The Dimuon Trigger of the ALICE - LHC Experiment

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The dimuon trigger of the ALICE–LHC experiment

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ABSTRACT

We describe the trigger system of the ALICE dimuon spectrometer, based on RPC detectors. The background rate is at least one order of magnitude less in ALICE than in LHC p–p experiments due to the lower luminosity in ion running. Hence we study the possibility to operate the RPCs either in streamer or proportional mode. We report a study done with cosmic rays concerning gas mixtures for streamer mode. The aim is to minimize the streamer charge for a better flux capability of the RPC and a smaller cluster size, as needed for ALICE. We also give the results of a beam test at SPS where the RPC was placed in the vicinity of a hadron absorber, simulating the operation conditions in ALICE.

1. Physics Motivations

The suppression of the production rate of the J/Ψ and Υ resonances by Debye screening effect [1] will be a signature of the Quark Gluon Plasma (QGP) formation in heavy ion collisions at LHC. In order to study this issue in the dimuon decay channel, the ALICE collaboration, devoted to heavy ion at LHC, decided recently to upgrade the

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central part of the detector by adding a muon spectrometer at forward angles [2]. This spectrometer measures the complete spectrum of heavy quark vector mesons i.e. J/Ψ, Ψ', Υ, Υ', Υ'' via their muonic decay in p–p and ion–ion collisions. An independent normalization is obtained by measuring open charm and beauty production which are not affected by final state interactions and are not sensitive to the nature of the medium (i.e. confined or deconfined). The observables which determine the general conditions of the collision such as the centrality are provided by the central detectors [3] of ALICE.

2. Spectrometer Overview [2]

The main elements of the dimuon spectrometer are shown in Fig 1. The angular acceptance goes from 2° to 9° ($2.5< \eta <4.0$). It consists of a front absorber of low Z material starting 90 cm from the vertex, a large dipole magnet with a 3 T.m. field integral and 10 planes TC1–TC10 of high granularity tracking chambers. At the end of the spectrometer, two stations MC1–MC2 of RPCs protected by a 1.2 m iron wall (muon absorber in Fig 1) are used for muon identification and triggering. The spectrometer is shielded throughout its length by a dense absorber (small angle absorber in Fig 1) which surrounds the beam pipe.

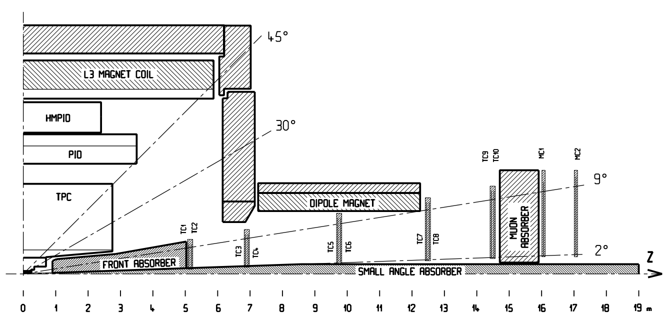

Fig. 1. Spectrometer overview

3. Description of the Trigger System [2]

The trigger is based on a cut in the muon transverse momentum (so-called LVL1 trigger) using the dipole deflection, taking advantage of the high p_t of the muons from resonances. A subsequent cut (LVL2) on the dimuon mass can be done.

The dimuon signal from resonances must be sorted out from the large multiplicity of background muons from pion, kaon and charm decay and soft background (mainly electrons leaking out from the beam shield and the iron wall). The heaviest system at LHC is Pb–Pb at $\sqrt{s}$ =5.5 TeV/nucleon where 4000–8000 charged particles (mainly pions and kaons) per unit of rapidity are produced in a central collison. In such events, a mean number of 12 background muons and 40 prompt soft background hits (per gas plane) are expected on the trigger. Hence, the set-up requires a high level of segmentation.

3.1. Trigger Set-up

Two trigger stations MC1 and MC2 are located at 16 and 17 m from the interaction point. They cover an area of about 6×6 m^2 with a 0.6×0.6 m^2 opening in the centre to accomodate the beam pipe and shielding (Fig 2).

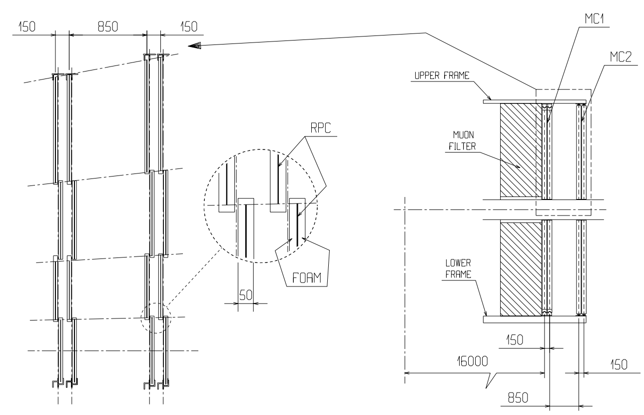

Fig. 2. Trigger set-up

Each station consists of two planes of single-gap RPCs [4] and each plane is read out on both sides of the gas gap via orthogonal strips (x–y readout). A total of about 30k strips are needed to account for the high multiplicity in Pb–Pb collisions. We require a 3/4 majority coincidence both in x and y to reject soft background hits. In the bending plane of the dipole (x, vertical), the strip width increases from 1 to 3 cm almost linearly with the radial distance from the beam axis and so does at first order the magnetic deviation. With this set-up, we obtain a deviation of about ± 4 strips for a p_t=1 GeV/c muon, whatever its location on the trigger. In the non-bending plane y, the strip width is 2 and 3 cm (inner and outer part of the trigger respectively) and we ask the track to point back to the interaction point.

3.2. Trigger Electronics

The information from the trigger chambers is treated by a dedicated trigger electronics (LVL1 electronics) to perform the cut on the single muon transverse momentum. To do that the LVL1 electronics defines "roads" between MC1 and MC2 which width corresponds to a given p_t cut (a narrow "road" corresponds to a high p_t cut and a small magnetic deviation and vice-versa). The "road" description is loaded in memories of the trigger chips. Two p_t cuts are foreseen : $p_t > 1$ GeV/c for the "J/Ψ trigger" and $p_t >$ 2-3 GeV/c for the "Υ trigger" at low rate.

The trigger chips give a decision on valid "roads" including the sign of the deviation for each p_t threshold. The information of all the LVL1 circuits ($\sim$ 1000 circuits) is finally collected and two valid "roads" of unlike sign essentially are required to build the final dimuon trigger. These operations must be done in less than 600 ns. The LVL1 rates should not exceed 1 kHz. We aim to read out all the spectrometer plus ITS information when a LVL1 decision occurs, though some scaling is possible in case the rates are too high.

A subsequent cut on the dimuon mass can be done by fast processing within 100 μs (called LVL2 trigger). The LVL2 rate allows to read out the full ALICE barrel detectors in coincidence with the muon spectrometer which opens some interesting physics perspectives especially in Pb–Pb collisions.

3.3. Trigger efficiency and rates

The trigger efficiency has been calculated with an almost complete simulation of the set-up, including the trigger detector segmentation and the treatment of the information by the LVL1 electronics.

The trigger efficiency as a function of p_t, for perfect ("Reference") and segmented trigger plane ("Chambers + Strips") is represented in Fig 3 for two selected p_t cuts (left part : $p_t \simeq 1$ GeV/c, right part : $p_t \simeq$ 2.3 GeV/c) at 50 % efficiency.

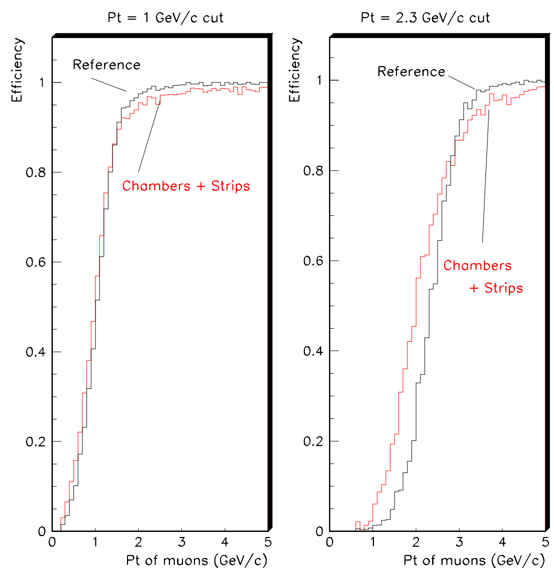

Fig. 3. LVL1 trigger efficiency versus muon p_t (two p_t cuts)

For the same p_t cuts, the trigger efficiencies are given in Table 1 for the resonances (J/Ψ, Υ), for background (pion and kaon decay into muon), charm and beauty decay [5]. The effects of the detector do not exceed a few percent.

Table 1. LVL1 trigger efficiency for signal and background

	Efficiency : $p_t = 1$ GeV/c	Efficiency : $p_t \simeq 2.3$ GeV/c
J/Ψ	75% (detection)	
Υ		92% (detection)
Backgr. (sngle μ)	85% (rejection)	97% (rejection)
Charm (sngle μ)	71% (rejection)	95% (rejection)
Beauty (sngle μ)		74% (rejection)

The LVL1 trigger rates are deduced from these efficiency calculations and shown in Table 2. The trigger rates are about 1 kHz in Pb–Pb and

Ca–Ca running. The trigger chamber segmentation is sensitive in case of Pb–Pb collisions and induces for instance about 30 % increase of the LVL1 rates for the $p_t = 1$ GeV/c cut. We give also in Table 2 the expected detection rate of resonances J/Ψ and Υ after all cuts.

Table 2. LVL1 trigger rates (minimum bias)

		Pb–Pb	Ca–Ca	p–p
L (cm^{-2} s^{-1})		10^{27}	10^{29}	10^{31}
Min. Bias (Hz)		8000	3 10^5	10^6
		Unlike sign μ–μ rate at LVL1		
$p_t > 1$ GeV/c	Tot (Hz)	900	1200	20
	J/Ψ (Hz)	1	2	1
$p_t > 2.3$ GeV/c	Tot (Hz)	200	50	1
	Υ (Hz)	0.01	0.03	0.01

4. Gas mixtures for streamer mode

From FLUKA simulations [6], we estimate that the maximum rate on the ALICE trigger chambers reaches 50 Hz/cm^2 in Ca–Ca running (10 Hz/cm^2 in Pb–Pb and p–p), close to the beam shielding. Most of this background is created by soft charged particles leaking out from the beam shielding and the iron wall. The simulation accuracy has been cross-checked during two running periods at SPS in 1996 and 1997 (see Ref. [7] and last section). We have found that the experimental background yields close to a thick hadron absorber are reproduced within 50 % by the simulation. Hence, our requirement concerning the flux capability of the trigger detector is fixed to 100 Hz/cm^2 at present. This value is certainly the last limit of the operation in streamer mode with low resistivity RPCs (keeping also in mind that we will have at LHC a continuous irradiation on the whole surface of the chambers). Nonetheless, in the first part of our R&D program, we have started to investigate gas mixtures for streamer mode which lower the pulse charge at maximum in order to optimize the rate capability of the RPCs.

4.1. Cosmic ray test set-up

We use a 50×50 cm^2 RPC with strips 3 cm wide terminated on a 50 Ω resistor at one end and connected to the front-end electronics (FEE) at the other end. The trigger consists of a coincidence of 3 scintillators which matches the geometrical acceptance of one strip of the RPC (so-called "central strip"). The efficiency is defined as the ratio N_2/N_1 with :

- N_1 : coincidence counting rate of the scintillators
- N_2 : coincidence of scintillators and chamber (taking actually the logical OR of 5 strips centered around the "central strip")

We also record the "neighbour efficiency", removing the "central strip" when counting N_2 : small values of the neighbour "efficiency" are obviously correlated with a small cluster size (number of fired adjacent strips) which is an important parameter for the RPC operation at LHC.

4.2. Selected gas mixture

We have tested gas mixtures of Ar, Isobutane, Forane ($C_2H_2F_4$), SF6 and CO2 in various combination percentage.

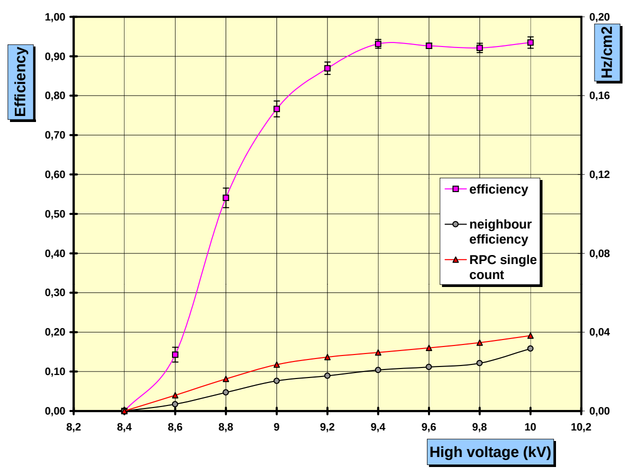

Fig. 4. RPC efficiency for the gas mixture Ar 49% Isob 7% Forane 40% SF_6 4%

An example of efficiency curve is shown in Fig 4. On the same plot the "neighbour efficiency" is represented as well as the RPC single counting rate (right scale). The discriminator thresholds in the FEE were set at 35 mV.

Some results are given in Table 3. The value of the running high voltage (HV) in Table 3 is chosen about 400 V above the "knee" of the efficiency curve and corresponds to a RPC efficiency close to 100% (apart from geometrical inefficiency).

The mixture Ar 49% , Isobutane 7% , Forane 40% , SF_6 4% gives the best results i.e. good efficiency, low "neighbour efficiency", small charge, small rise time and very stable pulses.

Table 3. Parameters of various gas mixtures

Gas mixture	H.V.	neighbour efficiency	charge (pC)	amplitude (mV)	time resol (ns)
Ar 49% Isob 7% SF6 4% For 40%	9500	11 %	48 ±25	113 ±44	≤ 2
Ar/Isob 80/20 SF6 4%	7300	13 %	70 ±40	144 ±51	≤ 2
Ar/Isob 70/20 For 10%	6700	46 %	330 ±160	393 ±173	

Two other gas mixtures usual for streamer mode are listed for comparison in Table 3. The mixture without Forane (line 2 of Table 3) gives quite good results too but the pulses exhibit a lot of secondary peaks. The characteristics of the mixture without SF6 (line 3 of Table 3) are quite different, showing the necessity of the addition of a small percentage of a very electro-negative gas like SF6 to reduce the pulse charge.

We have also found that addition of CO2 leads to rather unstable gas mixtures.

5. RPC operating in the vicinity of a hadron absorber

In ALICE, energetic hadrons (~100 MeV) emitted during the ion collision intercept the beam shielding and develop hadronic showers. The charged particles leaking out from this thick absorber are responsible for most of the background on the trigger.

In Aug-Sept 97 we have performed an experiment at CERN/SPS where a hadron beam of 120 GeV/c momentum was dumped in a thick lead absorber (100 cm long in the beam direction and 60×60 cm^2 of section) which simulates the ALICE beam shielding. A RPC (50×50

cm^2) was placed on the side of the lead absorber, orthogonally to the beam, at 60 cm from the beam entry face. The lateral thickness of lead between the beam axis and the the RPC was varied between 20–40 cm.

The goal of the experiment was twofold :

- Cross-check the simulation absolute yields of hits with the actual detector ones
- Operate the RPC in such “unusual” conditions : the simulations indicate for instance that the incident angle of the particles on the detector is peaked at 50^0

The RPC was operated in streamer mode with the gas mixture described in line 1 of Table 3.

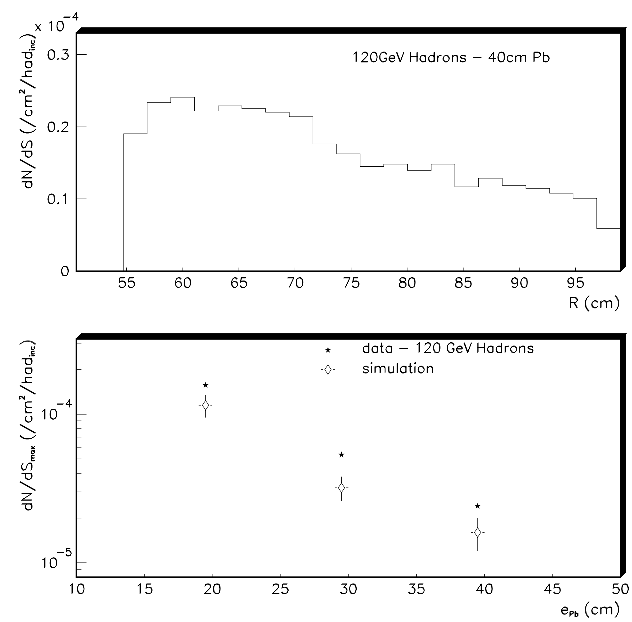

Fig. 5. Upper part : background hit radial distribution (see text)
Lower part : comparison of maximum yields to simulation results

The general behaviour of the RPC during the test was quite satisfying. We show in the upper part of Fig 5 the background radial distribution measured with the RPC for a lateral Pb thickness of 40 cm. The experimental distribution starts at about 55 cm because the first strip of the RPC is 15 cm away from the absorber due to the mechanical support. In the lower part of Fig 5 we compare the experimental and simulated maximum yields, close to the absorber, for three values of the lateral Pb thickness. The simulation slighly underestimates the absolute yields but the radial decrease (not shown on the figure) is well reproduced. The simulation was actually performed with GEANT+FLUKA, including the MICAP interface for the treatment of low energy neutrons. FLUKA simulations are in progress.

Finally we show the experimental cluster size distribution in Fig 6, for 2 cm wide strips. We get a mean value of 1.4 strips fired which is quite satisfactory.

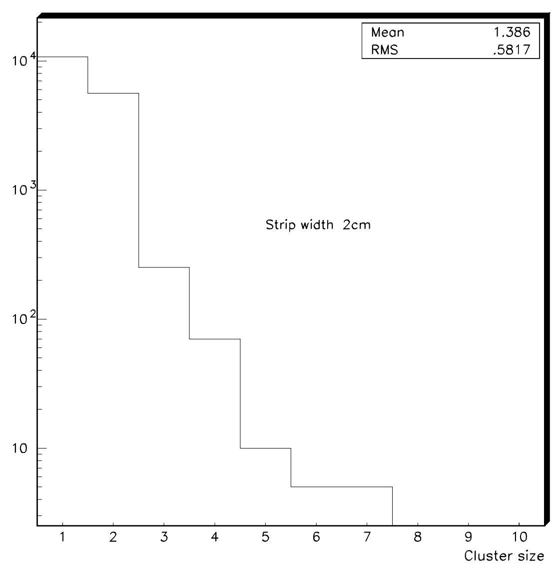

Fig. 6. Experimental cluster size distribution

During this test we have also exposed the RPC directly to the beam. In these conditions, the cluster size was about 1.2 strips. The rate capability that we have achieved is not relevant since the resistivity of the RPC was not optimized.

Similar tests are planned in 98 in streamer and proportional mode with low resistivity RPCs.

6. Acknowledgements

I would like to thank Prof R. Santonico and his group for their help concerning the RPC detector.

7. References

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