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Proposal of muon trigger on the ATLAS end-cup region

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ABSTRACT

The use of scintillator hodoscopes to get time mark and high p_t triggering for end-cap muon system is proposed. The system of scintillator counters (SC) should cover the region of $1.5<|\eta|<3$ and consist of 4 SC planes installed before and behind the end-cap magnets. The total square of the system is $\approx$ 400 m^2, a mass of scintillator is $\approx$ 4 tones, the number of PMs is $\approx$ 1680. The expected time accuracy is $\leqslant$ 1 ns, p_t cut off is 10 GeV.

A possibility of new high rates Resistive Plate Chamber creation for the purposes of μ-triggering is under discussion.

A mixed SC & RPC triggering system is also proposed.

1. INTRODUCTION

It is known /1/ that the Resistive Plate Chambers (RPCs) /2/ are good candidates as trigger hodoscopes for muon triggering in the ATLAS/1/ are . These detectors have good time resolution (< 1ns), large response for m.i.p.(amplitude of signal > 100 mV/50 Omh), good space resolution (≈ few mm), possibility to work at strong magnetic fields (up to 2 Tl), low cost of materials and rather simple mass production technology. But the RPCs counting rate should not exceed 50-100 Hz/cm^2. Therefore, RPCs can not be used in the end-cap region at $|\eta| > 2$, where the muon fluxes exceed 100 Hz/cm^2.

In the end-cap region, at $1.5 < |\eta| < 3$, for muon triggering purposes we propose to install 4 hodoscopes of scintillating counters (SCs). These SCs hodoscopes give a possibility to have a good time resolution (< 1 ns) and cut-off muons with low p_t.

We also discusse our plans for developing a new type of RPCs with counting rate (> 1kHz/cm^2).

2. SCs END-CAP TRIGGERING SYSTEM

We propose to put SCs planes before and behind the end-cap magnet, as shown in Fig.1. The region covered by the SCs system would be $1.5< |\eta| <3$. Charged particles rates in this regions are /1/ : $< 10^2$Hz/cm^2 for $1.5<|\eta|<2$; $<10^3$Hz/cm^2 for $2<|\eta|<3$.

Estimated values of magnetic field in the points of PMs alignment do not exceed 0.3 Tl.

A crucial point in realization of this system is a necessity to work in strong magnetic fields, thus it needs to have a PM, working in these fields. At the moment there is only one industrial produced PM for that. It is Hamamatsu R2490-05 PM /3/. The cost of R2490-05 is 1600 US $ per unit. Thus the cost of the system is mainly due to the cost of PMs. Therefore we intend to develop a PM for strong magnetic field in russian industry. It should be cheaper (about 100 US $). Expected characteristics of this Russian PM are listed in Table 1. First prototype of high magnetic field immunity PM will be ready in July 1993.

Table 1. Expected characteristics of the Russian PMs, for high magnetic environments.

Current amplification -	$3*10^6$ (0 kG);
	$1*10^6$ (5 kG);
	$1*10^5$ (10 kG);
Rise time -	3 ns;
Pulse width -	8ns;
Transit time -	15ns;
Quantum efficiency at 410 nm -	20%;
Tube diameter -	36 mm.

To receive effective p_t-trigger we propose to use two highly segmented scintillator planes installed before and behind the end-cup magnet. Proposed for $p_t > 10$ Gev segmentation is shown in Fig 2 (a,b). In this case the counters inefficiency due to particle fluxes and counter dead time would be much smaller than 1%.

For a radius less than 4m a construction of SCs is shown in Fig. 3 (a). For a larger radius another construction of SCs can be designed and is shown in Fig. 3(b). The difference between two versions of SCs is due to a limited light attenuation length of the scintillators and large areas of outer SCs.

The counters are made from polystyrene based scintillators. As WLS we plan to use PMMA based shifters with a attenuation length better than 3m. The thickness of SCs is varying from 5mm for inner counters up to 25mm for outer counters. The minimal number of photo-electrons should be not less than 10. The total area of the trigger system, covered by SCs is ≈ 400 m^2, a mass of scintillator being ≈ 4 tons, and the number of PMs benig ≈ 1680.

Due to light registration from both ends of the SCs it is possible to compensate time dependence of the trigger signal from a place of a particle passing and to have reasonable resolution.

Functional scheme of the trigger signal shaping is shown in Fig. 4. A signal from the PM is amplified to a necessary level and then passes through the constant fraction shaper (CFS) which shapes it with the time position independent from the input signal amplitude. After the CFS pulses from both ends of the counter pass to the mean-timer scheme (MT), which form a trigger signal proportional to $(t_1+t_2)/2$, where t_1 and t_2 are light propagation times from emission points to PMs.

Taking into account expected parameters of the SCs designs (light emission time for the scintillator and the WLS, the PM pulse rising time 3 ns and minimal number of photo-electrons-10) we can reach the time accuracy about 1 ns (sigma).

These expectations are confirmed by our experience with the trigger scintillating system of the Target Neutrino Facility in IHEP /4/. Obtained characteristics are 2 ns time accuracy, 98% efficiency with the average number of photo-electrons about 5 for PMMA scintillator and the slow PMs with the rising time of about 10 ns.

Dead time for the proposed counter design can be defined as follows:

$$T_{dt} = T_{pl} + T_{le} + T_{pmt} + T_s,$$

where:

$T_{pl}\approx 10$ns is maximal light propagation time, $T_{le}\approx 5$ns is emission time for scintillator and WLS ($T_{le}\approx$ 3 ns for scintillator only), $T_{pmt}\approx 10$ns is PM pulse width, $T_s\approx 15$ns is dead time for a shaper.

Thus we can expect $T_{dt} \approx$ 40 ns. If we want to have occupancy less than 1%, the rate of the SC should be less than $2.5*10^5/S$ (Hz/m^2).

The p_t-trigger logic is rather simple. A hit in the first plane counter defines a window on the second plane, centred on the extrapolation of the first hit line interaction point. The width of this window defines the trigger momentum cut-off. This logic can be easily implemented with a system of coincidences between the two scintillating planes.

3. MIXED SC & RPC END-CAP TRIGGERING SYSTEM

In our opinion a more attractive version is a combination of RPCs and SCs in the end-cap trigger system, where RPCs will work in the region with rather small particle fluxes $\leqslant 10^2$ Hz/cm^2 ($1.5<|\eta|<2$) and SCs will work in region where particle rates are $\geqslant 10^2$ Hz/cm^2 ($2<|\eta|<3$). In this case the number of SCs channels are decreased by a factor of 1.5.

4. DEVELOPMENT OF RESISTIVE PLATE CHAMBER

Methodical investigation of a prototype of inexpensive RPC with the counting rate of $\geqslant$ 1kHz/cm^2 was started in June 92.

The counter prototype we built has a sensitive area of 120×120mm^2 and consists of two parallel plate resistive electrodes, connected to the high voltage supply, between which argon-isobutane (60% Ar in volume) gas mixture at ordinary pressure is filled. The gas gap was 2mm. The signals are read out by copper strips which are 10mm in width and 11mm in pitch. For resistive electrodes the commercial available material bakelit, having a bulk resistivity $\rho=10^{11}\Omega *$cm and dielectric constant $\varepsilon=3$, was utilized.

The counter was tested with cosmic rays and radiactive sources Cs^{137} and Ru^{106}. The main results obtained for our RPC are next: time resolution 2ns; pulse amplitude 200mV/50Ω, maximum counting rate (at efficiency 90%) 50Hz/cm^2, noise 0.1Hz/cm^2, efficiency plateau 95% start at 8.5 kV high voltage at discriminator threshold 50mV.

Our results are in coincidence with results of other RPC groups /2/, where the maximum counting rate 100Hz/cm^2 was reached. Certainly, these counting rates are not so high to use this RPC type for the end-cap trigger system at $|\eta|>2$.

The counting rate (N) is mainly due to the values of bulk resistivity (ρ) and the dielectric constant (ε): $N\sim 1/\rho\varepsilon s_0$, s_0 is the discharge dead area on the resistive electrode surfaces ($\sim$15mm^2). To have high counting rate as seen from this expression it is necessary to decrease the ρ value.

Now we have some material samples with low bulk resistivity $\rho=0.5*10^9\Omega*$cm and start investigations of a possibility to use this material for new high rate RPC.

At present from our experience with the RPC we do not see any phisical reasons to realize high rate RPC with N~ 1kHz/cm^2.

5. COST ESTIMATION

Roughly estimated cost of the proposed system may be found in table 2.

TABLE 2. **Cost estimations (end-cap SC hodoscopes).**

item	price for unit(US $)	amount	total cost (US $)
polystyrene	10^4/tonn	4 ton	40000
shifter	5/m	400 m	2000
PM*	100/unit	1680 unit	170000
electronics	20/chan.	1680 chan.	34000

Total sum is 246 US k$.

*In case of the HAMAMATSU R2490-05 PM usage the total sum is about 2.7 US M$.

In the case of RPCs usage only total cost is about 65 US k$. In mixed version (SCs and RPCs) the total cost is about 200 US K$.

6. R & D PLANS

We see our R & D plans as follows:

1) Development prototype of russian PM
   for high magnetic field environments -..............July 93.
2) Test of scintillators and WLS -....................March 93.
3) Test of full scale scintillating counter
   modules with magnetic field immunity PMs -.....September 93.
4) Development of new materials for high
   (>1 kHz/cm^2) counting rate RPCs -....................May 93.
5) Investigations of gas mixtures for high
   rate RPCs -..June 93.
6) Test of RPC prototype with rates $\geqslant 1$ kHz/cm^2 -......July 93.

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3) Hamamatsu catalog of photo multiplier tubes,Japan,1988.

4) V.V.Ammosov et.al.,"Characteristics of Prepared from Polystyrene Scintillator Manufactured in LHE,JINR", preprint JINR 13-88-779,Dubna,1988.
V.V.Ammosov et.al.,"Characteristics of Large Polystyrene Counters",preprint IHEP 89-210,Protvino,1989.
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FIGURE CAPTIONS.

Fig.1 Conceptual scintillating hodoscopes layout in the end-cap region.

Fig.2 Segmentation of the scintillating planes :

a) before end-cap magnet;

b) behind end-cap magnet.

Fig.3 Proposed design of scintillating counter:

a) with polystyrene light guides (for radius < 4m);

b) with WLS (for radius > 4m).

Fig.4 Functional scheme for the trigger signal formation.

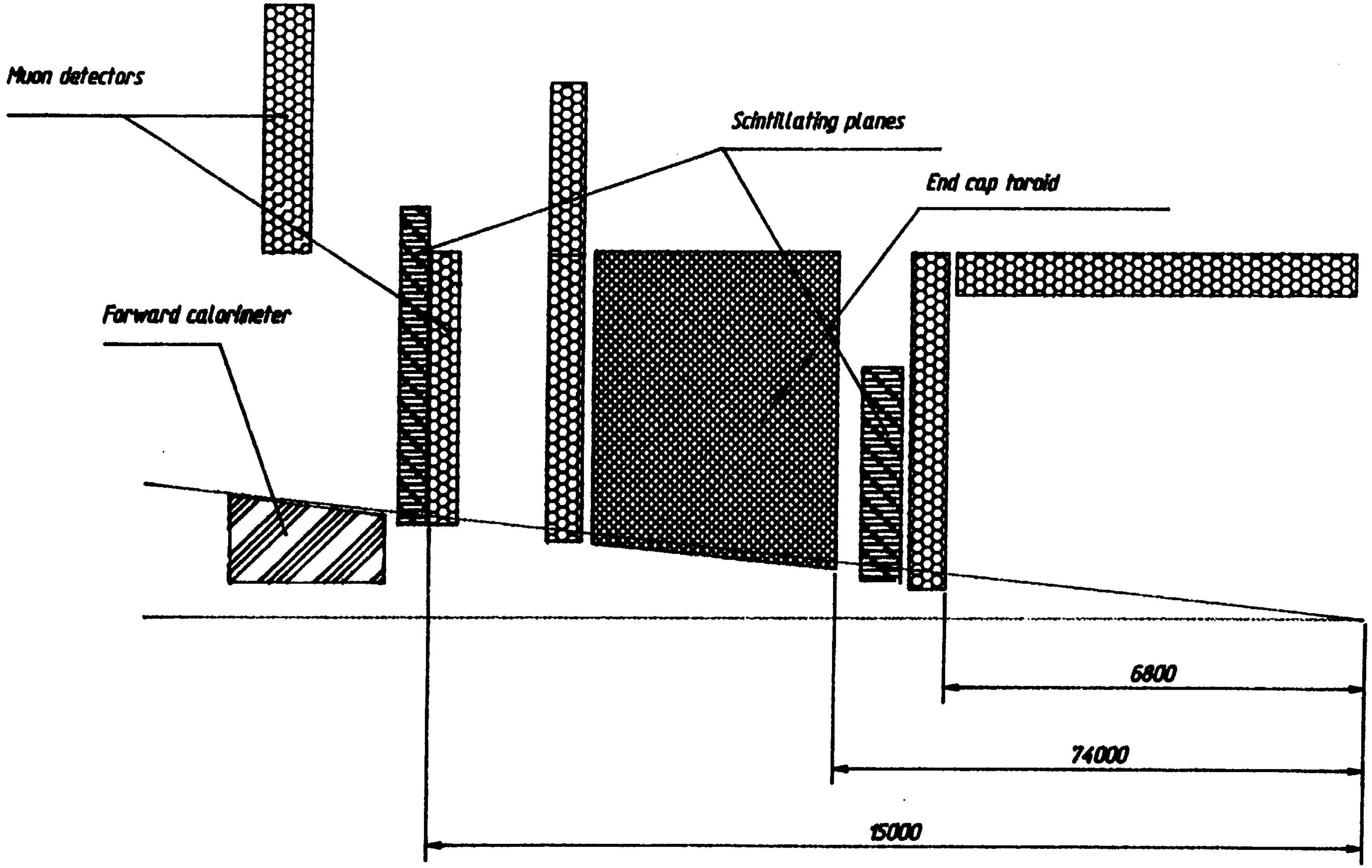


Fig. 1. Conceptual scintillating hodoscopes layout in the end - cup region

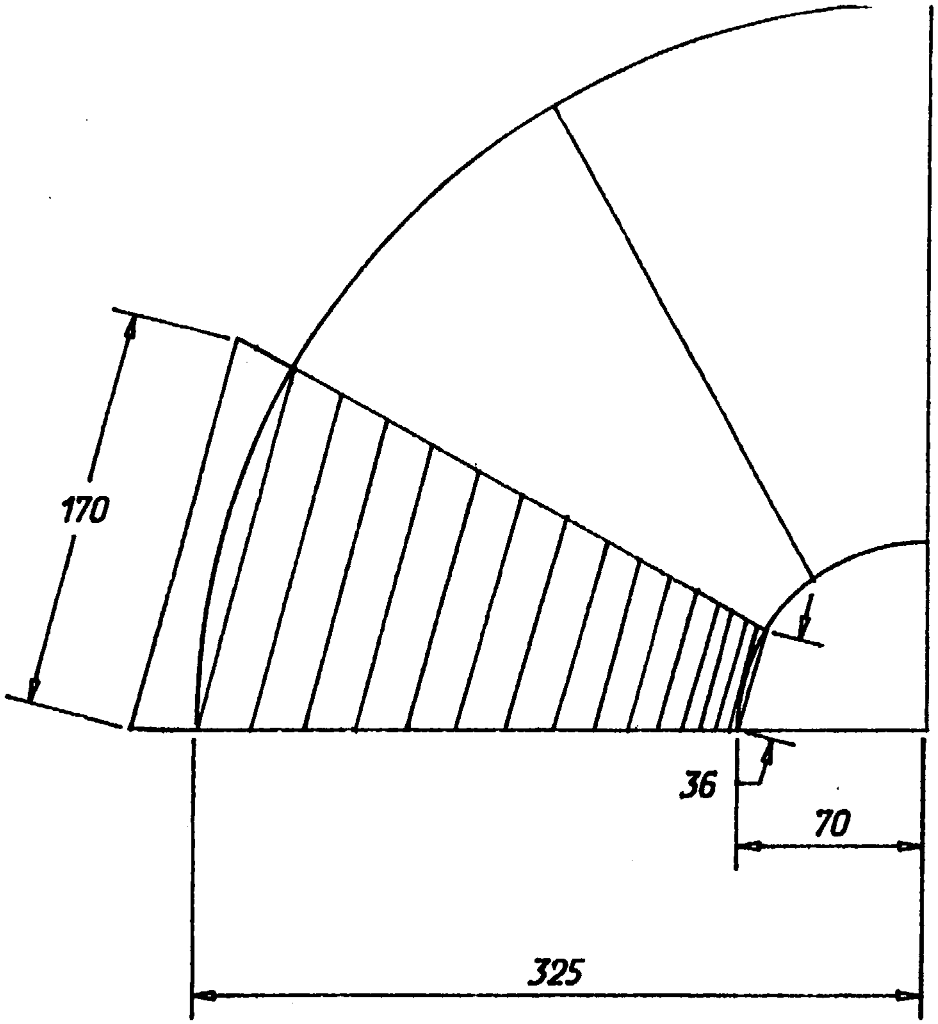
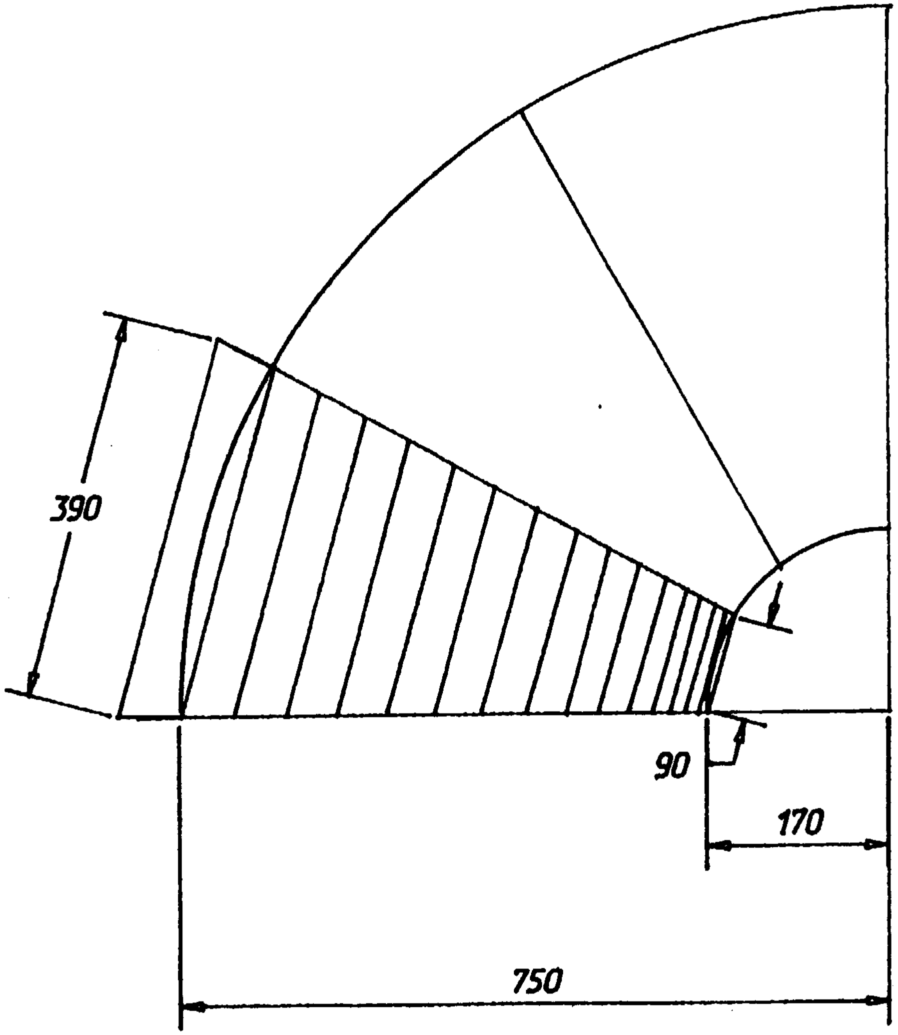


Fig. 2a. Segmentation of the scintillating plane before end - cup magnet (plane 1)

$S_1 = 5$ cm
$S_i = S_{i-1} + 1$ cm
$i = 2 - 10$
$S_j = S_{j-1} + 2$ cm
$j = 11 - 17$

S_i is width of i-th counter



$S_1 = 12$ cm
$S_i = S_{i-1} + 2$ cm
$i = 2 - 10$
$S_j = S_{j-1} + 5$ cm
$j = 11 - 15$
$S_k = 50$ cm
$k = 15 - 18$

S_i is width of i-th counter

Fig. 2b. Segmentation of the scintillating planes behind end - cup magnet (plane 2)

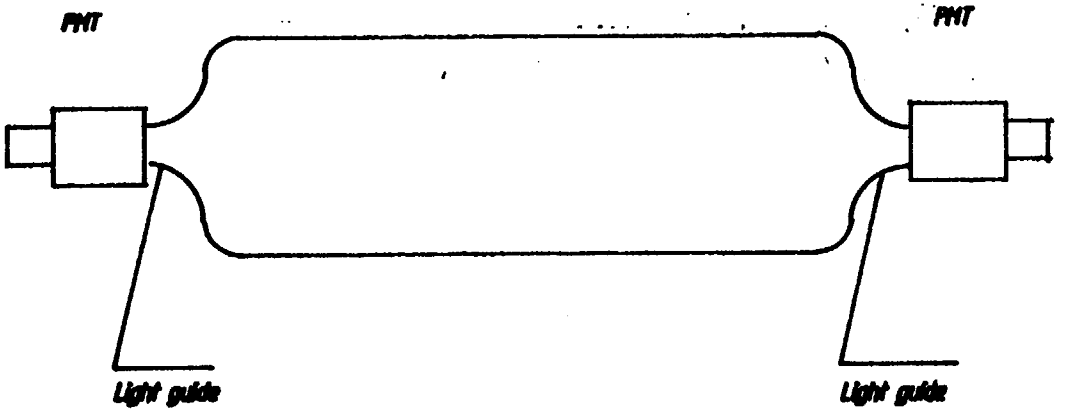


Fig. 3a. Construction of scintillating counter for planes 1 and 2 with numbers 1 - 10

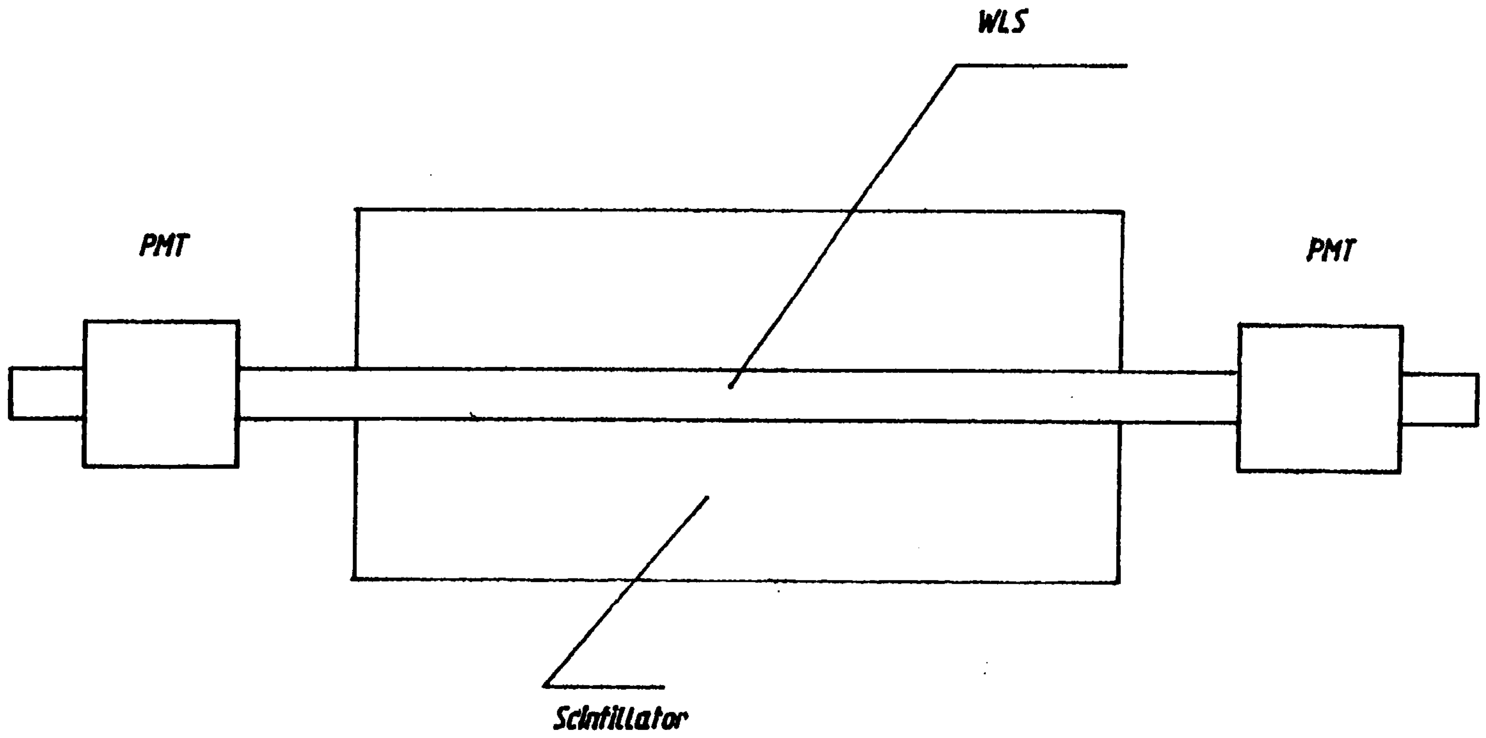


Fig. 3b. Construction of scintillating counter for plane 2 with numbers 11 - 17

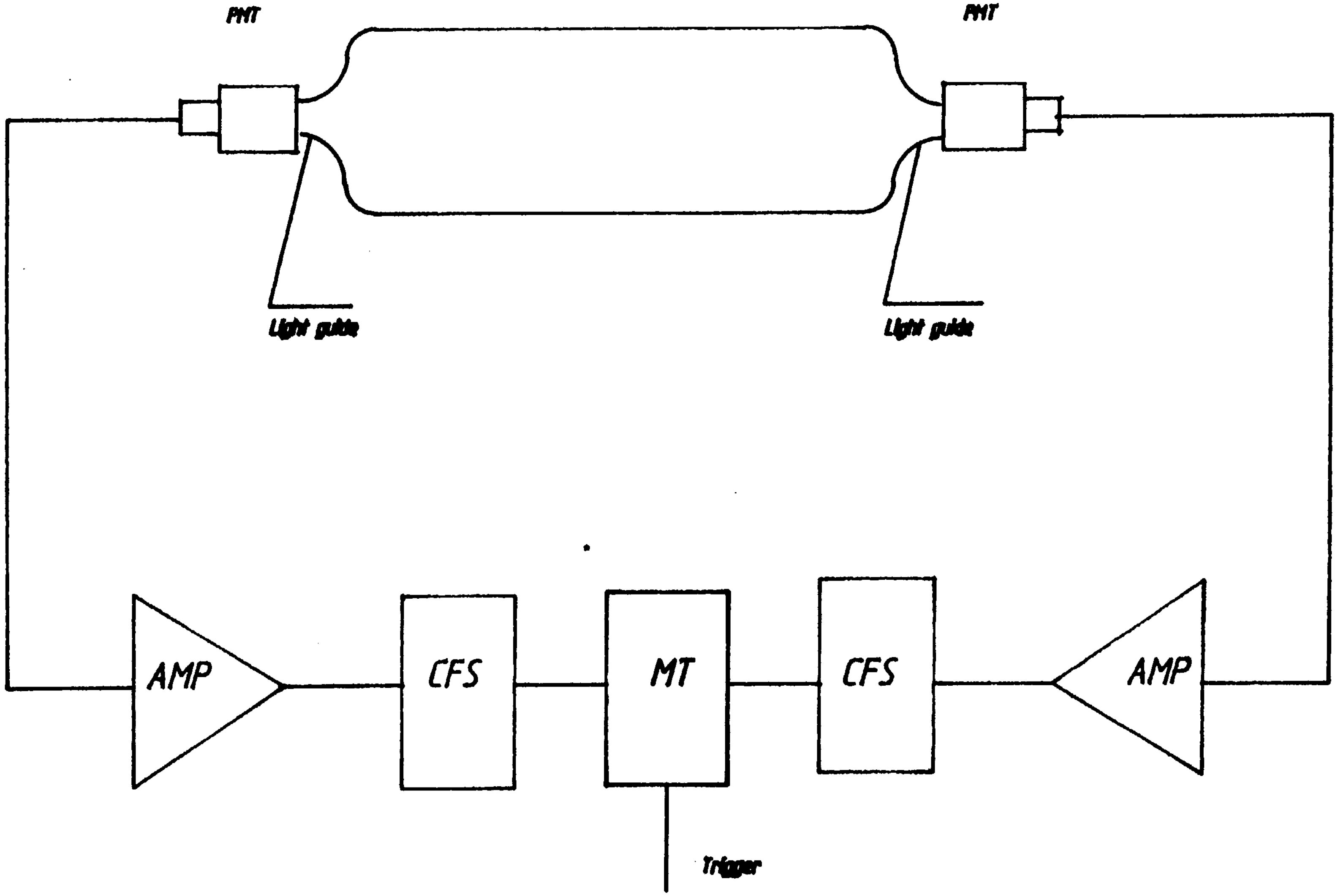


Fig. 4. Functional scheme for trigger signal formation.