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For a V0 detector dedicated to the pp→2μ+X physics in ALICE

B. Cheynis, L. Ducroux, E. Gangler, J.Y. Grossiord, R. Guernane, A. Guichard

IPN-Lyon, IN2P3-CNRS et Université Claude Bernard, Lyon-I, France

Abstract

In this report, we propose the construction of a V0 detector made of two large V0R and V0L arrays set on each side of the ALICE vertex. The V0R array will be hermetic and will cover the largest possible part of the dimuon spectrometer acceptance. It will measure the multiplicity (MR = 0, 1 or ≥2) and the time (TR) of the charged particles. It will thus be close to 100% efficient for the dimuon physics and will allow, in the case of pp→2μ+X reactions, an important rejection of the background events from beam-gas interactions. This rejection will be achieved on-line (when MR = 0) and off-line (when MR = 1). Furthermore, in conjunction with the V0L array signal (multiplicity ML = 0 or ≥1 and time TL), additional background collisions will be flagged with the help of timing measurements (TR - TL when MR≥2 and ML≥1), so that almost 100% of the background events will be rejected. As a consequence, physics will be covered up to the minimum p_t^{cut} value allowed by the spectrometer.

1 Introduction

The ALICE experiment is dedicated to the study of heavy ion interactions at LHC energies. It will also run with proton beams at reduced luminosity (10^{31} $cm^{-2}s^{-1}$) in parallel with the other experiments for which the maximum intensity of 560 mA per proton beam (1.1 10^{11} protons per bunch for a luminosity of 10^{34} $cm^{-2}s^{-1}$) is required. The apparatus must be optimized for these goals and particular efforts are made for overcoming the large multiplicity of the produced particles encountered in Pb-Pb collisions. Superimposed to the true events resulting from the collisions, background products originating from beam-gas interactions and subsequent interactions in surrounding materials can be produced. They can give fake triggers or extra tracks added to true events. In the first case, the level 0 trigger given by the T0 detector [1] will determine the event vertex to within a few cm, therefore will sign the background event. In the second case, the tracking of the particles in the TPC and/or the ITS will allow to find the interaction vertex and, consequently, will lead to exclude any tracks not coming from this vertex.

This background production will be very low for ion-ion runs, due to the low luminosity of the beams (10^{27} $cm^{-2}s^{-1}$ with Pb beams). For the pp runs, an evaluation of this effect has been made [1] in the case of the central detectors with rates of beam-gas interactions of 200 Hz/m in the warm straight (far) sections ($50<z<200$ m) and of 50 Hz/m in the short unshielded (close) region ($-20<z<20$ m). The conclusion is that it should remain low and be without influence on the physics.

Concerning the dimuon physics, similar conclusions seem to be valid for the ion-ion collisions. The possibility of measuring the collision vertex with the ITS detector prevents against significant beam-gas interaction contribution. The situation is expected to be very different in the case of $pp\rightarrow 2\mu+X$ reactions which are supposed to be recorded under "minimum bias" conditions. As a consequence, special care has to be taken so that the background contribution is recognized and suppressed. With this aim in view, we propose the construction of a V0 detector made of two large V0R and V0L arrays in such a way that the background rejection would be maximum.

2 Background in the pp→2μ reactions

For the pp reaction at a luminosity of 10^{31} $cm^{-2}s^{-1}$ (10^6 collisions per second), the opposite sign (OS) muon pair trigger rates are evaluated to be lower than 10 Hz for p_t^{cut} = 1 GeV/c [2] and lower than 50 Hz for minimum p_t^{cut} [3]. In this case, the p_t^{cut} value is given by the trigger electronics. If the like sign ($LS=\mu^+\mu^+ + \mu^-\mu^-$) muon pairs are included we must consider a twice larger rate. In the following, the simulated background rates will include triggers provided by at least two muons of any sign (AS).

A substantial number of beam-gas events will give tracks through the 33/38 m^2 planes of the MT1/MT2 chambers. If nothing is done, a lot of background triggers will obstruct the acquisition system and a part of them will not be recognized as produced by background interaction because no z-vertex measurement will be possible, neither with the help of the ITS detector when crossed by no secondary, nor by the muon trajectory reconstructions which provide too poor resolution.

According to the evaluation made in the framework of CMS [4] and adopted in the present situation of ALICE, the interactions in the far straight sections will lead to about 10^6 AS muons per second in both directions through the planes containing the trigger chambers. The pattern of the tracks at ±26 m from the ALICE vertex and during 0.5 sec [4] has been used in order to evaluate the number of coincidences. Due to the huge number of tracks to be treated, we have simplified the simulation by introducing a cut of 4 GeV/c on the muons entering the front absorber (only 0.4% of the muons are cut, which confirms a very broad distribution of the muons in the transverse directions [5]) before their flight through the dipole field, the tracking chambers and the muon filter. At least two AS muons through the trigger chambers in any direction and inside a fixed time gate are required. The number of triggers is given by the ALICE trigger decision algorithm [2]. About 10000 coincidences within a time window of 25 ns are calculated, which lead to 527 triggers (AS muons) when no cut on p_t is applied and 32 triggers (AS muons) above the p_t^{cut} of 1 GeV/c. This last number is in accordance with the result of Ref. [5].

Similarly, the beam-gas interaction in the close distance of ALICE (50 Hz/m) will produce secondaries, and a part of them triggers. Simulations of this background component and the corresponding induced triggers have been made. The minimum bias p-^{16}O reaction (7 TeV protons) is simulated with HIJING [6]. The charged particle multiplicity distribution is shown in Fig. 1. They are mainly pions. The average multiplicity is around 25 and ranges from 9 to about 60.

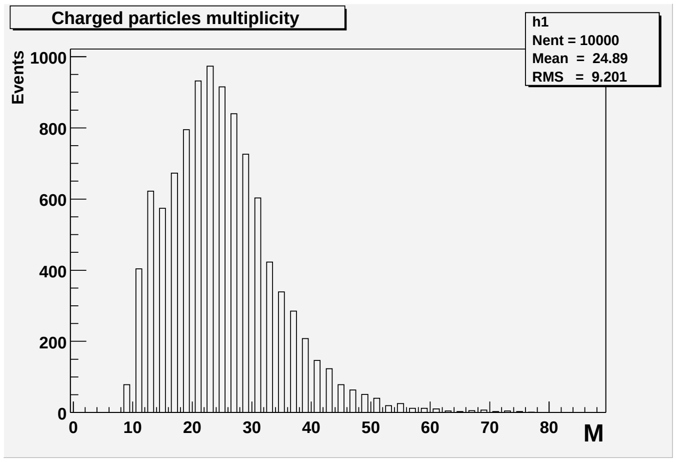

Figure 1: p-^{16}O collisions at 7 TeV protons.

The neutral and charged particles are transported with AliRoot through the ALICE set-up (Fig. 3) up to the ALICE trigger decision described in [2]. 15000 interactions uniformely distributed all along the 40 m space from -26.5 m, at the opposite to the dimuon arm, to 13.5 m, inside the spectrometer vacuum chamber have been used. They correspond to interactions during 7.5 s and lead to 76 triggers (AS muons). Their z-distribution is shown in Fig. 2. As expected, the beam-gas contribution comes mainly from long negative distances because the front absorber and the beam shield are not optimized for such distant vertices, and the pion decay probability in muon is the largest. If we apply a p_t^{cut} of 1 GeV/c, 22 triggers (AS muons) will survive.

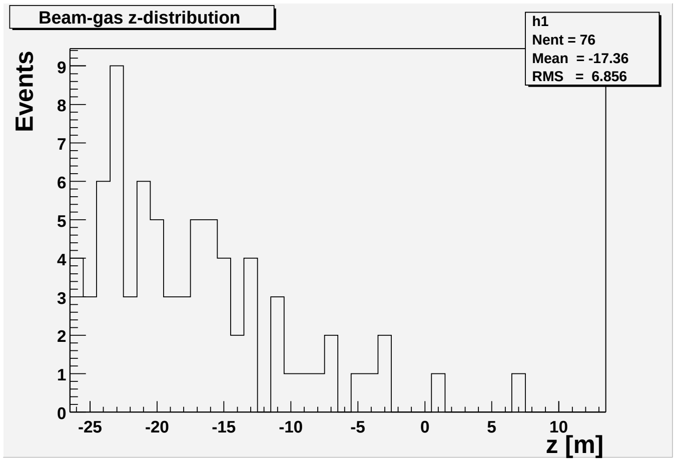

Figure 2: Triggers from 15000 beam-gas interactions as a function of their z-vertex.

3 Proposal

In the framework of the pp→2μ+X physics (and in the pA reactions when proton beam intensity is large so that the beam gas interactions are important), and in order to eliminate the background events from the data recording (on-line action) and from the surviving recording part of these events (off-line analysis), we propose a V0R counter (Fig. 3) which hermetically covers the largest possible part of the dimuon spectrometer acceptance (η = 2.5-4). This system will be made of several elementary cells. Each of them will allow to separate the signal given by one charged particle from the signal given by two or more charged particles on one hand, to reach a time resolution of the order of 150-200 ps on the other hand. The device will give the information MR (MR = 0 and MR $\neq$ 0 will be obtained on-line) and TR which will represent the number and the time of firing particles. A large device V0L (with multiplicity ML and time TL) should be set at the opposite direction relatively to the vertex. Several aspects of the utilization of the system can be foreseen, depending on the MR (ML) value(s) associated to the events. We give below the four different classes of events associated to dimuon triggers.

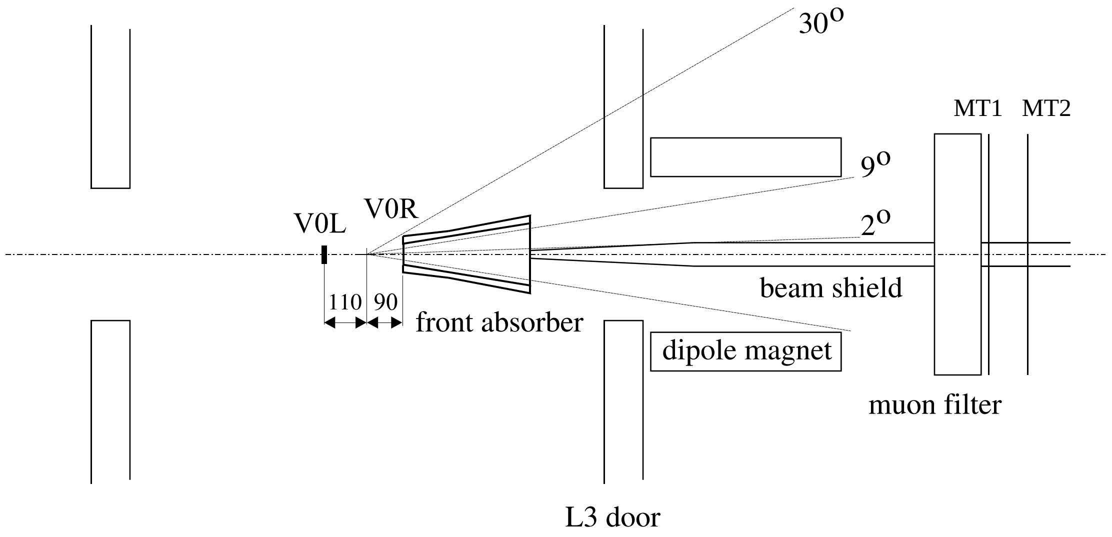

Figure 3: Layout of the V0R/V0L detector for the dimuon physics.

The four classes of events are:

(a) MR = 0 events: if the device provides the multiplicity information MR = 0, the event will be ignored. No physical event must belong to this class. Any dimuon trigger will be validated on-line by MR≠0 signal.

(b) MR = 1 events: if the data shows a multiplicity MR = 1, the event will be ignored. No physical event must belong to this class. Any dimuon trigger will be validated off-line by MR≥2 signal. MR≥2 will be given either by at least two separated cells, each recording at least one charged particle, or by one isolated cell recording two or more charged particles.

(c) MR≥2 and ML≠0 events: for this class of events which require information from the V0L array, the measurement of the time difference TR - TL will allow to flag dimuon produced along the vertex segment of the collision within the analysis time window of 25 ns. These time measurements are very selective for qualifying the event type. We will have to maximize their number.

(d) MR≥2 and ML = 0 events: for this class of events which do not give information in the V0L array, several additional constraints can be applied in order to reject false events. For example, we would compare the localisation of the observed impacts on the V0R plane with the crossing of the muons through this plane extrapolated from their trajectory reconstruction. In any case, the rejection criteria will not be as selective as the one of the former class. We will thus have to minimize their number.

4 Simulation results

The results of the simulation of the background rates (AS muons) and of charged particle multiplicity distributions from specific pp→2μ processes (OS muons) are given in the two next Sections. We try to show how important it is to adopt a fully hermetic array for V0R and a large dimension array for V0L.

4.1 Background counting rates

The several ALICE trigger rates from the physics [2] [3] and background events (present simulations) are gathered in Table 1 for two minimum p_t values. The counting rates corresponding to the four criteria listed above are given for the V0R/V0L geometries and locations described in Section 5.

2μ event type		Rates (Hz) for no cut on p_t		Rates (Hz) for p_t^{cut}=1 GeV/c	
		far	close	far	close
p-gas→2μ (AS)	any MR	**1054**	**10.0**	**64**	**3.0**
(a)	MR=0	**1052**	0.7	**64**	0.4
(b)	MR=1	2	0.7	0	0.4
(c)	MR≥2, ML≠0	0	**8.5**	0	**2.2**
(d)	MR≥2, ML=0	0	0.1	0	0.0
pp→ $\mu^+\mu^-$ (OS)	minimum bias	<50		<10	

Table 1: Trigger rates signal (luminosity of 10^{31} cm^{-2}s^{-1}) and background (3.5 10^{18} protons per beam and per second corresponding to a luminosity of 10^{34} cm^{-2}s^{-1}) for two minimum values of p_t. The signal rates are given by opposite sign (OS) muons. The background rates are given by any sign (AS) muons for far and close contributions and for each class of events ((a) to (d)) as listed in Section 3.

We can observe that the main background contribution originates from the far component. Its contribution is about one or two orders of magnitude larger than the physics signal according to the p_t^{cut} value. 90% of these dimuons have a p_t value smaller than 1 GeV/c. A hermetic V0R counter will allow to reject these events which all belong to (a) and (b), either on-line (MR = 0) or off-line (MR = 1). The close background contribution is up to two orders of magnitude smaller than the far background for similar p_t^{cut} condition. But, contrary to the far events, these close events are correlated mainly to MR≥2 and ML≠0 (c). The firing of both detectors will provide the time measurement TR - TL, and thus will give a clear signature of their origin if this time indicates a collision outside the vertex segment. In this case, the ML value may be only a few units. Its distribution obtained from the simulation is given in Fig. 4. That shows the importance to have a V0R array coupled to the most efficient V0L array in order to minimize the number of events with MR≥2 and ML=0 (d), situation which does not provide such an effective selection criteria. It has to be noticed that, according to the p_t^{cut} value, 15% and 25% of the close events belonging to (a) and (b) can be eliminated by the single V0R array. That makes even stronger the need of such an efficient device. Lastly, the possibility of validating on-line the dimuon triggers should allow the acquisition of all the events (at least two AS muons), even if the proton beam intensities are increased by a factor 10 or more. Therefore, the p_t^{cut} value will be the minimum cut given by the trigger electronics.

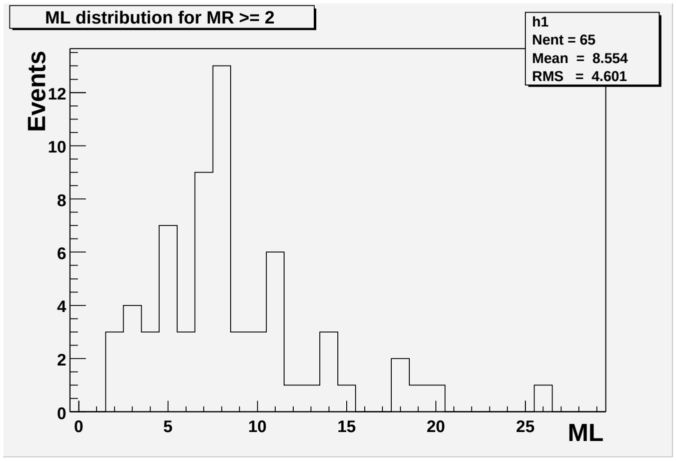

Figure 4: ML multiplicity distribution associated to MR≥2 background triggers produced in 15000 beam-gas interactions.

4.2 Sensitivity optimization of the device

In this Section we show results of simulations obtained with PYTHIA [7] and concerning some specific pp→2μ processes. The calculated charged particle multiplicity distributions are used to show how important would be a large transverse extension of the V0L array for an efficient measurement of the collision vertex.

Fig. 5 shows four multiplicity distributions of charged particles produced by the pp→ $\mu^+\mu^-$+X reaction and leading to the production of open charm (Fig. 5a) and Drell-Yan dimuons (Fig. 5b). Although the latter process has a very small cross-section as compared to the first one, it is shown as an example of dimuon events with low multiplicity. The two processes give the total multiplicity distributions MT. The number of impacts in the layer 6 of the ITS (MITS) is also shown and can go down to zero. If we suppose that one impact corresponds to one track and

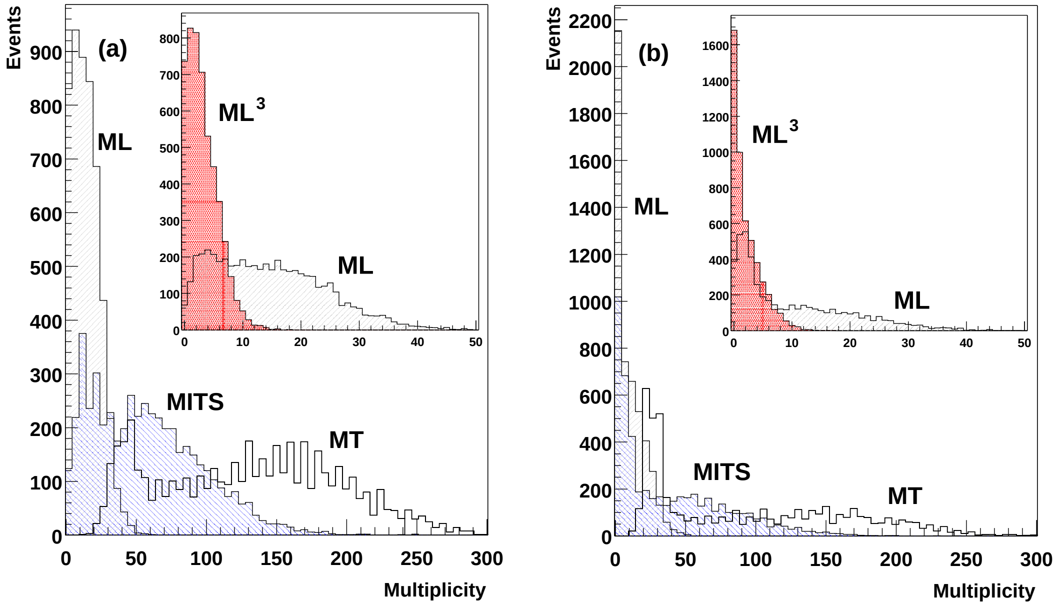

Figure 5: 5000 pp→2μ+X collisions at 7 TeV per beam leading to (a) open charm and (b) Drell-Yan dimuons. Total charged particle multiplicity distributions in the full space (MT), in the ITS acceptance (MITS), and in a V0L array as described in Section 5 (ML) and with reduced dimensions (ML^3).

that one track can provide the vertex, then, the ITS is 99.6% and 95.4% efficient for respectively the open charm and the Drell-Yan.

The multiplicity distributions of charged particles (ML) firing the V0L array as described in Section 5 have been calculated and compared to the similar distributions (ML^1, ML^2 and ML^3) given by a V0L array at the same location but with reduced dimensions. Fig. 5a and 5b give these distributions in the case where the V0L section is minimum (ML^3). A no zero multiplicity is required from an efficient system. It is clearly seen that the efficiency would be drastically lowered if the device does not present a large section.

Table 4.2 gives the results for each V0L dimension. The efficiency decreases from 99% to 85% for the open charm and from 92% to 66% for the Drell-Yan when the surface of the V0L array is reduced by a factor of about 10. It means that a non negligeable part of the events would be recorded without knowledge of their origin from the V0 counter. And the smaller the multiplicity, the larger is this effect. For any possible process with even lower multiplicity, the V0 counter would be partially blind if the transverse extension of the V0L array is not maximized. We thus propose the most efficient V0L array. It will allow to optimize the vertex determination of the physics events and the background events as well (see Section 4.1).

device	-	ITS	V0L			
covering (cm/cm)	(4π)	layer 6	4/16	5/11	5/9	5/7
multiplicity	MT	MITS	ML	ML^1	ML^2	ML^3
open charm (%)	100	99.6	**99**	**96**	**93**	**85**
Drell-Yan (%)	100	95.4	**92**	**83**	**77**	**66**

Table 2: pp→2μ+X collisions leading to open charm mesons and Drell-Yan dimuons. Percentage of events with a vertex given by the ITS and the V0L devices.

5 The V0R detector

5.1 Localization

The localization of the V0 device is not yet defined. It will depend upon several geometrical constraints which will have to be evaluated. The simulations have been carried out with a V0R array in front of the absorber, at 90 cm away from the vertex center (Fig. 3). Its surface was a ring of dimensions $R_{min} = 41$ mm, $R_{max} = 160$ mm. Taking into account the longitudinal extension of the vertex ($\sigma_z = 5.3$ cm), we calculate [8] that 88% and 94% of the two muons are seen by the V0R device for respectively the J/ψ and the Υ resonances. We must notice that this reduction of acceptance is calculated when no charged particle escorts the two muons. In fact, dimuons from J/ψ and Υ always come with at least one charged particle inside the V0R array. Then, no acceptance reduction is foreseen for those particular processes. Probably, very little effect is expected for any pp→2μ+X process. A small displacement of the system will not change this conclusion.

A similar detector could be adopted for the V0L array. Its location, at the opposite to the dimuon arm, is not so much constraint. The distance of 110 cm to the vertex has been used for the present simulations.

5.2 Elementary cell

The radiation level provided by the pp (Pb-Pb) reactions in a full V0R array made of scintillator can be estimated. For a detector thickness of 1 cm, the corresponding dose is about 270 MeV/kg. If we consider 10^6 interactions per second (8000) due to a luminosity of 10^{31} cm^{-2}s^{-1} (10^{27}) and a minimum bias cross-section of 100 mb (8000), and if we adopt an average multiplicity of 50 (2250) per event in the limit of the V0R coverage, we calculate a dose of about 0.22 rad (0.078). During ten months of pp collisions (only one of Pb-Pb collisions) with a machine which continuously delivers half of the luminosities mentioned above, we evaluate the dose per year to be about 2772/NC krad (101/NC) per elementary cell, NC being their number. This rough evaluation shows that there will be no problem using scintillator material, even if the luminosities at the beam intersection of ALICE are multiplied by a factor 10.

We propose to adopt standard blocks of polystyrene scintillator with shape to be defined. The thickness of the counters (possibly 1 cm) will be chosen so that a 100% detection efficiency is reached for the charge 1 particle and a clear separation between charges 1 and 2 is obtained. A reflector will be layed down on the lateral sides of the blocks (photocathode zone excluded) in order to get the best light collection for an optimized time response and to ensure the optical insulation with the adjacent elements. The fine mesh photomultiplier R5946 [9] of 39±1 mm in diameter will be coupled to the radiator.

The associated electronics channel will include a voltage divider, a fast amplifier, a constant fraction discriminator (resolution better than 100 ps), a mean timer, time and charge to digital convertors, all these electronics circuits with dead time smaller than 20 ns. Some of them will be developped and constructed in the laboratory.

5.3 Planning

The development of the elementary cell with its electronics circuits will be pursued during 2001 in order to have a final design of the arrays in 2002. We think that the construction of the device will be possible starting in 2003 and will take one year. The final setting-up and adjustement of the full system could be organized from 2004 for an operational instrument ready at the starting of the LHC.

6 Why a V0 counter in addition to the T0 counter

The V0 arrays (V0R and V0L) are dedicated to the pp$\rightarrow 2\mu$+X physics for which the level of background events is high. For a good rejection of this background, they have to be large (with a hermetic V0R). Each counter element must provide a time resolution of about 150-200 ps and a clean separation of one and two (or more) charged particles. On the contrary, the T0 arrays (T0R and T0L) are optimized for the Pb-Pb physics [10]. They do not have to be large to deliver a signal from Pb-Pb collisions and each element is supposed to provide a very good time resolution (50 ps) through the very large dynamics of the signals encountered in these collisions ($\approx$100). The required specifications for V0 and T0 counters are thus different. Consequently, each device is fully justified and should equip ALICE for its optimisation for the Pb-Pb physics and the pp physics as well.

7 Conclusion

In this note, we propose a V0 counter device made of two large arrays V0R and V0L and dedicated to the pp→2μ+X physics in ALICE. It will validate the dimuon trigger either on-line or off-line (hermetic V0R array) and will allow to measure the vertex of the collision (V0R and V0L arrays). The large background due to the large luminosity proton beam interacting with the residual gas will be eliminated with an efficiency close to 100%. Furthermore, such a device will allow to collect data up to the minimum p_t^{cut} value accepted by the spectrometer.

We will concentrate our efforts on the realization of the V0R array which is the most important for the dimuon trigger control.

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