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The Status of LUMI System

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1. Introduction

The fast luminosity monitoring on H1 at HERA and the investigation of γp-interaction at high energies will be performed by detecting correspondingly the bremsstrahlung process $ep \to e'\gamma p$ and the low Q^2 process $ep \to e'X$ [1,2]. Electron tagger (ET) and photon detector (PD) will be used to registrate e' and γ in the final state.

It is supposed to study among photon induced reactions first of all the process of hadron photoproduction. The total cross section for this process $\sigma_t(\gamma p)$ can be expressed vie the cross section of small angle ep-scattering:

$$\frac{d\sigma}{dy}(ep \to e'X) \cong \frac{\alpha}{2\pi}\frac{1+(1-y)^2}{y}\ln^2(\frac{Q^2_{max}}{Q^2_{min}})\sigma_t(\gamma p) \tag{1}$$

where $y = \frac{E-E'}{E}$, E, E' - energies of electron before and after scattering. Q - 4-momentum of virtual photon ($1.25 \cdot 10^{-8}\ GeV^2/c < Q^2 < 8 \cdot 10^{-3}\ GeV^2/c$ for given acceptance of the magnetic channel for ET). The fit of the existing data on $\sigma_t(\gamma p)$ at $20\ GeV^2 < s < 400\ GeV^2$ (s is the total energy squared in c.m. system in GeV^2, σ in μb):

$$\sigma_t(\gamma p) = (108.3 \pm 1.1) + \frac{45.7 \pm 8.6}{\sqrt{s}} + (1.72 \pm 0.35)\ln^2(\frac{s}{42.8 \pm 8.1}) \tag{2}$$

gives $\sigma_t(\gamma p) \cong 200\ \mu b$ at HERA energies. That corresponds to the rate 30 event/sec at ET.

This report gives a short description of present state of ET and PD installation, development of hardware and DAQ for them and trigger study for measurement of total photoproduction cross section. Details can be found in LPI reports available in computer readable form at DESY-IBM in F11LEV.LUMI.H1.INFO(LPI).

2. The LUMI-equipment perfomance

Detectors

The LUMI - system for H1-detector which was outlined in [1] consists of the electron and a photon arms. The main parts of them are the shower counter hodoscopes. The KRS-15 monocrystals are used as a Cherenkov light radiators. The size of one crystal is $20 \times 20 \times 200\ mm^3$ for the PD and $22 \times 22 \times 200\ mm^3$ for the ET. Chemical composition of KRS-15 is 78% of TlCl and 22% of TlBr. The temperature of melting is 450°C. The PD consists of $5 \times 5 = 25$ crystals while the ET - of $7 \times 7 = 49$. Cristals are viewed by photomultipliers FEU-147(made in USSR). The values of an operation high voltage for each FEU-147 are less than 2.5 kV, a current consumption is less than 1.5 mA for each PM - divider. The total power consumption is therefore about of 100 W for the PD and 200 W for the ET. The ventilator (PAPST LUFTER 4656N) will be used to dissipate the released heat. In addition detectors will be supplied with thermoresistors of PT100 (DEGUSSA AG) type for the Slow Control alarm system.

In order to protect the calorimeters from the increased radiation during the injection and the acceleration both detectors should be installed on the movable remote controled tables for removing to parking position (below the horisontal beam plane) and returning after the acceleration ends. The movable tables were designed at DESY and have been manufactured by MANNESMANN/DEMAG company. After the construction testing the following characteristics of the tables were obtained:

- The load rating of the moving platform of the tables is up to 350 *kg* (the total weight of each calorimeter with lead shielding is 250-280 *kg*).
- The measurement precision of the platform position is about ± 0.005 *mm*.
- The accuracy with which the platform is fixed with respect to the initial position (under a load about 270 *kg*) was achieved ± 0.07 *mm*. This is sufficient for our purposes.
- The speed of the moving platforms has two values: in a normal mode - 40 *cm/min* while in slow mode - about 10 *cm/min* (near by end positions), figure 1.

The tables may be operated in manual or program modes under Control counter KUEBLER G11 linked to the MAC II. Its schematic diagram is shown on figure 2. *ET* and *PD* are placed at distances of 34 *m* and 102 *m* from Interaction Point (IP) accordingly.

A water Čerenkov counter is used as the charged particle veto counter (*VT*) of photon arm for rejection events with γ-interaction between IP and *PD*. The stainless steel box is filled with distilled water, which is viewed by two photomultipliers FEU-85 (made in USSR). The length of the *VT* is about 30 *cm*. The test result of the counter prototype is satisfactory, the efficiency for the electrons passed the full length of the counter radiator is ~ 99%.

Photon detector front system and a shielding wall

The protection part of the photon arm (synchrotron radiation catcher, collimator and filter) should be used in order to reduce a synchrotron radiation background. The most amount of heat produced by this flux will be released in the filter and can be dissipated without forced cooling. The attenuation filter is the lead plates set with total thickness of ~ 2.2 *cm* (3.5 X_o) mounted in a common steel frame. The thickness of filter can be changed if it is needed in 0.5 X_o steps. In front of the filter there is a collimator, which is a lead module of 180x180x170 mm^3 size with the hole of 90 *mm* diameter. To absorb the scattered synchrotron radiation flux a steel pipe section of 900 *mm* long and of 110 *mm* in diameter is placed in front of the collimator. All mentioned elements should be screwed tighly to provide the thermal contact.

The iron wall shielding *PD* from proton's beam halo is placed behind the photon detector about 105 *m* from IP. It will be assembled of standart iron bricks. A length of the wall is ~ 190 *cm*.

3. Progress at Software Area for DAQ of H1LUMI Subdetector

General Notes

The development of software for DAQ of H1LUMI Subdetector was carried out at the Macintosh II (MAC II)'s MPW (version 3.0) environment. The standard SW packages and tools from H1 Central DAQ group (VMETOOLS [3], HHPACK [4], RTF - RTFLibraries - LoadRTF [5,6], BOS77-packages [7] for RTF and for LSC FORTRAN, Manhatten-application [8], SW packages for using Ethernet card) were installed or renewed, tested, used or integrated at own routines. The front-end processor FIC8230 [9] was succesfully integrated into DAQ of H1LUMI Subdetector. All software for FIC8230 was developed with RTF technology and debugged at FIC8230 board with VMEUA1-monitor [10] environment. The specific programs and routines for H1Lumi Subdetector were designed and created for MacII and for FIC8230. The programs for Mac II were realized mainly in the framework of LSC FORTRAN language with PASCAL insertions. The routines for FIC8230 were developed and created under RTF technology with 68K Assembler insertions.

On-Line Routine Prototype for FIC8230

It was issued the first release of On-Line Routine for FIC8230. This program was realized at RTF-technology framework. Interrupt handling routine was integrated into this program. On-Line Routine consists of two branches. The first branch (luminosity event branch) is built into forever loop at background level of FIC8230 running. The second branch (*PD* event branch) is the interrupt handling routine which is activated by the interrupt signal of the event at *PD* from H1LUMI Trigger Subsystem. It should exist the third branch (*ET* event branch)which will be developed late. There are two different parts of luminosity event branch: readout part and reconstruction part. Readout part of this branch consists of reading, decoding, linearization, processing and bank creation subroutines. The reconstruction part is similiar to LREC-part from H1REC-package [11] with some modifications. There are two source of data for On-Line Routine. The first is the source of luminosity events (bremsstrahlung events) and the second is the source of photon detector events with interrupt signals. Luminosity events are made with FADCMemoryImage application [12] from bremsstrahlung events which were simulated at IBM3090 with H1SIM [1] and transferred into Mac II storage with BOS EPIO IEEE format [13]. The *PD* events are simulated with special HW [14] with generating of interrupt signal per each event. Histogramms and plots are booked and filled at both branch of this routine with HHPACK-package [4]. It is possible to use Manhatten-application [8] at Mac II for swapping all histos and plots into Mac II memory and drawing this objects with nice LOOK-interactive environment at Mac II screen. This prototype of On-Line Routine for FIC8230 is the base for finishing of full-scale On-Line Routine. The main time scaling characteristics of created SW product are following:

a)the readout of luminosity events from FADCMemoryImage (74 channels) -
not real FADC :
READING........................... 0.376 - 0.426 *msec* per event;
DECODING........................ 0.956 *msec* per event;
LINEARIZATION.............. 1.363 *msec* per event;
PROCESSING..................... 1.169 *msec* per event;
BANKS CREATION........... 1.727 *msec* per event.

b)the reconstruction of luminosity events gets 40.0 - 179.0 *msec* per event. The average value of the reconstruction is 117.7 *msec* per event.

c)the readout of the *PD* events from real FADC1001 (25 channels):
READING........................... 0.177 *msec* per event;
DECODING........................ 0.322 *msec* per event;
LINEARIZATION.............. 0.464 *msec* per event;
PROCESSING..................... 0.398 *msec* per event;
BANKS CREATION........... 0.692 *msec* per event.

The memory usage at FIC8230 are following:
a)routine code (without indirect COMMONs) - 150K;
b)indirect COMMONs - 150K.

The present first release of On-Line Routine consists of near 60 program units (main, subroutines, functions, interrupt handling routines). There are some documents [15,16,17,18,19] which contain a more detail discription of these routines.

4. Progress at Hardware Area for DAQ of H1Lumi Subdetector

DAQ (hardware)

There are two main differences in the present version of the DAQ for H1LUMI subdetector with respect to the previous one [20]:

1) an additional processor FIC8230 has been inserted in the subsystem:

2) the FADC crate serves as a master subsystem crate.

These two changes cause a modyfied layout of some of the components but there are no principal changes in the connection with the H1 Central DAQ and H1 Central Trigger Logic. The new layout of the H1LUMI DAQ subsystem is shown on figure 3. In previous version the DAQ for photoproduction and luminosity branches, the H1LUMI trigger, slow controls and subsystem monitoring were under control of the single processor MAC II. The new version permits more flexible separation of these functions. The DAQ and Trigger definitions will be under FIC8230 responsibility. The subsystem supervisor and slow control will be controlled by Mac II.

Trigger

The trigger electronic has been assembled on the base of Fast and Fanout cards and prototype trigger electronics developed in LPI group [21]. The basic idea for L1 LUMI trigger is to detect the coincidence between the relevant trigger decision for internal LUMI logic and central H1 in a single banch [1]. An important feature of the ET and PD is the well time defined response. The output hits from detectors have ~ 40 ns width and are absolutely synchronized with HERA clock. So there is no reason to destribute intermediate L1 decisions among several bunches to collect the final decision. It is necessary only to compensate PD cables delay and to send in correct time the trigger bits to the central trigger. This is done by using anologue delay and shift registers. The physical conditions forming photoproduction, bremsstrahlung and other triggers were investigated in [21]. There are several suggestions to realize these triggers. It is foreseen such H/W, S/W realization that gives the most flexible cofiguration of trigger logic and selects relevant trigger with minimum efforts. So the subsystem must be able to do any reasonable conversion of input signals, to test any reasonable parameters of these signals and to form final solution.

We have following input signals to analyse in L1 trigger logic:

1) the hits from 49–25 channels of ET and PD:

2) the hits from VT counter:

3) the L1keep and a number of central L1 logic and bunch correlated signals.

In the LUMI system for trigger processing there are used the following conversions of input signals:

1) the analogue summation of output signals from detectors:

2) the comparison of the hits from each of 49–25 channels of the detectors and from summators with selected thresholds to form corresponding levels (0 or 1) for each signal (the current value of the thresholds is under S/W control):

3)the delaying and gating of analog and digital signals (the delaying and gating for digital signals can be also controled by S/W):

4) the conversion of hits from detectors and analogue summators by FADC.

These conversions provide sufficient set of output digital data to form flexible trigger with programable H/W logic and S/W processing.

The hardware trigger processing includes the following points:

1) the permanent checking of the energy conditions for each bunch (this is doing by comparison of the analogue sums with relevant thresholds and by boolean logic processing of the comparator output levels);
2) the topological checking - the number and the place of fired channels are tested (this is doing by cluster finder logic);
3) the checking of correlations - coincidences between internal subsystem trigger and central trigger signals are detected.

Cabling and power supply from detectors are under realization. Drift chamber preamplifiers are used as cable drivers in HERA tunnel. FADC and splited STC/VME crates are available now.

5. Trigger study for the total photoproduction cross section measurement

Measurement of the total hadronic photoproduction cross section in low Q^2 process $ep \rightarrow e'X$ requires the detection of the recoil electron [1,2,22]. In general there are four sources of electrons at ET:

1) photoproduction ($ep \rightarrow e'X$)	$\sim 30Hz$
2) bremsstrahlung on the residual gas	$\sim 40kHz$
3) bremsstrahlung on the proton beam	$\sim 400kHz$
4) off momentum electrons from the electron beam	$\sim 40kHz$

The task is to provide an effective trigger for photoproduction events rejecting considerably the background and giving an accepted rate for usefull events $\sim$ 1 Hz.

Trigger which uses only data from ET and from PD (without any information from main H1 setup).

This kind of trigger is based on the difference in angular distributions of electrons from photoproduction and from bremsstrahlung (figure 4 a). On figure 5 two-dimensional plots are shown for electrons at ET from photoproduction and from bremsstrahlung. Y-axis is vertical coordinate (cm) of electrons at forward plane of ET and X-axis is the energy of corresponding electrons. A clear difference between two distributions for these processes shows a way to suppress a background from bremsstrahlung. The first step is to reject the events with extremely small angles of electron emission which correspond for example to hit point of electron in the central layer of ET (figure 4 b). The second step is applying of different energy cuts. Two kind of cut have been considered: total deposited energy in whole ET and maximum deposited energy in one cell for each event. Results obtained for different energy cuts are summarized in table 1.

According to Monte Carlo calculations the most acceptable trigger for the selection of photoproduction events would be as follows:

- there is at least one fired ET cell with deposited energy $E_{cell} >$ 9-12 GeV;
- the ET cell with maximum deposited energy is placed outside of the central layer of ET (figure 4 b);
- there is no γ in photon arm: this gives a background rejection of 50 for an efficiency of the photon arm $\sim 98\%$).

This trigger gives a rate $\sim 1Hz$ of photoproduction events with background at a level of $\sim 40\%$. The momentum distribution of the accepted electrons from photoproduction which satisfy this trigger conditions is given on figure 6. It is seen that the accepted electron energy region should be reduced from $5.0\ GeV < E_e < 25.0\ GeV$ to $12.0\ GeV < E_e < 25.0\ GeV$.

It is possible also to use energy cuts for total energy (see table 1). Result will be almost the same.

Trigger which combines information from ET and from the main H1 setup.

In this case the nature of the background is random coincidence between electrons in ET and "something" in H1 detector. In general there are two kind of background in H1 detector:

1) beamgas interactions $\sim 300kHz$,
2) beamwall interactions $\sim 60kHz$.

Main source of electrons in ET is bremsstrahlung on the proton beam $\sim 400kHz$. Using photon arm information (there is no γ in photon arm) we can reject $\sim 98\%$ electrons from bremsstrahlung. And finally we will have about $\sim 8kHz$ nonidentified background electrons. Detection in a coincidence of scattered electron allows to suppress beamwall and beamgas background of $\sim 10^3$ [22]. Corresponding rate (N) of coincidence is

$$N = \frac{f(H1) * f(ET)}{f(HERA)} = 8 \cdot 10^{-4} \cdot f(H1) \qquad (3)$$

where f(H1) is a number of background interactions in H1 detector (beamwall or beamgas), f(ET) is the number of nonidentified electrons at ET ($\sim 8\ kHz$) and f(HERA) is the number of bunch crossing ($\sim 10^7$). That gives $\sim 240Hz$ beamgas interactions and $\sim 48Hz$ beamwall interactions.

In order to reduce the background further there is need to use standard H1 triggers. These triggers were investigated by MC simulation. Photoproduction events were generated with LUCVDM (low p_t part of LUCIFER program) and then 4500 events were calculated with H1SIM.V105 (GFLASH parametrization) program. For study of background we used standard H1 background files:

F21MAR.G312.SELECT9A.H1SIMOUT.CART beamwall and
H1KADR.BEAMGAS.GFLASH.NEWCOL.PART1...PART4 beamgas interactions.

The rate of different processes (photoproduction, beamwall and beamgas interactions) are shown in the table 2 at different trigger conditions (N_{BPC} is the number of fired wires in Backward Proportional Chamber, "*accepted*" particles - are particles in $0.6^\circ < \theta < 176^\circ$ angle range, "*visible*" particles - are charged particles with $P > 100\ MeV/c$ and gamma with $P > 300\ MeV/c$). Influence of different triggers on physical values is shown in tables 3 and 4 and also on the figures 7 and 8.

It is seen, that it is possible to use several triggers for picking out the photoproduction events and for suppression background. But only three triggers ($E_{BEMC} > 2\ GeV$, $E_{BEMC} > 5\ GeV$ and $N_{BPC} > 4$) give minimal distortion in distributions of particle multiplicity, transferse momentum and so on.

5. Conclusion

All components of LUMI system should be installed in HERA tunnel at the end of 1990 year. Up to this date hardware and software for ET and PD will be ready to work. We expect the test run in coming winter using e-beam if it will be available to measure different types of background.

In order to avoid damage of KRS cristals of ET and PD during the first stage of the HERA-running (when a background can be severe) the alternative calorimeters are proposed to be installed instead of the main hodoscopes. The alternative photon detector [23] consists of four identical modules which were manufactured at Lebedev Physical Institute and one module was delivered to DESY and tested. The alternative electron calorimeter is designed as a lead-scintiliator sandwich having the hodoskope structure. The photon and electron alternative calorimeters are planed to be send to DESY in the fall this year.

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Figure Captions

Fig. 1 Block scheme of the generator control for the moving tables:
A - the range switching point, B - the turning-off of a generator.

Fig. 2 Block scheme of moving table control for table 1 (the same for table 2).

Fig. 3 H1LUMI subsystem DAQ layout.

Fig. 4 (a) - angular distribution for bremsstrahlung electrons without HERA e-beam divergence (full histogram), with a nominal divergence (hatched histogram) and for low Q^2 electrons from photoproduction (open histogram);
b) layout of ET (central layer which corresponds to extremely small angle of electron emission is hatched).

Fig. 5 Two-dimensional plots (vertical coordinate of electrons at ET versus corresponding energy) for photoproduction (a) and for bremsstrahlung (b) processes.

Fig. 6 Momentum distribution of photoproduction electrons:
(a) - in the interaction point for full ET acceptence (open histogram), and at ET (hatched histogram)
(b) - for electron out of central layer of ET (open histogram) and with maximum deposited energy in one cell $E_{cut} > 10\ GeV$ (hatched histogram).

Fig. 7 (a) - Pt distribution for "*all*" particles (broken line), for "*accepted*" particles (full line) and for "*visible*" particles (hatched histogram);
(b) - multiplicity distribution for "*all*" particles (broken line), for "*accepted*" particles (full line) and for "*visible*" particles (hatched histogram).

Table 1. Suppression factor R for photoproduction and for background events.

for Ecell	$\geq 5.0GeV$	$\geq 7.5GeV$	$\geq 10.0GeV$	$\geq 12.5GeV$
R(photop.)	12.5	19	25	50
R(backgr.)	50	3700	8500	$\geq$ 25000
for Etot	$\geq 5.0GeV$	$\geq 7.5GeV$	$\geq 10.0GeV$	$\geq 12.5GeV$
R(photop.)	12	12.5	16.5	18
R(backgr.)	40	60	1400	6400

Table 2. Rates of different triggers (ET*H1 Main) in Hz.

H1 Main trigger	*Photoprod.*	*Beamwall*	*Beamgas*
$ZVTX$	5.2	4.8	2.8
$NOT_{TOF} * ZVTX$		0.2	0.4
$DC(R_{phi}) > 1$	4.9	0.5	0.4
$NOT_{TOF} * DC$		0.04	0.3
$E_{BEMC} > 2\ GeV$	22.9	23.1	23.4
$NOT_{TOF} * (E_{BEMC} > 2)$		1.3	1.7
$E_{BEMC} > 5\ GeV$	8.7	20.6	17.3
$NOT_{TOF} * (E_{BEMC} > 5)$		0.8	0.6
$E_{BEMC} > 7\ GeV$	4.0	19.2	14.6
$NOT_{TOF} * (E_{BEMC} > 7)$		0.7	0.3
$E_{BEMC} > 10\ GeV$	0.8	17.6	11.7
$NOT_{TOF} * E_{BEMC} > 10)$		0.5	0.2
$N_{BPC} > 4$	26.3	24.6	26.9
$NOT_{TOF} * (N_{BPC} > 4)$		2.6	4.0

Table 3. Average meanings of some values for different triggers (Ntot - multiplisity for all particles, Pt - transverse momentum).

	$< N_{tot} >$	$< P_t >$	$< P_t^2 >$
All particles	27.16 ± 0.10	0.249 ± 0.001	0.102 ± 0.001
Accepted	20.01 ± 0.09	0.259 ± 0.001	0.106 ± 0.001
Visible	16.34 ± 0.07	0.298 ± 0.001	0.127 ± 0.001
ZVTX	17.85 ± 0.17	0.305 ± 0.002	0.130 ± 0.001
$DC(R_{phi}) > 1$	17.21 ± 0.18	0.324 ± 0.002	0.148 ± 0.002
$E_{BEMC} > 2\ GeV$	16.87 ± 0.08	0.295 ± 0.001	0.124 ± 0.001
$E_{BEMC} > 5\ GeV$	17.79 ± 0.14	0.295 ± 0.001	0.124 ± 0.001
$N_{BPC} > 4$	16.31 ± 0.08	0.298 ± 0.001	0.126 ± 0.001

Table 4. Average meanings of charged particles multiplisity and transferse momentum for different triggers.

	$< N_{ch} >$	$< P_t >$	$< P_t^2 >$
All particles	14.89 ± 0.05	0.316 ± 0.001	0.145 ± 0.001
Accepted	10.12 ± 0.05	0.345 ± 0.001	0.159 ± 0.001
Visible	9.99 ± 0.01	0.349 ± 0.001	0.161 ± 0.001
ZVTX	11.36 ± 0.11	0.354 ± 0.002	0.165 ± 0.002
$DC(R_{phi}) > 1$	11.07 ± 0.11	0.324 ± 0.002	0.148 ± 0.002
$E_{BEMC} > 2\ GeV$	10.14 ± 0.05	0.346 ± 0.001	0.159 ± 0.001
$E_{BEMC} > 5\ GeV$	10.33 ± 0.09	0.347 ± 0.002	0.160 ± 0.001
$N_{BPC} > 4$	9.98 ± 0.05	0.348 ± 0.001	0.160 ± 0.001

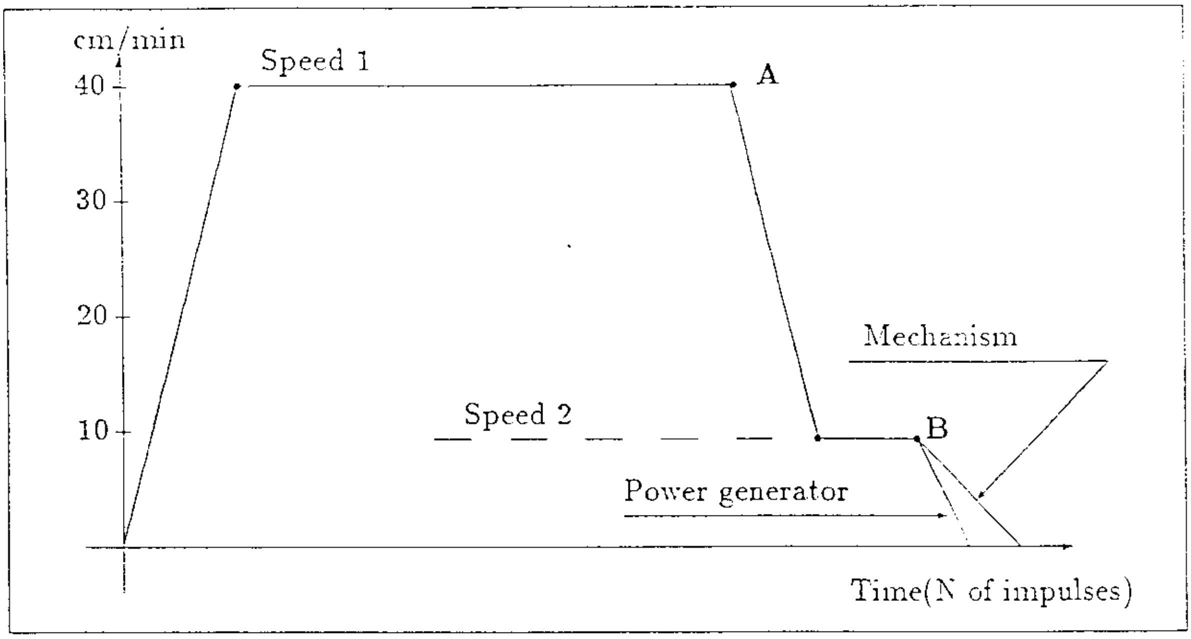


Figure 1.

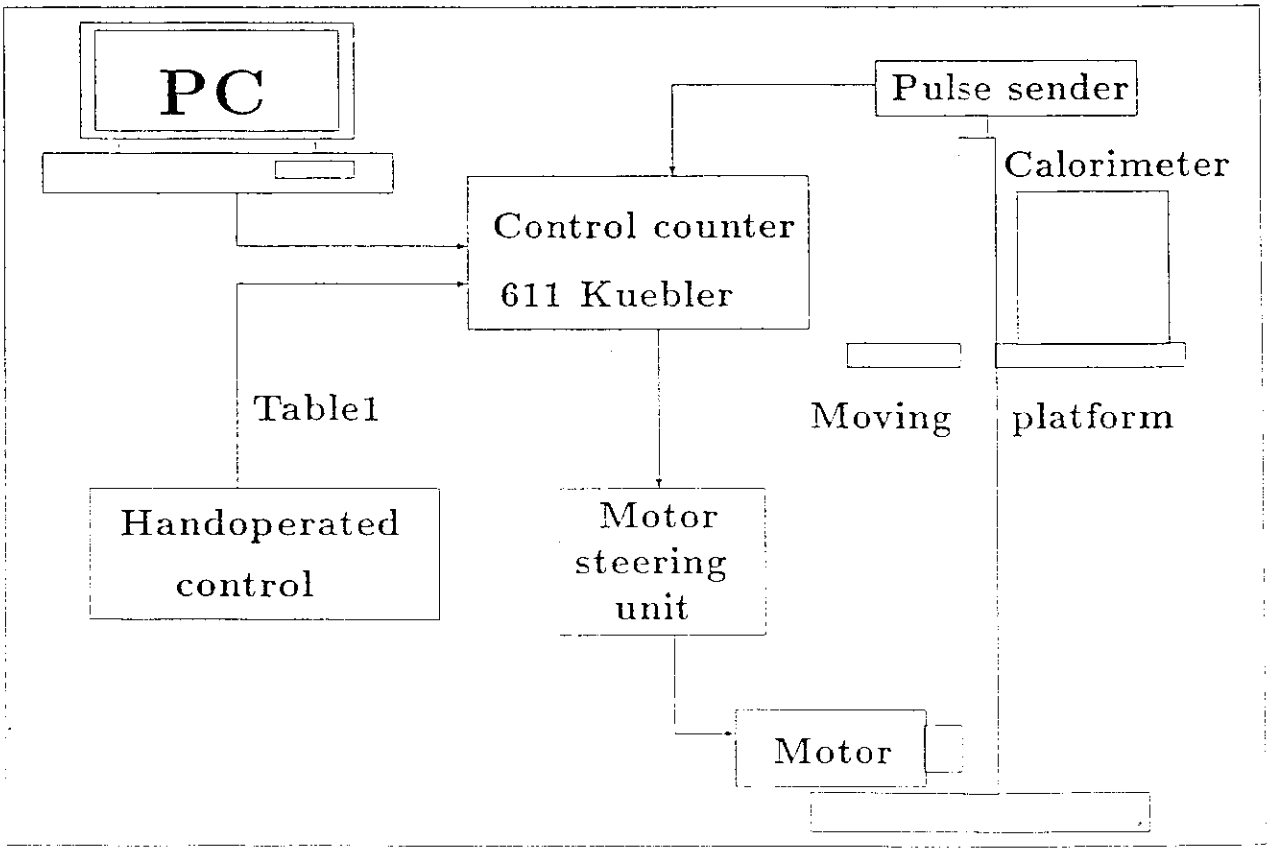
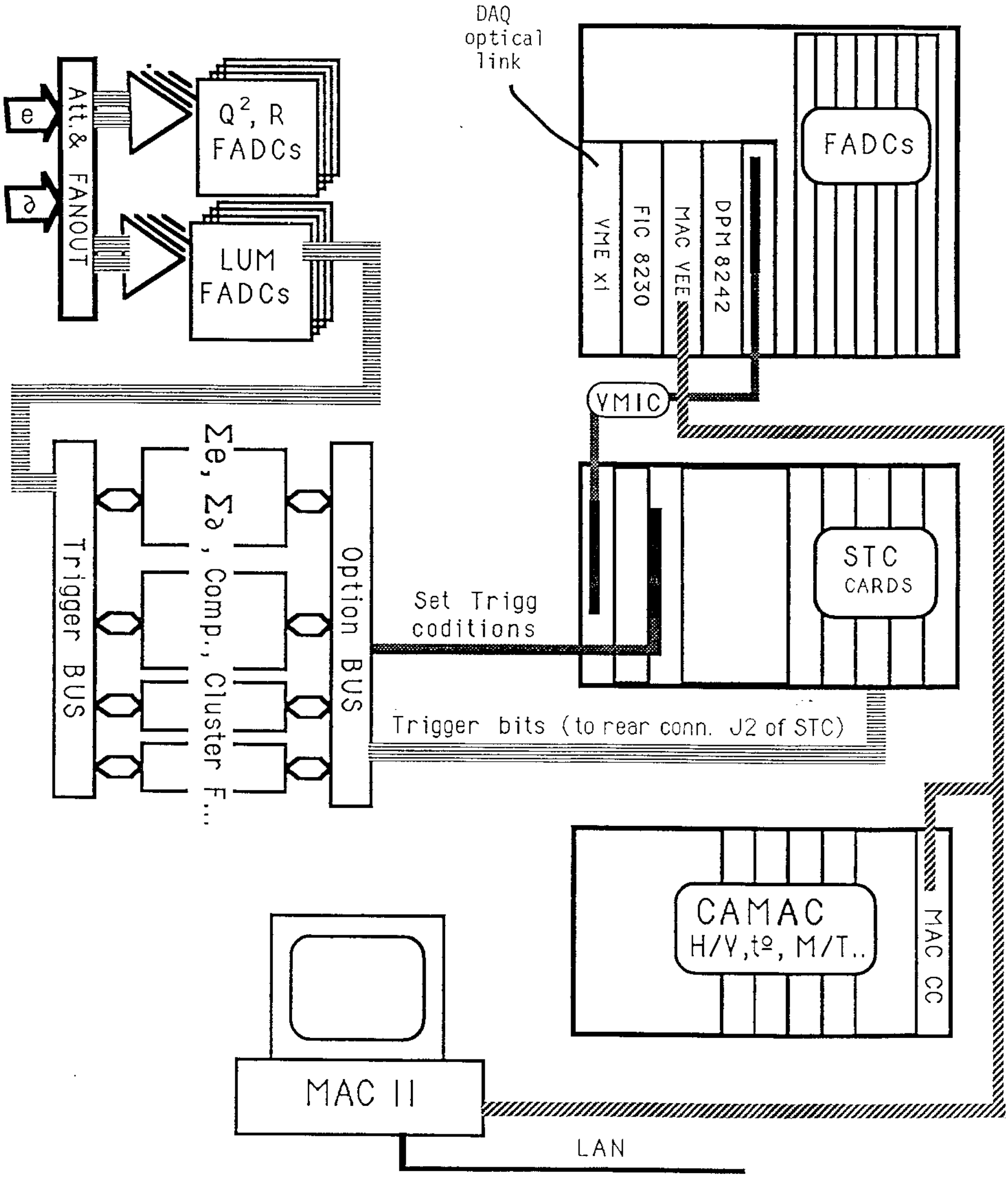


Figure 2.


DAQ optical link
FADCs
VME x1
FIC 8230
MAC VEE
DPM 8242
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Att.& FANOUT
Q^2, R FADCs
LUM FADCs
Trigger BUS
Σe, Σ∂, Comp., Cluster F...
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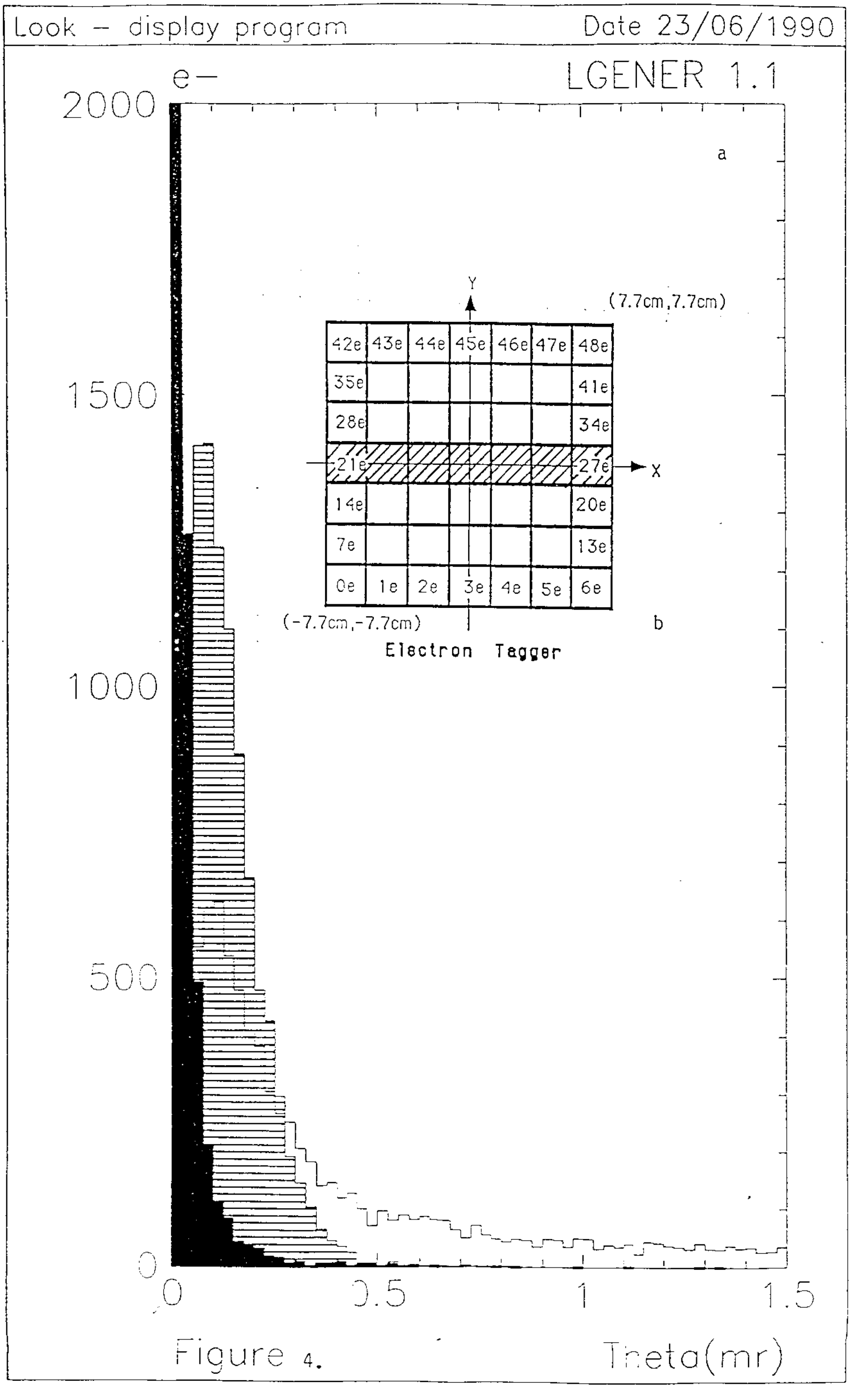
Trigger bits (to rear conn. J2 of STC)
CAMAC H/V, tº, M/T..
MAC CC
MAC II
LAN

Figure 3.


Look - display program
Date 23/06/1990
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2000
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0
0
0.5
1
1.5
a
Y
(7.7cm,7.7cm)
42e
43e
44e
45e
46e
47e
48e
35e
41e
28e
34e
21e
27e
X
14e
20e
7e
13e
0e
1e
2e
3e
4e
5e
6e
(-7.7cm,-7.7cm)
b
Electron Tagger
Theta(mr)

Figure 4.

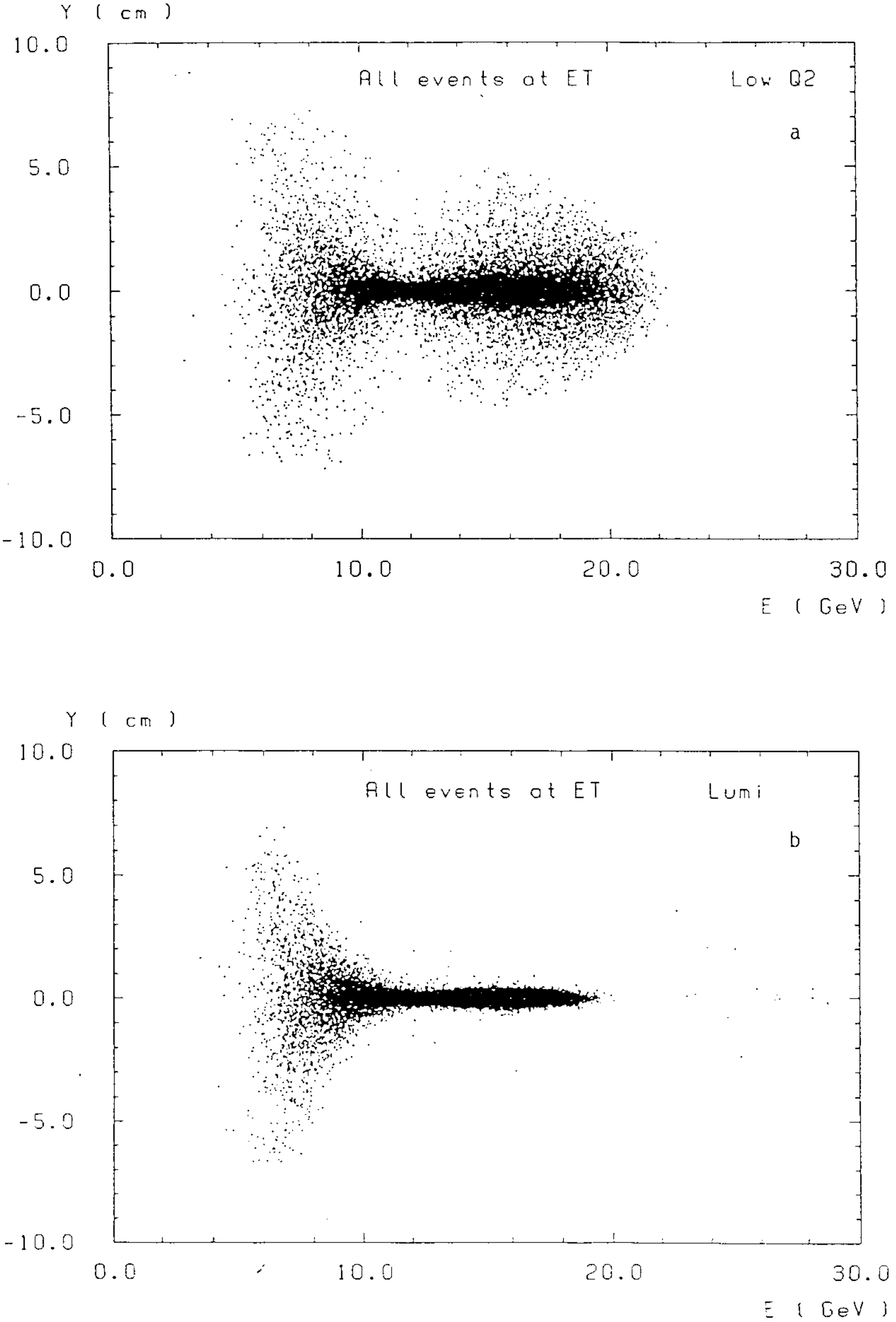
Y (cm)
10.0
5.0
0.0
-5.0
-10.0
0.0
10.0
20.0
30.0
E (GeV)
All events at ET
Low Q2
a
Y (cm)
10.0
5.0
0.0
-5.0
-10.0
0.0
10.0
20.0
30.0
E (GeV)
All events at ET
Lumi
b

Figure 5.

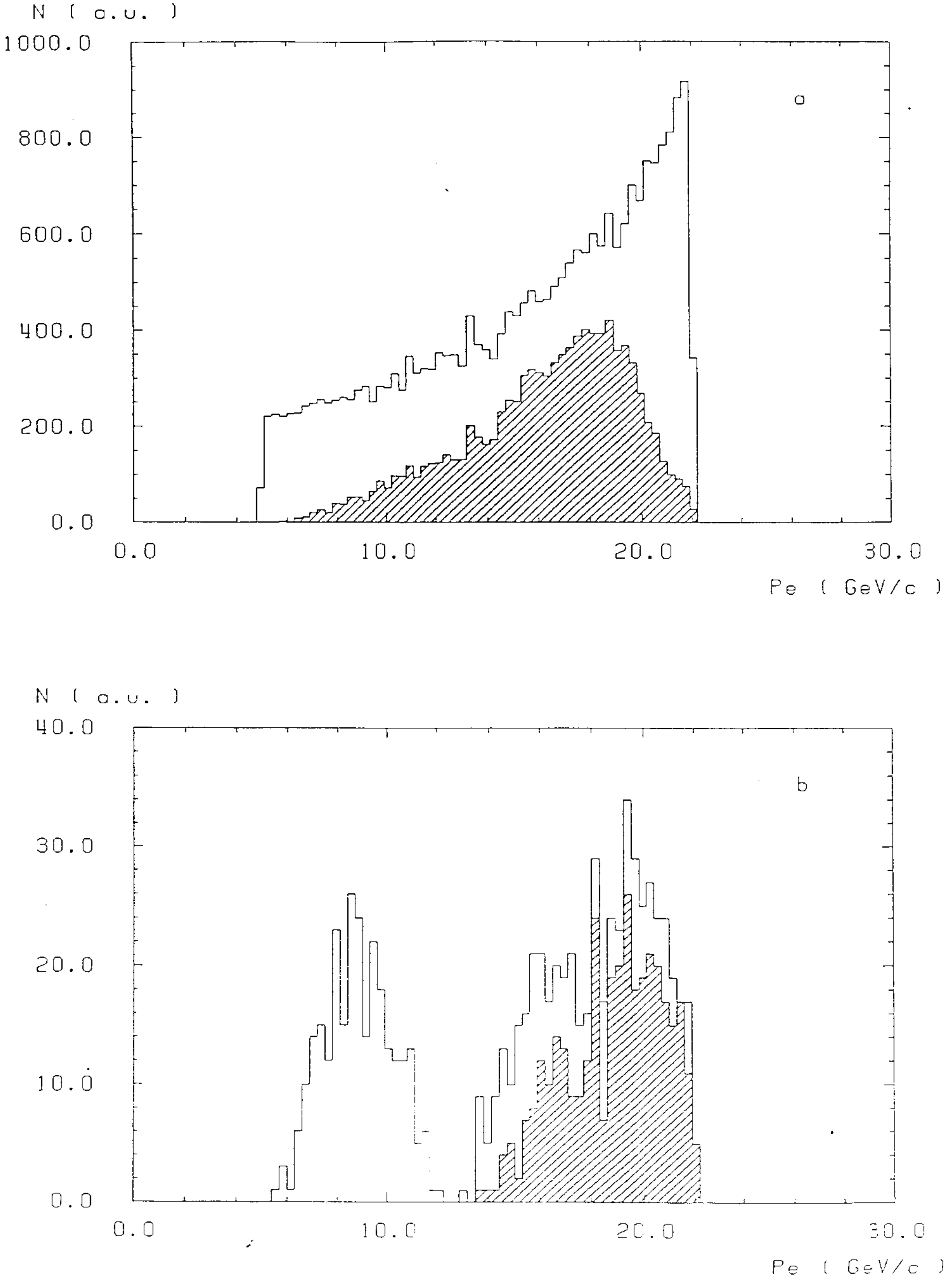
N (a.u.)
1000.0
800.0
600.0
400.0
200.0
0.0
a
0.0
10.0
20.0
30.0
Pe (GeV/c)
N (a.u.)
40.0
30.0
20.0
10.0
0.0
b
0.0
10.0
20.0
30.0
Pe (GeV/c)

Figure 6.

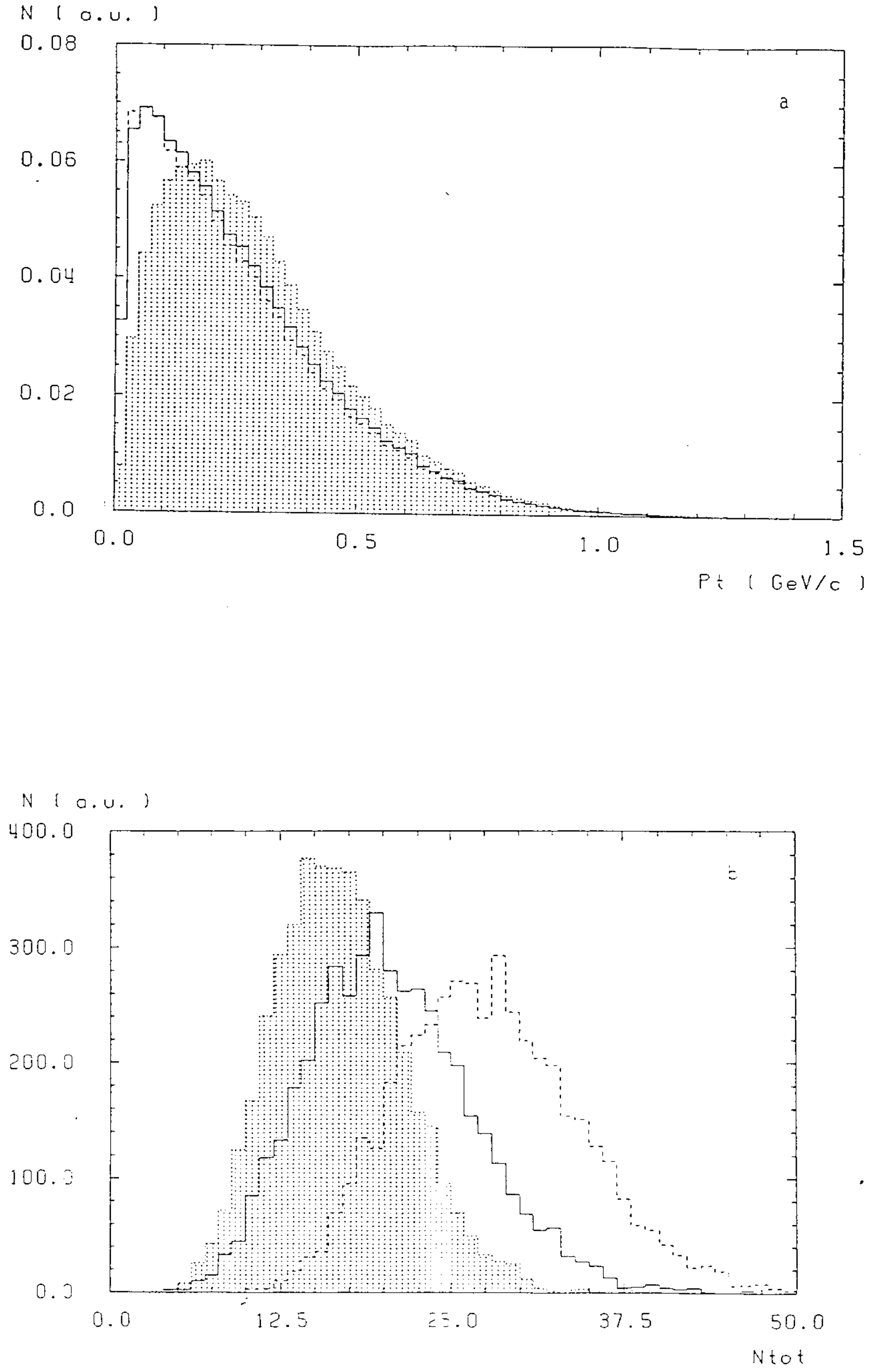
N (a.u.)
0.08
0.06
0.04
0.02
0.0
a
0.0
0.5
1.0
1.5
Pt (GeV/c)
N (a.u.)
400.0
300.0
200.0
100.0
0.0
b
0.0
12.5
25.0
37.5
50.0
Ntot

Figure 7.