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Upgrade of the DIRAC trigger system

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1 Introduction.

The multilevel trigger system of DIRAC [1–3] was successfully running during several years of the data taking, each year acquiring new features. Nevertheless, now it is time for the global upgrade of the trigger and readout systems. In this Note we concentrate on the trigger system.

The reasons for the trigger upgrade are multiple:

- The changes in the trigger system are mandatory due to foreseen implementation of a new readout electronics developed in JINR by V.Karpukhin. It is planned that in the 2006 run the scintillating fiber detectors SFD, the vertical VH, horizontal HH and ionization IH hodoscopes and all Cherenkov counters will be equipped with this electronics (for short, further it is named the DDT system – DIRAC Data Transfer system).
- Some new detectors will be implemented (aerogel Cherenkov counters and perfluorobutane gas Cherenkov counters) and the structure of many previously used detectors will change (SFD, VH, preshower detectors PSh, muon detectors Mu). It is expected that the microdrift chambers MDC will be implemented, too. On the contrary, the microstrip gas chambers MSGC will not be used in the setup anymore.
- Some new types of trigger have to be arranged, in particular, for detection of πK atoms.
- It has been decided that the neural trigger stage, DNA/RNA [3], has to be cancelled. As a consequence, pretrigger T0 can be cancelled, too.
- The previous trigger system was subject to partial upgrades every year of the DIRAC running. Though the trigger performance was quite acceptable, this has led to too complicated schematics and not optimal logical schemes. As a result, the trigger maintenance became rather complex.

In this note general features of the trigger electronics and logic are described.

2 Front-end electronics.

Front-end electronics of PSh and Mu detectors will not change except for different (increased) number of channels due to additional scintillator slabs. In PSh the front-end electronics comprises linear fan-in/fan-out modules LeCroy 428F and LeCroy discriminators 4416 (or 4413). In muon detectors it includes constant fraction discriminators LeCroy 3420 and CAEN C808 followed by meantimers CAEN C561. Like before, meantimers here fulfill the task of coincidences between the two muon counter layers.

Other detectors participating (actually or presumably) in the Level 1 trigger (VH, HH, IH and all Cherenkov counters) will employ the DDT system. The core of this system is the ADC/TDC board (16 or 8 channels, depending on software selectable TDC time resolution) with comparator outputs for trigger purposes. The boards will be placed just nearby the detectors, hence the front-end electronics of these detectors moves from the electronics barrack into the experimental zone. Electronic logic in the barrack will receive from the experimental zone logical signals (LVDS level) which arise at the comparator outputs when the input signals exceed the set thresholds.

The situation is slightly different for the Cherenkov counters. In 2006 there will be three types of Cherenkov counters used: nitrogen counters (the old ones), counters filled with perfluorobutane (C_4F_{10}) and aerogel counters. For short, further they are named $\mathrm{Ch_N}$, $\mathrm{Ch_F}$ and $\mathrm{Ch_A}$, respectively. In any Cherenkov counter more that one photomultiplier is used: 10 in $\mathrm{Ch_N}$, 4 in $\mathrm{Ch_F}$ and 4 or 2 in $\mathrm{Ch_A}$. Signals from all PMs of a counter have to be linearly summed for trigger purposes and at the same time the original individual signals have to be preserved for analysis.

Linear summing is not possible in the DDT board, so it has to be done in advance of the board in another unit. Then the board will receive the original signals together with their analog sum. To do this there are two options: either to use commercial linear fan-in/fan-out modules (like LeCroy 428F or CAEN N625) or to develop a dedicated NIM module. It is preferable to develop a dedicated unit which can be used for all Cherenkov counters in DIRAC. This assumes also replacement of old linear adders for the nitrogen counters which had a large and unremovable offset instability. The advantages of the dedicated module option are:

– less modules (5 instead of 9 commercial ones);

– lower price;

– no available modules of this type in Electronic Pool.

There exists a preliminary agreement with the JINR electronic engineer about development of the dedicated linear adder with parameters suitable for the DIRAC Cherenkov detectors.

In order to handle LVDS signals coming from the DDT system to a common logic, two other modules have been developed by V.Karpukhin:

– pulse width shaper (K436): CAMAC, 16 channels LVDS in, 2x16 LVDS out, 10–100 ns output width range;

– level translator (K434): CAMAC, 16 differential signals in (LVDS, ECL, TTL etc.), 16 LVDS out, 16 ECL out.

LVDS signals coming to the electronic room from the DDT board trigger outputs are shaped in K436 and then converted in K434 to ECL levels. At this point they are ready to be used in the trigger logic based, like before, mainly on ECL logic modules.

Meantimers are not used anymore in VH and HH channels. For trigger coincidences the signals from only one end of the scintillator slabs will be used. This will result in ± 1.5 ns jitter of trigger (full width) corresponding to different light collection time from the nearest and the most distant from PM hits in VH. The jitter of the HH signals will be even more, ± 5 ns, but trigger timing will be defined by VH like before. The jitter of trigger will not affect the setup time resolution or precision of tracking in drift chambers but requires some modifications in software analysis procedure and has consequences for on-line monitoring as commented below in Sect.5.

3 First level trigger.

Signals of different slabs of every hodoscope are logically summed before the coincidences. The summing is fulfilled in the OR modules LeCroy 4564 or in the majority coincidence schemes LeCroy 4532 which provide OR outputs in addition to majority outputs which are used in some types of triggers (identical pion pairs $\pi^-\pi^-$ or $\pi^+\pi^+$, double e^+e^- pairs).

There are arranged also the OR signals for limited groups of VH and PSh slabs which may be hit when a particle crosses the new Cherenkov $\mathrm{Ch_A}$ and $\mathrm{Ch_F}$ counters (this high momentum kinematic region is further named as *K-region*). The exact slab numbers have to be defined by simulation. In the aerogel counters the signals of three counters with different refractive indices in each arm are also logically summed.

Trigger primitives for building of the Level 1 trigger are formed in two logic matrices LeCroy 2365, separately for each arm. The module 2365 accepts up to 16 signals and provides up to 8 logical combinations at two 8-channel output connectors. Then the primitives of both arms are combined, together with the IH signals and with the coplanarity mark, when applicable, in another coincidence matrix in order to form different types of the first level trigger. Probable layout of the matrices for one arm and for both arms is shown in Fig. 1.

The signals V1, H1, PSh1 and Mu1 at the inputs of the left matrix of the figure are logic sums (OR) of all elements of these detectors; $\mathrm{Ch_N1}$ and $\mathrm{Ch_F1}$ are signals of Cherenkov counters filled with nitrogen and perfluorobutane, respectively; $\mathrm{Ch_A1}$ is a logic OR of three aerogel counters $\mathrm{Ch_A1\text{-}1}$, $\mathrm{Ch_A1\text{-}2}$ and $\mathrm{Ch_A1\text{-}3}$ with different refractive indices; $\mathrm{V1_K}$ and $\mathrm{PSh1_K}$ are OR signals of the V1 and PSh1 elements in the *K-region*; $\mathrm{V1_{maj}}$ and $\mathrm{H1_{maj}}$ are signals from the majority coincidence schemes, arising when the number of hit slabs in V1 or

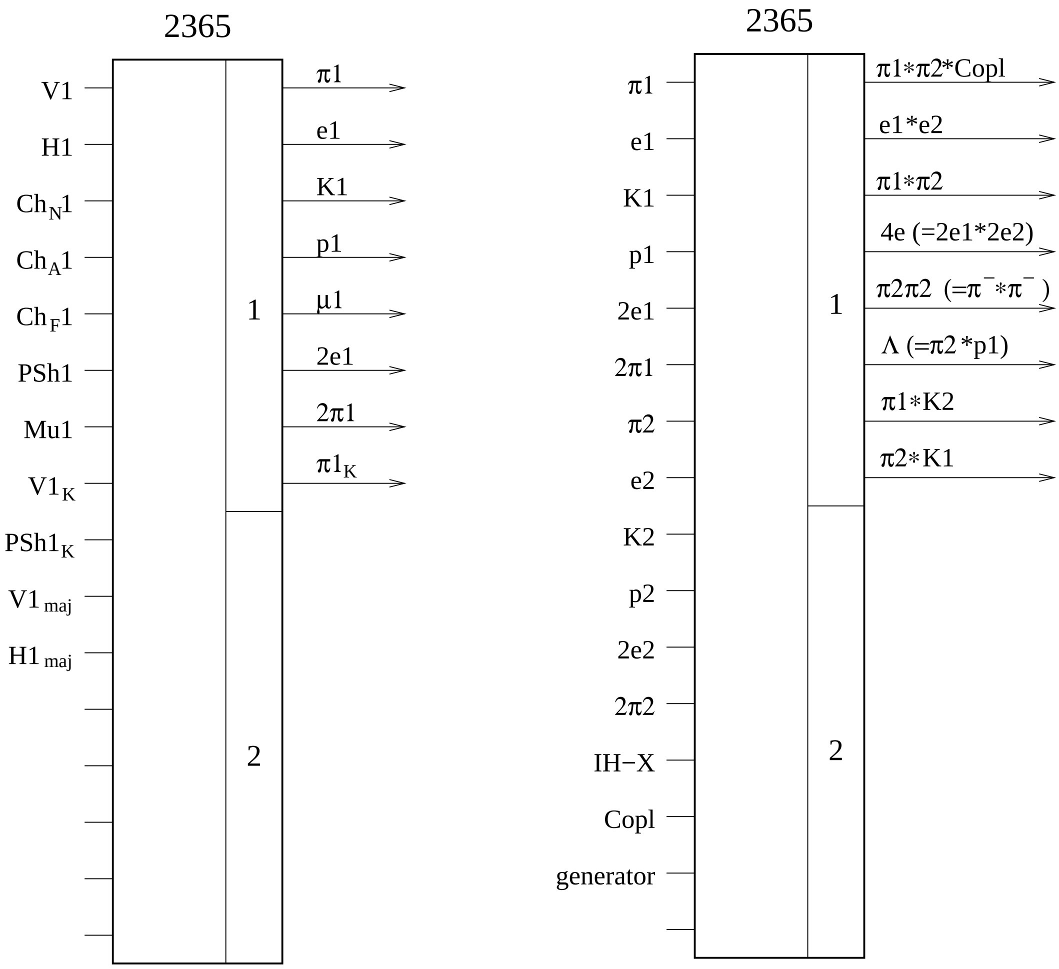

Figure 1: Signals at the inputs and outputs of the logic matrices. Left: coincidence matrix for one arm (here for Arm 1). Right: coincidence matrix for signals of both arms. The shown sample of the output logical combination is an example: in fact any combination can be arranged . Abbreviations are explained in the text.

Name	Trigger formula	Selected particles
$\pi 1$	$\mathrm{V1} \cdot \mathrm{H1} \cdot \mathrm{PSh1} \cdot \overline{\mathrm{Ch_N 1}}$	π, μ,K,p
e1	$\mathrm{V1} \cdot \mathrm{H1} \cdot \mathrm{PSh1} \cdot \mathrm{Ch_N 1}$	e
K1	$\mathrm{V1_K} \cdot \mathrm{H1} \cdot \mathrm{PSh1_K} \cdot \overline{\mathrm{Ch_N 1}} \cdot \overline{\mathrm{Ch_F 1}} \cdot \mathrm{Ch_A 1}$	K
p	$\mathrm{V1_K} \cdot \mathrm{H1} \cdot \mathrm{PSh1_K} \cdot \overline{\mathrm{Ch_N 1}} \cdot \overline{\mathrm{Ch_F 1}} \cdot \overline{\mathrm{Ch_A 1}}$	p
$\mu 1$	$\mathrm{V1} \cdot \mathrm{H1} \cdot \mathrm{PSh1} \cdot \mathrm{Mu1}$	μ
2e1	$\mathrm{V1} \cdot \mathrm{H1} \cdot \mathrm{PSh1} \cdot \mathrm{Ch_N 1} \cdot \mathrm{V1_{maj}} \cdot \mathrm{H1_{maj}}$	two particles, at least one of them is an electron
$2\pi 1$	$\mathrm{V1} \cdot \mathrm{H1} \cdot \mathrm{PSh1} \cdot \overline{\mathrm{Ch_N 1}} \cdot \mathrm{V1_{maj}} \cdot \mathrm{H1_{maj}}$	two particles, none of them is an electron
$\pi 1_K$	$\mathrm{V1_K} \cdot \mathrm{H1} \cdot \mathrm{PSh1_K} \cdot \overline{\mathrm{Ch_N 1}} \cdot \mathrm{Ch_F 1}$	π, μ in the *K-region*

Table 1: Trigger primitives for Arm 1.

H1 is ≥ 2.

Trigger primitives available at the outputs of one-arm matrix are shown in Table 1. The name of a primitive does not mean that particles exactly of this type are selected but defines some class of particles (in the rightmost column) which satisfy the selection criteria.

On the right of Fig. 1 the matrix is shown which generates the first level subtriggers at the outputs. The matrix receives the trigger primitives from both arms, the ionization hodoscope signals IH-X, which are OR of the two X-planes of IH, and the mark 'Copl' issued by the coplanarity processor. The output signals may include, for example, the subtriggers:

$\pi 1 \pi 2$:	$\pi^+\pi^-$ pairs
$e1e2$:	e^+e^- pairs
$\pi 1 \pi 2 Copl$:	$\pi^+\pi^-$ with coplanarity $\bullet$
$4e$:	double e^+e^- pairs
$\pi 2 \pi 2$:	$\pi^-\pi^-$ pairs
Λ:	Λ-hyperon decay products
$\pi 1$*K2*:	$\pi^+\mathrm{K}^-$ with coplanarity $\bullet$
$\pi 2$*K1*:	$\pi^-\mathrm{K}^+$ with coplanarity $\bullet$,
K1K2:	$\mathrm{K}^+\mathrm{K}^-$ pairs

where the 'atomic' subtriggers are marked with a black circle $\bullet$.

The above set of subtriggers is an example only: actually the matrix can be quickly reprogrammed if another logical combination is requested. The same concerns the matrices of the previous level which produce the one-arm trigger primitives. In particular, inclusion of the preshower detector in trigger is questionable; if necessary, it can be easily excluded from the coincidence formulaes.

All subtriggers are subject to masking in the next module, where the needed combination of simultaneously running triggers is defined by the loaded trigger file. Further step is an individual prescaling of the enabled subtriggers in order to provide optimum relative rates of the different type subtriggers. Finally the prescaled signals are logically summed and this sum is the first level trigger T1. Individual marks of different subtriggers are recorded in the trigger mark register and hence the trigger type for any event can be recognized in off-line analysis and on-line monitoring programme.

In the previous trigger system the first level trigger was additionally synchronized with the signals of the vertical hodoscopes V1 and V2. So, there were three types of gates: synchronized with Arm 1, synchronized with Arm 2 and non-synchronized. In the new scheme *synchronization of trigger with some spectrometer arm is not foreseen* because with the DDT system such synchronization gives no advantages. The electronic scheme becomes more simple and transparent. In addition, the missing before possibility to take data with a trigger from any single arm appears.

The level 1 trigger signal starts the event acquisition in the modules of the DAQ system and initiates the event evaluation in the second level trigger processors.

4 Second level trigger

In the upgraded system there will be two trigger levels instead of previous three. Now the Level 1 trigger is followed by the drift chamber trigger processor which in the old system had the name 'T4' and further we shall keep this name. The neural trigger DNA/RNA which stepped between T1 and T4 will not be used anymore because it almost does not increase the suppression provided by T1·T4 but makes the general scheme much more complicated.

Processor T4 (consisting of track finder and track analyzer) reconstructs tracks in the drift chambers using the hit wire numbers and selects the events with low relative momenta of two opposite sign particles. Drift times are not used in real time. The track analyzer memory contains 'tables of relevance' obtained for atomic pairs by simulation. The processor compares parameters of the experimentally detected tracks with those contained in the memory and takes decision to accept or to clear the event. Positive decision leads to the event readout.

One track analyzer unit contains only one set of tables describing a specific event type: $A_{2\pi}$ or $A_{\pi^-K^+}$ or $A_{\pi^+K^-}$ atom. So, in full configuration the second level trigger has to comprise three identical analyzers with different tables loaded. Nevertheless, in 2006 only two units will be available (the third one and one spare are expected in 2007). For this reason it is planned to use one analyzer for selection of $A_{2\pi}$-type events (T4$_\pi$) and another one for $A_{\pi^- K^+}$-type (T4$_{\mathrm{K}^+}$). For $A_{\pi^+ K^-}$ events only Level 1 selection will be provided in 2006.

As explained in the previous Section, in addition to 'atomic' subtriggers, the first level trigger includes several subtriggers used for calibrations and for study of other physics processes. Such subtriggers must bypass the selection criteria imposed by T4. This is realized with sending of trigger marks of all subtriggers, which should not be suppressed by T4, to a dedicated input of the T4 module. When T4 receives the signal at this input, it becomes transparent, i.e. always generates positive decision.

T4$_\pi$ processor will be started with the $\pi 1 \pi 2 Copl$ subtrigger. What subtrigger to use for starting of the T4$_{\mathrm{K}^+}$ processor (the same $\pi 1 \pi 2 Copl$ or $\pi 2 K1$) will be decided during the measurements. This depends on real experimental conditions and on performance of the new Cherenkov detectors.

5 Consequences for the data monitoring.

The data handling procedure has to be tuned due to modification of the electronics. For software analysis (both on-line and off-line) the following hardware changes are the most essential:
1) implementation of the DDT system;
2) no meantimers: the PM signals from only one end of the VH and HH counters are used in trigger;
3) no trigger synchronization with any definite spectrometer arm.

In the old scheme a digitized time code of the detector signal directly defined its timing with respect to trigger. Moreover, in VH and HH the timing did not depend on coordinate due to meantimers. For this reason even raw time spectra in the on-line monitoring programme were rather narrow and hence any deviations in performance could be easily observed.

With use of the DDT system raw spectra provide very limited information. First, without going into details, the timing of the hit is here the difference of two time codes, one of them corresponding to the hit itself and another to the trigger signal. Furthermore, even having done this subtraction, the VH and HH time spectra are still rather wide. To obtain narrow spectra, the *software meantimer* has to be organized. That means that the half-sum of times corresponding to PM signals from the opposite ends of a scintillator slab has to be calculated and displayed in the process of on-line monitoring.

Additional steps are needed to match timing information in the drift chambers and in the hodoscopes.

Nevertheless, these software complications are repayed by numerous advantages of new features and better performance of the readout and trigger electronics. One could mention among them:

— increased data transfer rate and removal of previous limitation from the buffer memory volume, hence more data per spill can be acquired;

— new information is collected: amplitudes for VH, HH and SFD, timing for Cherenkov counters;

— no long signal cables (in the case of DDT), hence no attenuation, better resolution;

— logically and instrumentally more simple trigger scheme leading to better reliability and easier maintanance.

6 Preparations for implementation.

In order to implement the new trigger system some works in hardware and software have do be done:

Hardware

– production of the shapers K436 and level converters K434 for LVDS signals, about 20 modules of each type;

– development and production of linear adders for the Cherenkov counters, 6 modules;

– manufacturing of new patch panels for signal cables coming from the DDT boards to the electronics room. Production of many single twisted pair cables for alignment of the VH and HH individual counter signals before arrival in the trigger logic.

Software

– simulation of new tables for the track finder and of three sets of tables for the track analyzers $T4_{\pi}$, $T4_{K^+}$ and $T4_{K^-}$;

– determination of the ranges of the VH and PSh counters which are hit when a particle crosses the *K-region*;

– determination of the range of the VH counters corresponding to kinematics of the Λ-decay;

– test of π and K coplanarity in the $\pi^{\pm}K^{\mp}$ atom breakup.

Dismounting of an old trigger system and assembling of a new one will start only after the test of a full chain of the DDT system.

References

[1] L.Afanasyev et al. NIM A479 (2002) 407.

[2] L.Afanasyev et al. NIM A491 (2002) 376.

[3] P.Kokkas et al. NIM A471 (2001) 358.