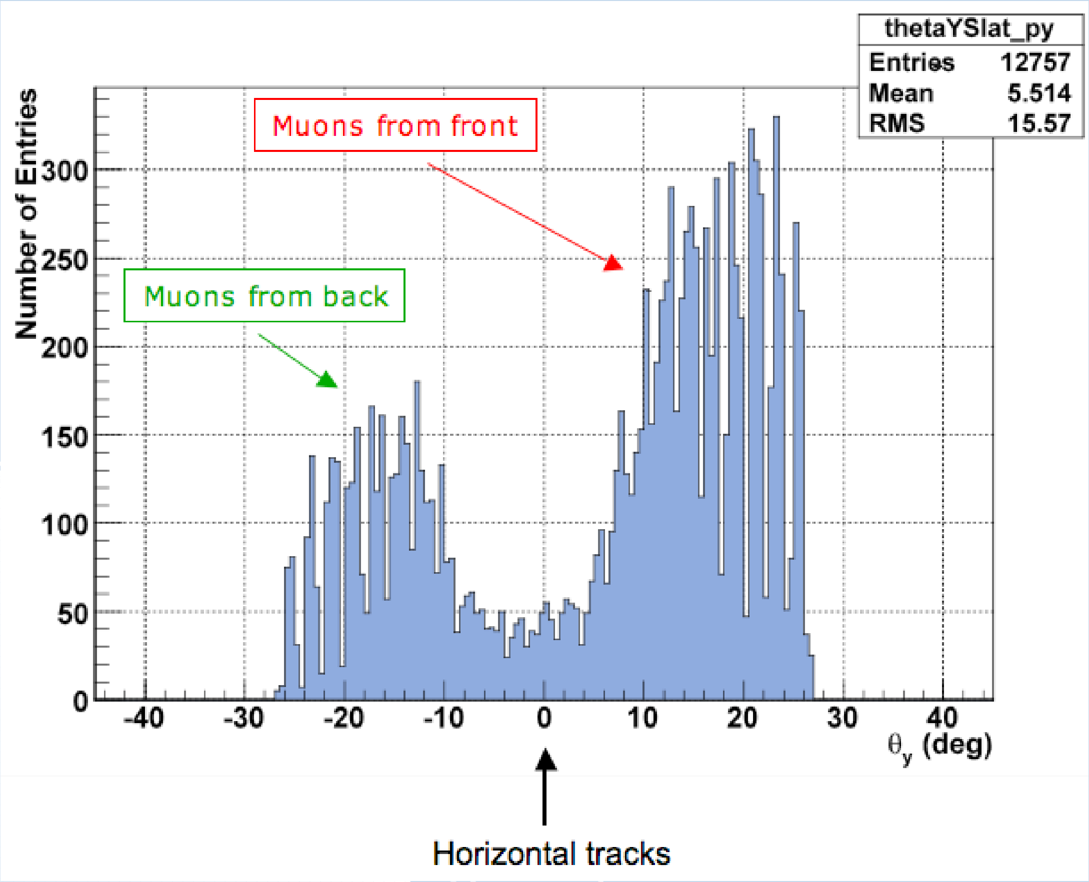


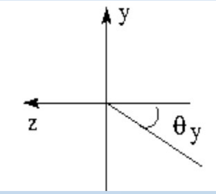
the ALICE Muon Spectrometer is not designed to detect cosmic rays

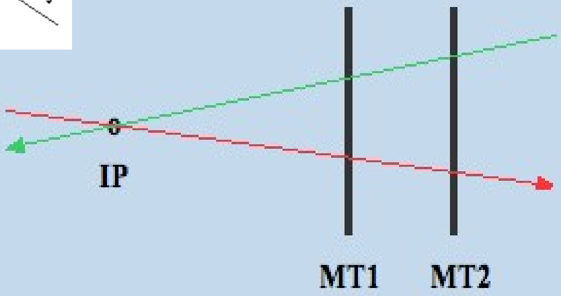
To study the ***global features*** of the system, the nearly horizontal tracks triggered are very useful for our aims

Trigger chamber efficiency (II)

angular distribution of detected cosmic muons



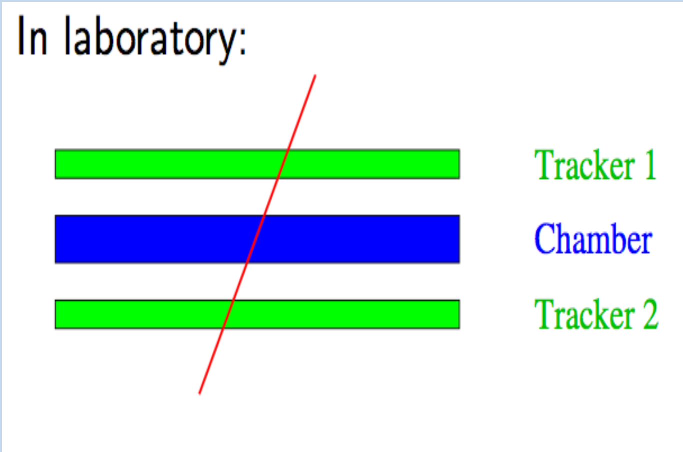


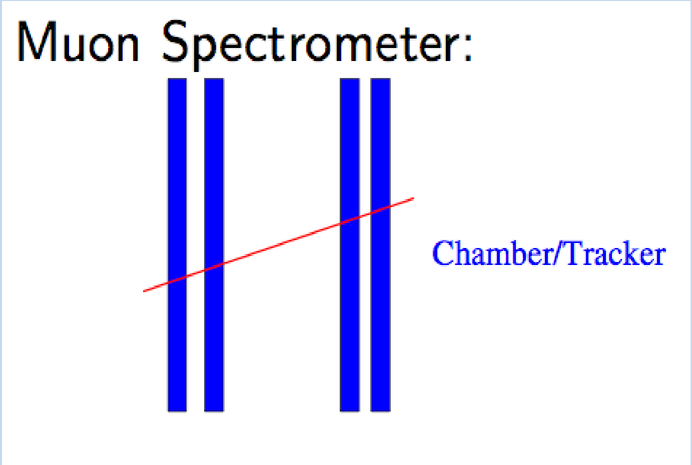


- θ_y ***angular distribution*** reflects the cosmic muon zenithal angle distribution
- ***Distribution not symmetric***: lower efficiency for muons from the back due to difference in timing between the two stations

Trigger chamber efficiency (III)

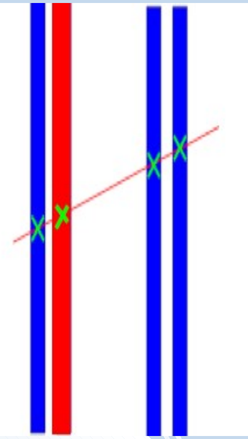
Experimental set-up



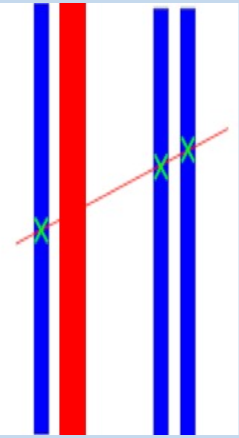


The trigger algorithm searches for hits in at least 3 out of 4 trigger chambers. We define:

$N_{4/4} =$



$N^{12}_{3/3} =$



The ***efficiency*** for plane **a** is given by

$$\varepsilon_a = \frac{N_{4/4}}{N^{a}_{3/3} + N_{4/4}}$$

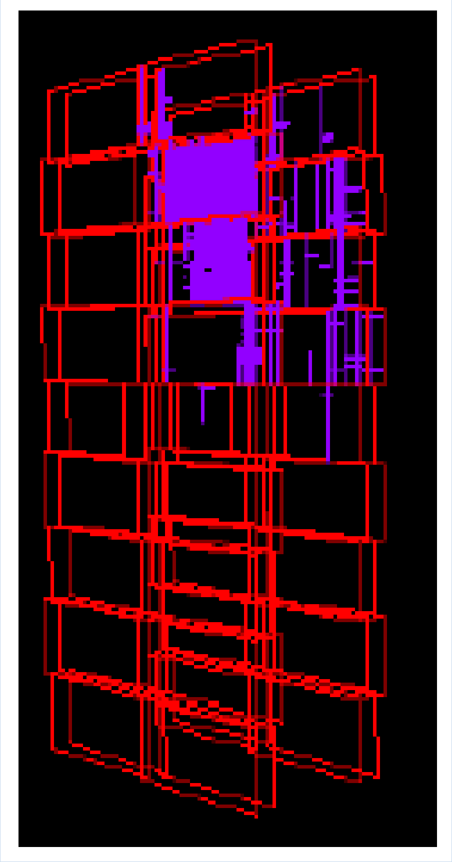
Trigger chamber efficiency (IV)

Selection of ***tracks*** in data analysis for efficiency evaluation

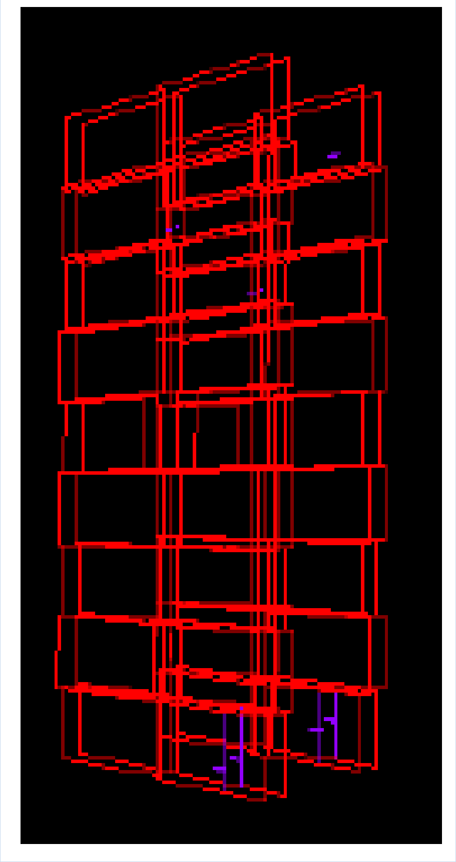
1) ~ 60% shower
2) ~ 40% single tracks

used in efficiency calculation

Total trigger rate :
~ 0.18 Hz (Streamer)
~ 0.23 Hz (Avalanche)



Event display of a cosmic shower



Event display of a cosmic muon

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1) Overview of the trigger system of the ALICE Muon Spectrometer:

2) Commissioning measurement and results:

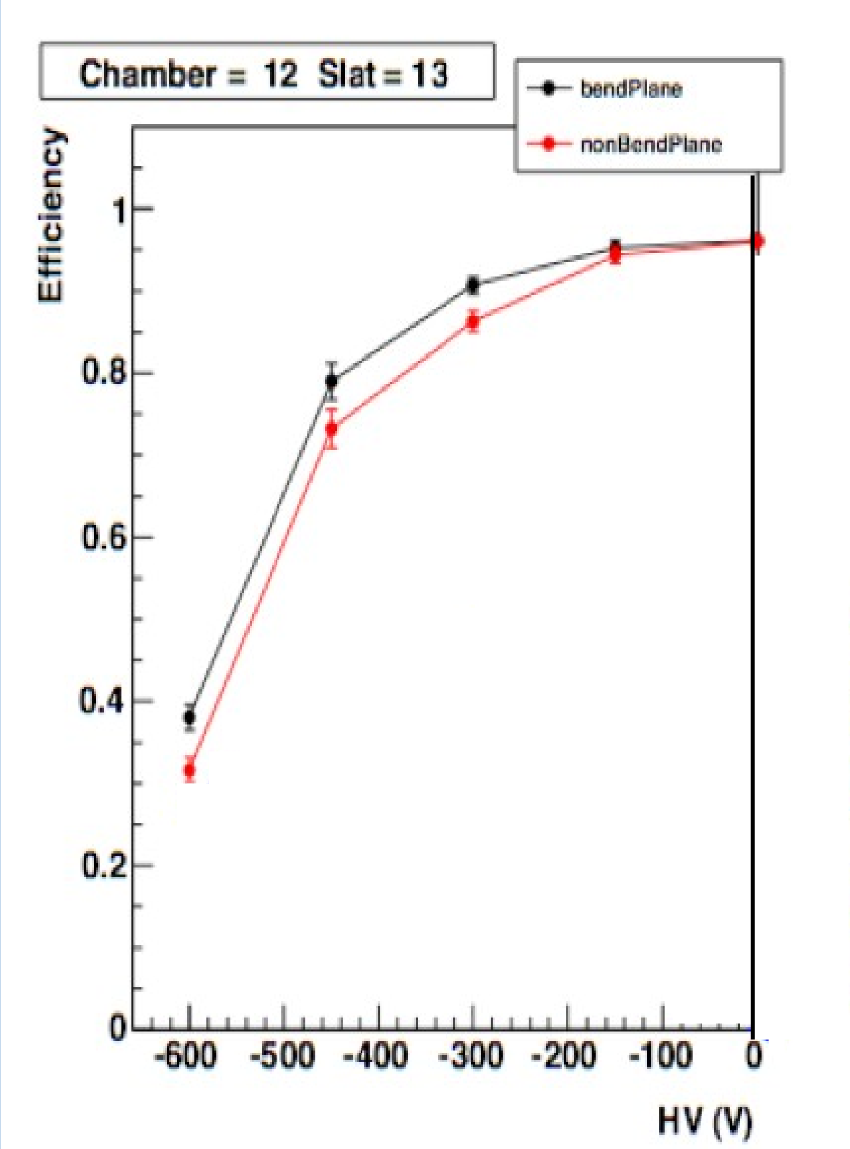
- Tests in Streamer mode (March-April 2009)

- Tests in Avalanche mode (August-September 2009)

RPC status: efficiency vs. H.V.

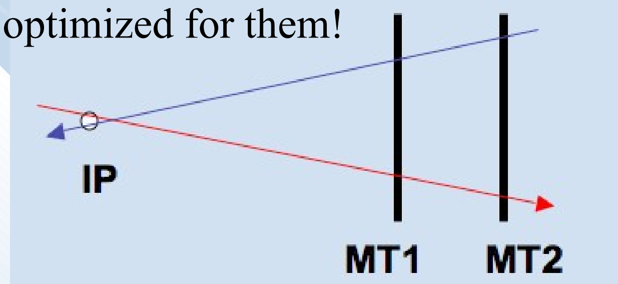
RPC working point in streamer:

Cosmics run (Mar-Apr 2009):
The goal is to find the working voltage by H.V. scan from a "nominal" H.V. value (corresponding to H.V. = 0 V in the plot) **determined during a period of preliminary tests.**



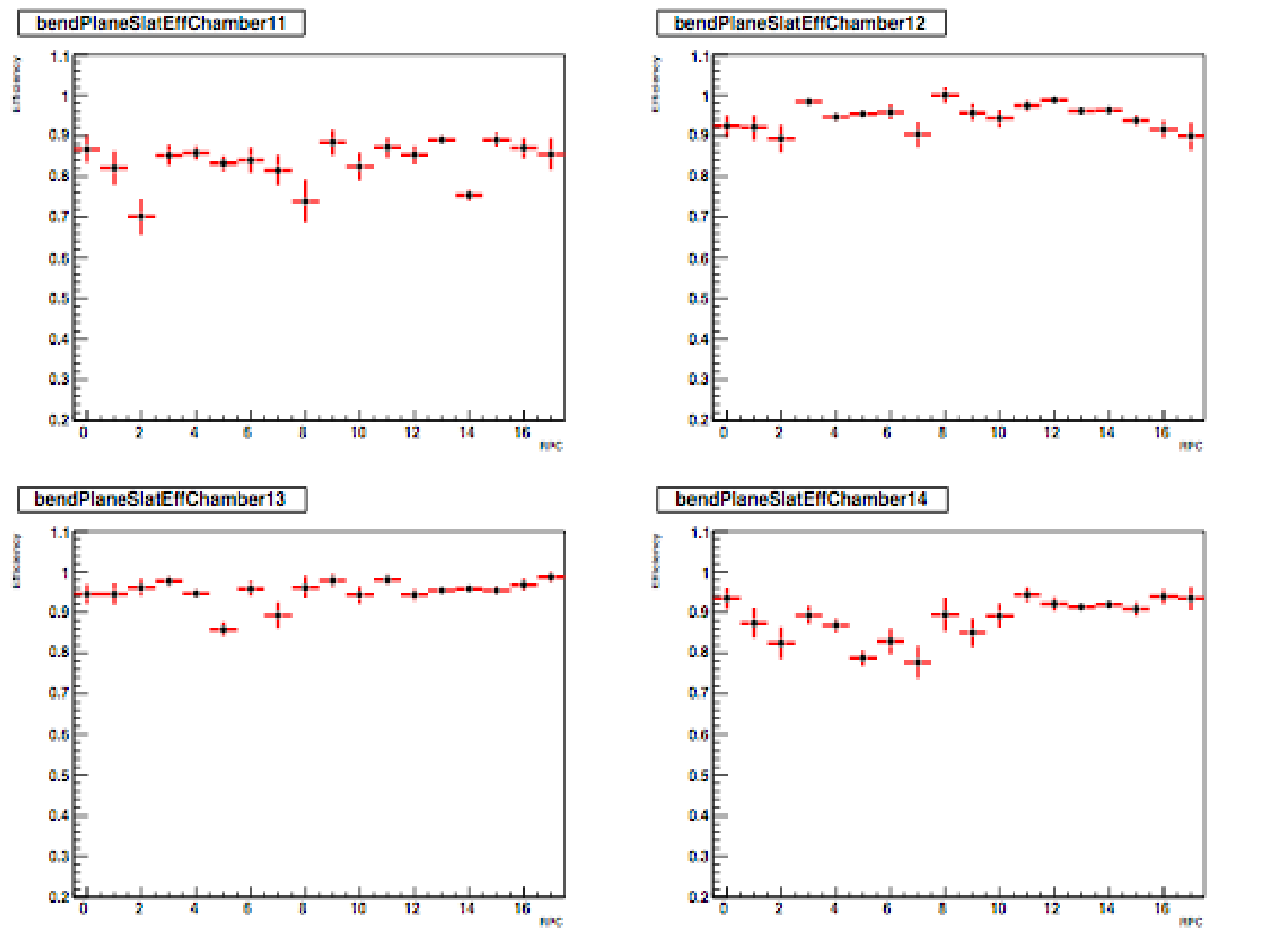
CAVEAT

Difficult to determine the absolute value of RPC efficiency due to specific cosmic run conditions:
1) Low statistics
2) Systematic effects : cosmics from the direction opposite to IP. The timing between the two trigger stations is not optimized for them!



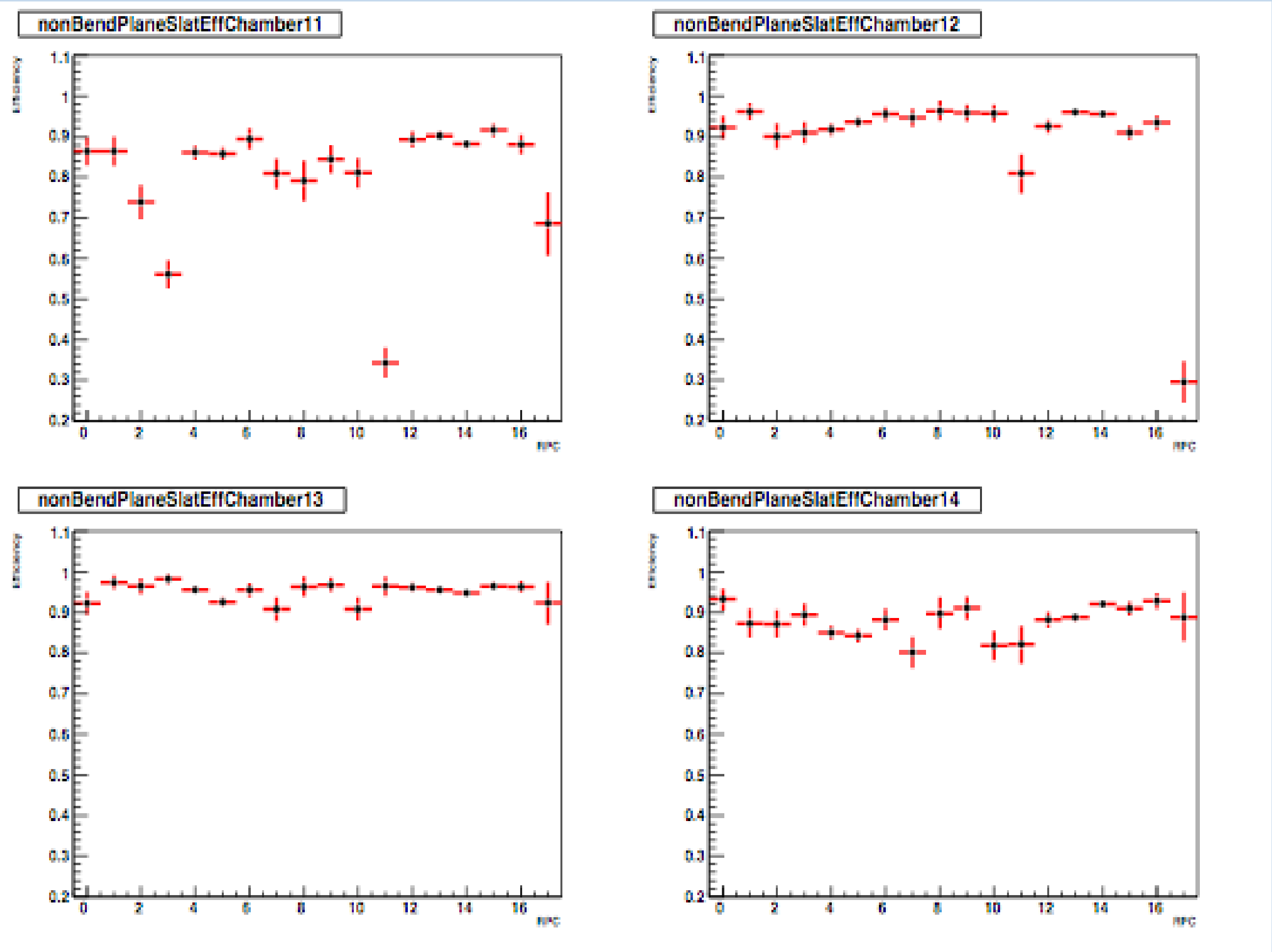
"Efficiency" in the bending plane (per slat) for all the 4 stations (<u>streamer mixture</u>)

Check of the status of the system



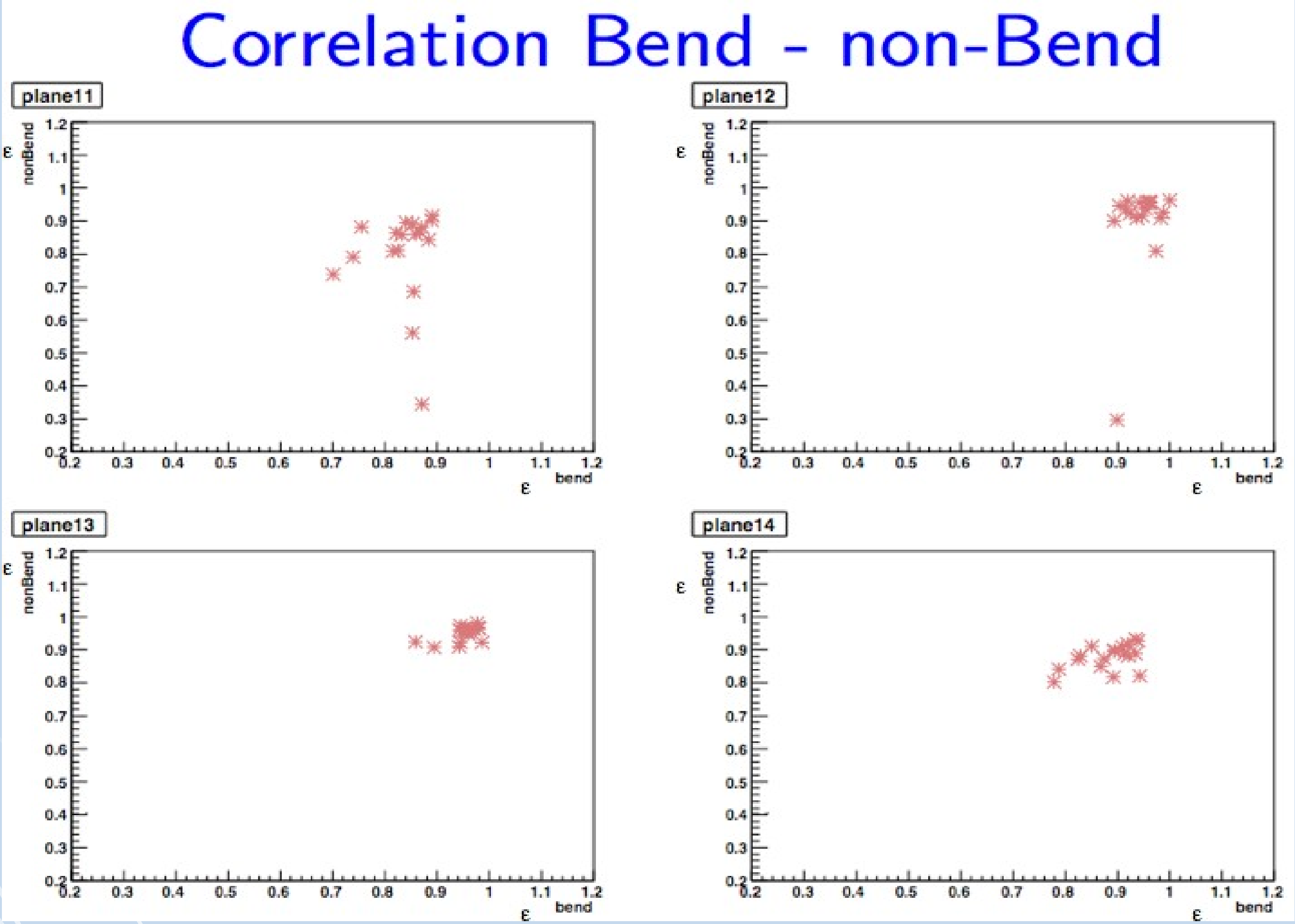
"Efficiency" in the non bending plane (per slat) for all the 4 stations (__streamer mixture__)

Check of the status of the system



Correlation between bending and non-bending efficiency (<u>streamer mixture</u>)

Hardware issues can be more clearly understood considering this graphic



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- Tests in Streamer mode (March-April 2009)

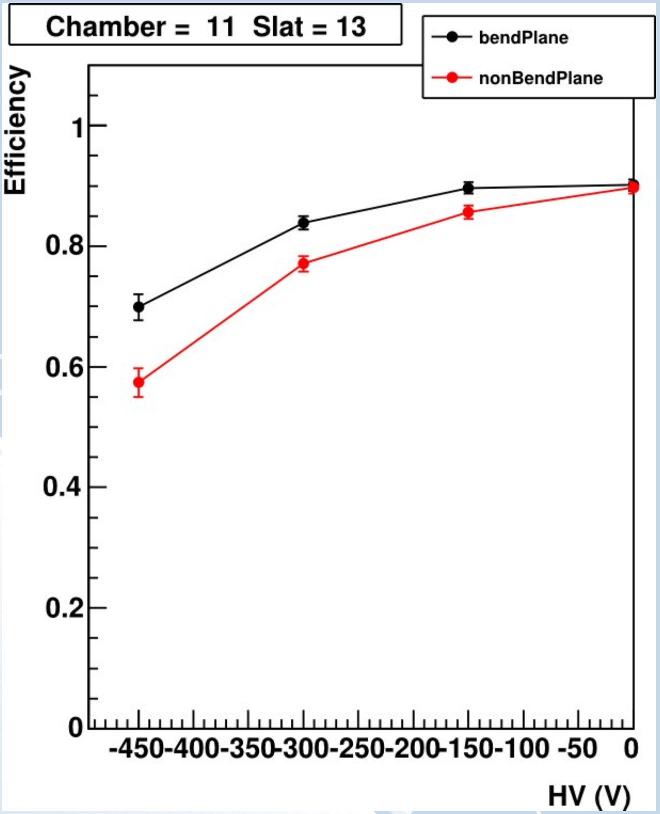
- **Tests in Avalanche mode (August-September 2009)**

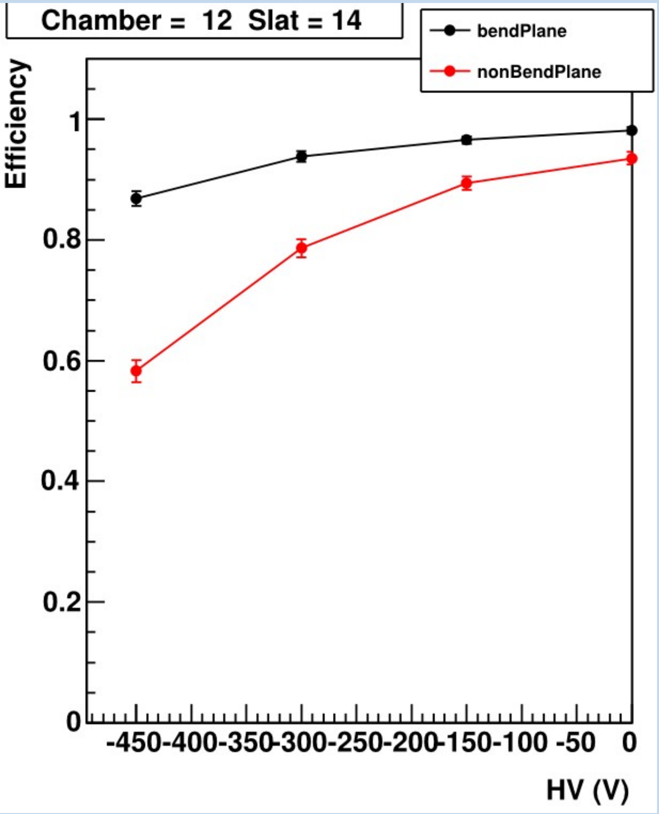
RPC status: efficiency vs. H.V.

RPC working point in avalanche:

Cosmic run (Ago-Sep 2009):

The goal is to find the working voltage by H.V. scan from the "nominal" H.V. value estimated with preliminary test .





"Efficiency" in the bending plane (per slat) for all the 4 stations (avalanche mixture)

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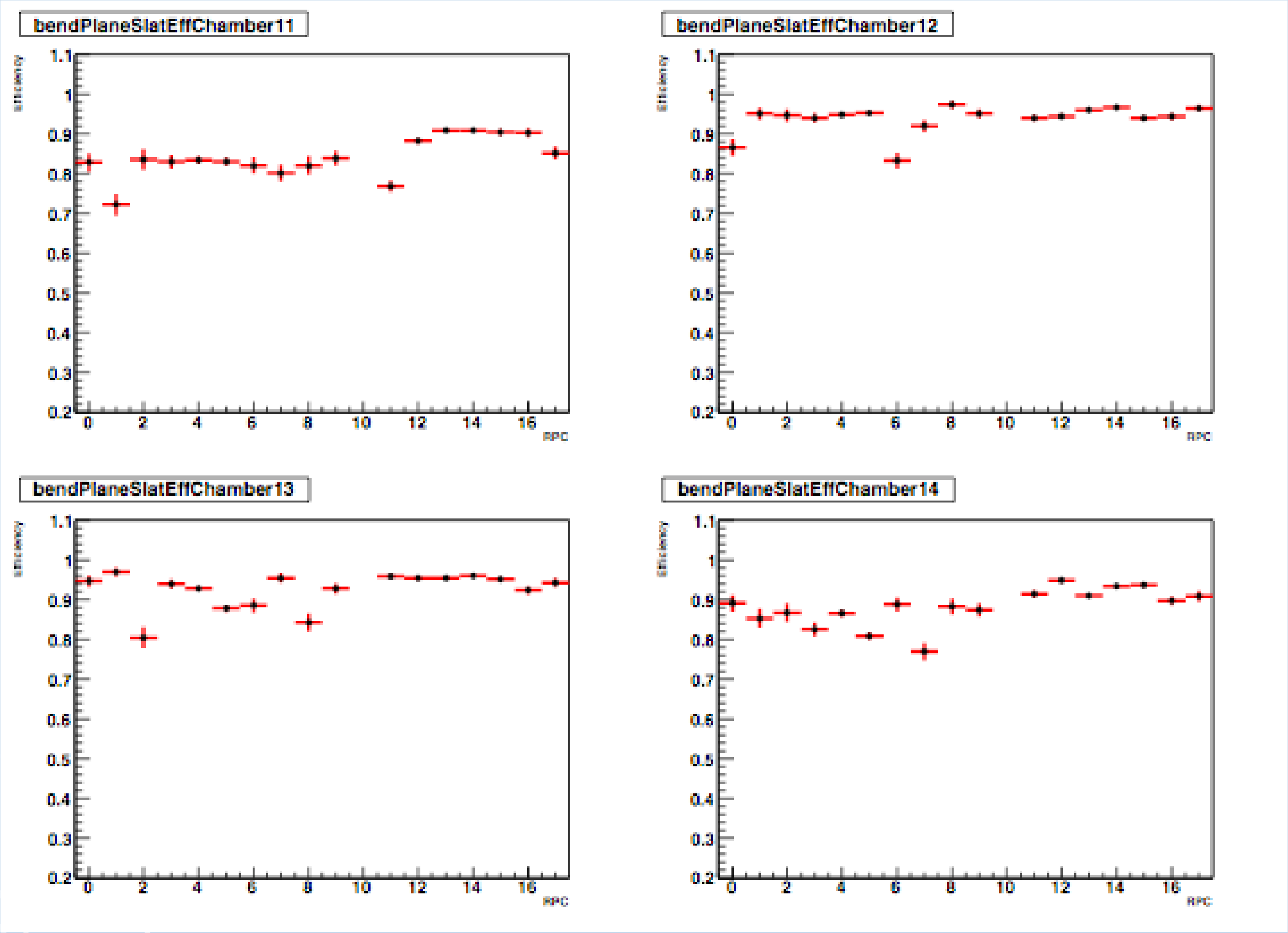

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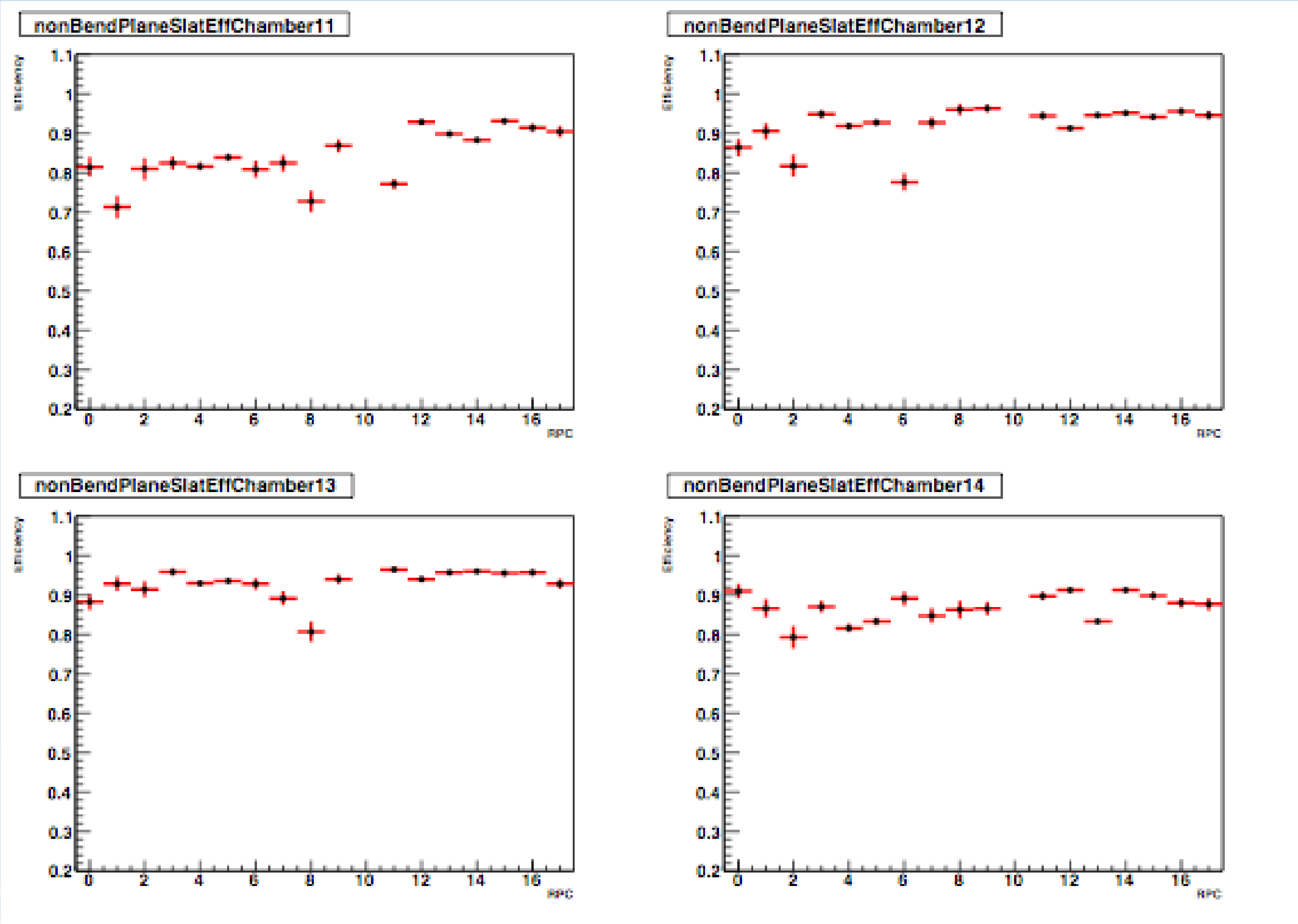


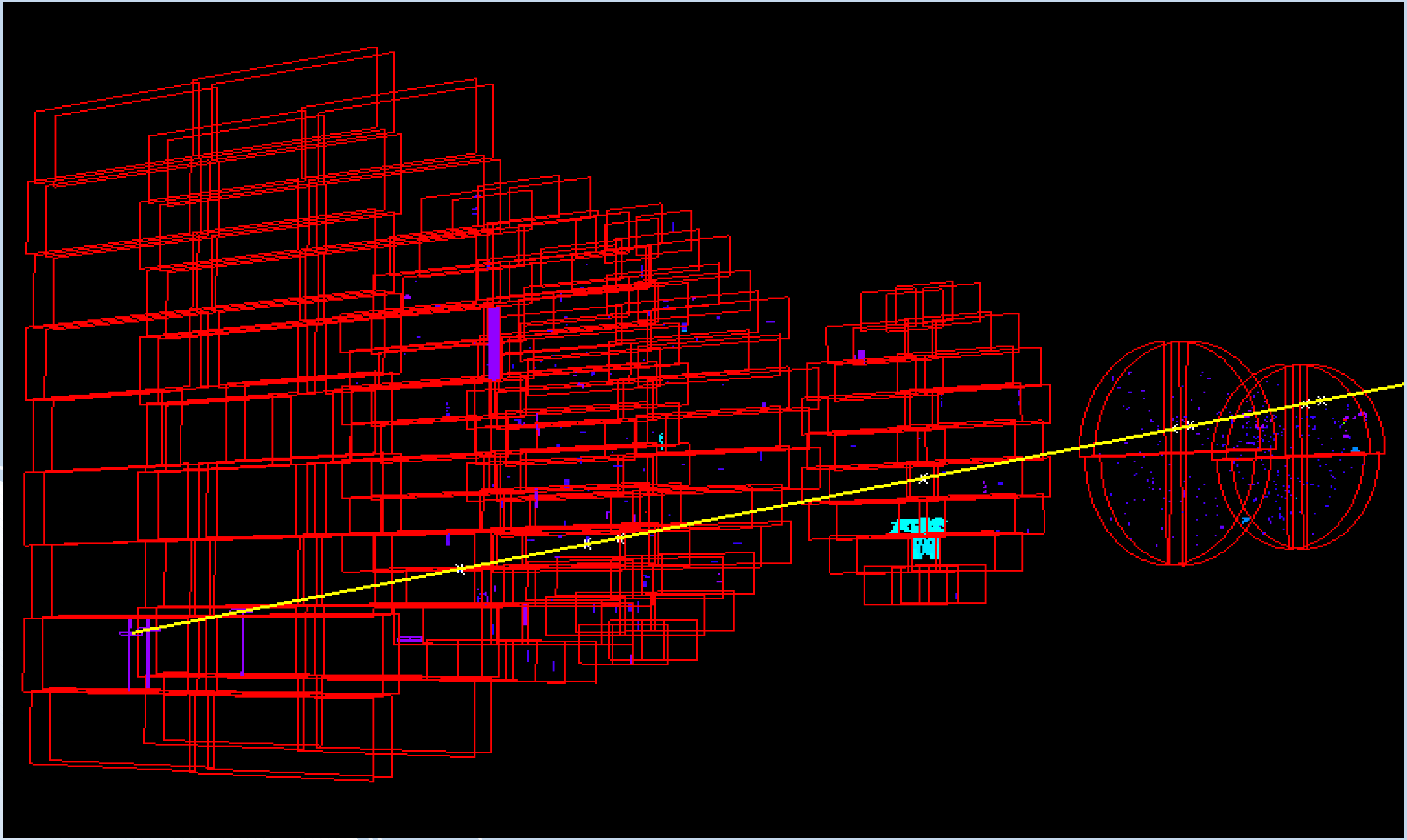
Conclusions

First and successful long-term test of the full detector in **avalanche mode**

MTR and **MTK** were stable and permanently operational, all along the cosmic run

The run has allowed to *test the muon spectrometer in a configuration very close to the final one* (almost all the detection and read-out elements active)

A muon track in the ALICE Muon Spectrometer with dipole magnet OFF



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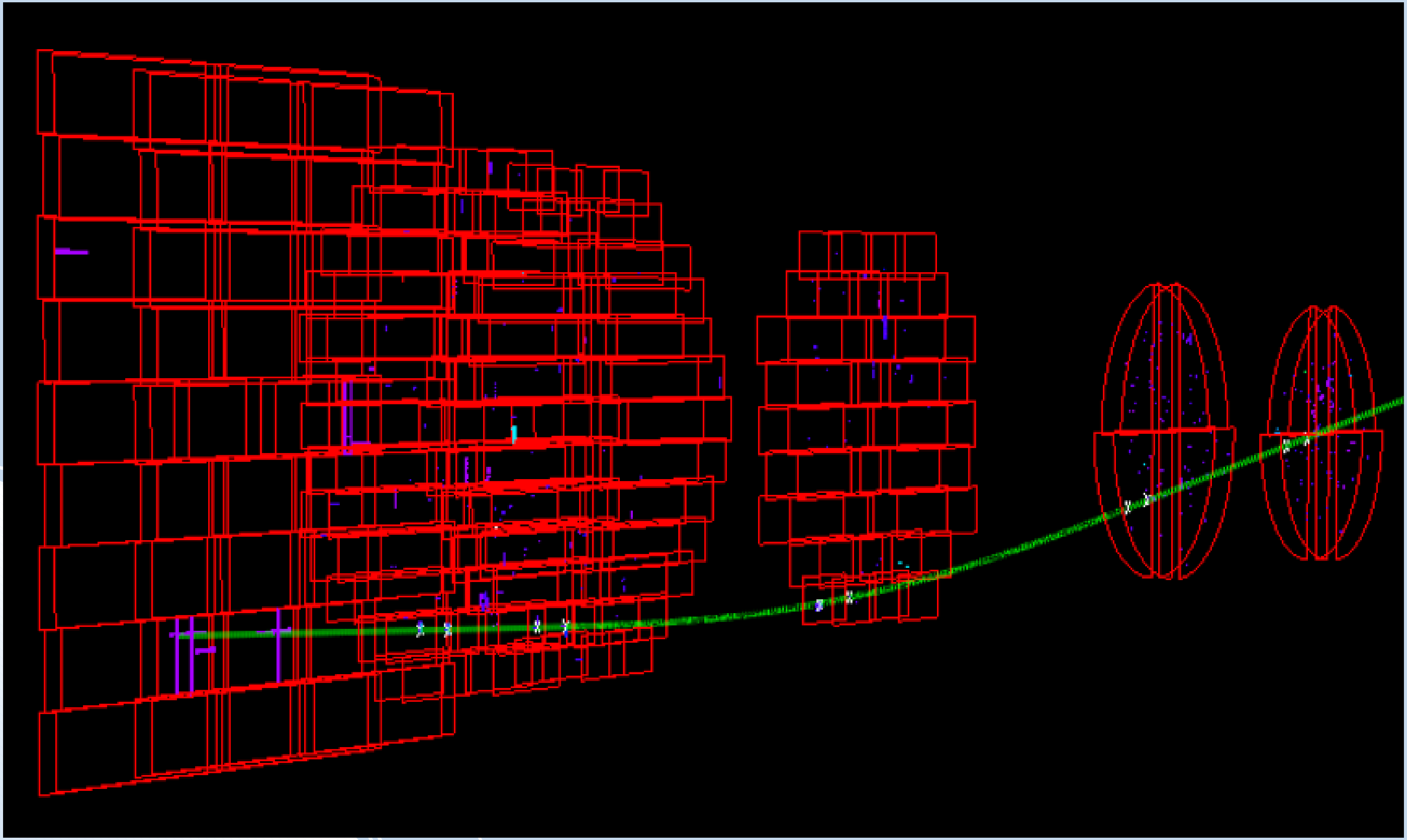
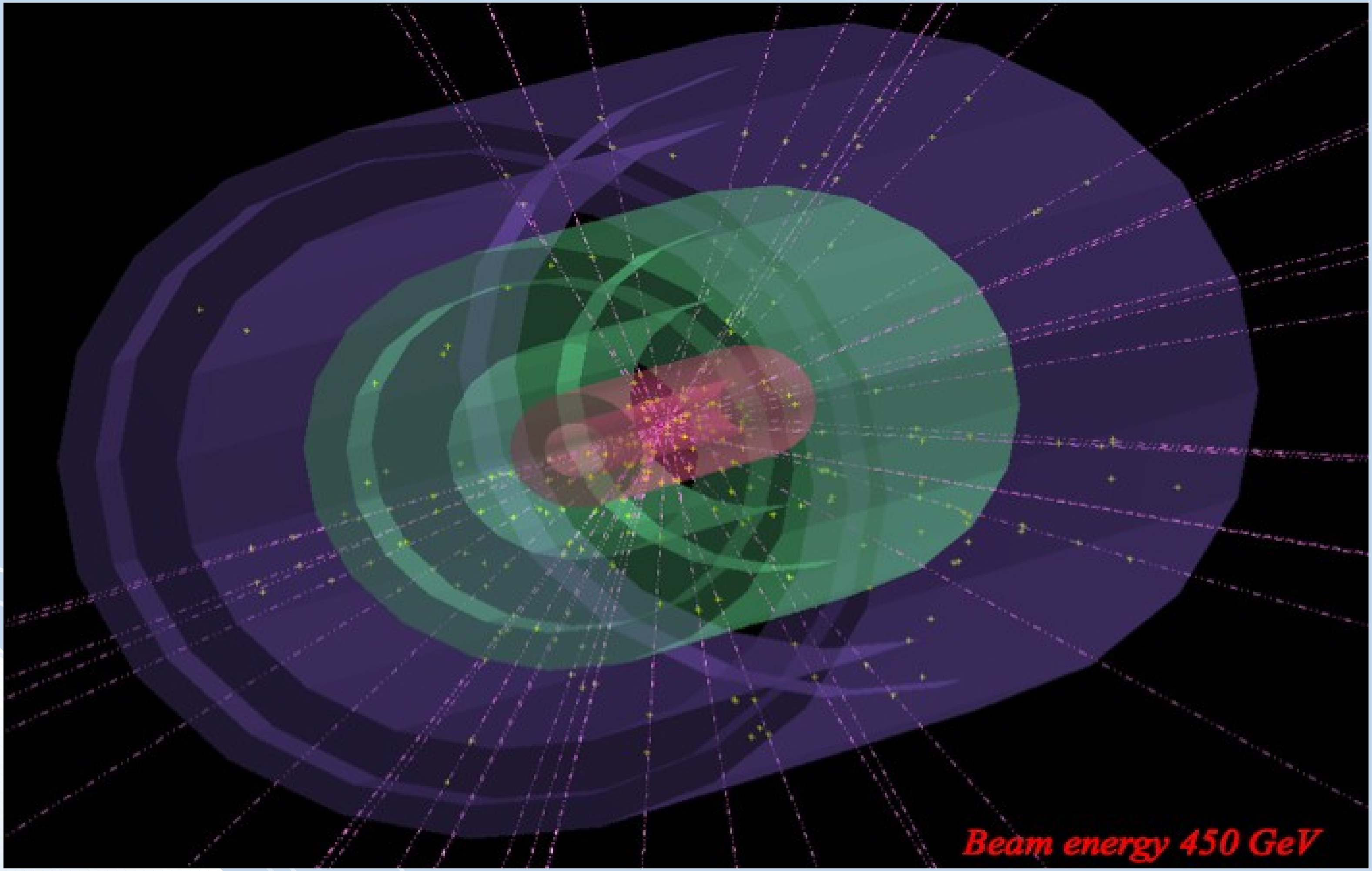
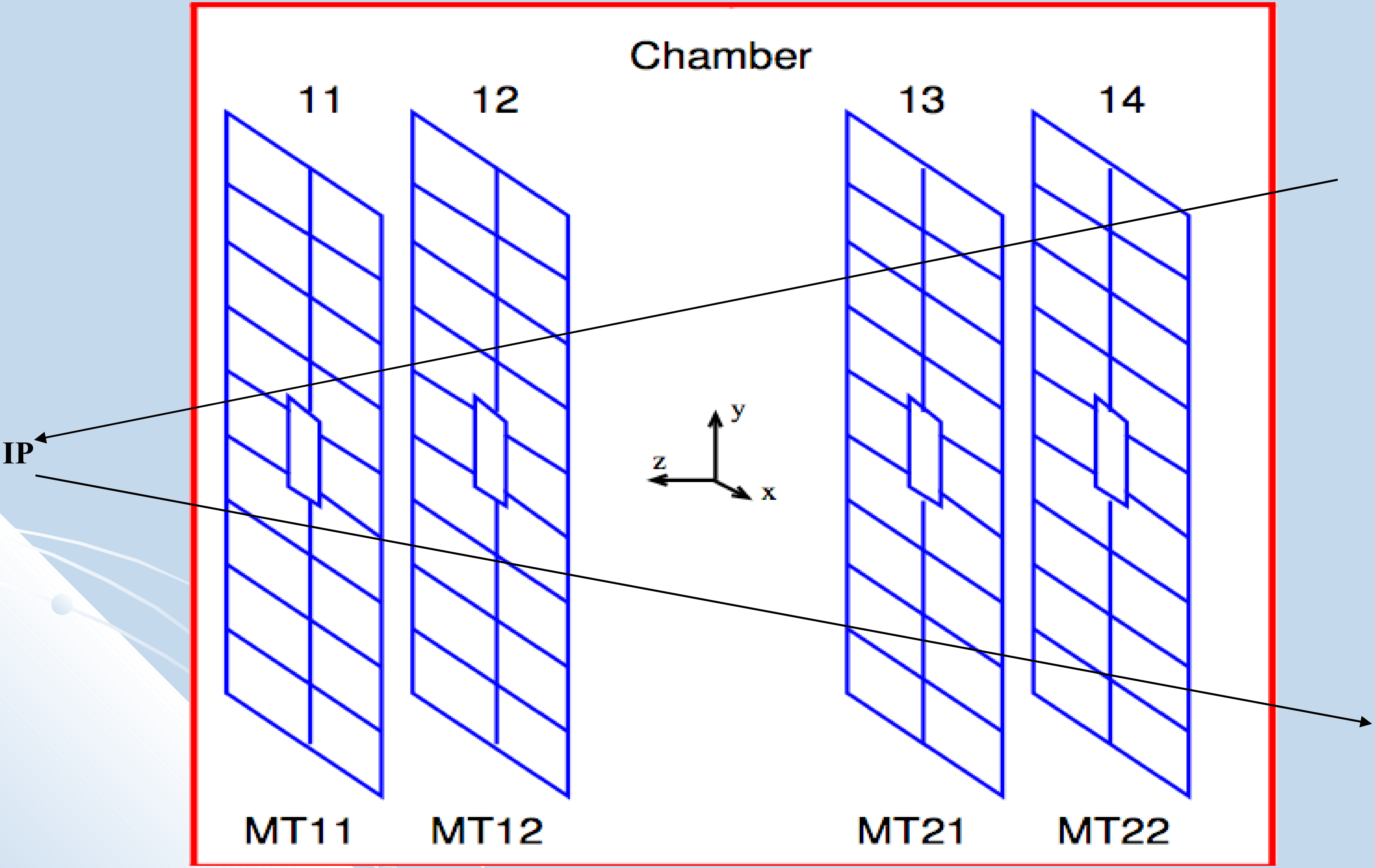
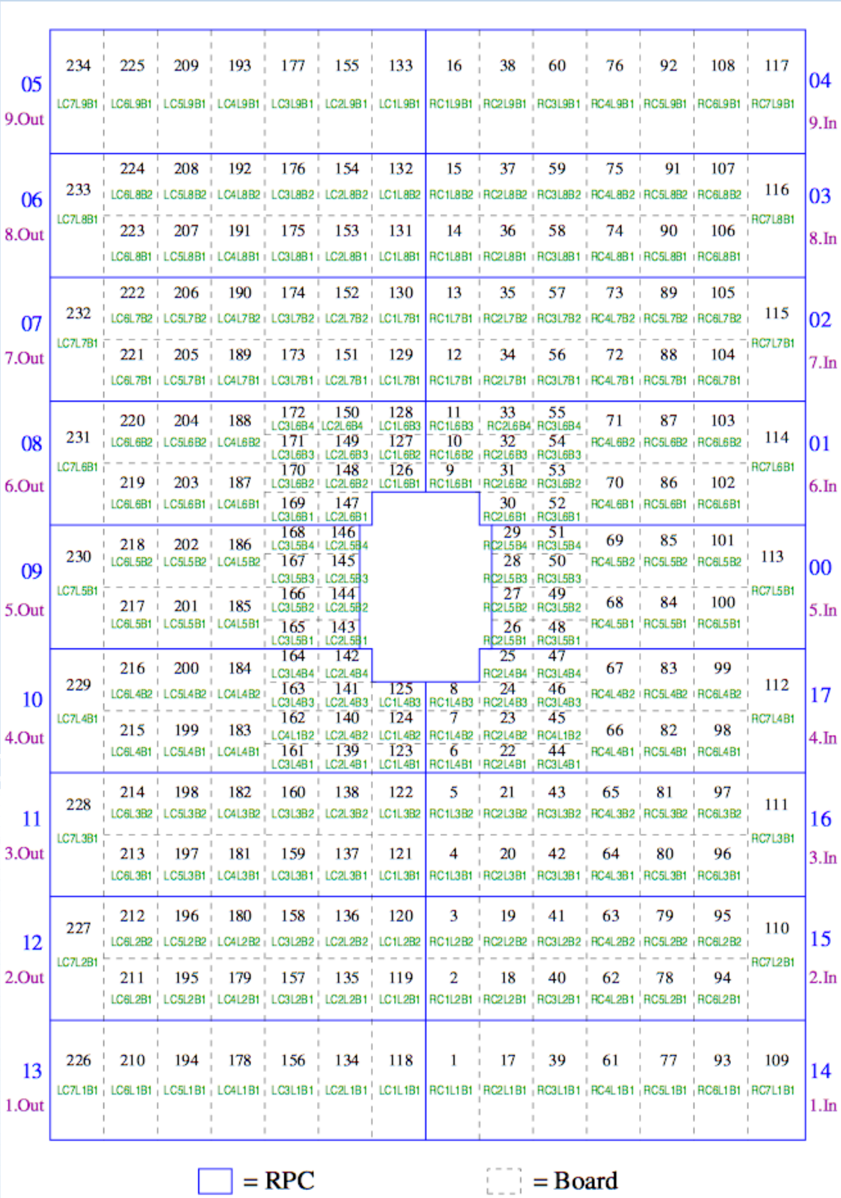


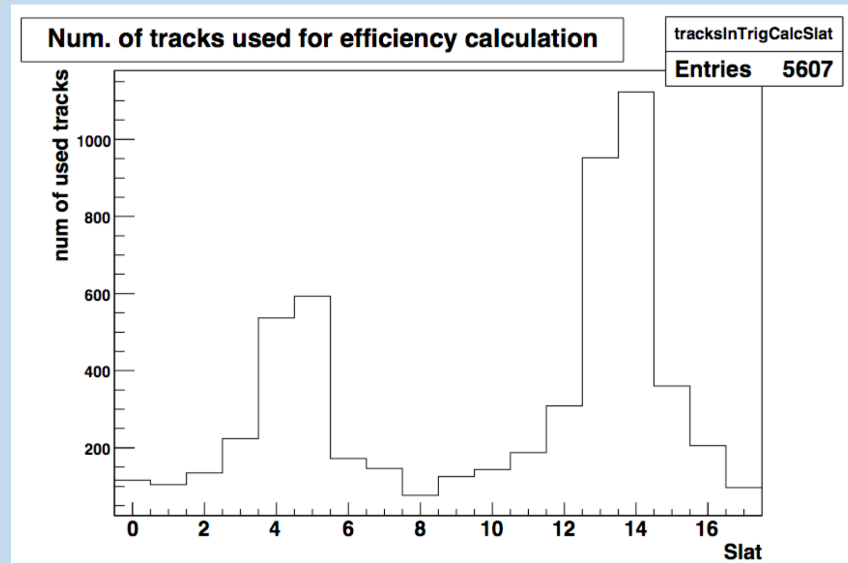
LHC restart: ALICE first event !!!

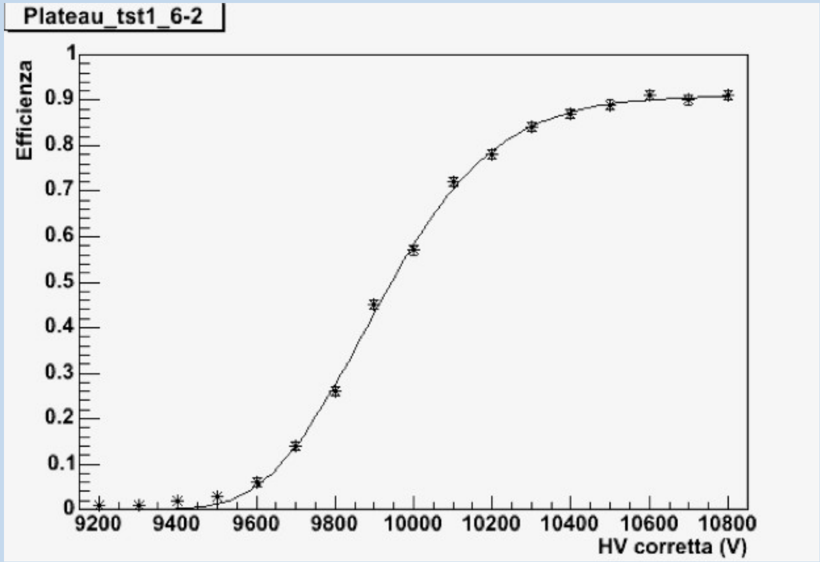


A handful of tracks have been reconstructed pointing back to a unique vertex


Chamber
11
12
13
14
IP
y
z
x
MT11
MT12
MT21
MT22

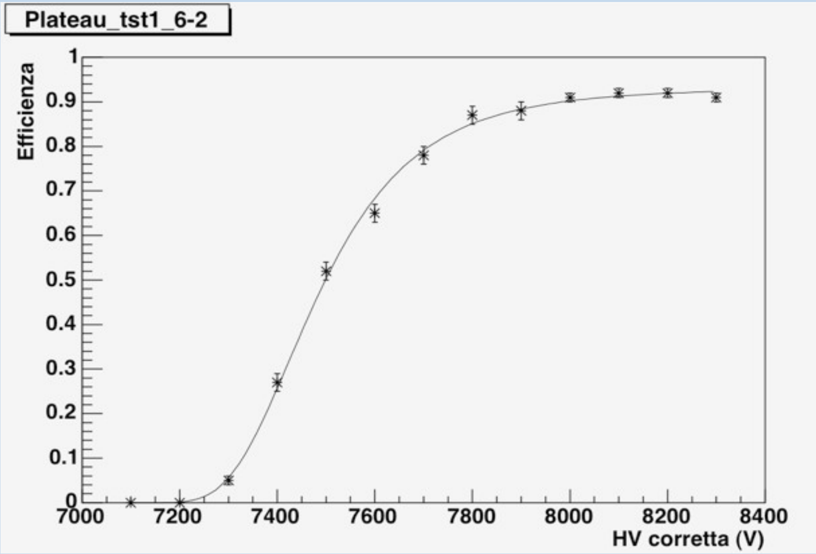

05
9.Out
06
8.Out
07
7.Out
08
6.Out
09
5.Out
10
4.Out
11
3.Out
12
2.Out
13
1.Out
04
9.In
03
8.In
02
7.In
01
6.In
00
5.In
17
4.In
16
3.In
15
2.In
14
1.In
= RPC
= Board


Num. of tracks used for efficiency calculation
tracksInTrigCalcSlat
Entries 5607
num of used tracks
1000
800
600
400
200
0
2
4
6
8
10
12
14
16
Slat

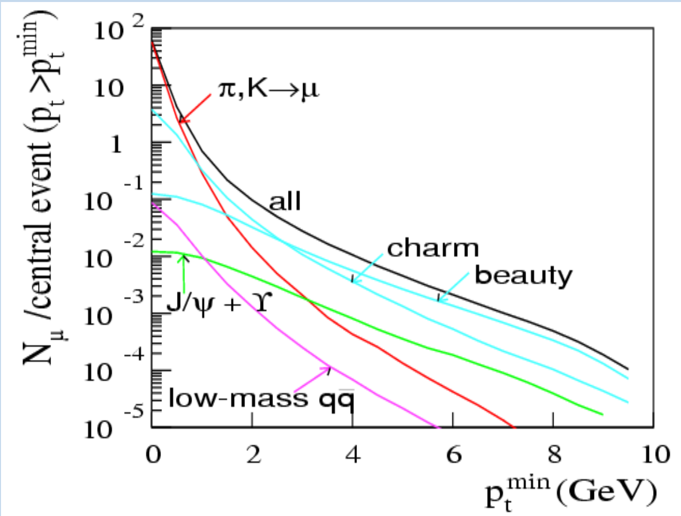


Avalanche

Streamer



The principle of the trigger (I)



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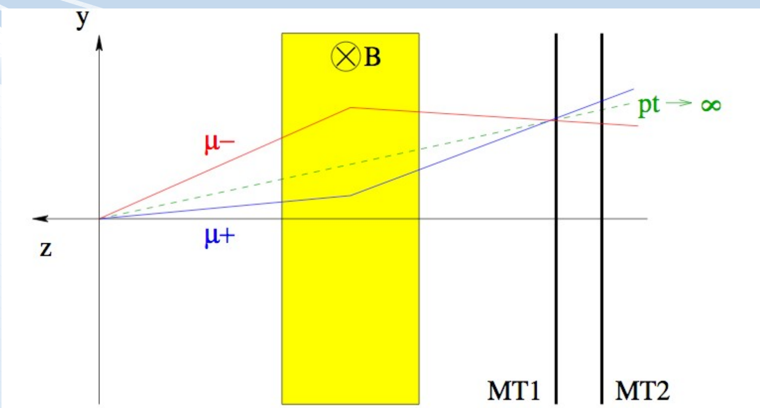
  low $p_{t\ cut}$ = 1 GeV/c

  high $p_{t\ cut}$ = 2 GeV/c

- Trigger signals for single μ, like-sign and unlike-sign μ pairs

8 strips in the vertical direction and 1 in the horizontal direction.



PRINCIPLE:

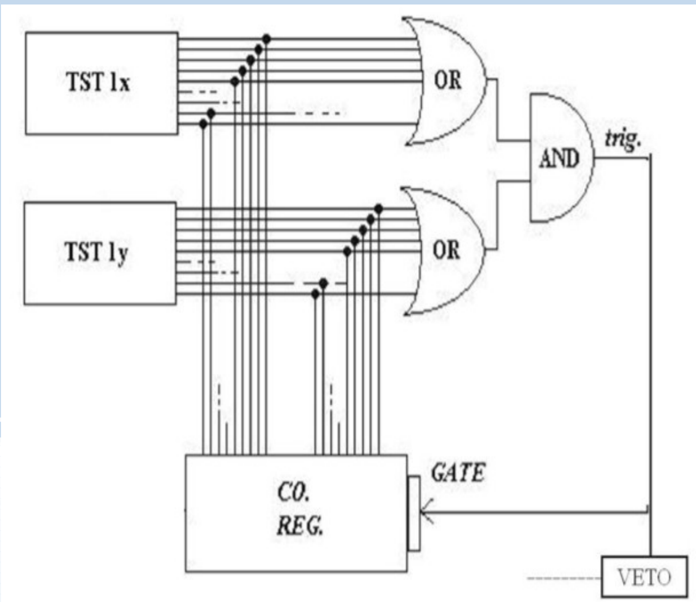
cut on p_t ⇔ cut on deviation between MT1and MT2

→ select tracks in a road of a given width

Noise measurements - The Autotrigger method

The noise of the detectors is quantified by the dark counting rate, i.e. the counting rate of the detectors with no beam or irradiation, when the hits are only due to cosmic rays and intrinsic noise.

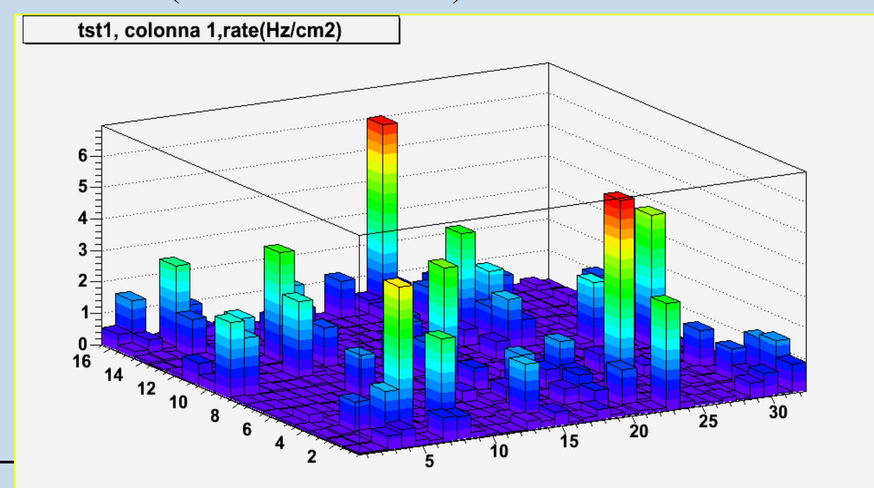
The counting rate is measured locally with the ***autotrigger method*** : the trigger is given by the detector itself, selecting events with at least one hit on both strip planes. The logical scheme of the electronic chain for the autotrigger measurements is shown below.



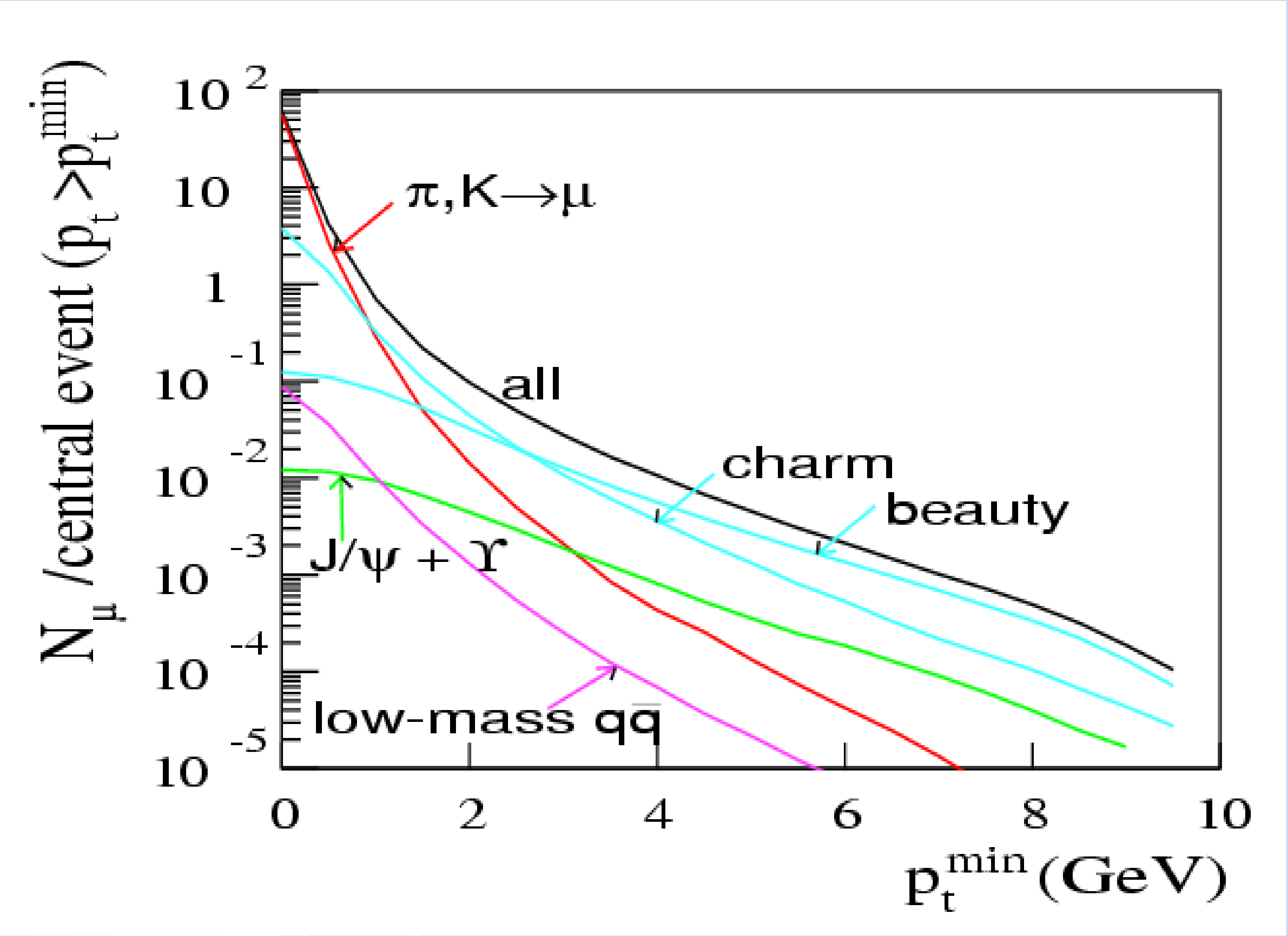
Logical scheme of the electronic chain for the autotrigger measurement.

The detector surface can be divided in **cells** defined by the crossing of strips in the two direction. Such a method provides the noise map of the detectors, which makes the detection of noisy spots possible.

Here there is the noise map obtained with gap 1210 (left) at the voltage of 8300 V (streamer mixture)



Taglio in impulso trasverso



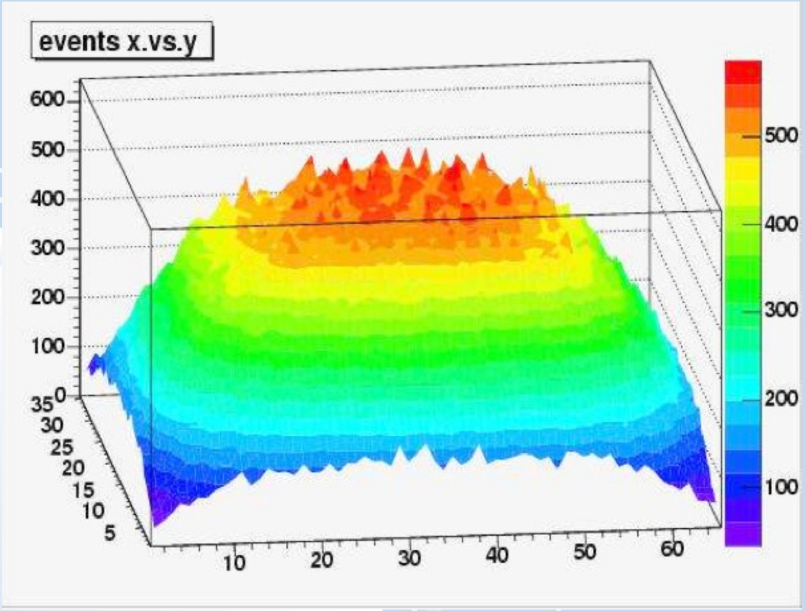
Efficiency maps (I)

To evaluate better the uniformity of the detectors , and to detect any imperfection, though small, **efficiency maps** are measure at two voltage value.

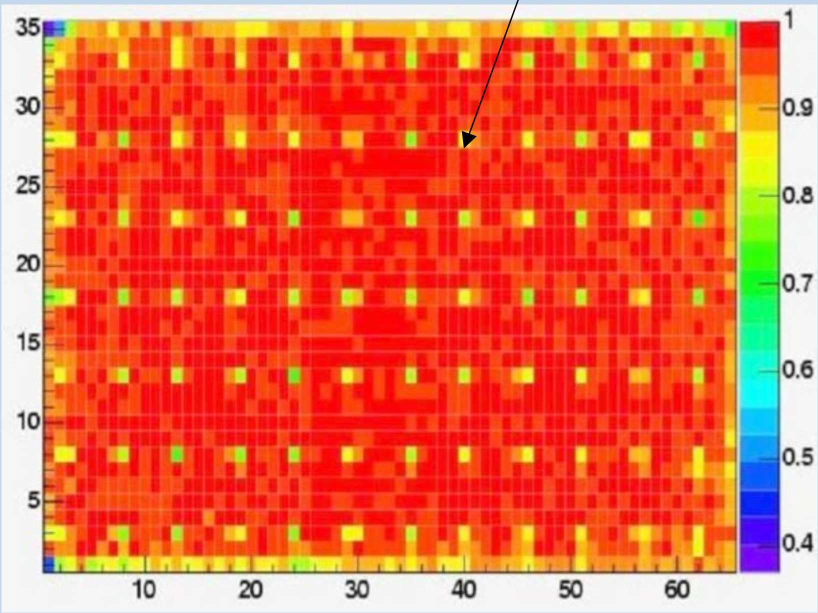
In *Streamer mode* we chose **8200 V** and **8100 V**.

In *Avalanche mode* we chose only **10800 V**.

The cells for efficiency maps are about 2x2 cm^2 large. With a 1000000 events run (~ 10 h acquisition time), the statistics is of about 500 events in central cells, 100 in peripherical cells , 50 in the very side cells. The resolution is of the order of the centimeter, so that, in the efficiency map, even the spacers that keep the distance between the electrodes costant (whose diameter is 1 cm) can be resolved.



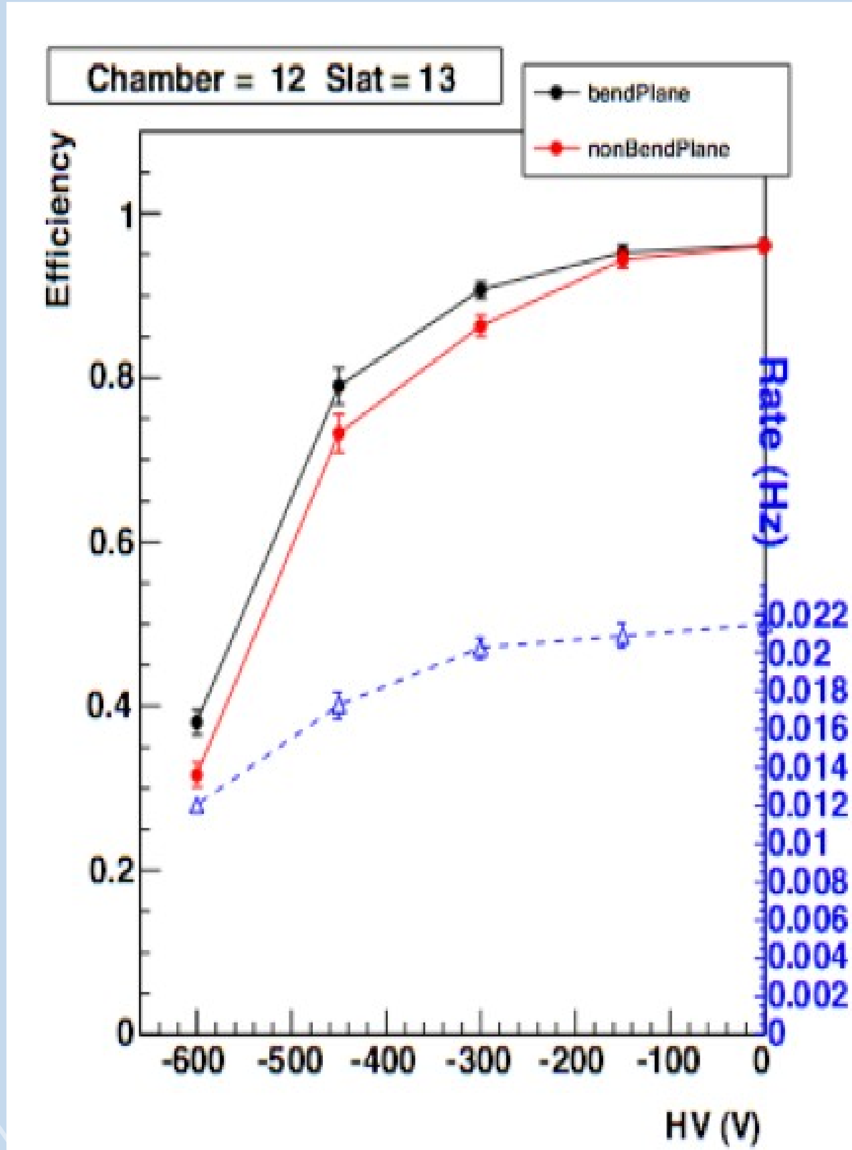
Distribution of triggered events for efficiency measurement over the surface of a half chamber. Units are given in cells. The area of the cells is 2x2 cm^2



Efficiency map of a half chamber operated at 8200 V . Units are given in cells. The area of the cells is 2x2 cm^2

Temperature - Pressure HV correction

$$V_{eff} = V \frac{T}{T_0} \frac{p_0}{p}$$



Chamber = 12 Slat = 13
bendPlane
nonBendPlane
Efficiency
1
0.8
0.6
0.4
0.2
0
Rate (Hz)
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-600
-500
-400
-300
-200
-100
0
HV (V)

$$N^{12}_{3/3} =$$