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Proposal for new Detectors to Increase the Photon Tagging Acceptance

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Abstract

It is proposed to upgrade the H1 detector by the addition of two new electron calorimeters, which have to be installed in the HERA tunnel close to the e-beam line at positions $z \simeq -38$ m and $z \simeq -188$ m respectively. The new calorimeters will allow to extend the present acceptance for tagged photoproduction events to the low y range, $0.04 < y < 0.25$, and thus significantly improve the capability of H1 to study γp processes. The most important gain is expected in the triggering of charm and vector meson events. It is proposed to use crystal Čerenkov detectors, similar to those used in the H1 Luminosity Monitor. They provide good energy measurement, give sufficient spatial resolution and have proven to work successfully at high rates and hard radiative conditions.

1 Introduction

A large part of HERA physics comes from photoproduction. Quasi-real photons ($Q^2 \sim 0$) in energy range $0.3 \leq E_\gamma/E_e \leq 0.8$ are presently tagged in H1 with the "electron tagger", an electromagnetic calorimeter located 33.4 m upstream of the interaction point. The energy E'_e in this calorimeter is related to the photon energy E_γ

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

We propose to build two new electron taggers located 38 m and 188 m respectively from the IP to enlarge the acceptance to lower y-values where the photon flux is largest and thus a bulk of γp events are produced.

The proposal will first present the gain in physics, then describe the mechanical realisation and conclude with a time and price estimate.

2 Motivation

We see three advantages of tagged photoproduction compared to untagged events. Firstly, without a measurement of the scattered electron the photon energy (E_γ) and virtuality (Q^2, typically up to few GeV^2) are not known. All cross sections represent then an average over a certain y and Q^2 range. Detecting electrons scattered over very small angles ($\theta \leq 5$ mrad) ensures $Q^2 \leq 0.01$ GeV^2 for the virtual photons. Furthermore, with the proposed extension, one could split the measured data in at least 3 energy bins of photon-proton centre of mass energy $W_{\gamma p}$=150-250 GeV (present tagger), $W_{\gamma p}$=95-135 GeV and $W_{\gamma p}$=60-76 GeV (see Table 1). Using the crystal calorimeters [1], with a typical resolution of $\sigma(E)/E \sim (10 \div 12)\%/\sqrt{E}$, the energy can be further subdivided within the bin. This would allow to measure 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.

Table 1: Parameters for the present electron tagger at 33 m and the two proposed detectors at 38 m and 188 m. All calorimeters are made from segmented KRS crystals. A total charm cross section of 0.6 μb was assumed. Depending on the parameters of the e-beam optics the values for the acceptances may vary by 10-20%.

Position [m]	Detector segmentation	$W_{\gamma p}$ [GeV]	$\sigma(ep)$ [μb]	$\sigma(c\bar{c})$ [μb]	Tagging efficiency [%] $J/\Psi \rightarrow \mu^+\mu^-$	D^*
33.4	7×7	150–250	1.7	0.066	9.7	14.
38.0	3×3	95–135	1.9	0.060	9.0	16.
188.0	5×5	60–76	3.0	0.078	14.3	20.

For a measurement of the parton density in the photon the variable

$$x_\gamma = \frac{\Sigma(E - p_z)^{(jets)}}{2yE_e}$$

is more accurate at low x_γ, if y is determined from the electron tagger than by the Jacquet-Blondel method.

Another important variable is inelasticity

$$z = \frac{p \cdot p_{J/\Psi}}{p \cdot q} = \frac{(E - p_z)_{J/\Psi}}{2yE_e} \,,$$

wich is used to disentangle elastic ($z \geq 0.98$) from inelastic ($z \leq 0.9$) vector meson production. For example, in the determination of the gluon density with J/Ψ mesons produced via the boson-gluon fusion it is essential, that inelastic events are selected. On the other hand the cross section for elastic J/Ψ production is an interesting quantity [2] and the contamination of inelastic events should be minimized. Inelasticity z could be better measured with the help of the electron tagger, since y_e from the tagger is more accurate than $y_{Jacquet-Blondel}$ for events with energy from the photon remnant lost in the beampipe. Thus the extended tagging system will help to disentangle elastic from inelastic production over a larger y-region than presently possible.

A second aspect of an extended tagging system is the trigger. In the production of vector mesons or heavy quarks (mainly $c\bar{c}$) only little transverse energy is produced and the event topology with the information available at the first trigger level looks very similar to beam gas interactions. In fact, all untagged photoproduction triggers in H1 are dominated by proton-gas background. A coincidence with any information from the electron beam reduces the trigger rate considerably. Depending on the real conditions, such as a vacuum in the beam pipe, electron beam tilt at the IP etc., the reduction factor of the order of 150-200 has been achieved using the present electron tagger. Taking into account that a typical tagging acceptance for γp events amounts to 10-12%, **this gives a factor of 15 to 20 improvement in the signal to background ratio**. At the design peak luminosity of HERA with 58 mA electron and 160 mA proton current the accidental coincidence rate of a track trigger with the electron tagging system is expected to be of the order 140 Hz (see table 2), which is within the capability of the first level trigger. When evaluating $R_{etag*\overline{\gamma}}$ rates in the table 2, it was taken into account, that the gamma arm veto [1] is less efficient for very low energy photons ($E_\gamma \simeq 1 \div 3$ GeV). We also assumed the same vacuum in the beam pipe as it is now. The coincidence rates shown in the rightmost column, can be further reduced by the r-z trigger on level 1 [3] and the new L2 and L3 triggers available in 1995 and 1996. It has to be mentioned, that even at the design parameters of HERA a typical average running conditions will be rather around I_e=40 mA and I_p=150 mA, and thus expected rates will be by a factor of 1.5 less than those given in the table 2.

With such a simple condition ($etag * 1track$) the acceptance for $c\bar{c}$ events can be tripled from presently 11% to about 35% and for D^* from 14 % to 50 %. This increase in trigger acceptance is important to fully exploit the silicon vertex detector [4], which will partially be installed in 1995 and will be fully operational in 1996.

Table 2: First level trigger rates for the full tagging system containing three crystal calorimeters. The tagger rate was scaled with the electron current and corresponds to the design current of I_e=58 mA. The tracking trigger rate was scaled with the proton current and extrapolated to I_p=160 mA.

Position [m]	$R_{\gamma p}$ [Hz]	R_{etag} [kHz]	$R_{etag*\overline{\gamma}}$ [kHz]	$R_{1track*\overline{TOF}}$ [kHz]	$R_{etag*1track*\overline{\gamma}*\overline{TOF}}$ [Hz]	
					γp signal	background
33.4	20	400	60	6	10	36
38.0	24	320	70	6	11	42
188	40	510	110	6	16	66

A third motivation for the extended electron tagger is a precise calibration of the planned forward proton spectrometer (FPS) [5]. Events of the kind $ep \to ep(\rho^0 \to \pi^+\pi^-)$ can be fully reconstructed. The measurement of the energy and angle of the scattered electron in the tagger and the two pions in the central jet chamber of H1 respectively predicts the proton energy. This gives an energy calibration of the proton tagger.

3 Realisation

3.1 Detectors

On the basis of the positive experience with H1 Luminosity System in 1992-1994 we propose to build similar detectors, which will differ only in size. These are total absorption Čerenkov calorimeters, made of 2×2 cm^2 KRS-15 crystals, with a hodoscopic structure. The properties of these calorimeters are summarized in the table 3. The values given for the resolution have been reached at HERA. The detectors possess high radiation resistance, provide good energy, coordinate and time resolution and are relatively compact. Each cell of the calorimeters is read out by a separate FEU-147 photomultiplier [6] with a 20 mm diameter cathode coupled to the crystal with an optical contact. A fast cables with the propagation speed better than (4.4 ns/m)$^{-1}$ are needed for the ET-3 to be in time for the first trigger level (2.2 μs).

The anticipated level 1 triggers for both new taggers require a simple condition $E_{dep}^{tot} > E_{thr}$, where E_{dep}^{tot} is total deposited energy in the calorimeter, with a typical value of $E_{thr} \simeq 10$ GeV. Such a high threshold is allowed by the accepted energy range of scattered electrons from ep-collisions and will easily discriminate against the noise and possible low energy background. An additional γ-veto condition from the photon arm (no signal in both Photon Detector and Veto Counter) will suppress high background from the Bethe-Heitler process $ep \to e\gamma p$ with an efficiency 85-90 %.

Table 3: Properties of the H1 electron taggers.

Parameter	unit	ET-1	ET-2	ET-3
Position, $-z$	m	33.4	38.0	188.0
Aperture $x \times y$	mm^2	154×154	40×60	100×100
Lateral granularity	cells	7×7	2×3	5×5
Chemical composition		$TlCl(78\%) + TlBr(22\%)$		
Radiation length, X_0	cm	0.93		
Moliere radius, R_m	cm	2.10		
Crystal length	cm	20		
Radiation hardness	Rad	$> 6 \cdot 10^7$		
Energy resolution, σ_E/E	%	$1 \oplus 10/\sqrt{E}$, (E in GeV)		
Position resolution, $\sigma_x = \sigma_y$	mm	$0.3 - 1.2$		
Time resolution, σ_τ	ns	< 3		

The lateral dimensions of the calorimeters are chosen on the basis of the acceptance studies described in the next section. In principle, a smaller size of 4×4 crystals would be sufficient for the detector at $z = -188$ m. We propose a calorimeter with 5×5 cells, which is an exact copy of the exististing Photon Detector used in the Luminosity Monitor, and which therefore can be also used as a spare for the Photon Detector.

Both new detectors are planned to be installed on movable platforms. In case there will be no space for such a platform at the position of 38 m, a small calorimeter can be mounted on a fixed support and will permanently stay in the HERA median plane. In such a case it has a larger risk to be damaged by radiation because of possible accidents with the electron beam. Therefore, as a backup solution, a simple water Čerenkov counter with $\sim 5X_0$ converter in front of it could be prepared. A similar detector is presently used as a veto counter in the H1 Luminosity System. Such a detector will not provide a sufficient energy resolution, but can be used with high efficiency in the trigger. The energy of the detected electron will then be defined by the geometrical acceptance of the device.

3.2 Acceptance

The acceptance studies have been performed using a fast simulation package `H1LUMI` [7], upgraded to include all magnet elements of the electron beam line down to $z = -190$ m. Present HERA optics for the electron machine (before the installation of the spin rotator equipment) is described e.g. in [8]. Detailed simulations showed that there are two available areas where the acceptance for scattered electrons can be significant: $30 - 39$ m and $180 - 190$ m. Finally, taking into account already existing detector at 33.4 m, we propose to install two new taggers at the positions $z = -38$ m and $z = -188$ m respectively. Small possible variations of the beam parameters at the IP (horizontal and vertical tilt of ± 0.15 mrad and offset of ± 1 mm) have been taken into account in our simulation. They typically lead to 10-20 % changes in the acceptances of the electron taggers to photoproduction. Note, that in real conditions these acceptances can be defined with a good precision from the data, using $ep \to e\gamma p$ events. This reduces the uncertainty related to the precision with which real beam conditions can be simulated. Fig. 1 shows acceptances of all three detectors for photoproduction at the nominal beam conditions (zero tilt and offset).

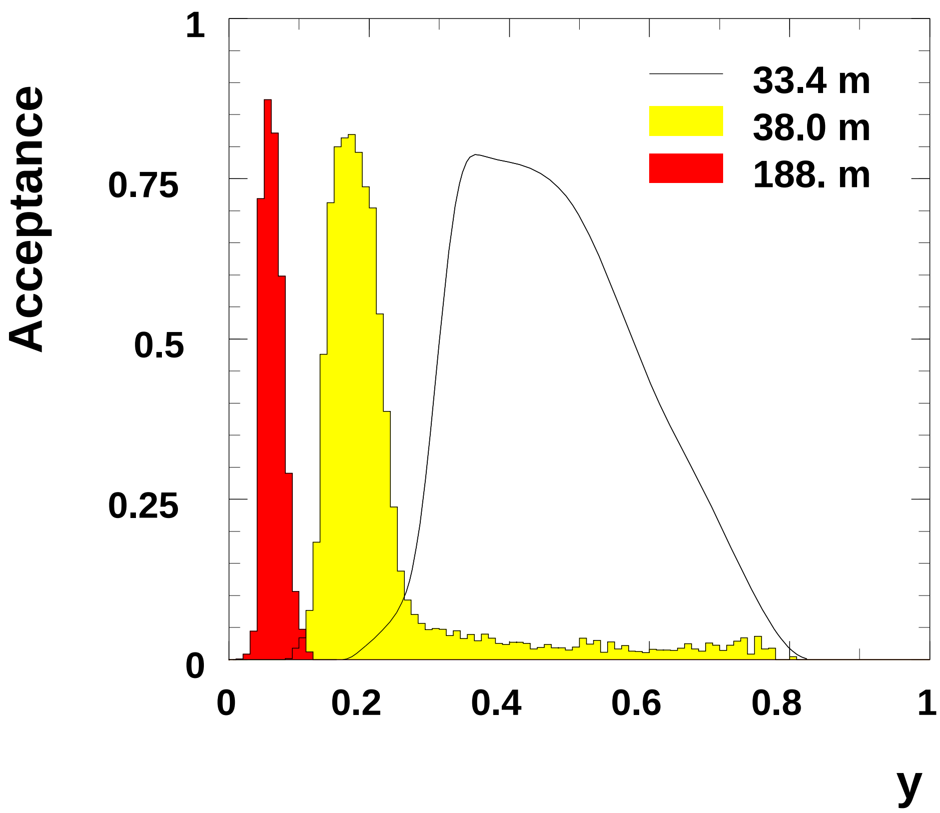

Figure 1: Acceptances of three taggers for photoproduction at the nominal e-beam conditions.

One can see, that the proposed upgrade extends the present y-interval where the tagging efficiency is above 10% from $0.25 < y < 0.75$ to a significantly lower y-range: $0.04 < y < 0.25$, where the bulk of the photoproduction events are produced.

As it was mentioned earlier, a lateral size of the calorimeters can be chosen on the basis of the transverse distributions of the accepted electrons at the front plane of the detectors. These distributions are shown on fig. 2. In addition, fig. 3 illustrates a correlation between the energy of the detected electron and the horizontal coordinate of the entry point at both detectors. One can conclude, that precise coordinate reconstruction may help to define the energy better, especially in case when a significant part of the electromagnetic shower is leaking from the detectors.

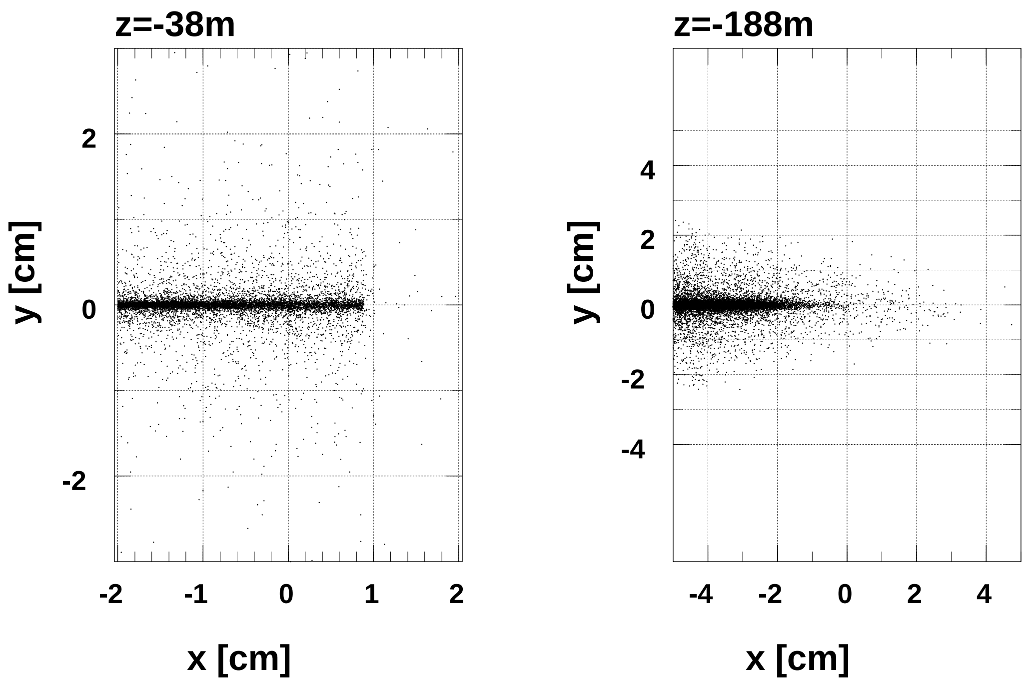

Figure 2: Entry point distributions for scattered electrons in γp events at $z = -38$ m and $z = -188$ m respectively.

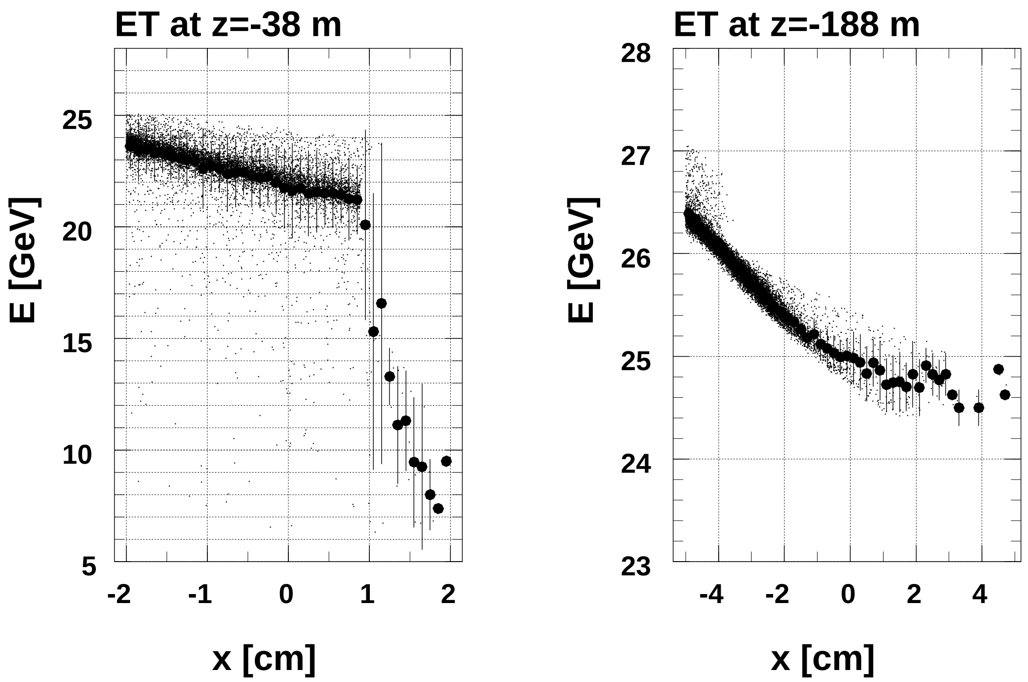

Figure 3: Energy-coordinate correlation of scattered electrons in γp events at $z = -38$ m and $z = -188$ m respectively. Filled circles represent average values with one sigma error bars.

3.3 Modification of the beampipe

To realize the proposed project two sections of the present electron beam pipe (27–37 m and 160–188 m) have to be modified. The new construction of the vacuum pipe has to allow for an installation of the detectors at distances of 3.5 cm (38 m) and 5.0 cm (188 m) from the beam axis respectively, and should contain exit windows for scattered electrons situated in $0.5 \div 1$ m before the detector's front plane. An actual design and construction is expected to be done by DESY.

4 Manpower and Cost

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

Equipment	Cost [kDM]	Responsible institut	Status
$\check{C}_{water}$	5	LPI	
KRS crystals	150	LPI	ready
Photomultipliers	30	LPI	ready
Cables	20	Zürich	
Power supplies	20	DESY	exist
Trigger and DAQ	15	DESY, LPI	
Movable platform	10	DESY	exist
Beampipe modification	60	DESY	
Total Costs	**310**		

The construction of the calorimeters, their installation in the tunnel and further comissioning will be done by LPI group. It also will be responsible for the preparation of the trigger and data acquisition for these detectors. All work related to the modification of the vacuum chamber will be done by DESY.

5 Time planning

The largest of the two KRS detectors is ready and assembled in Moscow. It will be delivered to DESY in October, 1994. The second small calorimeter is scheduled for the beginning of 1995. The technical design of the modified vacuum chambers will be finished in April 1995. Installation and full system tests are planned for the shutdown 1995/6.

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