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© World Scientific Publishing Company**THE PIXEL FAST-OR SIGNAL FOR THE ALICE TRIGGER
IN PROTON-PROTON COLLISIONS**D. ELIA^{a,*}, G. AGLIERI RINELLA^b, A. KLUGE^b, M. KRIVDA^{b,c}, M. NICASSIO^{a,d}^a *Istituto Nazionale di Fisica Nucleare Sez. di Bari, Bari, Italy*^b *CERN, European Organization for Nuclear Research, Geneva, Switzerland*^c *Institute of Experimental Physics, Kosice, Slovakia*^d *Dipartimento IA di Fisica del Politecnico e dell'Università, Bari, Italy**Domenico.Elia@ba.infn.it*

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The silicon pixel detector of the ALICE experiment at LHC comprises the two innermost layers in the inner tracking system of the apparatus. It contains 1200 readout chips, each of them corresponding to a 8192 pixel matrix. The single chip outputs a digital Fast-OR signal which is active whenever at least one of the pixels in the matrix records a hit.

The 1200 Fast-OR signals can be used to implement a triggering capability: few details on the pixel trigger system and some of the possible applications for the event selection in p-p collisions are presented.

1. Introduction

ALICE is a general-purpose heavy-ion experiment designed to study the physics of strongly interacting matter and the properties of the quark-gluon plasma in nucleus-nucleus collisions at LHC. The ALICE apparatus has several features that make it also an important contributor to proton-proton physics. A complete reaserch program on p-p collisions is planned: it aims both to set the baseline for the understanding of the heavy-ion data and to explore the new energy domain^{1,2}.

The two innermost layers of the ALICE inner tracking system, placed at 3.9 cm ($|\eta| < 1.95$) and 7.6 cm ($|\eta| < 1.5$) average distances from the beam line, are equipped with hybrid pixels and constitute the Silicon Pixel Detector (SPD)^{1,3}. The SPD is composed by 120 basic modules (half-staves), 40 in the inner layer and 80 in the outer layer. Two silicon sensor matrices (ladders) on each half-stave are bump-bonded to 10 readout chips for a total of 1200 chips for the entire SPD (400 in the inner layer and 800 in the outer layer). In each chip the prompt discriminator outputs are OR-ed to generate a Fast-OR pulse whenever one or more pixel cells record a hit: this feature can be used to implement a unique triggering capability

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for ALICE. A schematic illustration of the SPD in the ALICE apparatus and some details of one of the 120 half-staves are shown in Fig. 1.

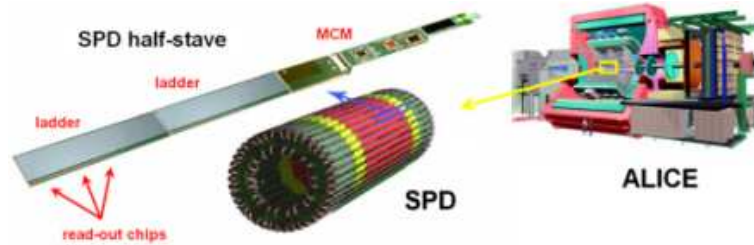


Fig. 1. The SPD in ALICE and some details of a single half-stave: sensor ladders, readout chips and Multi Chip Module (MCM).

In the following sections, after a short description of the Pixel Trigger system (PIT) architecture, some Fast-OR based algorithms for triggering in p-p collisions will be presented and discussed.

2. Pixel Trigger system architecture

The 10 Fast-OR bits of each half-stave are continuously transmitted on the output optical link by the MCM to the control room, with a clock frequency of 10 MHz (bunch crossing frequency in heavy-ion operation¹). The PIT has to extract and process all the 1200 Fast-OR signals in order to be able to deliver an input signal for the Level 0 trigger decision in the ALICE Central Trigger Processor (CTP). The system targets a maximum latency of 800 ns from the interaction to the input to the CTP, matching the required latency for the Level 0 trigger⁴. The architecture of the PIT is schematically shown in Fig. 2. The 120 optical fibers from the SPD are connected to an optical splitter close to the CTP: data are sent both to the readout electronics in control room and to the electronics boards of the PIT.

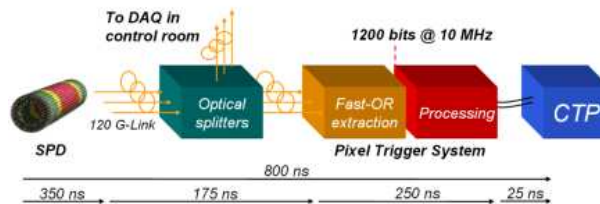


Fig. 2. The architecture of the Pixel Trigger system.

The first block of the PIT de-serializes the optical data and extracts the 1200 Fast-OR bits from the data flow. The last block implements the processing algorithm and generates the input to the CTP: it is constituted by an electronic board based on a FPGA with a large number of pins and large logical capacity⁵.

3. Fast-OR based algorithms

Studies have been carried out within the ALICE simulation and reconstruction framework (AliRoot⁶) in order to evaluate the performance of Fast-OR based algorithms for contributing to event selection in p-p collisions. In particular triggers for minimum bias events, high multiplicity events and events with primary tracks in the acceptance of the High Momentum Particle Identification Detector (HMPID) have been taken into account. The basic event sample used consists of 50000 p-p collisions at $\sqrt{s} = 14$ TeV generated by Pythia⁷. Fig. 3 shows the corresponding multiplicity distribution of charged particles, in the pseudorapidity range $|\eta| < 1.5$.

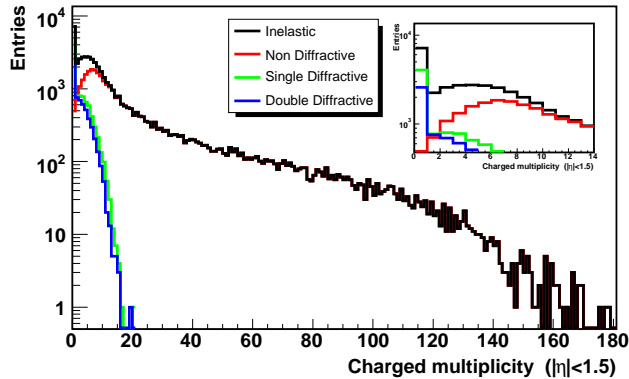


Fig. 3. Distribution of charged particle multiplicity in $|\eta| < 1.5$ as generated by Pythia in p-p collisions at 14 TeV for different process types.

The sample contains single and double diffractive (SD and DD respectively) as well as non diffractive events (ND) with the following percentages: 17.8% SD, 12.7% DD and 69.5% ND. All primary charged particles, including products of strong and electromagnetic decays, have been taken into account. Details on the three above mentioned applications of the Fast-OR trigger are given in the following sub-sections.

3.1. Minimum bias trigger

The minimum bias trigger has to select p-p collisions with the highest efficiency and the lowest bias, allowing a good rejection of the background (mostly coming from interaction of the incoming protons with the residual gas in the beam pipe). Two independent arrays of scintillator counters (VZERO detector^{1,8}), placed at both sides of the interaction point along the beam line, have been designed for minimum bias trigger and background rejection. Combining the VZERO trigger signals with the SPD Fast-OR is useful due to the complementarity of the two detectors in the geometrical acceptance. Different algorithms have been investigated and the condition of requiring at least one Fast-OR signal in the whole SPD (GlobalFO)

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has shown a very good performance⁹. The following combinations have been taken into account:

$$\begin{aligned}
 \text{MB1} &= (\text{GlobalFO} \text{ .OR. } \text{VZERO-OR}) \text{ .AND. } \text{notBG} \\
 \text{MB2} &= (\text{GlobalFO} \text{ .AND. } \text{VZERO-OR}) \text{ .AND. } \text{notBG} \\
 \text{MB3} &= (\text{GlobalFO} \text{ .AND. } \text{VZERO-AND}) \text{ .AND. } \text{notBG} \\
 \text{MB4} &= (\text{GlobalFO} \text{ .OR. } \text{VZERO-AND}) \text{ .AND. } \text{notBG}
 \end{aligned}$$

where, based on the arrival time of the particles in one or both the counters, interactions happening within the two stations are selected (VZERO-OR and VZERO-AND conditions) and those happening outside are rejected (notBG). To check the background rejection capability of such triggers, p-O collisions simulated by Hijing¹⁰ have been also reconstructed and analyzed. As an upper limit estimate of the beam-halo contribution to the background, beam-gas collisions occurring more than 20 m away from the nominal p-p interaction point have been taken into account⁹. The fractions of p-p and background events selected by each trigger combination are summarized in Table 1.

Table 1. Efficiency (in %) of the different trigger conditions.

Trigger	Non Diff	Single Diff	Double Diff	All inel	Beam-gas	Beam-halo
MB1	100.0	72.2	86.1	93.3	8.1	2.7
MB2	99.3	58.6	65.8	87.8	5.4	1.2
MB3	97.7	39.2	41.9	80.2	0.2	$< 10^{-3}$
MB4	99.7	59.5	70.9	88.9	5.6	1.5

Note: p-p and background events are expected to have quite different rates, in particular the rate for beam-gas collisions should be one order of magnitude smaller².

The effect of the trigger selection on various physics distributions has been studied. As an example, in Fig. 4 the trigger bias on the generated track variables η and p_T is shown.

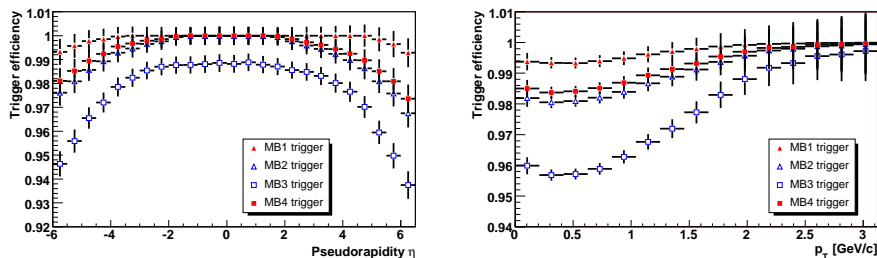


Fig. 4. Trigger bias on pseudorapidity (left) and transverse momentum (right) distributions.

In the central η region covered by the SPD the effect on the pseudorapidity distribution is negligible for all the triggers but MB3: in this last case the bias, essentially due to the VZERO-AND condition, is less than 2%. Distortions on the

transverse momentum spectrum are also within few percents. In conclusion, triggers MB1 and MB4 are the most efficient with p-p collisions and will be fine for background rates not far from the current estimates. MB2 is still very good as an alternative option preserving bunch crossing identification. Finally MB3 is the most powerful in the background rejection and produces a limited bias at event and track level.

3.2. High multiplicity trigger

A Fast-OR based trigger can be used to select high multiplicity events: this would allow to study the evolution of some physics observables (e.g. p_T spectra, strangeness content) with a reasonable statistics. The left panel in Fig. 5 shows the correlation between the number of active Fast-OR signals on the inner SPD layer (nFO_{inn}) and the charged multiplicity in the corresponding pseudorapidity range $|\eta| < 2$. The panel on the right illustrates the effect on the multiplicity spectrum when events are selected applying lower cuts (30, 60 and 90) in nFO_{inn} .

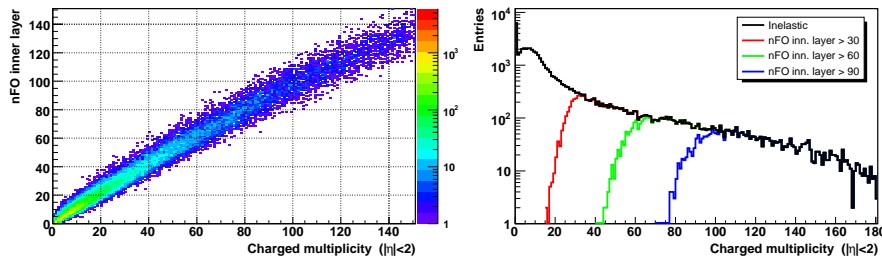


Fig. 5. Correlation between number of active Fast-OR signals and charged multiplicity (left) and effect of applying lower cuts in nFO_{inn} (right).

High multiplicity triggers have to include VZERO conditions to allow background rejection, so they can be defined as:

$$HM = (nFO_{inn} > nFO_{min}) .AND. VZERO-AND .AND. notBG$$

ensuring a low residual background contamination ($< 10^{-4}$). How large to set the threshold depends on various background sources and is currently under study.

3.3. Trigger for tracks in the HMPID

Due to its small acceptance coverage the HMPID is traversed by charged primary tracks only in about 10% of the Pythia minimum bias p-p events¹. Increasing the fraction of events with tracks throughout the detector would be certainly very useful for some calibration issues and possibly for dedicated physics studies.

Primary tracks reaching the HMPID are expected to traverse the SPD chips in defined regions. This is confirmed by the simulation: Fig. 6 illustrates the location of the active Fast-OR signals produced by those tracks on the two SPD layers.

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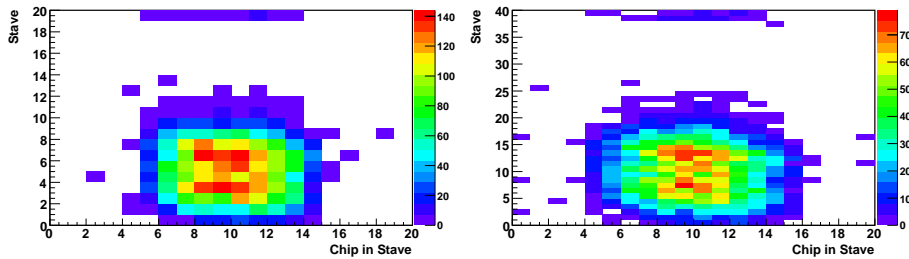


Fig. 6. Location of the active Fast-OR signals produced by tracks reaching the HMPID, on the inner (left) and the outer (right) SPD layer.

A topological condition requiring a minimum number of active Fast-OR signals in defined fiducial regions onto the inner and the outer SPD layer (R1 and R2 respectively) can be used. As an example the following coincidence condition:

$$RT = (nF0innR1 > nF0minR1) .AND. (nF0outR2 > nF0minR2)$$

can be tuned to increase the fraction of interesting events up to a factor 7. The bias introduced by such trigger has to be carefully studied to understand whether selected events may be used for physics.

4. Conclusion

The Fast-OR signal available from each of the SPD readout chips can be used to contribute to the p-p event selection in ALICE. The Pixel Trigger system collects and processes 1200 Fast-OR signals, generating an input to the CTP. It targets the latency constraint of 800 ns: this allows to implement Fast-OR based algorithms for the Level 0 trigger. Both p-p and beam-gas events have been generated and reconstructed through the ALICE detector in order to study the performance of various trigger conditions. Applications to minimum bias, high multiplicity and special events for the HMPID have been discussed.

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