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V.A.Butenko, V.M.Grebenjuk, V.A.Drozdov,
A.S.Kurilin*, F.V.Levchanovsky, Yu.F.Lomakin,
V.I.Prikhod'ko, A.G.Volod'ko

POSSIBILITY OF USING RICH-DETECTORS IN A TRIGGER

* Institute of Physics, Belorussian Acad. of Sci , Minsk

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Proposed scheme of using RICH-counters in a trigger for fixed-target experiments

First of all we want to mention the main characteristics of the particle identification in the high and ultra-high energy region:

1. Many particles pass through the detector simultaneously.
2. The interaction rate is high enough ($\sim 10^6$ int./s), which imposes some limitation on the rapidity reaction of a detector.
3. Particles are identified far enough from the interaction vertex ($e^\pm$- identification in e.m. calorimeters, $\mu^\pm$- identification behind the iron wall, etc.). It leads usually to the impossibility of using the results of identification in a lowest level trigger ($\sim$100÷200 ns).
4. It is difficult, practically impossible, to use threshold Cherenkov counters for the identification of the particles with momenta $\geqslant$100 GeV/c. Moreover, for the identification of secondary particles it is sometimes much better to use detectors other than Cherenkov ones:
a) for $e^\pm$- identification it is convenient to use e.m. calorimeters, which allow the e/h-separation up to $10^{-3}\div 10^{-4}$,
b) for $\mu^\pm$- identification their penetration properties are used.

Thus, one is needed actually to identify only hadrons - π, K-mesons and protons - in the experiment.

However, it is well known that the main part of secondary hadrons ($\geqslant$90%) are π-mesons. So, if we can identify K -mesons and protons, we can classify all the others as pions.

In this article we suggest to solve this problem by using RICH- detectors in some specific way. We consider the possible scheme of the Multi-Particle Spectrometer for UNK[4] as a typical fixed-target apparatus where:

- there is an analyzing magnet,
- RICH-detectors are placed behind this magnet,

- there are at least three scintillation (or equivalent) pad hodoscope planes which are placed in front of and behind the magnet and behind the RICH-detectors (the third one). Within this scheme from hodoscope information it is possible fast enough to determine both the particle momentum and the coordinate of the Cherenkov ring image center in the photodetector plane. A similar scheme for the determination of the particle momentum or transverse momentum was used in the NA-10 experiment[5], is used now in E-771[6] and is proposed to be used in several new experiments both in fixed-target and in collider future programs[7,8].

Moreover, the particle momentum being determined gives us the possibility to calculate the values of the radii of the Cherenkov rings for different types of particles at that momentum and the center coordinate gives us the possibility to define the part of the corresponding ring in the sensitive region of the finite dimension photodetector.

After that it is possible to compare fast enough the distances from the hodoscope defined center to fired elements of the photodetector with values of Cherenkov rings radii for different types of hadrons and to identify them. Additional confirmation of the validity of such identification goes from the comparison of the number of hits in the sensitive part of the ring with the number of photons for the definite type of the hadron.

We know that for a gas-radiator with the definite index of refraction, n, one has:

$$\theta^2_{Cher} \simeq 2(n-1)-1/\gamma^2 = 2(n-1)-\frac{m^2}{p^2+m^2}$$

$$N_{Cher\ ph} = N_0 \cdot L \cdot \sin^2\theta_{Cher} \simeq N_0 \cdot L \cdot \theta^2_{Cher}$$

$$R_{cher\ ring} = f \cdot tg\theta_{cher} \simeq f \cdot \theta_{cher},$$

where θ^2_{Cher} is the square Cherenkov angle, which is the function of the particle momentum (p), its origin (m) and the characteristic of the gas-radiator (n-1); f, L - are the focus distance of the detector optics used and the length of the radiator, and N_0 - is a constant which depends on the photodetector properties.

Naturally, for unambiguous particle identification one must have as minimum $\Delta R \geqslant 2\delta$, where $\Delta R = R_{\pi}-R_K$ (or R_K-R_p, etc.) is the difference of radii for the particle momentum defined by hodoscopes and δ - is the size of the photodetector sensitive element (pixel size).

By the special selection of the geometry, optics and gas-radiator we can achieve the condition when in a certain momentum region the radii for π/K/p are noticeably different and the number of Cherenkov photons is as large as possible.

It should be mentioned, that in the momentum region (20÷150) Gev/c, for any gas-radiator the radii for pions are changed only by < 20%, but the radii for kaons and protons can be made noticeably different.

In order to reduce the number of particles crossing an individual Cherenkov detector for satisfying the above mentioned conditions, we propose to install at least two sets of Cherenkov detectors with different gas-radiators for different momentum regions (for example - (20÷70) GeV/c and (70÷150) GeV/c) with 4÷6 azimuthal sections in each set (see Fig. 1).

The magnetic field strength is also important (especially in fixed-target experiments) for the azimuthal splitting of secondary particles.

For photodetectors we propose to use the fastest devices like multianode PMTs or photodiodes matrix in the following scheme. Photon signals from the photocathode must be amplified and divided into two fluxes. One flux goes to a small (rough) matrix (16×16 or 32×32) of photodetector elements with fast readout (<0.5μs) for the preliminary decision, this decision is supposed to be used in the trigger. Multianode photomultipliers or equivalent devices can be used for this type of elements. The second flux goes to the fine - structure matrix (100×100 or 200×200) of photodetector elements. For this purpose a CCD or photodiode matrix can be used. Signals from these elements are stored if the event is accepted or cleared, if not. The final identification of the particle is done in off-line analyses of signals from the fine-structure matrix (see Fig.2).

RICH - Trigger Electronics Proposed for the Multi-Particle Spectrometer UNK.

Considering the layout of the hodoscopes H_1, H_2, H_3 and photodetectors (PD), the magnetic field strength and the parameters of RICH detectors we preliminarily calculate the expected values for radii of Cherenkov ring images R_j, number of photons $N_{Cher\ j}$, radiated by expected particles (protons, K- and π-mesons), and coordinates, X_c, Y_c, of ring image centers in the PD plane.

These values for the whole accessible range of track angles in the XZ and YZ planes are then stored in the memory look - up tables (LUT). Hence the task of the trigger electronics is to measure with hodoscopes the particle emission and deflection angles, extract from the memory look-up tables the R_j, $N_{Cher\ j}$, X_c, Y_c values and then, having read out the information from PDs of every RICH detector and calculated real R_j, $N_{Cher\ j}$, values, compare these two sets of values within the given range of errors. This will allow one to select event candidates and generate the trigger signal.

This trigger electronics was designed with the following initial parameters:

- trigger decision time < 500 ns;
- maximum number of particles detected by RICH - 2 (if more, an 'accept' signal is generated and particle identification is performed by off-line analysis);
- size of hodoscopes and photodetectors: H_1 -20×32 pads; H_2, H_3 -32×48 pads; PD -32×32 pixeles of rough matrix; H_2 and H_3 have 6 segments each (corresponding to 6 RICHs) measuring

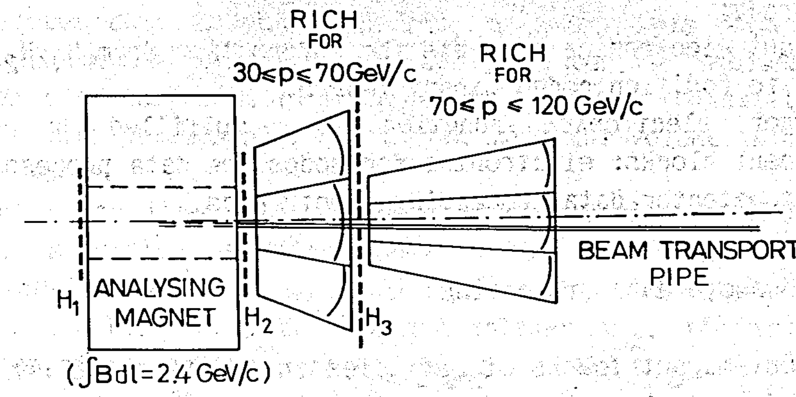


FIG. 1. Proposed scheme of hodoscopes-RICH set up for the Multi- Particle Spectrometer UNK. $H_1 \div H_3$ - pad hodoscopes.

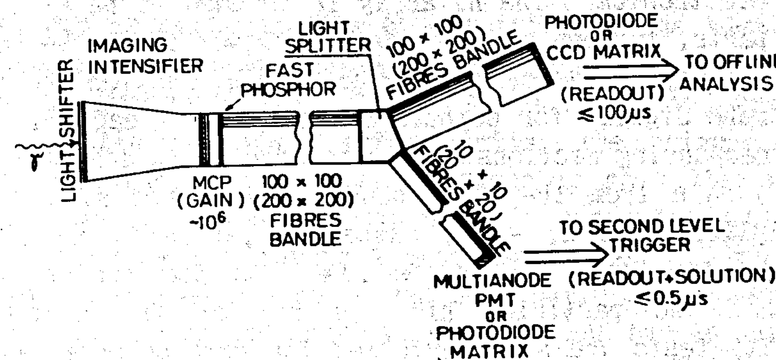


FIG.2. Proposed scheme of individual RICH photodetector for the Multi-Particle Spectrometer UNK.

16×16 pads;
- read out electronics converts the information from H_1,H_2,H_3 and PDs to position coded binary-images.

Trigger electronics functions are fulfilled by two independent blocks: electronics for hodoscope data processing and photodetector data processing electronics.

a)Hodoscope data processing

As post-magnet tracks of particles in the YZ plane remain unchanged and depend only on the particle emission and deflection angles , one can find these angles for the particles that have passed through the RICH detector by triple coincidence of its signals with those of PMTs arrayed in proper rows of hodoscopes. To do that, signals from 16 PMTs in the row of H_2 and H_3 and 32 PMTs in the H_1 row are logically added. This 'OR' signal corresponding to the given track projected onto the YZ plane is transferred to the coincidence scheme for primary selection and starting of trigger electronics. The H_1 array is assumed to be divided into two parts, 10 rows each, (upper and lower about the beam axis). Logically added row signals of each H_1 section are the common strobe signals for coincidence schemes of each of the three corresponding sections of the hodoscopes H_2 and H_3 (see Fig.3). Signals from the coincidence schemes are also used for multiplicity tests, - the number of particles per RICH detector section must not exceed two. As the probability exists that two particles hit one row of the section, multiplicity tests are also performed for rows selected with related coincidence schemes.

After being selected in the coincidence schemes, active rows signals from H_2 and H_3 sections and from two H_1 parts come to the priority encoder which identifies the excited row number (Fig.4). By this number the multiplexer selects the active row whose information is also encoded with the priority encoder. Position codes of excited cells of the

hodoscopes come as addresses into 6 memory LUTs from which the information on expected radii, number of photons and center coordinates of ring images is read and transmitted to the PD data processing electronics. Each LUT volume is 8K 40--bit words.

The delay time of the hodoscope electronics is found by simple summation of delay times at the input register t_{RG}, the AND-OR gates t_{AND-OR}, the excited row priority encoder $t_{row\ enc}$, the row selection multiplexer t_{mx}, the priority encoder of the active pads $t_{cell\ enc}$ and RAM t_{RAM}:

$$T=t_{RG}+t_{AND-OR}+t_{row\ enc}+t_{mx}+t_{cell\ enc}+t_{RAM}=8+10+20+8+20+35=100ns$$

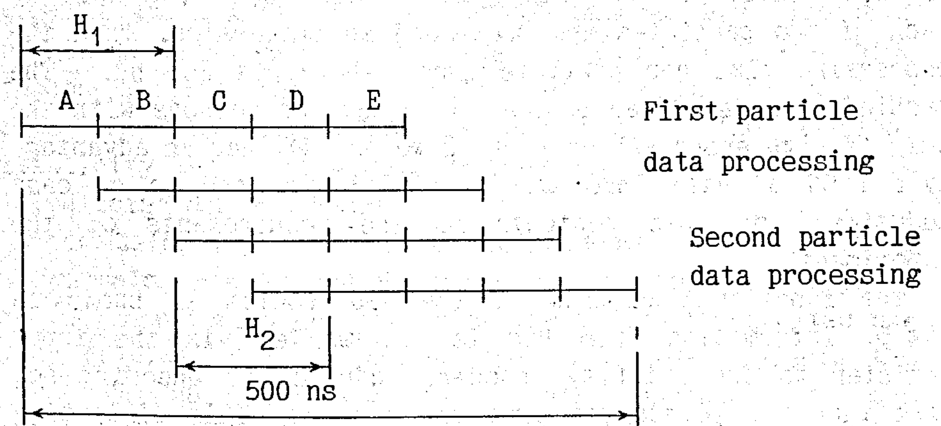
These delay times are for TTL ICs, while with ECL ICs they can be reduced by a factor of two.

b)Photodetector data processing electronics

PD data electronics measures radii of Cherenkov ring images R_x to compare them with expected R_π ,R_K ,R_p values, and counts PD cells excited by a particle to be identified. The number of counts is then compared with the expected number of photons N_π, N_K, N_p. Once the comparison gives the values within the given error limits, the trigger signal 'accept' develops. To reduce electronics cost the data on each of two particles are processed in succession. Then the processing time per particle must not exceed 250 ns. The problem formulated can be solved by tabular methods with the help of high speed RAM or PROM. However, RAM has an advantage over PROM of easy information substitution and so of easy adjustment of LUTs contents to the requirements of the experiment.

The functional diagram of the electronics is shown in fig.5. Information from PDs is transmitted via the input register to the priority encoders adjusted to encoding not more than two points per area of 16 cells. This limitation follows from the fact that the conditional probability for more than two points to appear on the area indicated is small enough. Programmable logic arrays are used as the priority encoders here. The code from the encoder is part of the LUT address, and the expected values for X_c, Y_c, the ring image center coordinates, form the other parts of the LUT address. So with the help of the table of 16K×5 one can determine the unknown radius R_x. The radius R_x obtained is compared within error limits to the ring image radius in LUT, expected for one of the particles. After that the signals from all the PD points excited by the given particle are added and the sum is compared to the expected number of photons radiated by the particle. The operation is accomplished in two steps. First, with the help of PROM, the number of '1' bits in position codes of radius reference LUTs are counted and the resultant codes are summed up by conventional adders. Secondly, either N_π, or N_K, or N_p value is subtracted from this sum and the result is compared to the allowed deviation from the real value of respective N.

For pipelining the data processing blocks are connected via registers. Let us calculate the total operation time of the trigger electronics on condition that the data on not more than two particles are processed and the number of excited PDs over 16 cells is also not more than two.



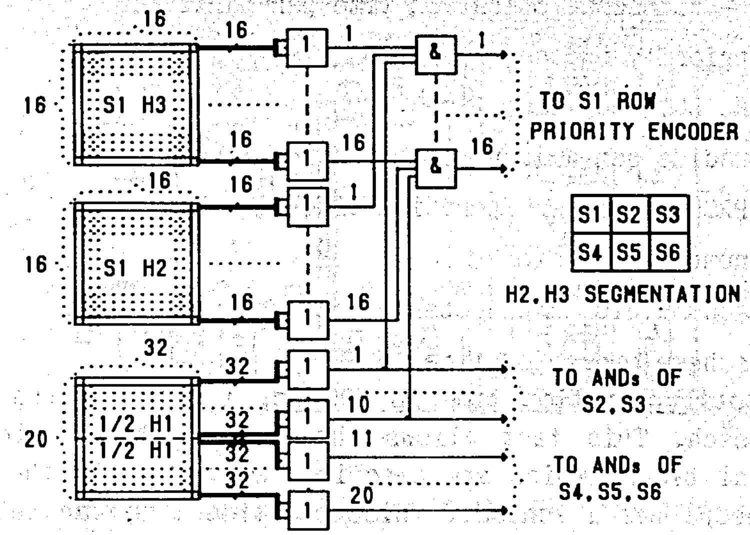


FIG.3. The hodoscope coincidence scheme.

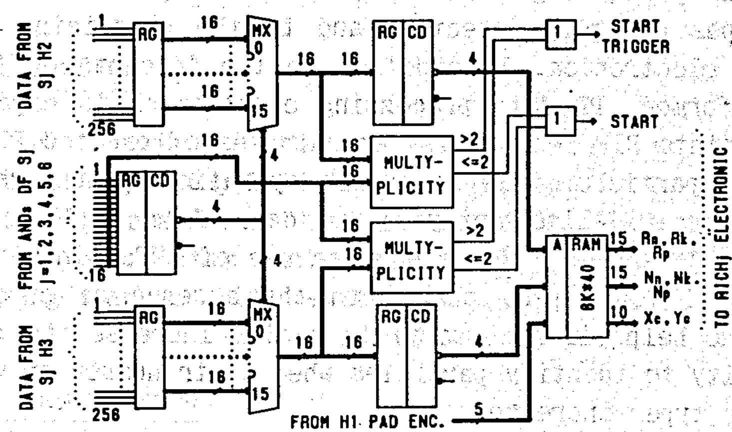


FIG.4. The encoders and LUTs of the hodoscopes.

H_1, H_2 - hodoscope operation time per particle

A - priority encoder operation time

B - R_X LUT operation time

C - radius comparison LUT operation time

D - PROM and adder operation time to calculate number of photons

E - accumulator and number of photons comparison scheme operation time

The total operation time is 500 ns, i.e. 8 intervals of ≈60 ns each. This fact allows the use of TTL ICs in the functional blocks which are described above. As in the case of hodoscope based schemes, this operation time can be made shorter by using ECL, but the electronics cost will be higher.

The task of designing the first level trigger for the RICH detector is rather easily fulfilled by the application of tabular methods, high operation speed being achieved by parallel processing of the signals from each row of hodoscopes and photodetectors and by the pipelining of the trigger electronics. In addition to the 'accept' or 'reset' signal formed, PD data processing electronics is capable of writing into FIFO memory the coordinates of excited PD cells for each particle. This makes the operation of a high level trigger or off-line analyses of data from full scale PD arrays more easier and faster. The use of LUTs minimizes the variety of PCB types, thanks to the absence of crossings. LUTs also help (if necessary) to easily increase the trigger capability to identify particles when their number or variety of their types increases.

The hardware can be considerably decreased, if the trigger is adjusted to the particle identification of one or two types only (Figs. 4,5 present the schemes for the identification of three types of particles).

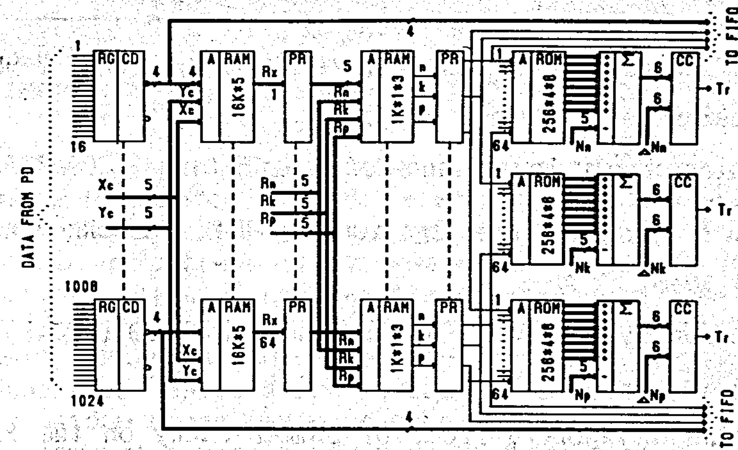


FIG.5. The functional diagram of the PD data processing electronics.

We think that this way of using the RICH-detectors is possible for the low level trigger (<1 μs) with good reliability.

Conclusion

In this article the method for the fast particle identification, using RICH-detectors in the low level trigger scheme, is proposed for the Multi-Particle Spectrometer UNK. We believe that this method can be applied to further in fixed-target and collider experiments.

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REFERENCES

1. DELPHI Technical Proposal, CERN/LEPC 83-3,LEPC/P2 (1983)

2. SLD Design Report (April 1984)

3. R.Meunier, Nucl. Instr. and Meth. A235 (1985) 290÷295.

4. Workshop Physical Investigations on UNK, Serpukhov. (1983) 43÷67.

5. L.Anderson et al., Nucl. Instr. and Meth. 223 (1984) 26÷39.

6. B.Cox and D.Wagoner, Proc. of Summer Study on the Physics of SSC 1986 (1986) 83.

7. P.H.Garbincious, Fix Target Beauty Physics Experimental Programs, FERMILAB-Conf.-88/39

8. SDC Expression of Interest. 24.5.1990.

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