The trigger system of the muon spectrometer of the ALICE experiment at the LHC

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Outline

1. Introduction
2. Muon Trigger System
3. Commissioning results
4. p-p collisions
5. Conclusions

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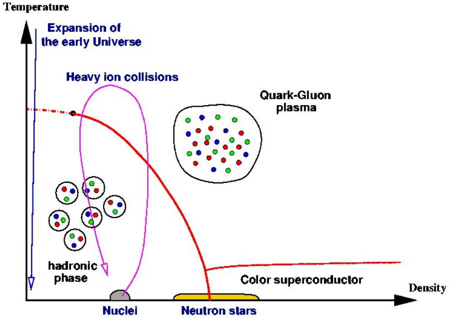
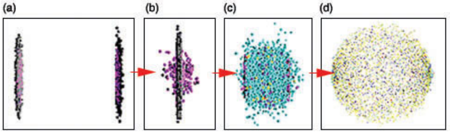
ALICE (A Large Ion Collider Experiment): the only experiment @LHC designed to study heavy-ion collisions.

Main goal: study of a new state of matter.
QCD predicts that, at the critical temperature of 150–180 MeV, hadronic matter undergoes phase transition to a deconfined state of quarks and gluons: the Quark Gluon Plasma (QGP).

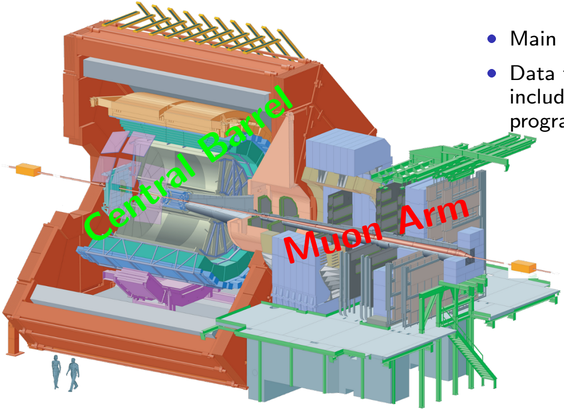


Main features:

- Track and identify particles from $\sim 100 MeV/c$ to $\sim 100 GeV/c$.
- Reconstruct short-lived particles.
- Cope with a large multiplicity environment (up to $\left.\frac{dN}{dy}\right|_{y=0} = 8000$).
- Track low p_{t} muons in the forward region $-4 \leq y \leq -2.5$



The ALICE experiment



- Main goal: heavy-ion collisions
- Data taking in *p*-*p* collisions also included in the ALICE physics programme

ALICE in numbers

- $\sim$ 1000 members
- 111 institutes
- 31 countries
- 18 sub-detectors
- 10000 tons
- $16 \times 16 \times 26m$

Central Barrel

- $|\eta| \leq 0.9$
- Hadrons, electrons and photons
- $p_t \to 0$

Muon Spectrometer

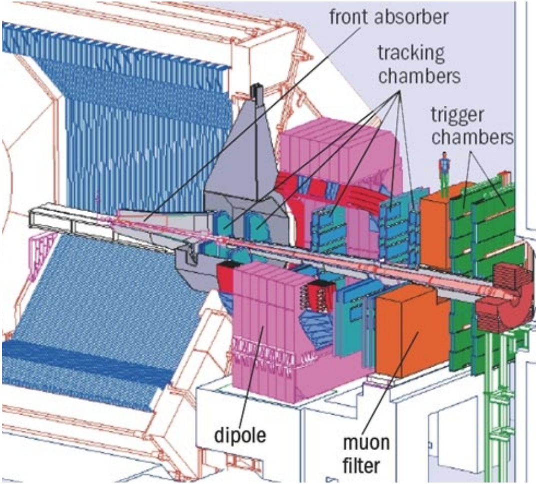
- $-4 \leq \eta \leq -2.5$
- muons
- $p_{muons} > 4GeV/c$

Forward Detectors

- large η
- Interaction trigger
- event centrality

Muon Spectrometer

- Quarkonia (J/ψ, ψ' and $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$) down to $p_t = 0$
- Open heavy flavours via single muons and dimuons
- Electroweak bosons (Z_0 and $W^{\pm}$)



Expected mass resolutions

	Single muon p_t cut
$\sim 70 MeV/c^2 \rightarrow J/\psi$	$1 GeV/c$
$\sim 100 MeV/c^2 \rightarrow \Upsilon$	$2 GeV/c$

Tracking System

- 5 stations of 2 planes of Cathode Pad Chambers (CPC) each
- 1.1M read-out channels
- spatial resolution $< 100 \mu m$ (bending plane)

Trigger System

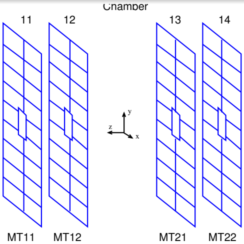
- See next slides

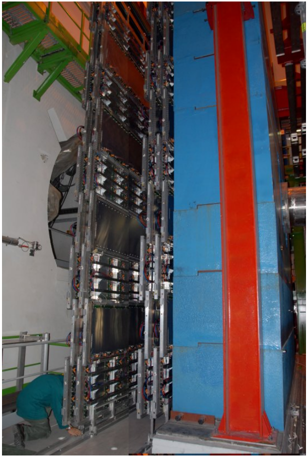
Outline

Trigger System

Setup

- 4 planes of detector arranged in 2 stations of 2 planes each
- the two stations are located 16 and 17 m away from the interaction point
- 18 RPCs (Resistive Plate Chambers) per plane, read on both sides with orthogonal strips
- each plane $\sim 5.5 \times 6.5 m^2$, with $\sim 1.2 \times 1.2 m^2$ central hole (beam pipe and shielding)
- 21k strips (1, 2, 4 cm pitch) and readout channels
- projective geometry: different strip pitch and length on each plane





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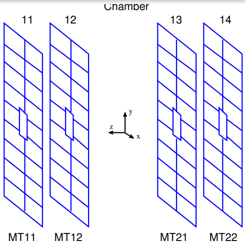
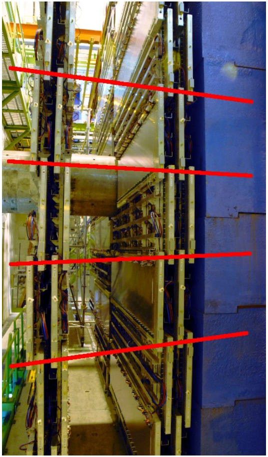
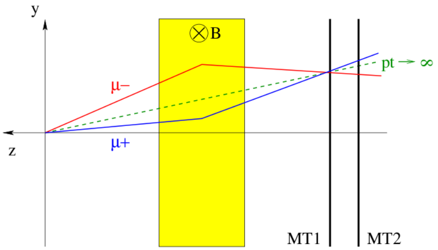




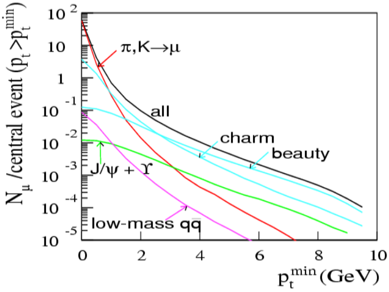
Trigger System

A muon p_t cut is needed to reduce the background arising from light meson decays



Principle of the trigger

p_t cut using correlation between position and angle: deflection in dipole + vertex constraint



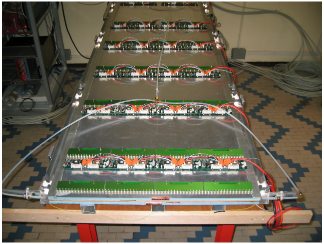
Triggers

- Two different p_t cuts can be programmed and applied (ex. $1GeV/c$ and $2GeV/c$)
- Latency time $\sim 800ns$ $\rightarrow$ used as one of the L0 ALICE triggers
- 5 trigger signals sent to the CTP (Central Trigger Processor): Single μ, UnLike and Like sign dimuon high and low pt
- Max trigger rate allowed by ALICE DAQ: $\sim 1kHz$

Trigger System - RPCs

Requirements

- Muon detection efficiency $\geq 95\%$
- Rate capability $\sim 100 Hz/cm^2$
- Fast response $\sim 2ns$
- Low sensitivity to γ and neutrons
- Large area covered



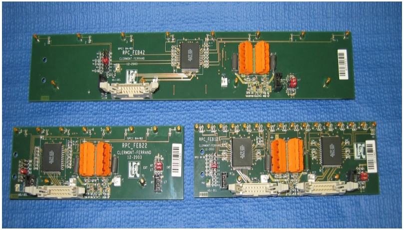
- 72 RPCs
- Single gap, low resistivity Bakelite $\sim 10^9 \div 10^{10} \Omega cm$
- Area $\sim 70 \times 280 cm^2$ (3 different shapes)
- Gas gap: $2mm$

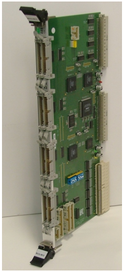
A-A collisions: *Streamer* mixture
Good spatial resolution, low occupancy
$50.5\%\ Ar,\ 41.3\%\ C_2H_2F_4,\ 7.2\%\ i-C_4H_{10},\ 1\%\ SF_6;\ RH\ 40\%$

p-p collisions: *Highly saturated avalanche* mixture
Detector lifetime
$89.7\%\ C_2H_2F_4,\ 10\%\ i-C_4H_{10},\ 0.3\%\ SF_6;\ RH\ 40\%$

Front End Electronics

- 20992 front end channels
- A DUaL Threshold electronics (ADULT)
- $\sim$ 2800 FEE boards produced (including spares) of 6 different types





- 242 Local Trigger Boards
- 16 Regional Trigger Boards
- 1 Global Trigger Board
- 2 boards for DAQ interface (DARC)
- 1 board for Local Board trigger configuration (JTAG)
- 1 Front-End Test (FET) pulse generator

Trigger decision

- Trigger algorithm in bending plane (X) and orthogonal plane (Y) implemented in FPGA
- Requires 3 out of 4 planes fired both in bending and non-bending

Outline

Timeline

- Summer 2007: Detector installed in ALICE
- 2008: three periods of cosmic rays data taking running in *streamer mode*. In September ready for LHC startup
- 2009: two periods of cosmic rays data taking running both in *streamer* (2 weeks) and in *avalanche* (5 weeks) mode.
- October 2009: Detector ready for the p-p collisions running in avalanche mode
- 2010: p-p data taking, monitoring of the system performances and fine tuning of working parameters

Streamer Mode

- Lab. characterization for each RPC: test bench with cosmic for efficiency, noise and working voltage studies.
- After installation in situ, very different environment conditions: dark current and noise monitored regularly. Efficiency measurements with quasi-horizontal muons.
- Efficiency scan to refine the working voltage for each RPC

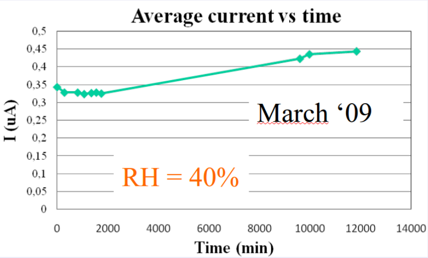
Avalanche Mode

- Test bench on spare RPCs. HV voltage optimization, efficiency measurement with cosmics and electronic thresholds optimization.
- In situ: efficiency measurements with quasi-horizontal muons, dark current and noise monitoring, humidity optimization.
- Efficiency scan to optimize the working voltage for each RPC

Current stability

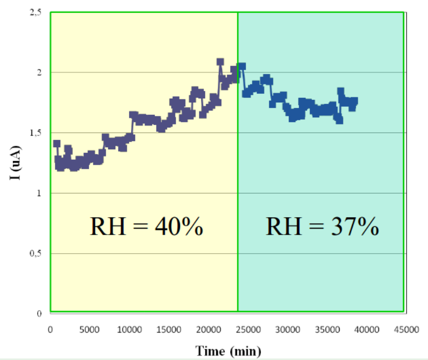
Streamer Mode

- Mean dark current measured during cosmic rays data taking in March 09
- Relative Humidity: $\sim 40\%$
- Small collective increasing trend



Avalanche Mode

- Mean dark current measured during cosmic rays data taking in August 09
- Small collective increasing trend with $RH = 40\%$, inverted with $RH = 37\%$

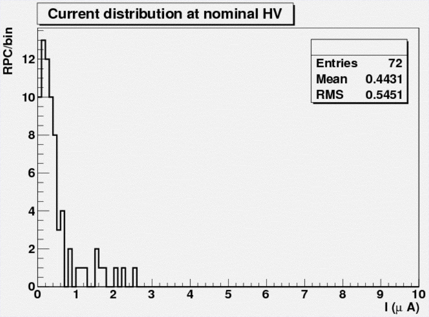


Commissioning results

Current distribution

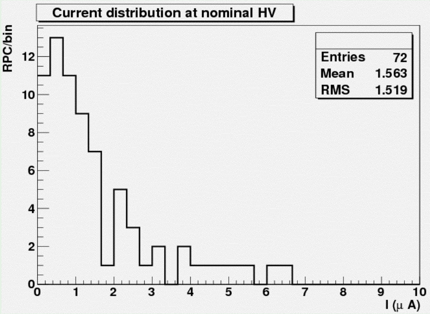
Streamer Mode

- Working voltage: $\sim 8kV$
- $I_{mean} = 0.44\mu A$



Avalanche Mode

- Working voltage: $\sim 10.3kV$
- $I_{mean} = 1.56\mu A$



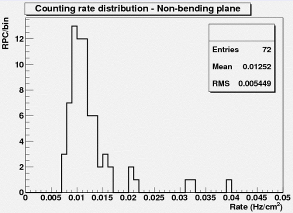
- Higher in avalanche than in streamer
- Few RPCs have $I >> I_{mean}$: Ohmic contributions.

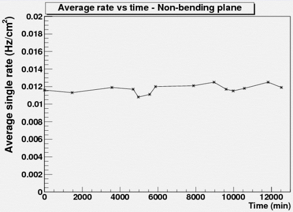
Commissioning results

Dark rate

Streamer Mode

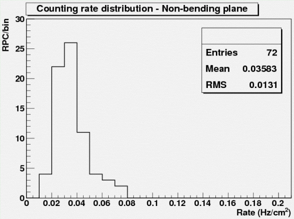
mean rate: $0.013 Hz/cm^2$ no trend in time seen

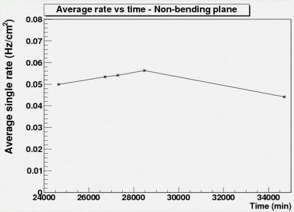




Avalanche Mode

mean rate: $0.036 Hz/cm^2$ no trend in time seen

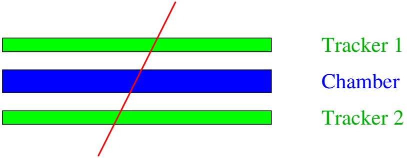




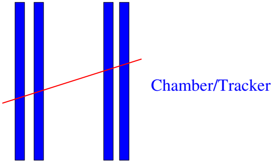
Trigger chamber efficiency

$$\varepsilon = \frac{\#\text{ of times chamber gives signal}}{\#\text{ of times a muon crosses the chamber}}$$

In lab:

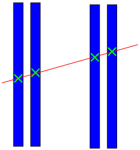


In ALICE:

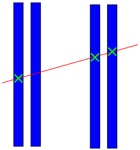


The trigger algorithm searches for hits in at least 3 out of 4 chambers.
Define:

$N_{4/4} =$



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



The efficiency for the chamber a (for example) is given by:

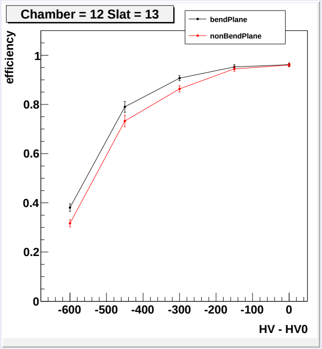
$$\varepsilon_a = \frac{N_{4/4}}{N^a_{3/3} + N_{4/4}}$$

Commissioning results

Efficiency scan

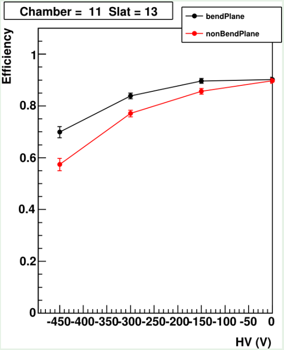
Streamer Mode

- Cross check of the efficiency curves
- Fine tuning of the working voltage



Avalanche Mode

- Efficiency scan performed
- WV optimized for 40% of RPCs (limited by statistics)



Caveat

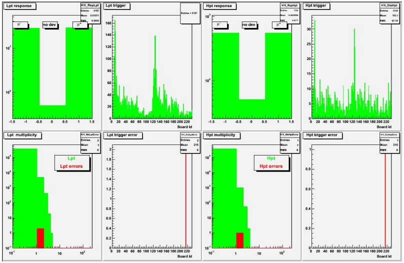
- Muon spectrometer not designed to detect cosmic rays: systematic effects in efficiency measurements

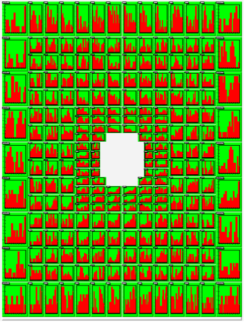
Monitoring tools

Front End Test generator

Inject synchronous RPC like pulse to check:

- Front-End electronics
- trigger algorithm in combination with various mask pattern
- timing dispersion by varying FET clock phase
- test readout mask





Online-Offline monitoring tools

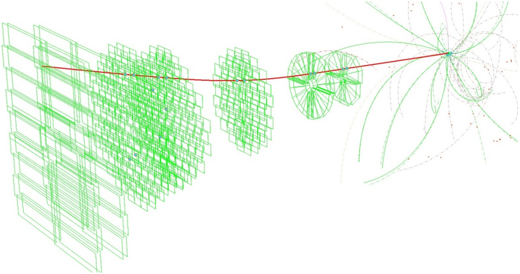
based on the official ALICE software (AliRoot)

- Online: MOOD and AMORE
- Offline: Quality Assurance
- to check strip multiplicity, deviations
- Local/Global trigger algorithm
- dead and noisy channels

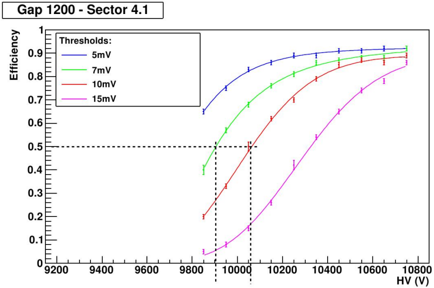
Outline

Data taking

- November '09: pp collisions at $\sqrt{s} = 900\,GeV$
- Starting from March '10: pp collisions at $\sqrt{s} = 7\,TeV$
- Muon trigger rate: following the beam intensity, it reached 40Hz up to now

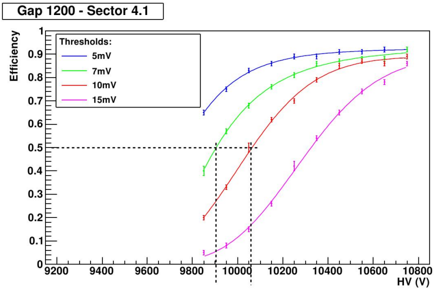


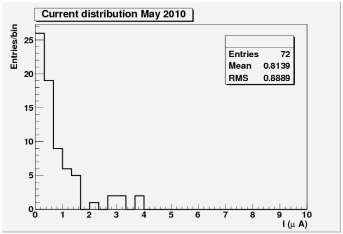
- Studied in lab the possibility to lower the threshold: the goal of the HV lowering is to reduce ageing effects

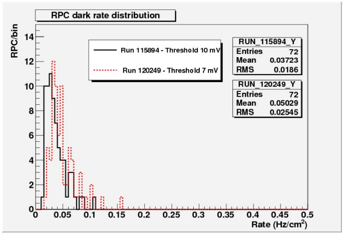


p-p collisions

- $I_{mean} = 0.8\mu A$
- Studied in lab the possibility to lower the threshold: the goal of the HV lowering is to reduce ageing effects
- Ongoing studies in situ: thr lowered from 10mV to 7mV. Negligible change in the dark rate, but better efficiencies (see next)
- $\bar{R}(thr = 10mV) = 0.04Hz/cm^2$ and $\bar{R}(thr = 7mV) = 0.05Hz/cm^2$



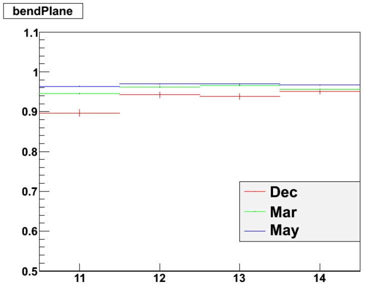




Efficiencies

- Efficiencies monitored periodically.
- Useful tool to detect issues
- Starting form November: fine tuning of RPC parameters

		thr.
Dec	First p-p measurements	10mV
Mar	HV fine tuning and interventions on the electronics	10mV
May	Few electronic interventions	7mV



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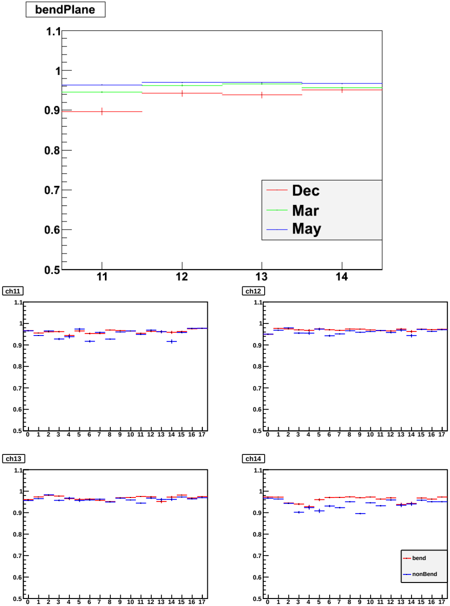
Present Efficiencies

- Data taking in May
- Threshold 7mV
- All RPCs with an efficiency above 90% on both cathodes.
- Mean value above 95%.



Outline

Summary and outlooks

- Muon trigger system fully commissioned both in streamer and in avalanche mode.
- All the RPCs have an efficiency above 90%
- RPC current and dark rate under control.
- Developed fundamental Online-Offline tools to monitor the electronics behaviour.
- Studies to reduce ageing effects in avalanche mode ongoing.