CDR

Auxiliary Plane

for

The Triple Coincidence Experiment with Big Bite

UPDATE: September 2001

1 Introduction

We present a CDR for the Auxiliary Scintillators Plane. We already started the purchase and manufacture process as be presented in the document.

2 Conceptual design

2.1 PMs

The design is based on Hamamatsu -R1450, which is a 10 stage linear focused tube. The gain is $5 * 10^6$, the QE 28% at 420nm, the rise time is 1.8ns, and the transit-time spread 0.76ns. The Glasgow group have 92 in total with bases (E974-11,3C) and mu-metal that were used as part of the focal plane detector of the old Glasgow 180 MeV photon tagger at Mainz. See figure 1. The bases chain is configured for high rate. The last 3 stages are zener-dyode stabilized. The detectors have been run at 5 MHz. We think we could get enough of these PMs in good condition for the front plane.

We got two of these tubes to Tel Aviv for a check. With 350x24x2 mm^3 detector and 10 cm long trapezian (24 to 16 mm) light guide we measured triple/double coincidence ratio of 97%. We also verify that with a 140 Gauss magnetic field and the proposed magnetic shield (see 2.4), there is no observable effect on the gain.

We expect the rest of the tubes to arrive to Tel Aviv from Mainz. We will check them individually and select the required number of tubes plus spars.

2.2 Scintillators

The dominant consideration which determines the size/number of scintillators in the auxiliary plane is the singles rates. Our current estimate is about 5-10 MHz for the full acceptance. With the current design of about 60 counters we expect an average rate of about 100-150 kHz per counter.

Based on the GEANT simulations study by John R.M. Annand (*http://hallaweb.jlab.org/equipment/BigBite/*) and appendix A to this report, it is clear that with about 60 counters the time of flight / momentum resolutions are limited by the size/number of E /DE counters and not the auxiliary plane counters.

Based on tests that were done at TJNAF by Guy Ron (a summer student) and Bogdan Wojtsekhowski (*http://hallaweb.jlab.org/equipment/BigBite/*) and confirmed by tests at Tel Aviv University, 2 mm counters with a single PM on one side give good results with just a couple of MeV electrons and cosmic ray muons, which produced less light than expected from the (250-600 MeV/c) protons we wish to detect. The simulations discussed above also show that counter thickness of 2 mm will not affect the momentum resolution, appreciably.

The active area we wish to cover is 1400x350 mm^2 (Doug). Therefore the size of the 56 proposed scintillators is : 350 x 24 x 2. We will allow a 1 mm gap between counters. The material is EJ-204, cut and diamond milled by ELJEN Technology. See the enclosed figure 2. We already ordered the scintillators.

2.3 Light guides

about 85 x (24 to 18) x 6 mm^3 trapezian light guides. The scintillator (2 mm) is glued to a grove in the center of the light guide face. The light guides will be glued (with or without 2mm disk) to the PM. The material proposed is BC-800/BICRON. See figure 2. We have the material at hand.

2.4 Magnetic shielding

The expected field is roughly 0.2 kG (Doug/LeRose) in the tube axis direction. The current design is based on individual soft iron cylinders of external diameter 42mm and internal diameter of 32mm. $R_{in}/R_{out} = 0.76$ and the shield is extended more than two external radii beyond the photo cathode plane. We also use an inner mu-metal 0.8 mm thick, 95 mm long, with external diameter of 24.7 mm (see figure 1).

The iron and the mu metal leaved a residual field below the tube sensitivity threshold. With a selonoid that produce an axial filed of about 140 Gauss and a scope we could not see a change in the gain of an LED line.

About 2-3 mm on the low part of the iron cylinders will be shaved off to enable to attached them to a common plate. Several iron cylindrical shields will be mounted on the same plate. The plates will be mounted on the frame using mounting screws. The iron cylinders will also be used to mechanically fix in place the scintillator-PM assemblies. See Figure 3.

2.5 Mechanical design

The array of scintillators will be assembled on a self supporting frame that can be lifted by a crane and mounted on the detector structure, which will be designed by TJNAF. The frame design is shown in Figures 4. It has already been purchased. The array will be mounted on it by the Tel Aviv Univ. machine shop. It will be then dismounted and be shipped to TJNAF.

2.6 Internal cables

There will be two high voltage/signal patch panels along the two long sides of the frame. The HV original Jack plug (see figure 1) will be connected to a standard HSV connector. The lemo input to a BNC output connectors will be used for the signals. The arrangement will allow to pull out a detector-PM assembly that needs to be replaced.

2.7 Electronics

We plan to use the same electronics as used for the trigger scintillators. See the " BigBite trigger specification and costing" report for details.

2.8 Comment

Changes in the sizes and the exact shapes of the components are possible during the purchase and manufacturing process.

3 Cost estimate

Status is marked as follows: [0]-already purchased, [1]- price quotation and delivery time is available, [2]-estimate. All prices are in USD.

1. prototyping of counters - 3k [status:0]
2. Scintillators and light guides - 7 k [status:0]
3. construction of the frame - 2k [status:0]
4. Mechanical design and construction of the plane - 4k [status:2]
5. patch panel on the counter 70 HSV 70 BNC - 2k [status:2]
6. shipping/insurance etc. - 5k [status:2]

.... subtotal (items 1-6) 25k

8. cables and panels to signal and HV (detctor-area)- ???
9. cables and panels to signal and HV (area-counting house)- ???
10. HV cards 6x LeCroy 1461 (12 ch) - 11.5k
11. pulse splitters and delay box - 4k
12. discriminators 4 x LeCroy 3412 (16 ch.) - ???
13. common gates (64 ch.) STR136D -4.5k
14. or unit (64 ch.) LeCroy 4564 - ?
15. TDC 2 x CAEN VME775 (32 ch.) - 8.5k
16. QDC 2 x CAEN VME792 (32 ch.) - 6k
17. lemo cables 1-16ns length - ?
18. He bag between plane - 2k

.....................................The total is about 100k dollars.

Tel Aviv University has available the total fund required for items 1-6 of this project. We plan to build the Auxiliary Plane at Tel Aviv and ship it to TJNAF.

4 proposed schedule

preliminary review at TJNAF - July 2001.

end of design/approval by TJNAF - 31 Aug. 2001 purchase of materials - 1 Sep -1 Nov. 2001

machine shop and constructions - until 31 Dec. 2001

ressambled of the detector at TJNAF - Feb 2002

BigBite commission and one measurement of a triple coincidence - summer 2002

5 Appendix A: MC studies of BigBite momentum resolution without MWPCs.

John R.M. Annand and D. Hamilton used a Geant-4 simulation to calculate the resolution of the momentum reconstruction on the basis of the scintillator position information only.

The current report uses the position information as well as the measured TOFs to estimate the momentum resolution expected with the planned auxiliary and trigger scintillator planes only (no MWPCs). The calculation was done using the Geant-3 simulation, courtesy of Vladimir Nelyubin.

The assumptions for the simulation and the analysis are as follows:

- Auxiliary plane at the EFB with active area 350x1400 mm^3 covered by 64 elements. The scintillator thickness is 2 mm.
- Trigger plane parallel to the auxiliary plane at a distance of 98 cm upstream with 32 elements, according to the Glasgow design.
- The momentum reconstruction based on the fired scintillors was done using the parameterization developed by Vladimir Nelyubin.
- The time spread for the trigger plane (2 PMs) is a Gaussian distribution with $\sigma = 150ps$
- The time spread for the auxiliary plane (1PM) is a Gaussian distribution with $\sigma = 1ns$.
- For calculating the TOF from the target (TGT) to the trigger plane we assumed that we can refer to a "start time" signal obtained from the electron spectrometer with a time spread described by a Gaussian distribution with $\sigma = 1ns$.

The momentum reconstruction on the basis of the scintillator position information only is shown in figure 5 and 6 for incident protons with momentum 300 $\pm$10 and 500 $\pm$10 MeV/c, respectively. In general, the conclusion of the preliminary report by John R.M. Annand is confirmed. Based only on the scintillator hit position, the resolution is about $\pm$20%. This is already acceptable for achieving the goal of the SRC proposal to identify a correlated pair since one expects an up to about 100 MeV/c spread due to the pair cm motion. We can do better if we use the TOF information, in addition.

The plot labeled " TOF 0-1" is the momentum calculated based on the TOF between the auxiliary (0) and the trigger planes (2). The path was calculated between the centers of the fired counters.

The plot labeled " TOF tgt-2" is the momentum calculated based on the TOF between the target and the "E" trigger plane (2). To calculate this quantity we used the hit positions to calculate the path length from the target to the plane. The path length as a function of nf-nb is shown in fig 7. We used a very simple parameterization for this path:

for nf-nb<7 linear fit: 302.-1.727(nf-nb) cm,

for nf-nb>7 constant: 290. cm.

Since this is the dominant component for the resolution, we also show in Figs. 5 and 6 the expected momentum resolution if the reference signal (from the electron spectrometer) would be 0.5 ns -better then presently available, but not unachievable.

Conclusions:

With the current design the momentum resolution using the scintillator position information only is about $\pm 20\%$. This can be improved substantially by doubling the space resolution of the trigger scintillators. In Fig 8 we show how that can be achieved by splitting the DE counters with no need to add extra PMs.

The use of TOF can improve the resolution by about a factor of two. Assuming we can get a reference time from the electron HRS with a resolution of 1ns it will improve the momentum resolution to $\pm 10\%$. A 0.5 ns will make it $\pm 5\%$.

The identification of the correlated pairs can be done even with the scintillator position information only (better than $\pm$ 100 MeV/c). Better resolution (better than $\pm$ 50 MeV/c) can help and can be obtained by using the TOF information and/or doubling the number of bins in the trigger plane as proposed.

6 Appendix B: Double hits in the spectrometer

In the last meeting at TJNAF Bogdan raised the question of the ambiguity caused by two particles in the spectrometer. The singles rates are high 5-10 MHz and two particles in the same event might cause a problem. See figure 9.

We start by a rough estimate for the probability of such double hits in the spectrometer. The TOF between the two scintillator planes for protons of 250 MeV/c - 600 MeV/c are 7-15 ns. With the time spread in the scintillators and the time resolution one can define a time window of 10 ns in which all relevant particles should appear. With a total singles rates of 10 MHz the probability for double hits is :

$10ns * 10^7 = 10\%$.

Figure 10(up) shows a simulated correlation between a scintillator in the front (nf) and the trigger scintillator (nb) for protons of 250-500 MeV/c. It is clear that for each one of the trigger plane units only 10-20 of the 64 front counters can be associated with a particle of interest. Figure 10(down) shows the relation between the front (nf) and the trigger scintillator (nb) in case of a a random connection between the two. This plot was obtained by mixing the hit in the front with the hit in the back from the next simulated event as well as the hit in the back from each event with the hit in the front of the next event. It is clear that the correlation observed for a "legitimate" particle is lost. Using MC we estimate that the probability of a random legitimate pair being produced is only 25 %. That reduces the relevant random coincidence rate of concern to less than 3 %. There are probably more options to identify the "real" particles from the random partners using the correlation between the TOF and the hit pattern. This can be studied further with the MC simulation, but it has not been done at this point. Even if we will have to abandon all the 3 % double hits, it will only be a minor effect.

7 Appendix C: Price quotations

7.1 Scintillators

75 counters 350 x 24 x 2 mm^3
EJ-204 cut and diamond milled by ELJEN Technology
$45 * 75 * 1.21 = 4,100 dollars$
lead time: 6-8 weeks

7.2 Light guide

3000 dollars (estimate).

7.3 Magnetic Shield

Ultra low carbon steel 37.3 mm ID, 50 mm OD, 275 mm long
$(81 * 70 + 3940) * 1.21 = 11,625 dollars$
lead time: 10 weeks
(We plan to use a simple soft iron metal.)

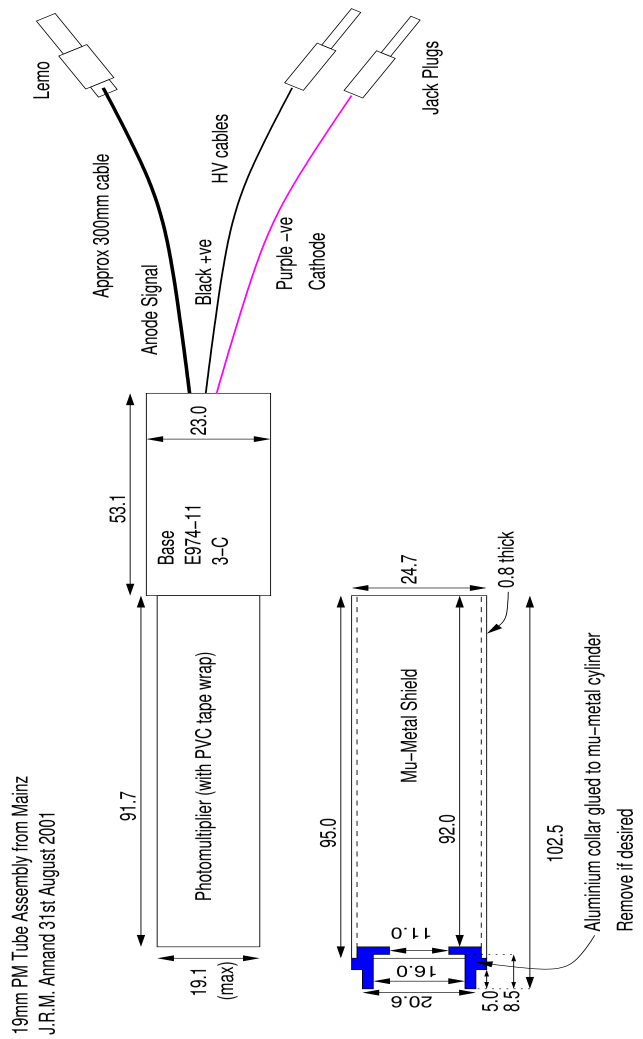

Figure 1: 19 mm PM assembly from Mainz. The original aluminium collar will be removed. The mu-metal will be pulled about 15 mm upstream the tube window and about 50 mm downstream the iron pipe.

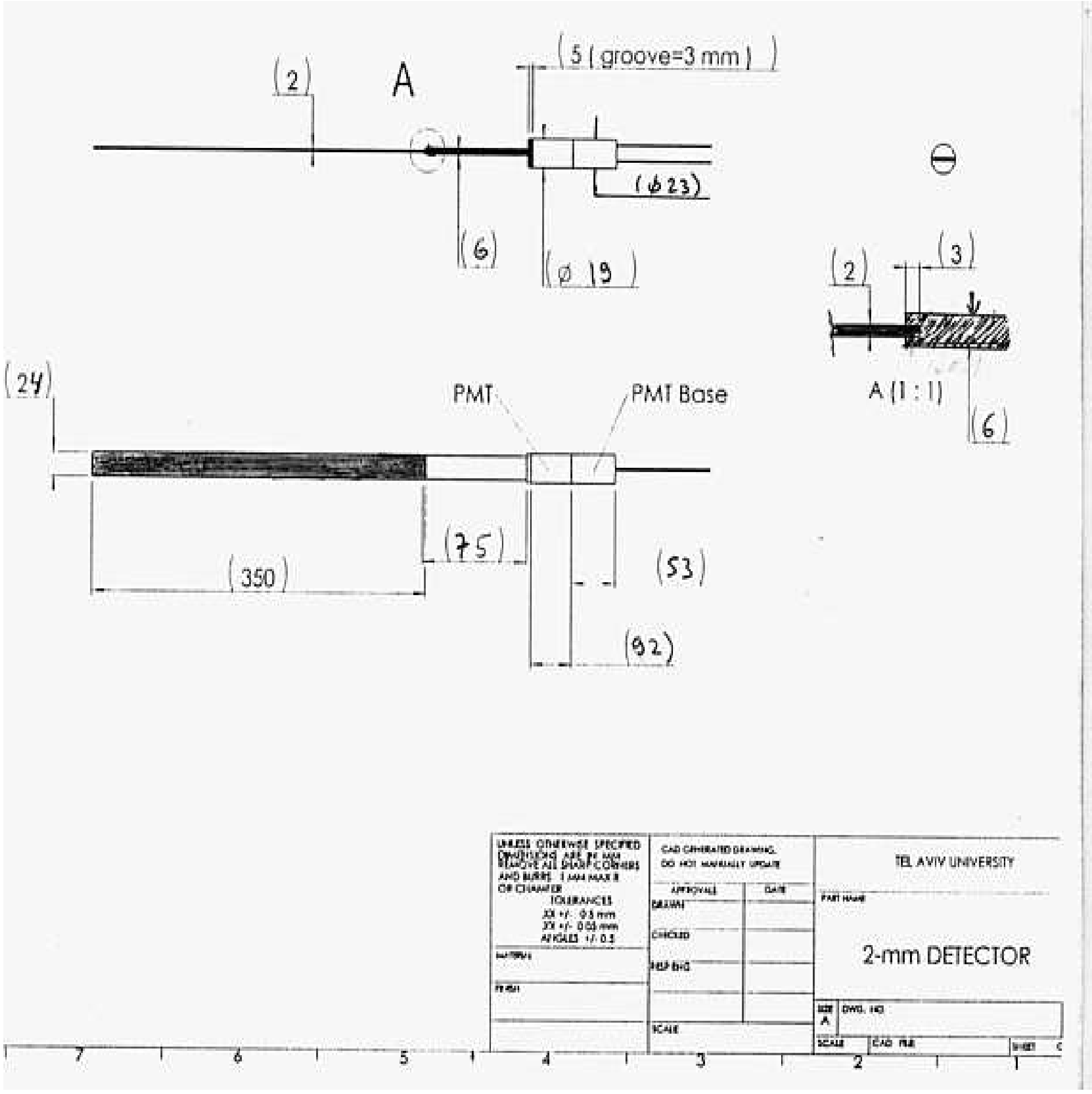

Figure 2: A single counter design: scintillator,light guide,PM.

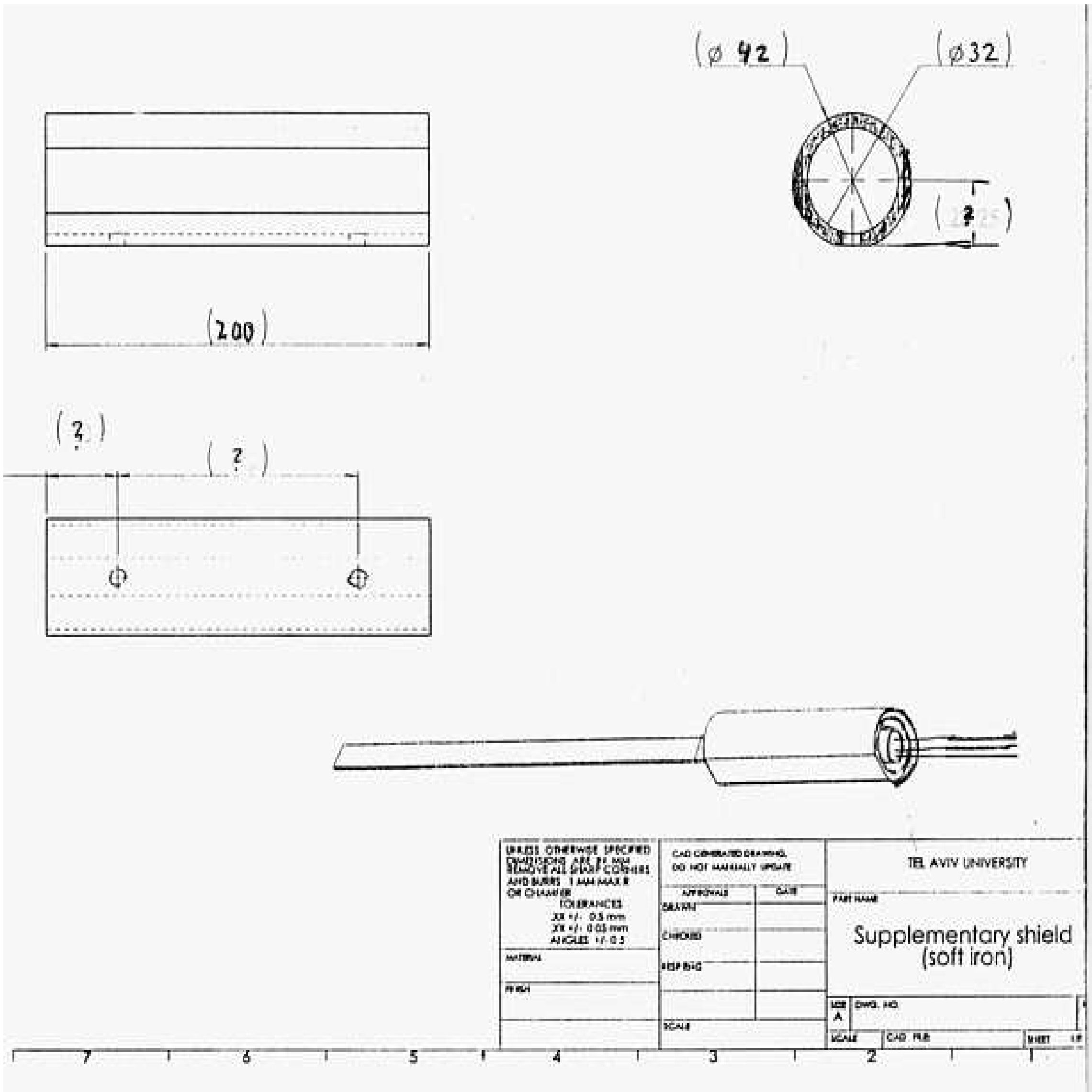

Figure 3: The iron cylinders used for magnetic shielding and to mechanically hold the scintillator-PM assembly.

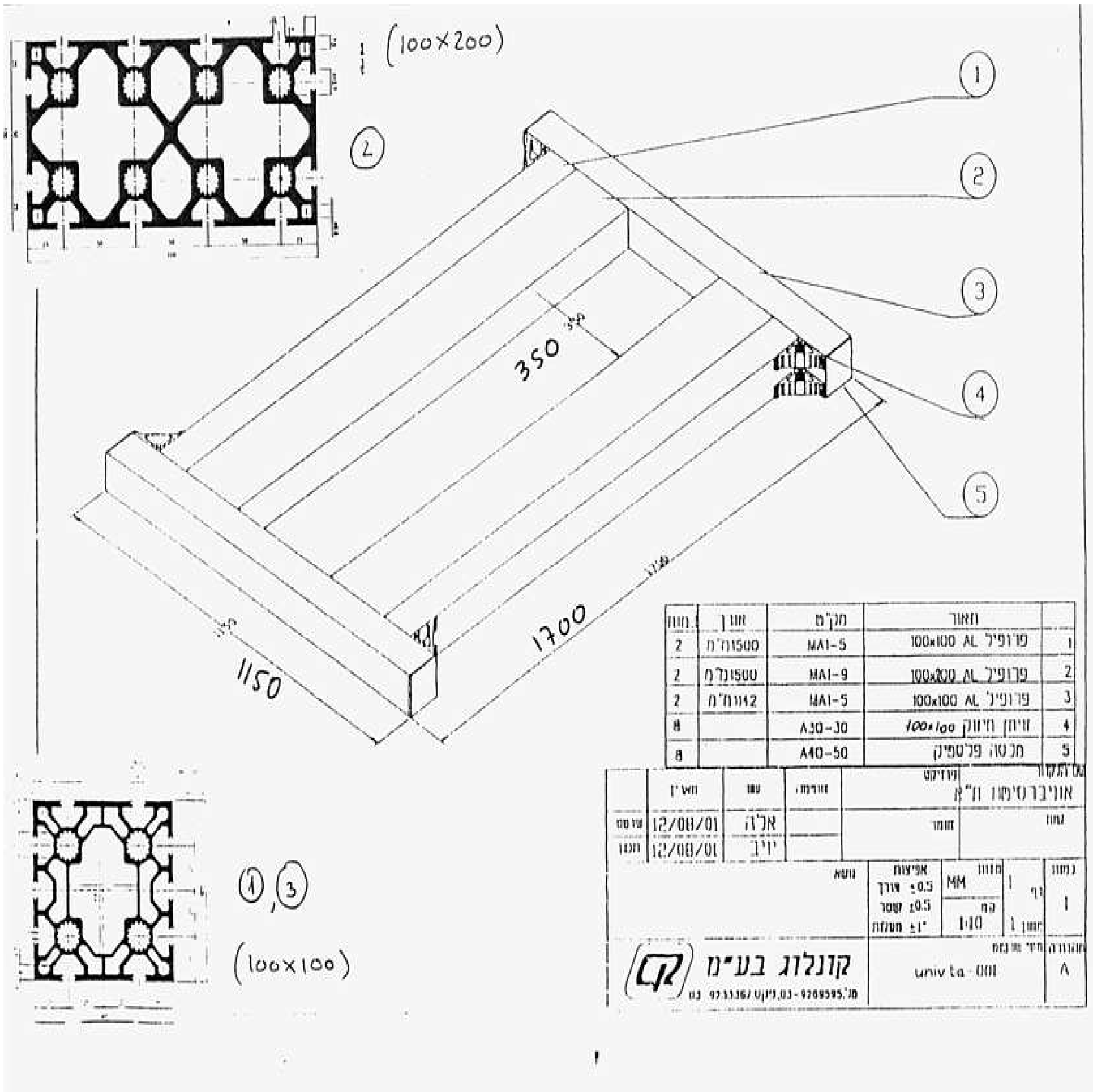

Figure 4: The frame design.

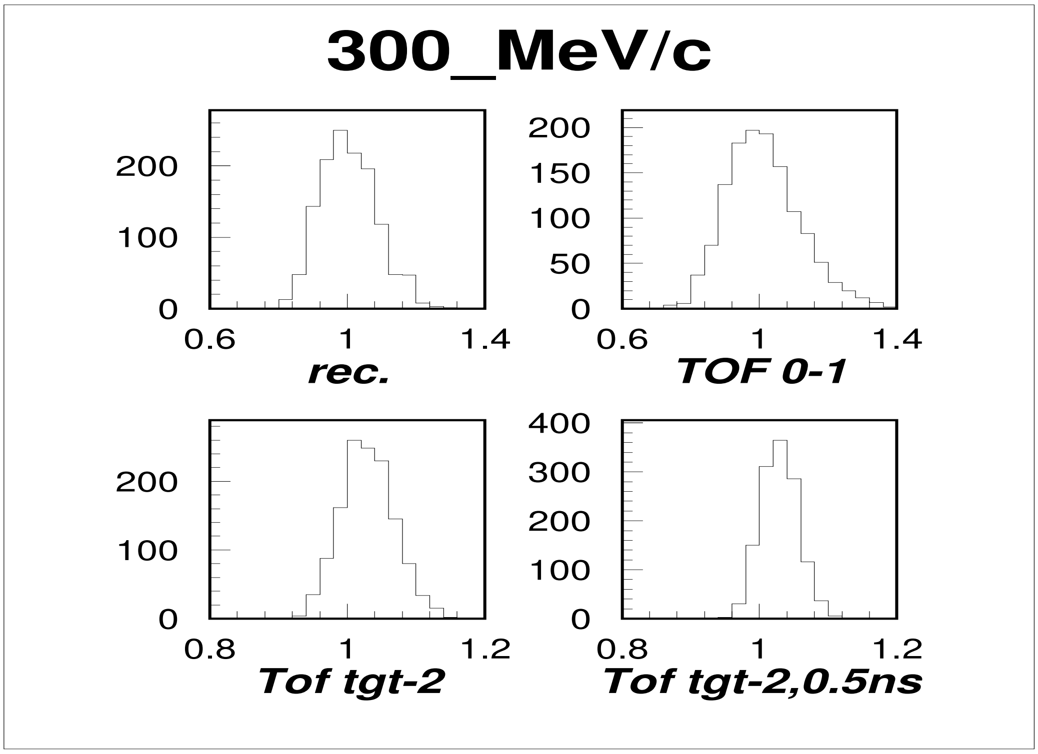

Figure 5: Measured momentum by counter hits only (rec), TOF between the front(0) and the back (2) planes (TOF 0-1)and the TOF between the TGT and the second plane (TOF tgt-2) for 1 ns and 0.5 ns resolutions. The incident particles are protons with 300 $\pm$ 10 MeV/c.

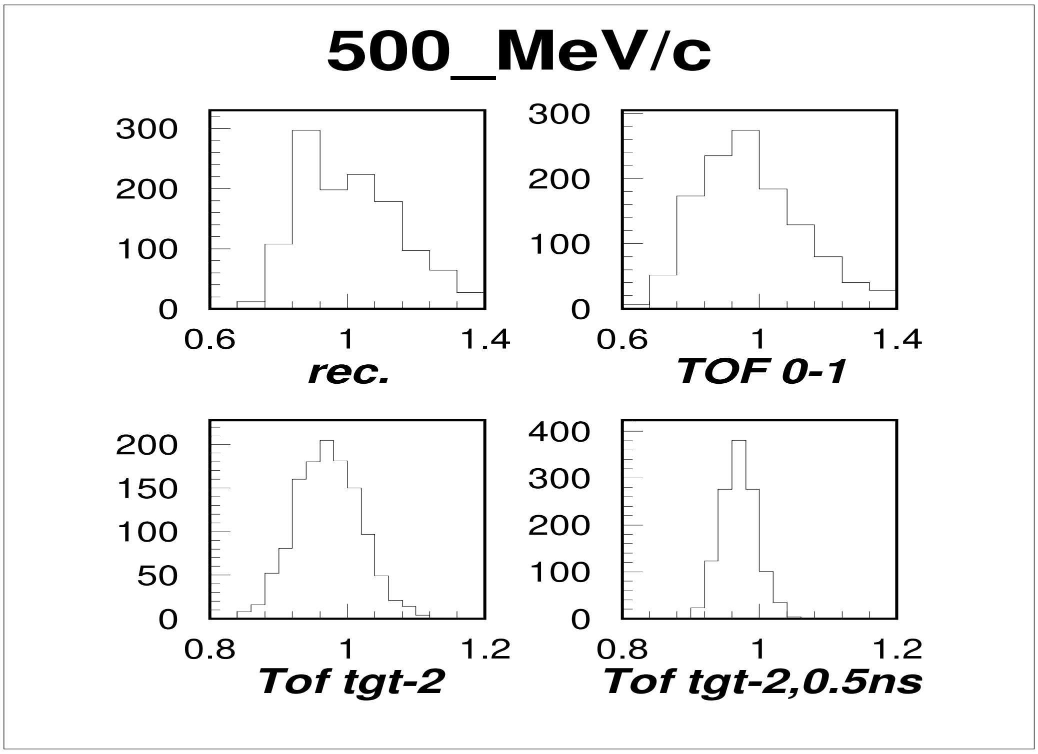

Figure 6: Same as the previous figure but for incident protons with 500 $\pm$ 10 MeV/c.

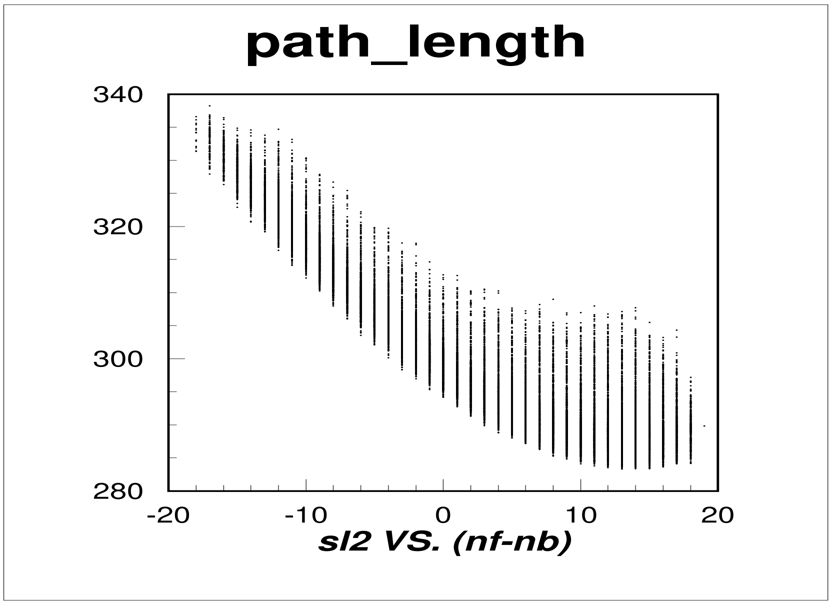

Figure 7: Path length versus nf-nb.

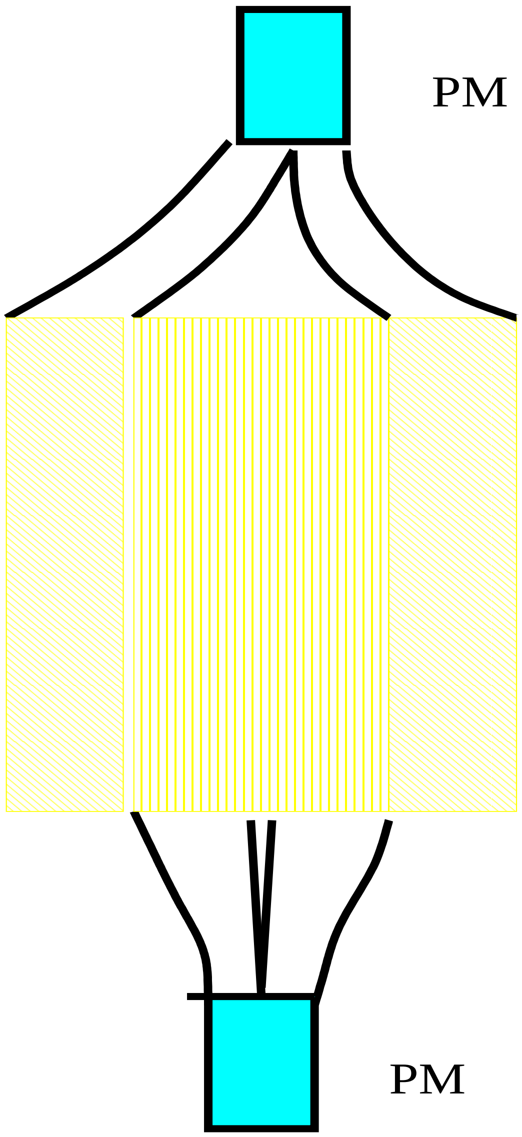

Figure 8: Proposed DE trigger counters design to gain better momentum resolution and lower singles rates for the same number of PMs

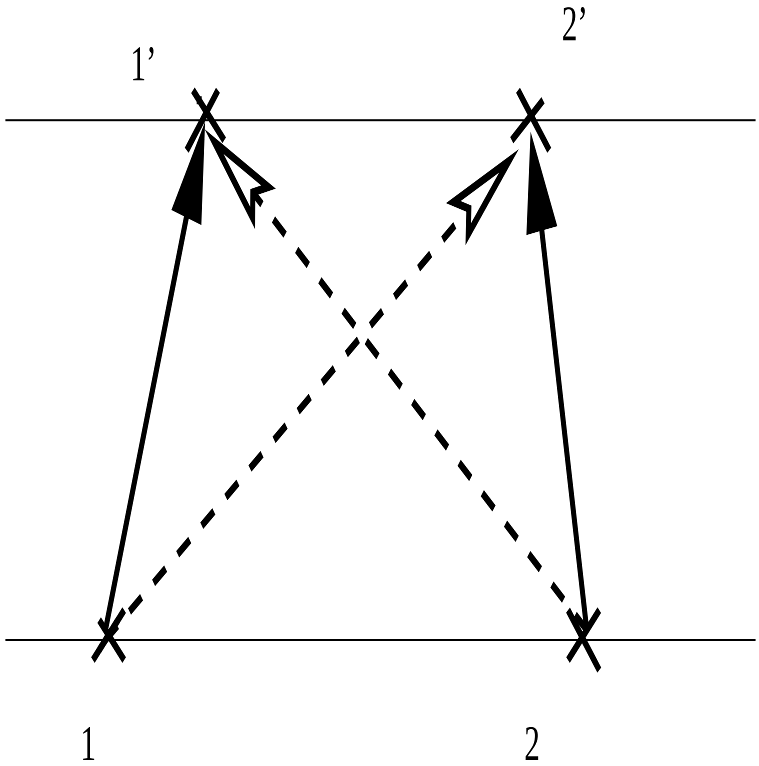

Figure 9: Double hit in the front and back planes. 1-1, and 2-2 correspond to the same particle. 1-2' and 2-1' represent possible alternatives in the case of two particles.

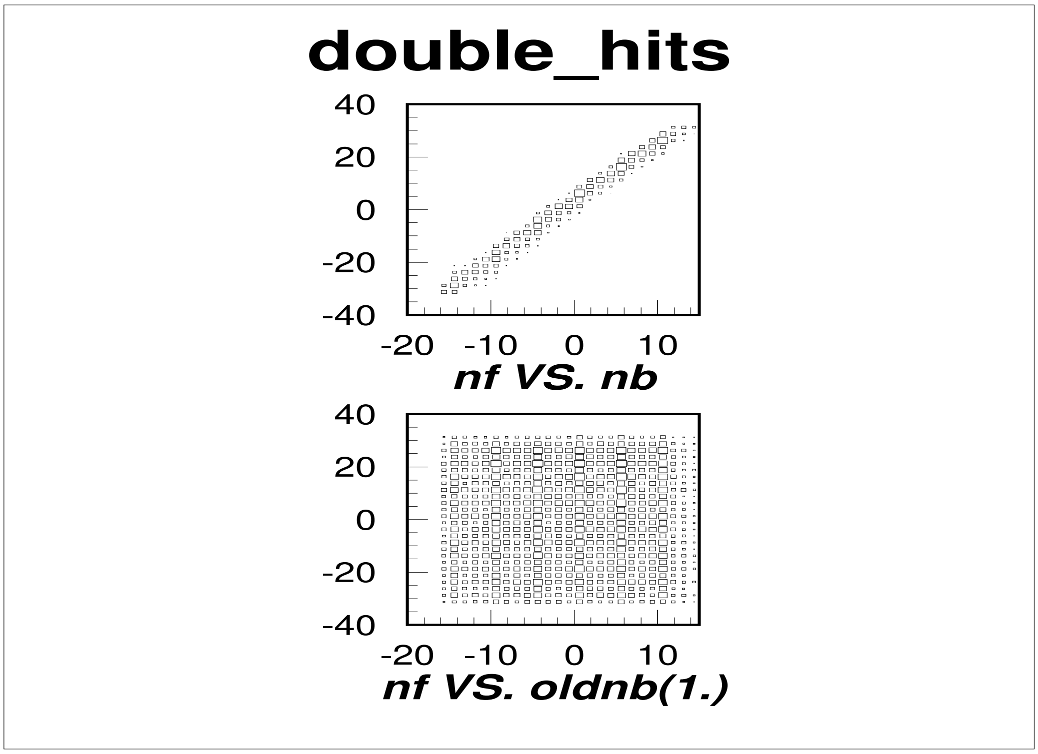

Figure 10: (up): The front(nf) and trigger(nb) counter numbers for each trigger counter that was fired. nb=-16,16 nf=-32,32. The simulation is for protons with momentum 250-600 MeV/c. (down): Uncorrelated hits of two different protons (both with momentum 250-600 MeV/c) in the front and the back planes