Comments for PPESP on Upgrade of H1 Forward Track Detector

Introduction

The H1 collaboration presented a proposal to the March meeting of the PPESP in which they requested a total of £ 260 000 and 7 man-years of technical effort in order to improve the H1 Forward Track Detector (FTD). The aims of this upgrade and the means whereby it is to be achieved are discussed in the proposal [1]. We have subsequently been asked to examine how the cost of the proposed upgrade may be reduced. This is considered in the following. An appendix is also included in which some simple calculations are presented which support the Monte Carlo simulations of the improvements expected from the upgrade.

FTD upgrade programme and costing

The proposal suggested that the programme for the upgrade of the FTD be as follows:

1. Build three new planar chambers at Daresbury.
2. Remove FTD from H1 at DESY.
3. Ship FTD to Daresbury.
4. Dismantle FTD.
5. Carry out minor modifications to the radial chambers.
6. Re-assemble FTD incorporating new planar chambers.
7. Ship FTD back to DESY.
8. Install FTD in H1.

The table of costs presented in the initial proposal associated with this programme is repeated below.

Item	Individual cost (£)	Quantity	Total (£)	Comments
Clean room	25 000	1	25 000	6 x 4 m^2
Surface tables, jigs etc.	15 000	1	15 000	
New planar chambers	20 000	3	60 000	3 new planars needed
Water and gas system changes	1 000	1	1 000	
New feed-throughs	200	45	9 000	
Shipping costs	8 000	2	16 000	DESY-UK-DESY
Internal cables	5 000	3	15 000	Manufactured complete
External cables	15 000	3	45 000	Manufactured complete
Pre-amplifiers	100	72	7 200	Manufactured complete
Column total			193 200	
Plus contingency			222 180	15%
Plus VAT			261 062	17.5%

Some savings in the amount requested from the PPESP may be made by modifying the programme for the upgrade as follows:

1. Build three new planar chambers at Daresbury.
2. Ship new planar chambers to DESY.
3. Remove FTD from H1.
4. Dismantle in DESY clean room.
5. Carry out minor modifications to the radial chambers.
6. Re-assemble FTD incorporating new planar chambers.
7. Install FTD in H1.

The above programme reduces the costs for the following reasons:

1. The costs for the clean room at Daresbury decrease as it is no longer necessary to provide the lifting gear needed to manipulate the FTD. Building a light tent structure of the necessary size with two filtered air-conditioning units will cost £ 12 000.
2. The modified programme obviates the necessity for the expensive transport of the complete FTD.

We have verified that the necessary DESY clean room space is available and have booked it provisionally for the period of the HERA upgrade. DESY have agreed to provide this space *gratis*.

A further measure, already discussed briefly with the PPESP, is to take the internal and external cables off the rear-most four wires of the radial chambers, two of which function with reduced efficiency due to charging effects, and use these for the new planar chambers. This poses no problems for the external cables, which run from the cable distribution area (CDA) at the rear of H1 to the electronics rucksack, and allows a saving of £ 45 000. The situation for the internal cables, those running from the FTD to the CDA, is less clear, however. Re-using these entails building new cable looms to connect the radial wires to the feed-throughs inside the FTD gas tank as this cabling must be re-organised. In addition, the cabling over the surface of the FTD must be completely re-done, and it is not clear whether the cable lengths available will suffice in all cases. This is a complex problem, solved in the construction of the original FTD only by building a scale model and using it to study the best possible cable layouts and resulting cable lengths. We have not been able to repeat this study as yet for the upgraded FTD and feel it is necessary to assume that we will have to make new cables for about 50% of the new planar channels in the FTD. Adding the cost of the required new cable looms means that there is an anticipated saving of £ 6 000 from the re-using of the internal cables.

We have attempted to locate as much as possible of the apparatus used in the construction of the original FTD. Two surface tables are available at Rutherford and we are arranging for their shipment to Daresbury. The gas tank used for the testing of the radial chambers has also been located at Liverpool and will be shipped to Daresbury. Some modifications will have to be made in order for this to be able to accommodate the new planar chambers and to repair the damage caused by the transport company who were responsible for shipping it to Liverpool from DESY. The resulting saving on the costs for equipping the clean room is £ 7 000.

The above measures lead to the following table of costs for mounting at DESY using the DESY clean room.

Item	Individual cost (£)	Quantity	Total (£)	Comments
Clean room	12 000	1	12 000	6 x 4 m^2
Surface tables, jigs etc.	8 000	1	8 000	
New planar chambers	20 000	3	60 000	3 new planars needed
Water and gas system changes	1 000	1	1 000	
New feedthroughs	200	45	9 000	
Shipping costs	1 000	1	1 000	UK-DESY
Internal cables	3 000	3	9 000	Radial/new cables
External cables	0	3	0	Use radial cables
Pre-amplifiers	100	72	7 200	Manufactured complete
Column total			107 200	
Plus contingency			123 280	15%
Plus VAT)			144 854	17.5%

Summary of costs

The modified programme allows a reduction in the costs listed here from £ 260 000 to £ 145 000. We note, however, that this scheme requires that we have six technicians at DESY for a period of approximately three months in order to dismantle the FTD, carry out the repairs to the radials, re-assemble the FTD incorporating the new planar chambers, perform gas and HV tests and install the modified FTD within H1. This will require that the H1 travel budget be increased by about £ 70 000 in the year in which the upgrade is performed.

References

[1] "Proposal to Upgrade the H1 Forward Track Detector", H1 Collaboration, presented to the PPESP in March 1998.

Appendix

Increase in planar segment finding efficiency

The addition of a new planar chamber to each planar module has a large effect on the efficiency for finding planar segments. An estimate of the size of the improvement may be made as follows.

Assume the cluster finding efficiency is c in all planar chambers The probability of finding a planar segment is then c^3, if three hits are required in three chambers. If at least three hits from four chambers are required, this increases to $c^4 + 4c^3(1-c)$. These quantities are shown in figure 1 below. The resulting changes in track finding efficiency, demanding that there be at least one of a possible three planar segments are as illustrated in figure 2, ignoring all complications due to segment linking etc. The current FTD operates with c in the range from about 0.8 to 0.9, dependent on the degree of confusion within the chambers arising as a result of the primary and secondary multiplicity. We see from the above, that the maximum possible efficiency for finding a planar segment on a track is currently about 85% (if c is 0.8) rising to nearly 100% after the upgrade. This number is not achievable, due to the effects of the hodoscope ambiguities, which reduce the overall tracking efficiency to about 50% in complicated events in the current FTD.

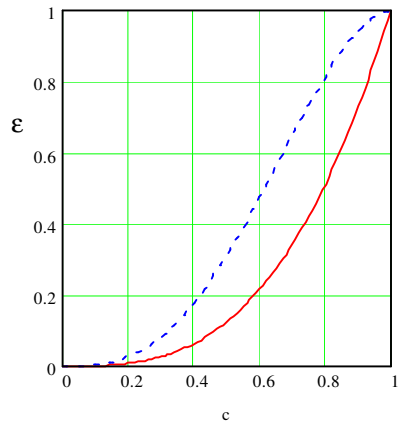

Figure 1
Segment finding efficiency with three planar chambers (full line) and four planar chambers (dotted line).

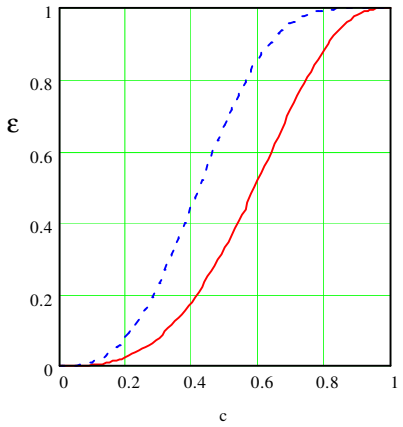

Figure 2
Efficiency for finding at least one planar segment on a track, 3 chambers per module (solid line) and 4 per module (dotted line).

Hodoscope ambiguities

A further problem of the current FTD is the large number of hodoscope ambiguities occurring in the planar modules at high multiplicity. An extremely rough estimate of the number of these may be made as described below.

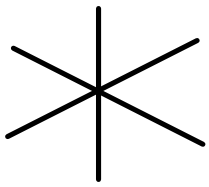

Figure 3
Representation of a planar segment.

A track passing through a planar module causes clusters of hits to be found in three chambers (ignoring the inefficiencies mentioned above). We can represent the resulting planar segment in 2D as shown in figure 3, in which the thickness of the lines is a schematic representation of the accuracy with which each of the planar clusters defines "its" co-ordinate, including the effects of the projection of the measurements to the plane illustrated.

If two tracks pass through a module, the situation is as in figure 4. In addition to the three-fold coincidences which represent the true track positions, there are 6 two-fold coincidences. A subsequent hit falling anywhere on the dotted lines will cause spurious track segments to be identified; "hodoscope ambiguities". If n tracks pass through the module, the number of lines on which this may occur is given by the number of two-fold coincidences, $3(n^2 - n)$. This leads to an area in which a subsequent hit will cause an ambiguity of $3(n^2 - n)wL$, where w is the "line thickness" and L the wire length. An estimate of the probability of this occurring can be made assuming that hits are uniformly distributed across the area of the chambers, L^2. The number of ambiguities after the passage of N tracks is then something like

$$N_a = \frac{3w}{L}\sum_{n=1}^{N-1} n(n-1).$$

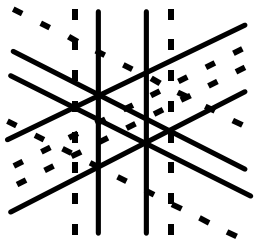

Figure 4
Two tracks in a planar module, illustrating area within which subsequent hits lead to hodoscope ambiguities.

Repeating arguments similar to these for the four planar chamber case leads to the expectation that the number of four-fold coincidence ambiguities is something like $12\frac{w^2}{L^2}\sum_{m=3}^{N-1}\sum_{n=1}^{m-1} n(n-1)$. Note that these formulae ignore many of the complications of the true system, such as the two track resolution, the actual wire lengths, etc. The expected rates of hodoscope ambiguities in the two cases are illustrated in figure 5, using w = 1 mm and L = 1 m. These should be considered as "ball-park" numbers only! No way of providing a numerical estimate of how many of these may be correctly resolved has been devised.

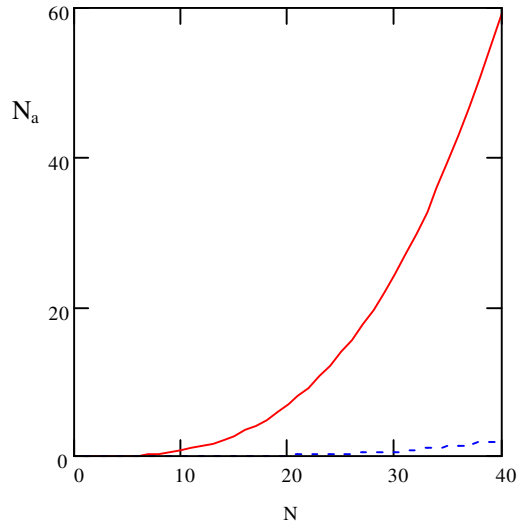

Figure 5
Approximate number of three-fold ambiguities in the current planar modules (solid line) and four-fold ambiguities in the upgraded planar modules (dotted line) as a function of the number of tracks through the module.

To conclude, the new planar chambers are seen to provide a significant improvement in the planar segment finding efficiency, and to reduce the number of hodoscope ambiguities by a large factor. Monte Carlo studies tell us that the combination of the above two effects raise the efficiency of the FTD for complicated events from the current 50% to above 90%.