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# TRIGGER ELECTRONICS FOR THE FORWARD AND BACKWARD HODOSCOPES OF ANKE

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The spectrometer ANKE [1] is in operation at the proton accelerator COSY in Jülich, Germany, to study proton-proton and proton-nuclear interactions at intermediate energies (up to 2.7 GeV). It includes, in particular, forward and backward scintillation hodoscopes which are used in a trigger logic.

Two sets of dedicated trigger electronics have been developed and produced. One of them, BDFD (Backward Detector and Forward Detector trigger) logic, is used in most experiments at ANKE. The other, FTRG (Forward TRiGger), is intended for experiments with two charged particles detected in the Forward Hodoscope.

The schemes of the hodoscopes and their position in ANKE are shown in Fig.1. The Forward Hodoscope consists of two planes: A and B with 8 and 9 scintillation counters, respectively. The plane B is shifted by a half-width of the counter in respect to plane A.

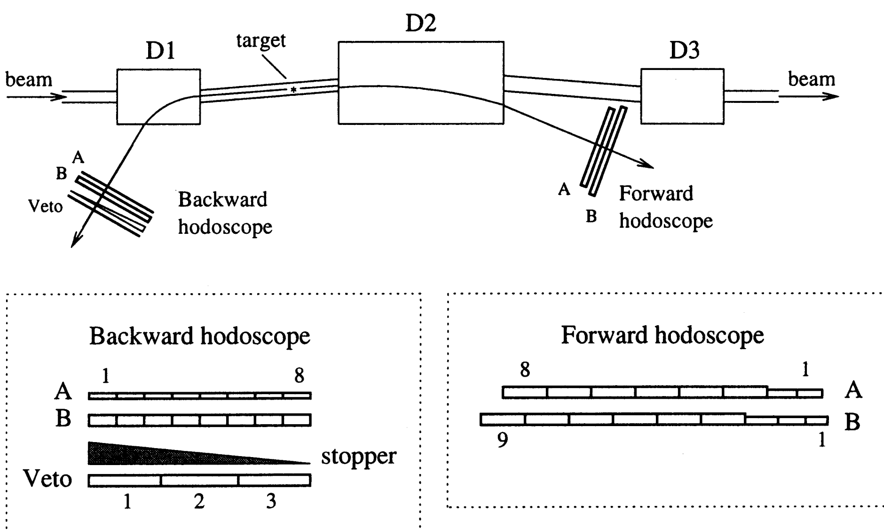


Fig.1. Schemes of the Forward and Backward hodoscopes and their position in ANKE. Other detectors are not shown. D1, D2, D3 are the ANKÈ dipole magnets. Not to scale.

The Backward Hodoscope includes planes A and B, each of 8 counters, and a Veto plane of 3 counters. The Veto plane is placed behind an iron stopper and prevents triggering by fast pions which penetrate through the stopper.

All the counters are viewed with two photomultipliers (PM) from the opposite ends of the scintillators (except the Veto plane counters which have only one PM per counter). The meantimer units [2] are used to remove dependence of the signal timing on the coordinate.

## BDFD system

The BDFD logic provides detection of any charged particle crossing the Forward Hodoscope or the Backward Hodoscope or two particles in coincidence in these detectors. It includes two CAMAC modules, Ftrig and Btrig. The input signals to these modules come from the meantimers of the corresponding counters.

### Ftrig module.

Due to a half-width shift of the counters in the planes of the Forward Hodoscope a particle can hit the counter $A_i$ and one of two counters $B_i$ or $B_{i+1}$. For this reason the Ftrig logic is constructed from "mini-towers", each of them, $T_i$, can be logically described as the coincidence $T_i = A_i \cdot (B_i + B_{i+1})$. The total trigger signal of the Forward Hodoscope is an OR of eight $T_1 \div T_8$ sections. Any combination of mini-towers $T_i$ can be enabled or disabled with CAMAC bus commands.

The scheme of the Ftrig module is shown in Fig.2.

Ftrig module specifications:
*inputs:* A-plane — 8, B-plane — 9, ECL levels;
Inhibit (disables FD trigger output signal), NIM level;
*outputs:* FD trigger, ECL — 2, NIM — 1;
OR A-plane, OR B-plane, ECL levels;
*output FD trigger signal width:* 20 ns;
*module width:* 1M.

### Btrig module.

The counting rate in the backward direction is low (less than $1000\,\mathrm{s}^{-1}$). For this reason the trigger logic for the Backward Hodoscope is done as a simple coincidence of signals in any counter of the A-plane and any counter of the B-plane in the absence of the Veto-plane signal:

$\mathrm{OR}(A_1 \div A_8)\cdot\mathrm{OR}(B_1 \div B_8) \cdot \overline{OR(V_1 \div V_3)}.$

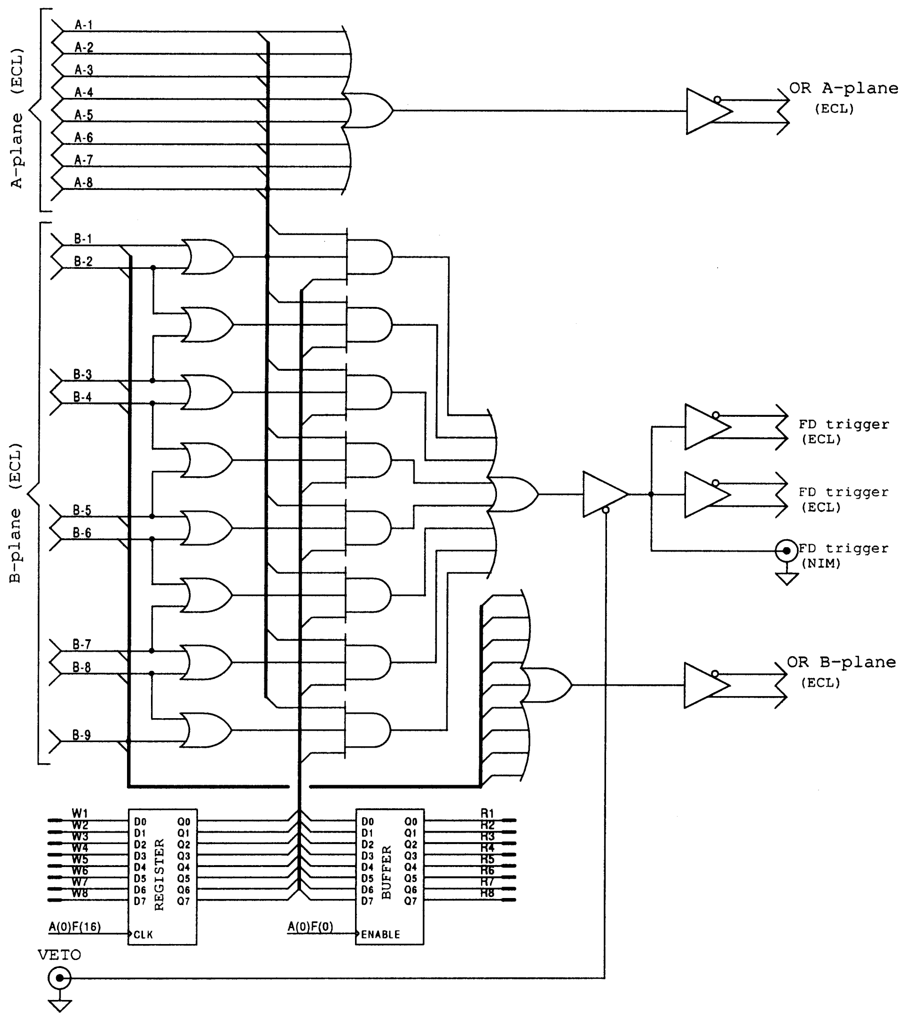


Fig.2. Scheme of the Ftrig module.

The joint BD/FD logic is also implemented in the Btrig module: there are options of only FD in the trigger, only BD or their coincidence FD·BD. The status of the logic is selected with CAMAC bus commands.

The scheme of the Btrig module is shown in Fig.3.

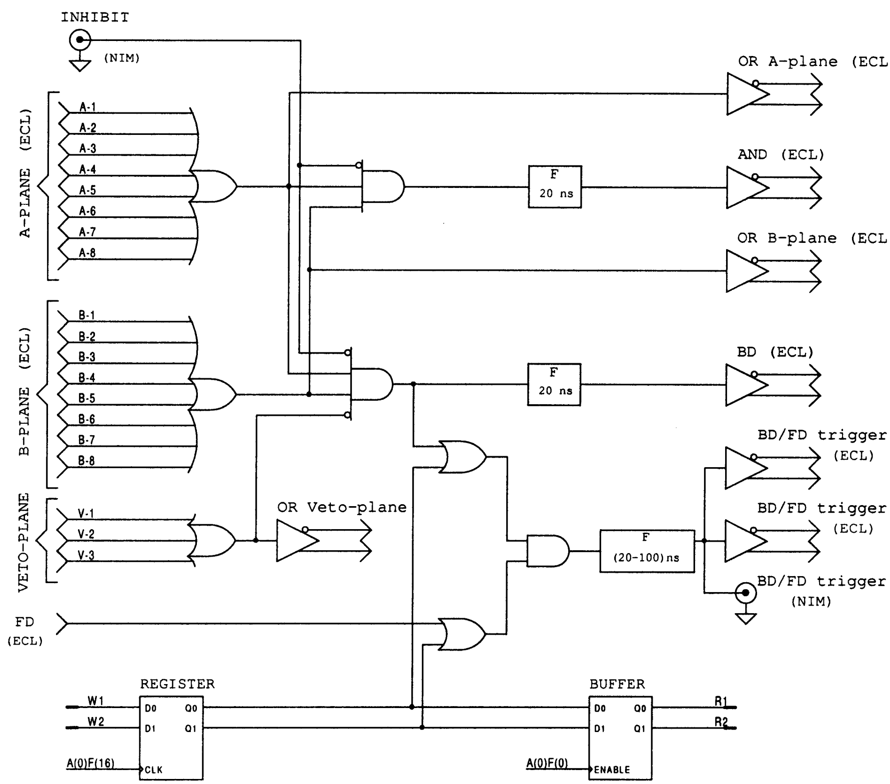


Fig.3. Scheme of the Btrig module.

Btrig module specifications:

*inputs:* A-plane — 8, B-plane — 8, Veto-plane — 3, ECL levels;
FD trigger signal, ECL level;
Inhibit (disables BD/FD output signal), NIM level;

*outputs:* BD/FD trigger signal (i.e. BD or FD or BD·FD depending

on the loaded parameter), ECL — 2, NIM — 1;
OR A-plane, OR B-plane, OR Veto-plane, ECL levels;
AND of A- and B-planes (irrespective of Veto-plane), ECL level;
BD trigger (irrespective of the loaded logic for the Btrig module), ECL level;

*output BD/FD trigger signal width:* adjustable at the front panel from 20 to 100 ns.

*module width:* 1M.

CAMAC bus commands for setting the operation modes of the Ftrig and Btrig modules are performed using the developed graphical user interface. The BDFD trigger system is successfully used for two years in most experiments at ANKE.

The counting rate in the Forward Hodoscope depends on the luminosity and may reach several tens of thousands per second while the ANKE data acquisition system (DAQ) is able to handle only few thousand per second. Hence, the trigger rate should be reduced to be consistent with the DAQ rate capabilities. In many experiments at ANKE further coincidence of the FD trigger signal with the signal from other detector groups is used to produce the final trigger (with the Backward Detector within the BDFD system or with the Side Detector and silicon detector placed near the target, both are not shown in Fig.1). However, there are physical processes of interest where particles hit only the Forward Detector. For efficient triggering in such experiments another trigger system, FTRG, has been developed.

## FTRG system

The purpose of the FTRG trigger is selection of events with at least two charged particles in the Forward Hodoscope. A simple majority logic is not applicable here as two particles may hit the same counter. Selection in FTRG is provided for any topology of two-particle events, i.e. for particles hitting the same or different counters in each of the two hodoscope planes.

To distinguish between the single and double particle hits in the same counter, charge discrimination is applied to the sum of signals from both ends of the scintillator. In long scintillators the signal timing depends on the particle hit coordinate. In this case the amplitude of the summed signal is a function of the *up* and *low* PM signal timing. To remove this problem a charge-sensitive shaper-amplifier [3] is used. The main features of this scheme are zero dead time and a flat top of the output signals. With flat top signals the output amplitude is not affected by variations of timing of the input signals and depends only on their pulse heights.

Analog signals from two opposite ends of every counter are first summed and integrated and then discriminated by a circuit with two thresholds. The thresholds correspond to single and double ionization loss levels.

The signals from the discriminator outputs are sent to the logic unit to produce a trigger decision.

The FTRG system consists of two identical summator-integrator modules for hodoscope planes A and B and one logic module.

### Summator-integrator

The scheme of the summator-integrator unit is presented in Fig.4. The module contains 9 identical individual channels, a common output channel and a CAMAC control part. Each of the individual channels has a pair of analog inputs from the *up* and *low* PMs of the corresponding counter (the 9th pair of inputs is not used for plane A).

In Fig.5 a simplified circuit diagram of one channel is shown. It includes a linear adder (U1) to sum the *up + low* PM signals and a shaper-amplifier part (U2 and U3). The integration time in the shaper-amplifier is 14 ns (optionally 28 ns depending on the jumper J1 position). The capacity C1 of the integrator is charged with a current from the ground pin of the delay line U3 during the presence of a signal from the adder U1. Then, during the propagation time in the delay line, the output signal from U2 is stable (flat top), the amplitude of this signal being proportional to the integral of the input current. When the signal leaves the delay line the inverted delayed signal discharges the integrator to base level.

For tuning purposes the outputs of all integrated signals are available at the front panel.

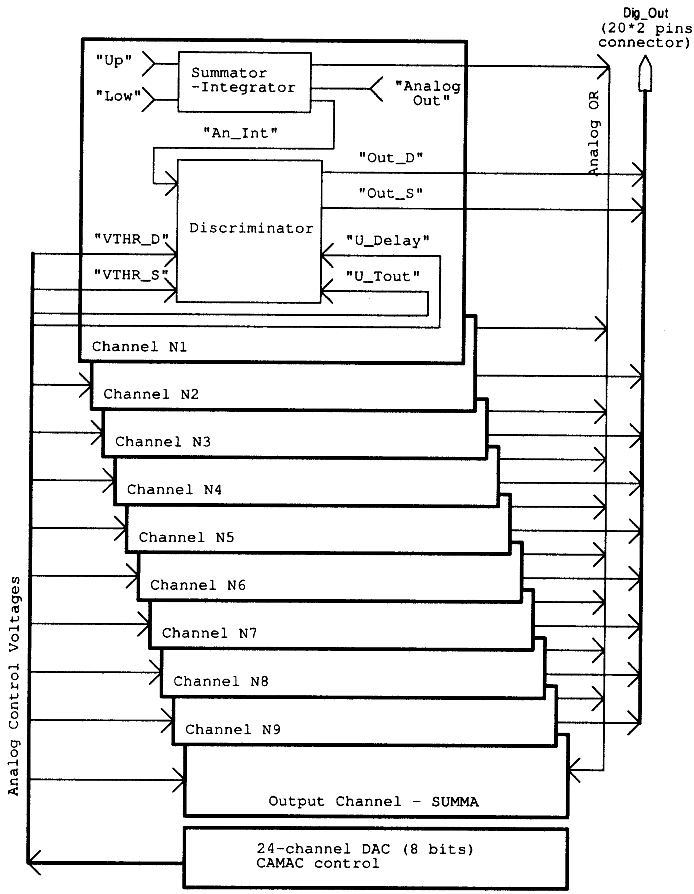


Fig.4. General scheme of the summator-integrator.

Individual (An_Int) and common (Analog_OR: OR of all the individual channels) integrated signals come to discriminators with two thresholds (for single and double particle detection levels). In Fig.6 a simplified circuit diagram of the discriminator stage for one channel is shown. The thresholds for single VTHR_S and double VTHR_D particle detection can be set individually with CAMAC commands in the range from 10 to 2550 mV with a step of 10 mV.

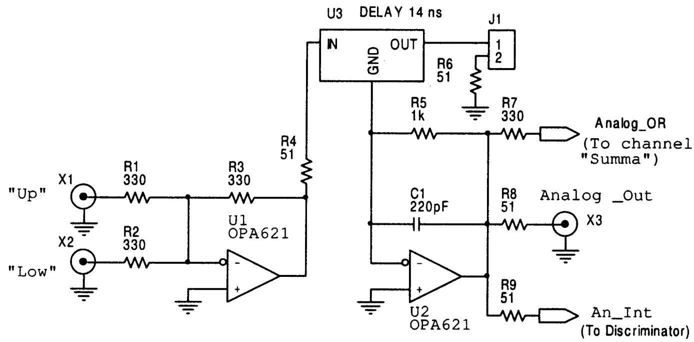


Fig.5. Simplified circuit diagram of one input summator-integrator channel.

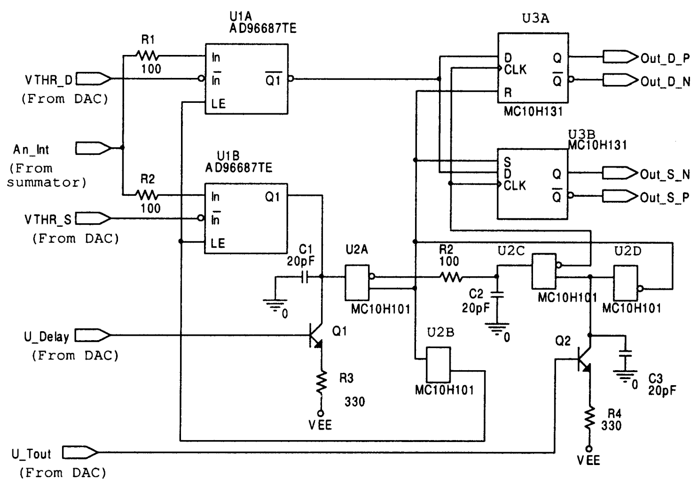


Fig.6. Simplified circuit diagram of one discriminator stage channel.

*Inputs.* VTHR_D, VTHR_S: double and single thresholds.
An_Int: integrated signal from the summator-integrator part.
U_Delay and U_Tout: control voltages for internal delay and output pulse width.

*Outputs.* Out_D_P, Out_D_N, Out_S_P, Out_S_N: ECL level positive (P) and negative (N) digital pulses from the double threshold (D) and single threshold (S) discriminators.

Two more parameters should be set for the discriminator channels using control voltages: internal delay (U_Delay) and output pulse width (U_Tout). The U_Delay value defines the moment of comparison in the double threshold discriminators in respect to a single threshold overshoot. The delay and the output pulse width are the same for all individual channels. For the common channel these two parameters are set independently.

Specifications for the summator-integrator unit:

*inputs:* 9+9=18 analog inputs from both ends of the scintillators on Lemo connectors;

*outputs:* 10 analog outputs for the integrated signals (9 individual and 1 common) on the Lemo connectors;
discriminator ECL outputs for individual and common channels on a 2x20 pin connector: 10 pairs of pins for the single threshold discriminators, the other 10 pairs for the double ones;

*thresholds:* from 10 to 2550 mV with a 10 mV step individually set with CAMAC commands;

*output pulse width:* from 8 to 120 ns set with a CAMAC command

*module width:* 2M.

All control voltages in the module are set with a 24-channel 8-bit DAC. The CAMAC functions F(17) (write) and F(1) (read) with subaddresses from A(0) to A(11) are used.

### Logic module

The logic module receives digital signals from two summators-integrators and combines them in accordance with the logical scheme defined by the loaded parameters. Any input signal can be enabled or disabled.

When two particles cross the Forward Hodoscope, they may hit the same counter or different counters in each plane. Let us consider the hit counter numbers for the cases of one and two particles hitting the Forward Hodoscope. All possible combinations are shown in Fig.7. We denote the discriminator output for channel #i in the A-plane as $AS_i$ for the single threshold output and $AD_i$ for the double threshold output. Similar signals for the B-plane are $BS_i$ and $BD_i$.

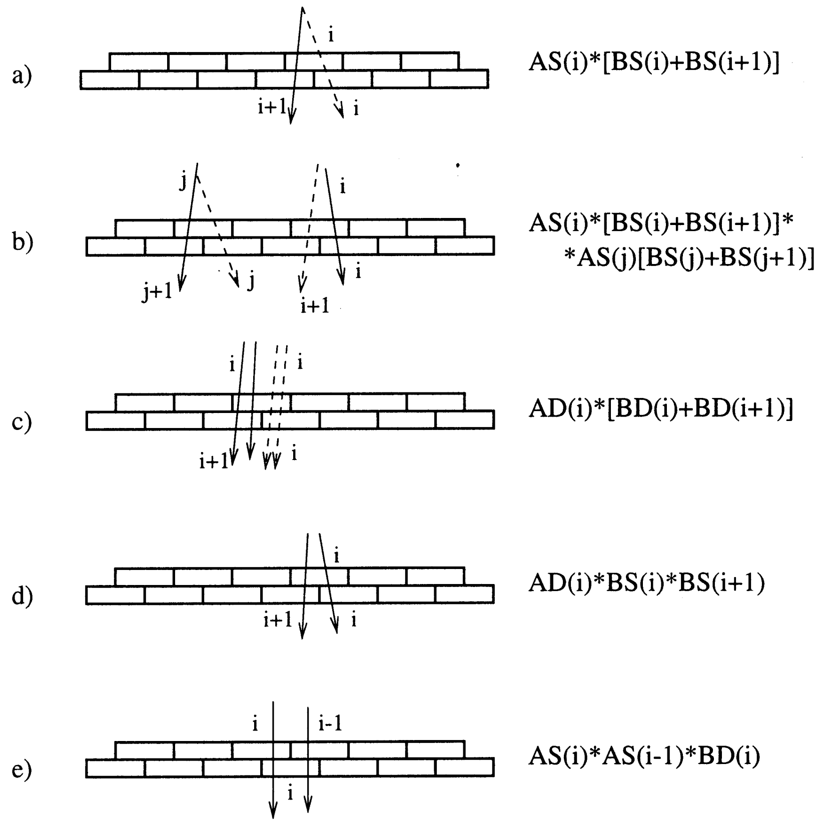


Fig.7. Possible combinations of hit counters in the Forward Hodoscope for single and double particle crossing.

For single particle events a hit in A-plane counter #i is accompanied by a hit in #i or #i+1 in the B-plane (Fig.7a). Such an event may be written as $AS_i \cdot (BS_i + BS_{i+1})$.

For double particle events there are several possibilities of hitting one or two different counters in each of the planes (Figs.7b–7e).

All logical functions describing the event topology shown in Fig.7 are realized in the FTRG logic unit.

It is possible to activate selection of any of these combinations or any logical sum of them. For example, simultaneous enabling of modes 7b–7e results in a trigger from two particles in FD while mode 7a alone detects any single particle and is similar to the FD trigger of the BDFD system described above.

Figures 8–10 describe the structure of the logic module. Its general scheme is shown in Fig.8. In Fig.9 a simplified circuit diagram of the double-single coincidence stage is presented. The scheme of the track selection stage is shown in Fig.10.

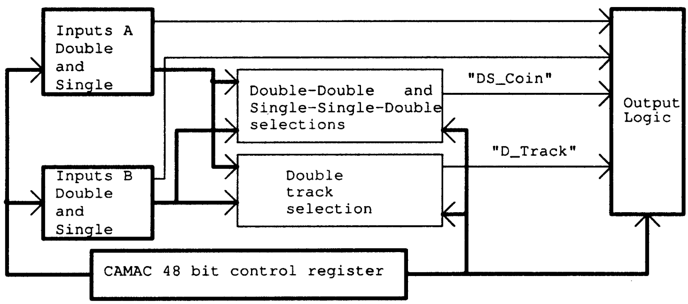


Fig.8. Scheme of the logic unit.

For the events with two hits in plane A (Fig.7b) one can request a selection by the value of the hit slab numbers difference. One can enable the difference $\Delta n$=1,2,...,7 (CC1-2 $\div$ CC1-8 inputs in Fig.10). Enabling all differences from 1 to N one obtains the selection of double hits with any distance up to N counters. Or, vice versa, if one enables the differences from N to 7, only the particle pairs with a distance $\geq$N are selected by the trigger.

Decisions of all active modes are combined with an OR function and this logical sum is the output trigger signal of the FTRG system.

Specifications of the logic module:

*inputs:* 40 ECL signals from summators-integrators at two 2x20 pin connectors

*outputs*: FTRG trigger signal, ECL — 4, NIM — 2

*output signal width*: 30 ns

*module width:* 2M

All control functions of the logic module are realized with a 48-bit control status register which is set with the CAMAC functions F(17) (write) and F(1) (read) with subaddresses from A(0) to A(2).

### Results of the beam test

The FTRG trigger has been tested with a beam. The trigger selectivity may be characterized by the reduction coefficient of the FTRG trigger rate in respect to the rate of a simple FD trigger described in the first section of this paper. This coefficient depends on the energy range of particles crossing the Forward Detector (which is defined by the experiment parameters: beam energy, current in D2 magnet etc.) and on background conditions.

The reduction coefficient is sensitive to fine tuning of the discriminator thresholds. The tuning procedure includes the measurement of discrimination curves for single and double threshold discriminators using real hodoscope signals. For double threshold tuning the double amplitude signals from the hodoscope are sent to the summator-discriminator inputs. The double amplitude is obtained by summing the hodoscope signal with its copy taken from a linear fan-out unit.

Single threshold values are normally chosen on the plateaus of the single threshold discrimination curves. The double thresholds should be set as high as possible but still on the efficiency plateau for the double particles from the momentum range studied. The lower the double threshold, the higher the probability for a single particle signal to exceed the double threshold due to the Landau tail in the energy loss distribution. Particles of lower energies can also produce large signals and so imitate double particle crossings. Both these effects decrease the reduction coefficient, hence for optimum operation of the trigger in conditions of medium energy experiments, where the energy losses essentially depend on the momentum, the thresholds should be adjusted for any specific energy. In particular, this dependence should be taken into account when protons with energies below 2 GeV have to be detected.

In the beam tests it was observed that the dominant part of the trigger rate comes from the mode in Fig.7c (when double ionization takes place in single counters of the A- and B-planes). It was 30 times as high as the rates of other double particle modes, 7b, 7d, 7e (this coefficient varies

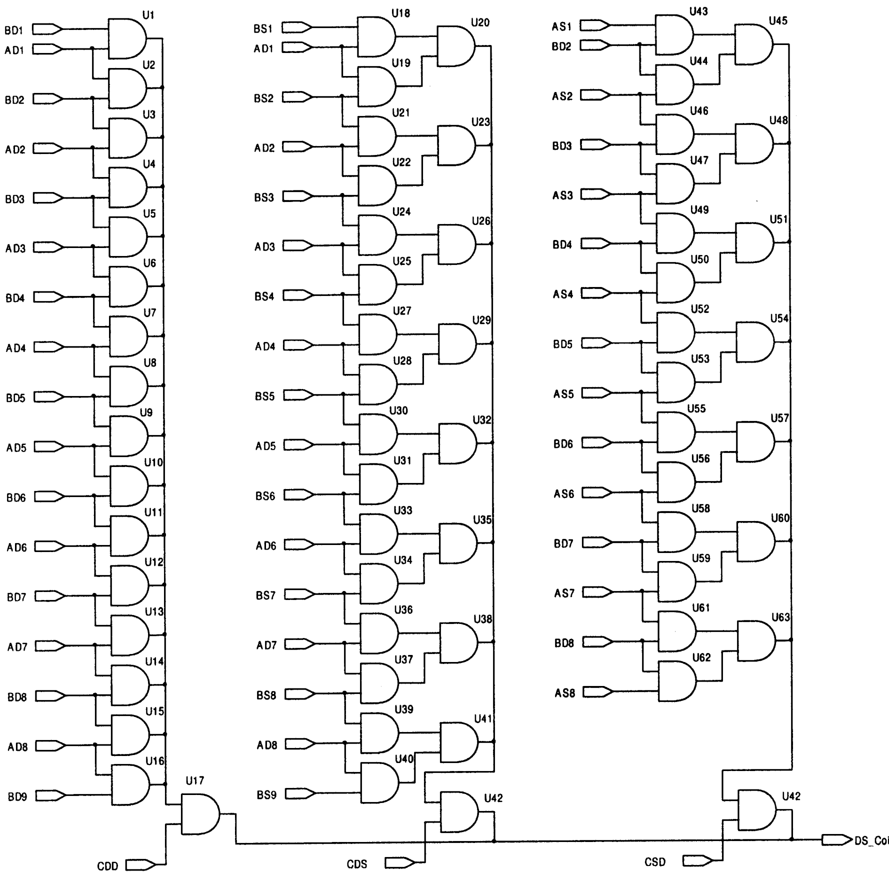


Fig.9. Simplified circuit diagram of the Double-Single coincidence stage of the logic unit.

*Inputs.* AS1÷AS8, BS1÷BS9: single threshold discriminator signals from the summator-integrator units of the A- and B-planes, respectively.
AD1÷AD8, BD1÷BD9: the same for the double threshold discriminators.
CDD, CDS, CSD: enabling of selection of event types c), d), e) (Fig.7), respectively, from the control register.

*Output.* DS_Coin: positive decision from the Double-Single coincidence stage.

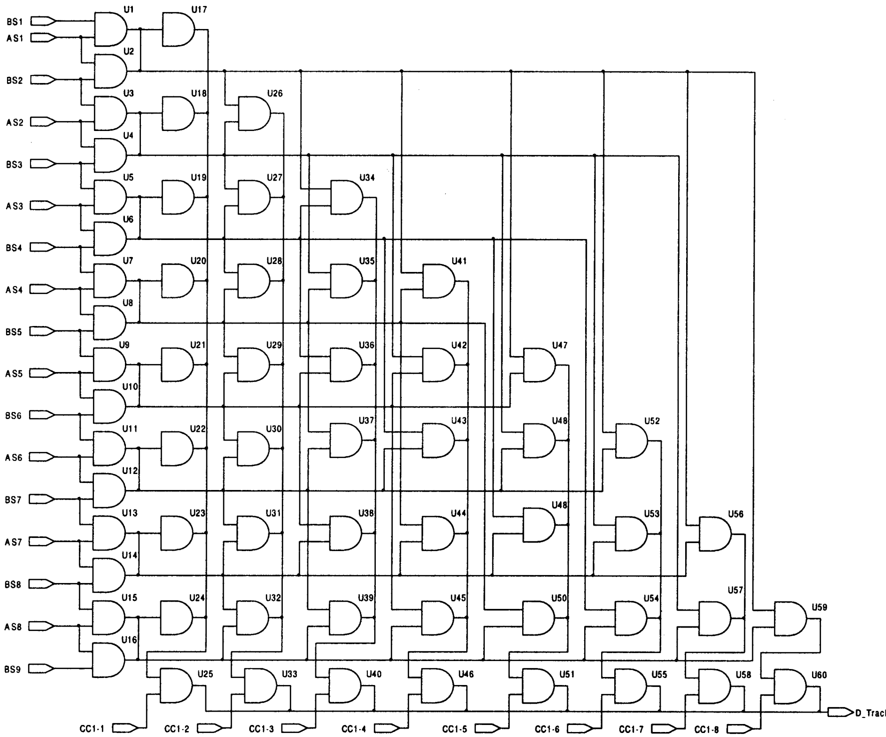


Fig.10. Track selection stage of the logic unit.
*Inputs.* AS1÷AS8, BS1÷BS9: single discriminator signals from the summator-integrator units of the A- and B-planes, respectively.
CC1-1: enabling of single particle mode a) (Fig.7)
CC1-2÷CC1-8: for event type b) (Fig.7) enabling of double track distances $1 \div 7$ (measured in counter numbers).
*Output.* D_Track: positive decision of the track selection stage.

with the beam energy and background conditions). This is obviously a consequence of single particle detection due to Landau fluctuations and admixture of slow highly ionizing particles. Another illustration of the sensitivity to the double threshold tuning was obtained in tests at the beam energy 0.8 GeV. The reduction rate coefficient 6.7 measured at the optimum values of the thresholds decreased to 4.5 when the double thresholds were lowered by 20%.

Then the FTRG trigger system was tested in measurements at the beam energy 2 GeV. Single thresholds were set at the level providing 100% efficiency of single particle detection, double thresholds corresponded to 95% detection efficiency of two particles crossing the same counter. At these conditions the counting rate of FTRG was $10 \div 11$ times lower than the simple FD rate.

The trigger efficiency for detection of two particles in the Forward Hodoscope was measured using the FD trigger as the final trigger with recording of the FTRG decision mark. In the off-line analysis the events of the reaction $pd \rightarrow ppn\pi^o$ with two protons in the Forward Hodoscope were identified and then the number of FTRG marks for these events was counted. The trigger efficiency was found to be 95%.

Hence, FTRG electronics provides an essential reduction of the trigger rate at a rather high efficiency.

The authors are grateful to R.Schleichert for essential support of this work.

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Дымов С. Н. и др. E10-2002-19
Триггерная электроника для переднего и заднего годоскопов установки ANKE

Описана триггерная электроника переднего и заднего сцинтилляционных годоскопов магнитного спектрометра установки ANKE на внутреннем пучке ускорителя COSY в Юлихе (ФРГ). Разработанные два набора триггерных модулей включены в состав общей триггерной системы ANKE и используются при проведении экспериментов. Для отбора пар частиц в годоскопе наряду с комбинаторной логикой используется дискриминация по заряду.

Работа выполнена в Лаборатории ядерных проблем им. В. П. Джелепова ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 2002

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Trigger Electronics for the Forward and Backward Hodoscopes of ANKE

Trigger electronics of the forward and backward scintillation hodoscopes of ANKE, the magnetic spectrometer placed at the internal beam line of the COSY–Jülich accelerator, is described. The two developed sets of trigger electronic modules are implemented in the whole ANKE trigger system and are used for the running experiments. For selection of double particle events in the hodoscope both the combinatory logic and the charge discrimination are used.

The investigation has been performed at the Dzhelepov Laboratory of Nuclear Problems, JINR.

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