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Proposal for Tagging High Energy Photon in the H1 Detector at HERA

H1 Collaboration

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Abstract

It is proposed that the H1 detector be upgraded by the addition of a new electromagnetic calorimeter. This is to be installed in the HERA tunnel close to the e-beam line at a position 8 m from the interaction point in the electron beam direction. The new calorimeter will extend the acceptance for tagged photoproduction events to the high y range, $0.85 < y < 0.95$, and thus significantly improve the capability of H1 to study γp processes. It is proposed that a lead-scintillator sampling calorimeter be used, similar to those in the H1 SPACAL system.

1 Introduction

Photoproduction accounts for a large part of HERA physics. Quasi-real photons ($Q^2 \sim 0$) in energy range $0.3 \leq E_\gamma/E_e \leq 0.8$ and $0.08 \leq E_\gamma/E_e \leq 0.15$ are presently tagged in H1 using the "electron taggers" ET and ET44, electromagnetic calorimeters located respectively 33.4 m and 44 m upstream of the interaction point. The energy E_e' in these calorimeters is related to the photon energy E_γ by:

$$y = 1 - E_e'/E_e \ \sin^2\theta/2 = 1 - E_e'/E_e + Q^2/E^2 \simeq 1 - E_e'/E_e = E_\gamma/E_e.$$

We propose to build an additional electron tagger, to be located at $z \simeq -8$ m from IP, to enable the measurement of low energy electrons and hence the tagging of photons at the highest possible energy.

2 Motivation

Electron-proton interactions occur via the exchange of the neutral and charged electroweak bosons, the interactions of interest here being mediated primarily by the photon. The energy and momentum of the photons exchanged varies over a huge range. If the four-momentum of the exchanged photon is denoted by q, then the virtuality $Q^2 = -q^2$ of the photons in the data so far studied ranges between zero, the photons are essentially real, up to values of around 5000 GeV^2. At high values of Q^2 the photon may be considered to be a very small object and probes the proton at the smallest scales yet achieved. Real photons, on the other hand, have long been known to possess structure themselves and indeed interact with the proton as though they were hadrons. This opens up the possibility of studying the hadronic structure of the photon.

The measurement of proton structure requires the identification of deeply inelastic electron-proton scattering (DIS) events; those in which a high Q^2 photon is involved. The rate of such interactions is much lower than that of the photoproduction interaction of real photons with the proton. Inevitably, some photoproduction events remain in the DIS sample and the number of these and their effect on the proton structure measurements must be understood if these are to be accurate. It is thus essential for the accurate measurement of proton structure that photoproduction be understood over the entire kinematic range in which it constitutes a background to DIS sample. The current H1 detector is only able to study photoproduction up to y values of ~ 0.8. The effect of the highest energy photon-proton interactions on the proton structure measurements is thus only poorly understood and this is a significant limitation on their accuracy.

In addition to the above, the study of photon-proton interactions is interesting in its own right. One of the first published H1 results was a measurement of the total photoproduction cross-section at a centre-of-mass energy orders of magnitude greater than was attainable before the advent of HERA [1]. The project proposed here will allow a further increase in the centre-of-mass energy of this cross-section measurement. With the proposed extension to the H1 detector the photoproduction data could be studied in at least 3 photon-proton centre-of-mass energy bins: $W_{\gamma p}$=150-250 GeV (present tagger); $W_{\gamma p}$=60-115 GeV (ET44 in 1996) and $W_{\gamma p}$=280-290 GeV (proposed ET-8). This allows the study of the energy dependence of various total and differential cross-sections, such as $\sigma(\gamma p \rightarrow all)$, $\sigma(\gamma p \rightarrow J/\Psi, \rho, \omega + X)$ etc. The dependence of the total photoproduction cross-section on $W_{\gamma p}$ with the position at which the new tagger would allow measurements to be made is illustrated on fig.1.

In addition to the measurement of the cross-section, the study of the hadronic final state allows complementary information to be obtained. For example the identification of jets in

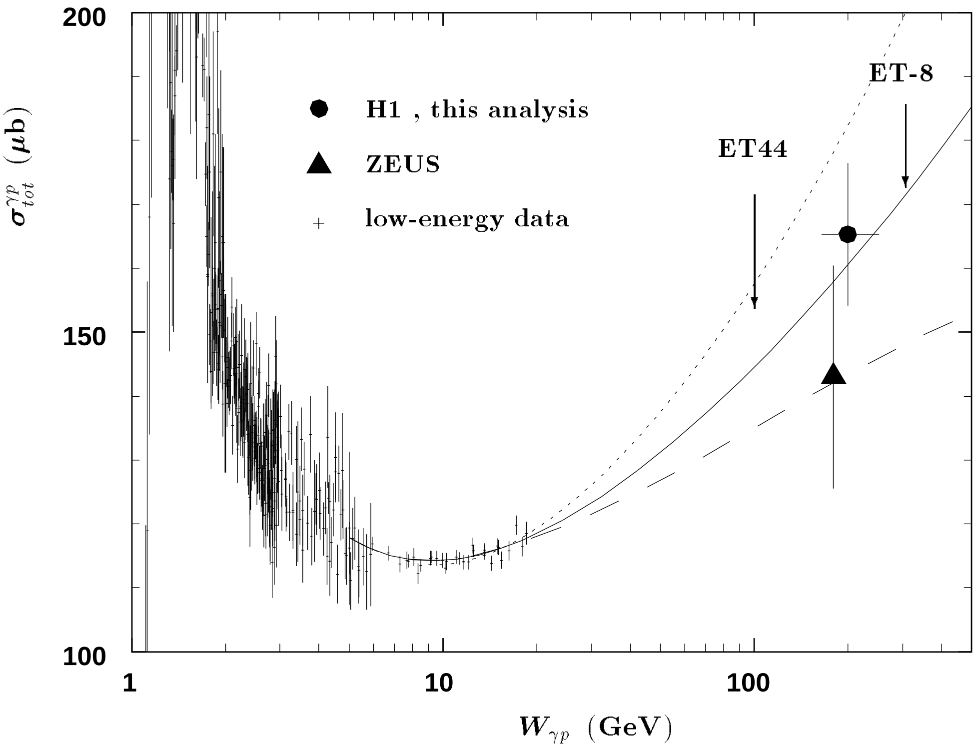

Figure 1: Total photoproduction cross section as a function of the γp centre-of-mass energy $W_{\gamma p}$. The arrows show the energies at which measurements made using the ET44 and the proposed ET-8 would contribute.

photoproduction events enables the reconstruction of the proportion of the photon's energy entering the hard interaction with the photon. Hence the partonic structure of the photon may be studied. Increasing the energy of the photons in such studies allows the study of partons carrying smaller proportions of the photon's energy which corresponds to the low Bjorken-x region that HERA has shown to be so interesting with regard to proton structure.

Another important application of the ET-8 is the measurement of the polarization of the electron beam at HERA. At HERA it is planned to change the natural transverse polarization of the electron beam to longitudinal polarization by means of a spin rotator [2], [3]. This polarization may be measured using the method proposed by the LEP Polarization Working Group at CERN [4] This is based on the measurement of the polarization of bremsstrahlung photons by using oriented monocrystals. The degree of polarization P_γ^c of the photons depends on y

$$P_\gamma^c = P_e^l[1 - (1-y)^2]/[1 + (1-y)^2]$$

where P_e^l is the degree of polarization of the electron beam. The maximum degree of polarization of the bremsstrahlung photons is for $y \approx 1$, and for the application of this method at H1 it is necessary to use the new tagger to select high energy photons.

Another measurement which demands selection of high energy photons is the investigation of the spin-dependent parton distribution of the photon by measuring the polarization of prompt photons produced in the high energy ep collisions [5], [6].

3 Realization

3.1 Detectors

The project will be realized by the addition of a further electromagnetic calorimeter to the H1-luminosity system. The maximum y value at which scattered electrons may be detected by the present system is $y \simeq 0.8$. The new calorimeter will extend this value up to $y \simeq 0.95$, increasing by 50 GeV the centre-of-mass energy of the photon-proton interactions. This technically challenging project requires the detection and accurate measurement of low energy electrons, down to 1.5 GeV, in a high radiation environment. The ET-8 must thus be radiation hard and have good energy resolution. In addition its response to hadrons must be well understood to facilitate the separation of the signals due to electrons from those due to hadrons. Large numbers of hadrons will interact in the region around the position of the new calorimeter due to losses from the proton beam.

The ET-8 will be incorporated into the H1 trigger system and will operate during all HERA luminosity running to provide a measure of the luminosity observed. The location with respect to the electron and proton beams and the dimension of the detector must thus be accurately known in order that its acceptance may be calculated with sufficient precision. In addition to the problems discussed above, the space available for the ET-8 between the magnets along HERA beam-line is very restricted.

Various technical solutions must be investigated before a final decision as to the most appropriated calorimeter type is made. Possible choices include: a total absorption crystal calorimeter; a lead-scintillator sampling calorimeter and a spaghetti type calorimeter. Although the combination of the total absorption crystal calorimeters and lead-scintillator calorimeters used in the existing H1 luminosity system, developed by the LPI group [7], have proved very successful, it is thought that a spaghetti calorimeter, as developed by H1 at DESY, may prove to be a better solution for ET-8 [8]. The spaghetti calorimeter has ~ 1.5 time better energy resolution than the total absorption crystals calorimeter and the combination with the scintillator hodoscope provides the necessary spatial resolution. The horizontal coordinate will be measured with the scintillator hodoscope with accuracy 1 mm (the width of the scintillator plate is 2 mm). The vertical coordinate of the electron hit at the detector will be determinated from the ratio of energy deposited in two modules. As the main part of the accepted events have the electron hit point near the boundary between two modules then the accuracy of vertical coordinate determination in this way will be $< 1mm$. Such spatial resolution provides < 5 % error in the energy measurement. The radiation hardness of the scintillating fibers was investigated in [9] and the expected irradiation level does not cause serious damage of fibers. The small radiation damage expected can be monitored by high rate (~ 100 Hz) Bethe-Heitler electrons.

The design for the ET-8 calorimeter is shown in fig. 2. This will be tested during 1996 HERA running. The detector will be installed on a fixed support and will stay permanently in the HERA median plane . The two scintillator veto plates are placed before and behind the scintillator fibres provide the rejection background signal in this part of fibres. The value of a Cherenkov light from the background particles in the light transmitters is orders of magnitude smaller (for the small lateral size of the light transmitter) than the signal from the electromagnetic showers in the calorimeter. Then it is not necessary to shield these light transmitters with additional veto plates.

The anticipated level 1 trigger for the new tagger requires a simple condition $E^{tot}_{dep} > E_{thr}$, where E^{tot}_{dep} is the total deposited energy in the calorimeter and E_{thr} the threshold energy which must have a low value, $E_{thr} \simeq 0.5 - 1.0$ GeV. A minimum ionizated particle deposits only 50 MeV. An additional γ-veto condition from the photon arm of the luminosity system (no signal in Photon Detector) will suppress the high background from the Bethe-Heitler process $ep \rightarrow e\gamma p$ with an efficiency ~ 98 %.

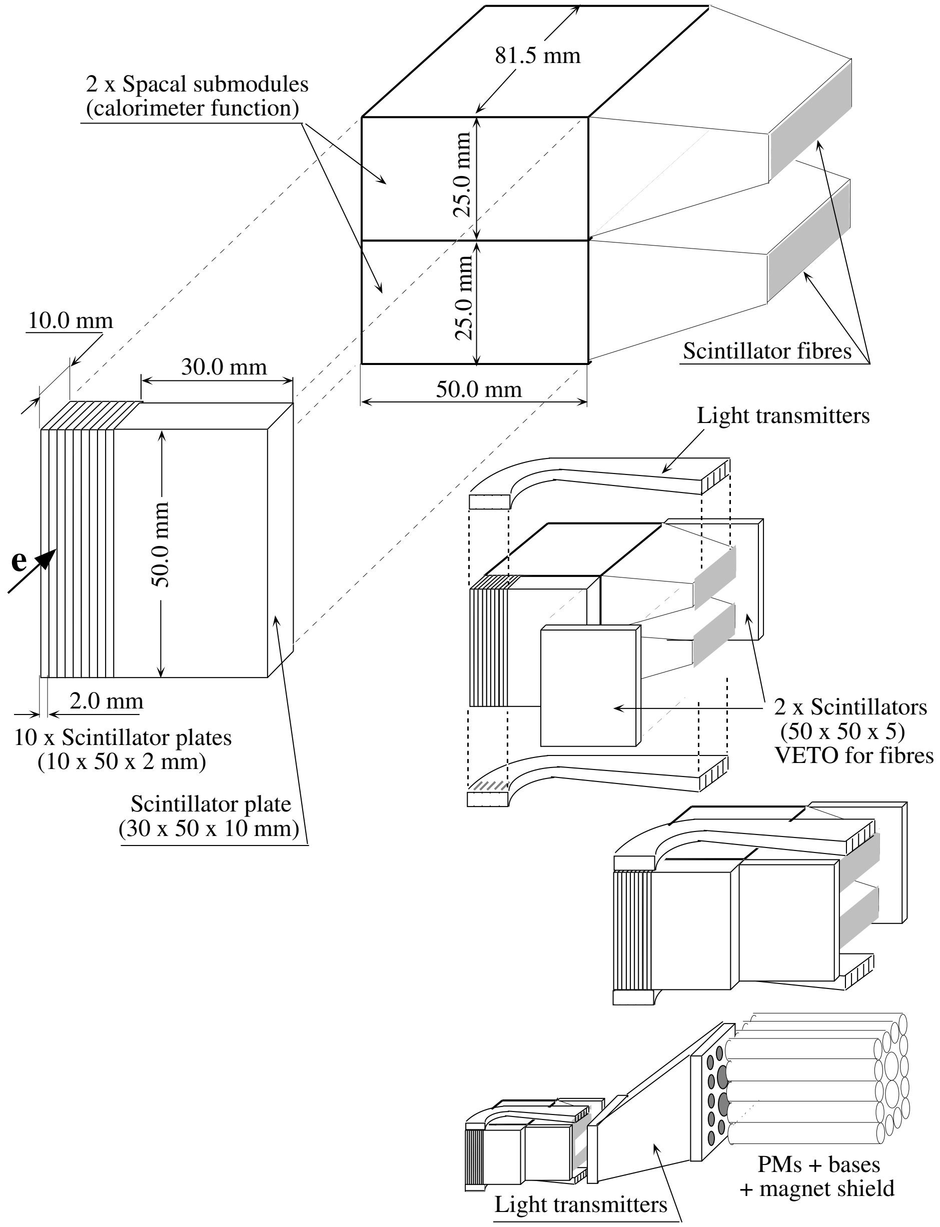

Figure 2: Design of the ET-8 calorimeter which will be tested during 1996 HERA running period.

3.2 Acceptance

Acceptance studies have been performed using a fast simulation package H1LUMI [10]. This models the current HERA electron ring optics (the proposed spin rotators have yet to be included) as is described e.g. in [11] . Several possible positions for the new tagger ET-8 were considered. After taking into account the apparatus currently present in the HERA tunnel, the space needed for the calorimeter itself and the access requirements for installation and sur-

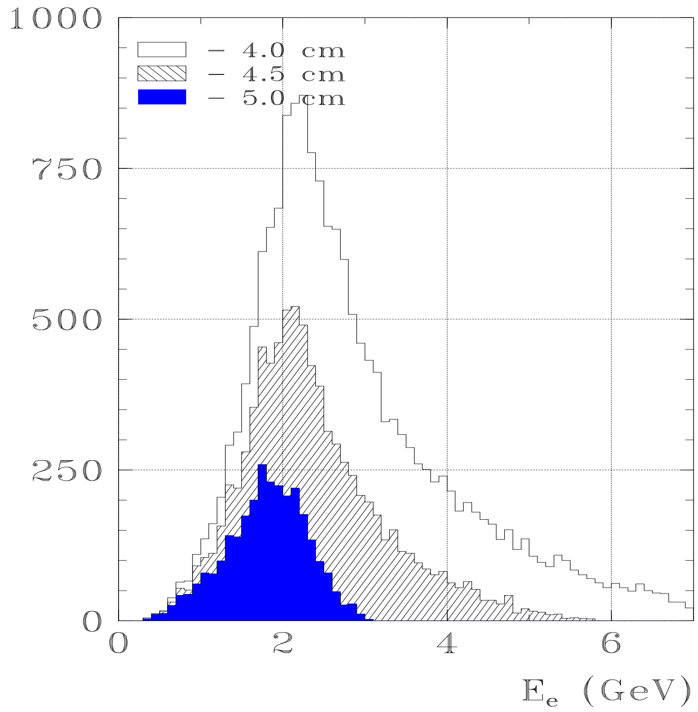

Figure 3: Energy distribution of the scattered electrons in ET-8 at the different distances from the e-beam axis.

veying, we propose to install the new ET-8 tagger at the position $z \simeq -8$ m. Small possible variations of the beam parameters at the IP (horizontal and vertical tilt of ± 0.15 mrad and offset $\pm 1mm$) have been taken into account in our simulation. They typically lead to 15-25 % changes in the electron tagger acceptance. The precise knowledge of the tagger position with respect to the electron beam is very important. According to the calculation an uncertainty $\pm$ 1 mm in the detector position gives about 15 % uncertainty in the acceptance determination. The acceptance can be defined with high precision from the data using $ep \rightarrow e\gamma p$ events, as is done for the present ET and ET44 calorimeters. This reduces uncertainties related to the precision with which real beam conditions can be simulated.

The next important point in the acceptance determination for ET-8 is the knowledge of the trigger threshold value. The uncertainty in the acceptance for different trigger thresholds is shown in table below. The uncertainty 10 % in the trigger threshold value is assumed for this case. One can conclude that the lower threshold is more preferable, but at real conditions the

E_{th} [GeV]	0.50	0.75	1.00	1.25	1.50
Δ A [%]	0.1	0.4	0.9	2.5	4.5

trigger threshold value will be determinated taking into account the pedestal and low energy background distributions.

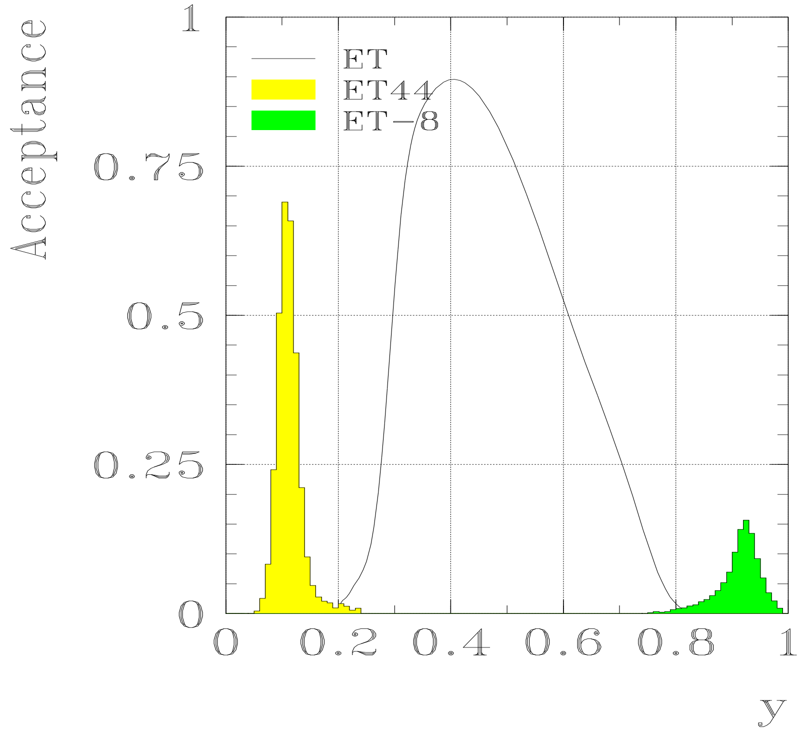

Figure 4: Acceptances of the three electron taggers for photoproduction with nominal e-beam conditions.

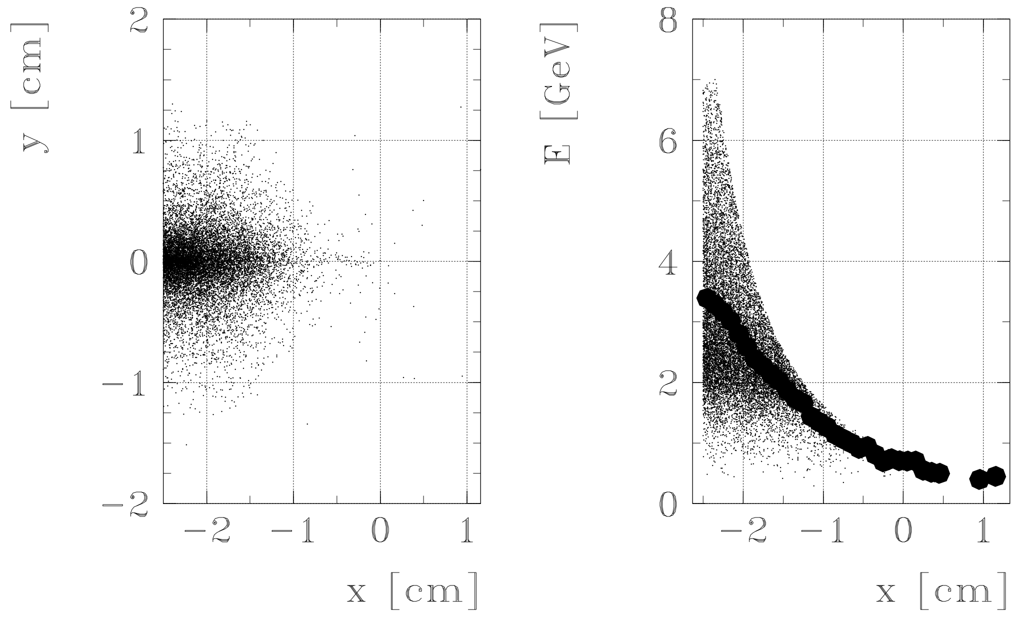

Figure 5: Entry point distribution and energy-coordinate correlation of scattered electrons in γp events. Filled circles represent average values with one sigma error bars.X is the coordinate from the center of ET-8.

The energy distribution of the electrons accepted by ET-8 at the different distances from the electron beam axis is shown on fig 3. The distribution represents the photoproduction process with $Q^2 < 10^{-2} GeV^2$. Fig.4 shows the acceptances of the electron detectors (ET, ET44 and ET-8) for photoproduction with nominal beam conditions (zero tilt and offset). One can see that the proposed upgrade extends the measurable y range to include the high y interval $0.85 < y < 0.95$.

The lateral size of the calorimeter can be chosen on the basis of the transverse distributions of the accepted electrons at the front plane of the detector. This distribution is shown on fig.5. In addition the same figure shows the correlation between the energy of the detected electron and the horizontal coordinate of the point at which it enters the detector. This illustrates that precise coordinate measurement is necessary for good reconstruction of the electron energy, allowing correction for those parts of the electromagnetic shower which leak out of the detector.

3.3 Modification of the beampipe

To realize the proposed project one section of the present electron beam-pipe, at $z \approx 8\,\text{m}$ has to be modified. The new beam-pipe has to allow for installation of the ET-8 at a distance of ~ 4.0 cm from the e-beam axis and should have an exit window which allows the egress of the scattered electrons with minimum degrading of energy. The DESY staff has the necessary expertise and equipment to design and build such a beam-pipe. One possible design has already been produced and studied in some detail. Construction is expected to be done by DESY.

3.4 Modification of the Inner Veto Wall

The proposed position of the ET-8 in the HERA tunnel at 8 m from interaction point in the electron beam direction is overlapped with position of the existed Inner Veto Wall. The Inner Veto Wall covers near beam area ($100 \times 90\ cm^2$) down to a radius of 11 cm and it consists of the four scintillator pairs shielded against electromagnetic showers by lead walls of 4 cm thickness [7]. Penetrating particles are then identified by coincidences between two scintillators with a time resolution of $\pm$ 3 ns. The time resolution achieved allows a clear time seperation between the background of the passing proton beam and event correlated hits during e-bunch passing.

There are several solutions to resolve the overlapping of the position of Inner Veto Wall and the position of the proposed new electron tagger ET-8.

- investigation of operation without the concerned scintillator pair;
- to increase the distance between the scintillator pair and beampipe;
- to increase the distance of the scintillators of the Inner Veto to house the ET-8 in between;
- to increase the Veto layers of the tagger;
- to cut out the scintillator pair and lead wall of the Inner Veto for insertion of the ET-8;
- to build and test a new Veto Wall to be placed at an another position.

All these possibilities will be investigate during 1996.

4 Manpower and Cost

Approximate cost for various parts of the proposed system is estimated in the table below.

Equipment	Cost [kDM]	Responsible institute	Status
Beampipe modification	50	DESY	
Inner Veto Wall	5	DESY	investigation
Cabling (HV, Coaxial)	7	DESY	
Power supplies	25	Zürich	exist
Electronics:			
a) Standard VME crate	10	DESY	exist
b) VME bus-extender	1.5	DESY	exist
c) VME FADC F1002	10	DESY	
d) Front-end	3	LPI	
Detector components:			
a) PM's and bases	10	LPI	ready
b) Raw materials	21	LPI/DESY	exist
c) Design and construction	15	LPI	
d) Test beam measurements	9	LPI	
Total Costs	**165.5 kDM**		

5 Time planning

The first ET-8 prototype is ready and will be tested during 1996 HERA running. Studies of radiation hardness of materials, choice of detector type and the final detector design will be completed in September 1996. Manufacture of the detector components, their assembly and test beam calibration of the entire detector will be completed by the end of November 1996. The technical design and manufacture of the modified vacuum chamber will be finished in December 1996. Installation and full system tests are planned for the shutdown 1996/97.

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