сообщения
объединенного
института
ядерных
исследований
дубна

E1-94-66

J.A.Budagov, V.V.Glagolev, W.Li[1], J.Siegrist[2]

POSSIBILITY OF THE SDC CENTRAL CALORIMETER IN SITU CALIBRATION USING $p + p \to W(e\nu) + X$ AND $p + p \to Z^0(e^+e^-) + jet$ INTERACTIONS

[1]Institute of High Energy Physics, Beijing, China
[2]SSCL, Dallas, Texas, USA

1994

Будагов Ю.А. и др. E1-94-66

Возможность калибровки центрального калориметра SDC в составе установки с помощью реакций: $p + p \to W(e\nu) + X$ и $p + p \to Z^0(e^+e^-) + jet$

Рассмотрена возможность калибровки центральных калориметров SDC в составе установки. Предполагается, что калибровка будет сделана с помощью отдельных электронов от распадов $W \to e\nu$ и $Z \to e^+e^-$, и импульсы этих электронов будут измеряться трековой системой. Рождение W-, Z-бозонов в pp-взаимодействиях при $\sqrt{S} = 40$ ТэВ было смоделировано с помощью программ PYTHIA и JETSET. Моделирование показывает, что для области $|\eta| < 2,5$ такая калибровка потребует по крайней мере 1 неделю. Мы предлагаем метод для калибровки адронного калориметра в составе установки SDC после калибровки электромагнитного калориметра. При использовании реакций $p + p \to Z^0(e^+e^-) + jet$ можно восстановить импульс Z^0 (для моды $Z^0 \to e^+e^-$) в э.м. калориметре. Далее надо использовать баланс поперечного импульса для определения импульса струи и калибровки адронного калориметра. Моделирование показывает, что такая калибровка может быть проведена на SDC за 2 месяца.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1994

Budagov J.A. et al. E1-94-66

Possibility of the SDC Central Calorimeter in situ Calibration Using $p + p \to W(e\nu) + X$ and $p + p \to Z^0(e^+e^-) + jet$ Interactions

The possibility of the SDC central e.m. calorimeter calibration in situ is considered. It is supposed that the calibration will be done by means of the isolated electrons from $W \to e\nu$ and $Z \to e^+e^-$ decays and the momenta of these electrons should be measured in the tracker. The production of W, Z bosons in the pp-interactions at $\sqrt{S} = 40$ TeV was simulated by PYTHIA and JETSET programs. Simulation shows that such calibration will take at least 1 week period for the region $|\eta| < 2.5$. We propose a method of the e.m. calorimeter using for the hadron calorimeter calibration. It is possible to calibrate the hadron calorimeter in situ after the e.m. calorimeter calibration. For the reactions $p + p \to Z^0(e^+e^-) + jet$ we could reconstract Z^0 momentum (via $Z^0 \to e^+e^-$ mode) with the e.m. calorimeter. Then the balance of the transverse momentum will be used to obtain the jet momentum and thus to calibrate calorimeter. Simulation shows that such calibration will take about 2 month period.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1994

1 SDC e.m. calorimeter calibration using electrons from decays of W and Z bosons

The simulation of W - e nu and Z - e e decays was carried out by PYTHIA 5.5 code. W, Z production cross sections ($\sigma(W) = 304,5$ nb, $\sigma(Z) = 98,3$ nb at $\sqrt{S} = 40$ TeV) were taken from 1990 LHC Workshop [1]. The Branching Ratios we used

Br R $(W \rightarrow e\nu\ ) = 10.5$ %

Br R $(Z \rightarrow e^+e^-\ ) = 3.245$ %

are taken from [2]. When simulation the segmentation $d\theta = d\phi = 0.05$ of the SDC central e.m. calorimeter was used. It is supposed that the SSC is running at a luminosity of 1.E+33 1/(s*cm**2).

The requirements for the energy resolution $\sigma(E)/E = a/\sqrt{E} \oplus b$ for the SDC barrel e.m. calorimeter are: a=0.14, b=0.01, and for the end cap one are a=0.17, b=0.01 [3]. Accordingly to the estimated e.m. calorimeter constant term budget [3] it is seen that the contribution of the estimated error on the tower to tower calibration should be about 0.2 %. To provide that the calibration coefficients for the e. m. calorimeter should be measured not worse than with 0.2 % accuracy. Let's denote by S the e.m. calorimeter signal, P - the electron momentum measured at the tracker and C - the e.m.calorimeter calibration coefficient. The energy reconstructed in the e.m. calorimeter is E=CS. On the other side P=E and C=P/S. From those equation we obtain that

$$\sigma(C)/C = \sigma(P)/P \oplus \sigma(S)/S \tag{1}$$

In this work using the PYTHIA generator at $\sqrt{S} = 40$ TeV we obtained energy and angle distributions for $W \rightarrow e\nu$ and $Z \rightarrow e^+e^-$ decay electrons. Let's now estimate what time takes the calibration of the e.m. calorimeter using e^+ and e^- from $W \rightarrow e\nu$ decays near the $\eta = 0$, $\eta = 1.4$ and $\eta = 2.5$ ranges (see Fig. 01).

For the range close to $\eta = 0$ one can conclude from the Fig.02 that the mean electron energy is about 36 GeV. In [3] it was found that P_t resolution of the tracker is about 0.7 % at those energy and pseudorapidity. The relative energy resolution is $\sigma(S)/S = 14/\sqrt{36} \oplus 1 = 2.5\%$. As a result, according to equation (1), $\sigma(C)/C = 0.7\% \oplus 2.5\% = 2.6\%$. Measuring the error of the mean of calibration coefficient to 0.1 % accuracy requires about 700 electrons per tower. We obtained that the yield of e^+ and e^- at the $\eta = 0$ is about

2E+04 events/(cell*year). The cell is $d\eta \times d\phi = 0.05 \times 0.05$ segment of the e.m. calorimeter. The accelerator year is 1.E+07 sec. So per one second it will be about 2.E-03 electrons/cell and the 700 electrons will be collected in 5 days.

The analogical calculations were done for the η regions close to $\eta = 1.4$ and $\eta = 2.5$. The estimation of the central e.m. calorimeter calibration time by isolated electrons (positrons) from $W \to e\nu$ decays could be represented in the next table.

	rapidity region		
	barrel e.m. calorimeter		endcap e.m. calorimeter
	center $\eta = 0.$	edge $\eta = 1.4$	$\eta = 2.5$
mean $e^{\pm}$ energy (GeV)	36	60	70
P_t tracker resolution (%)	0.7	1.	1.
e.m. calorimeter energy resolution $\sigma(S)/S(\%)$	2.5	2.8	2.3
number of the $e^{\pm}$ per (tower*year)	$2. * 10^4$	$1.6 * 10^4$	$1.3 * 10^4$
calibration time (days)	5	7	6

It should be noticed here that the results we obtained do not take into account W trigger efficiency and efficiency of the isolated electron detection.

The e.m. calorimeter calibration using the $Z \to e^+e^-$ decays also can be done. At this case the rate of events is about 10 % that of $W \to e\nu$ decays. Towers with $|\eta| > 2.5$ are away from the silicon and barrel straw-tube tracker rapidity coverage [3]. Magnetic field at $|\eta| > 2.5$ is about 3 times lower than for $|\eta| < 1.5$ region [3]. For that reason, in the rapidity range $2.5 < |\eta| < 3.0$, one of the acceptable ways would be the calibration with $Z \to e^+e^-$ decays using the invariant mass constraint.

The results of the $W \to e\nu$ and $Z \to e^+e^-$ decays simulation permit to estimate that in-situ calibration of the SDC central e.m. calorimeter will take at least one week for the rapidity region $|\eta| < 2.5$.

2 Central hadron calorimeter in situ calibration using $p + p \to Z^0 + jet$ interactions

This process is realized via subprocesses :

$f_i + \overline{f_i} \to g + Z^0$,

$f_i + g \to f_i + Z^0$

in the PYTHIA code.

The cross section at E(CMS)= 40 TeV is 98.3 nb for Z^0 production.

2.1 $Z^0 \to e^+e^-$ acceptance

As it said in the Technical Design Report (TDR) the dilepton SDC trigger will demand $P_t > 20$ GeV and $|\eta| < 2.5$ for each lepton. These conditions were applied to the e^+e^- from the Z^0 decay in the p p $\longrightarrow Z^0$ (e^+e^-) + jets reactions.

We have obtained 43 % for acceptance of such reactions using 100 % efficiency for each electron detection under the above mentioned conditions on the Pt and eta for electrons. This acceptance vs. eta of Z^0 eta is shown in Fig. 03 (upper plot). The TDR said that the global e efficiency within the detector acceptance is 85 % for analyses requiring isolated leptons. But in the case where the analyses requires two such leptons reconstructing to on shell Z boson, the lepton identification cuts are relaxed for the second lepton, and the efficiency for the second lepton is taken to be 95 %. So for Z^0 - e^+e^- the e^+e^- registration efficiency will be 85 % * 95 % = 80 %.

The acceptance for the reactions p p $\longrightarrow Z^0$ (e^+e^-) + jets will be 43 % * 80 % = 34 %.

2.2 Jet selection

We used the procedure for jet clustering in the whole eta, phi range. We have used three values as the parameters of the jet. They are Pt(1) for leader particle, R - radius of the cone in eta-phi space and Pt(jet) for the jet.

The hadron with its Pt above Pt(1) is used as the initial jet center. All particles inside of a cone with the radius R, centered on the initial axis direction are included to form a jet. The new axis direction is recalculated using these selected particles weighted by Pt. Then the new hadron set is defined in the cone with the new axis and radius R. This algorithm was repeating until the change of the jet direction in the iteration procedure does not exceed 0.1 in eta-phi space. This algorithm allows to correct determination of the Pt jet center independently of the starting axis direction. If the Pt for the selected jet is more than the cut Pt(jet) the jet is accepted. Then the multitude of the particles inside of that cone with radius R is terminated and the search for the next jet is restarted.

We notice here that the number of the selected jets strongly depends on the parameters Pt(1), Pt(jet). But the jet characteristics are mainly defined by the Pt(jet) and R parameters.

2.3 Jet characteristics

We apply the jet selection algorithm to the events accepted by the trigger. We used selection criterions R=0.6, Pt(1)=5 GeV, Pt(jet)=10 GeV. We also selected events with $Pt(Z^0) > 10$ GeV. The thresholds on the Pt values were applied to select the events without very wide and diffusive jets.

The jet multiplicity is shown in Fig. 03, lower picture. Then only the events with one jet satisfying the above criterions are chosen. Some characteristics of the events with Z^0 are represented in Fig. 04. The event transverse energy which is got by the jet is about 17% for the events with Z^0 (Fig. 04, lower plot). So we could expect some "background" of accompaning particlies in the case of the Z^0 - jet events.

The upper plot on the Fig.05 represents the ϕ angle difference between the jet and the Z^0. The selected jets are mainly in the opposite direction of Z^0. The Et(jet) - $Pt(Z^0)$ and Et(jet)/$Pt(Z^0)$ spectra are shown on the bottom on the Fig. 05. We used the Et(jet) value instead of the Pt(jet) because the first one is the measured value.

The Fig. 06 represents the characteristics of the selected jets.

2.4 The time estimation for the hadron calorimeter calibration

To obtain the rate N of events with one acceptable jet we used the following parameters:

$\sigma(p+p \rightarrow Z^0 + jet) = 98.3$ nb at the E(CMS)=40 TeV

Luminosity(L) = 1.E+33 1/(cm^2 *s)

Br Ratio (Br Z $\rightarrow e^+e^-$) = 3.25 %

Acceptance ($Z^0 \rightarrow e^+e^-$) = 34 %

Coefficient of the event selection (good jets) C.jet = 22 %. This coefficient is the percent of events with only one jet relative to the number of accepted (by trigger conditions) events.

The rate is:

N = σ * L * Br * Acceptance * C.jet = 0.24 events/s

The constant term for the barrel hadron cal. should be 6 % according to the Technical Design Report. We assume that the calibration coefficients for the hadron cal. should be defined with 2 % accuracy.

We will obtain the jet transverse energy using the distribution Et(jet)/$Pt(Z^0)$ (see Fig.05, lower plot), it gives us a relative accuracy of 31 %. The mean Et of the selected jets is about 40 GeV (see Fig. 06, right lower plot).

The relative accuracy of the barrel hadron cal. energy measurement is $67\%/\sqrt{40} \oplus 6\ \% = 12\ \%$. So the total relative accuracy for the calorimeter calibration coefficients $\sigma C/\overline{C} = 31\% \oplus 12\% = 33\ \%$. We need also to take into account the accuracy of the Z^0 Pt reconstruction from the $Z^0 \rightarrow e^+e^-$ decay.

2 % precision in mean values of calorimeter calibration coefficients $\sigma\overline{C}/\overline{C}$ needs 280 events with 33 % r.m.s. of measured calorimeter calibration coefficient distributions. The central hadron calorimeter has 60 (eta) * 64 (phi) = 3840 cells. If we demand 280 events for each cell it will take a total of 1.1E+06 events on the calorimeter. The time needed is 1.1E+06/0.24 = 4.6E+06 s = 54 days $\approx$ 2 months.

This rough estimate gives 2 months for hadron calorimeter calibration on the 2 % accuracy level. Higher precision calibration time estimates obviously need to consider questions connected to Z^0 Pt reconstruction, hadron shower sharing (R=0.6 means a matrix 12*12 elements) and subdivision of the calorimeter on the e.m., and two hadronic parts.

3 Barrel calorimeter jet response compare to electron and pion

A highly detailed description of the central SDC calorimeter [4] allows us to compare signals from jets, electrons and hadrons. The set of single jets was simulated using LU1ENT routine from the PYTHIA / JETSET generator. The u - quark was used as the jet initiated parton.

The tracking system and coil in front of the calorimeter were simulated with the magnetic field turned on.

We can see using the Pythia generator that the mean jet Et is about 40 GeV in the case where jet opposite to the Z^0 (see Fig 06, lower right plot). We simulate the set of single jets with E=50 GeV at the eta = 0.15. The jets were started toward to the center of the hadron calorimeter tower. The single pions and electrons were started with E = 50 GeV at the same eta and phi values for the calorimeter response comparison. We remind that the central hadron calorimeter consists of the two parts with varying steel plate thickness. Fig. 07 shows the energy deposition in the scintillator for e.m., hadron(1) and hadron(2) calorimeter parts from incident 50 GeV electrons, hadrons and jets. The left upper plot on the Fig. 07 gives us the calibration coefficient for the e.m. calorimeter at eta = 0.15 . If we take a look on the left lower plot on the same Figure we can see that jet loses about 50 % of it's energy in the e.m. calorimeter while the hadron loses about 25 % .

4 Conclusion

The results of the $W \to e\nu$ and $Z \to e^+e^-$ decays simulation permit to conclude that SDC central e.m. calorimeter in-situ calibration will take at least one week for the rapidity region $|\eta| < 2.5$.

Some estimates were made of the central hadron calorimeter in situ calibration time using the jet opposite to the Z^0. We showed that accordingly to the PYTHIA generator there are no such pure events i.e. events which have only the Z^0 and the compact jet in the opposite direction: each event has some accompaning "background" in the form of low energy jets and single particles. For the Z^0/jet events the calibration of the hadron central calorimeter takes a couple of months.

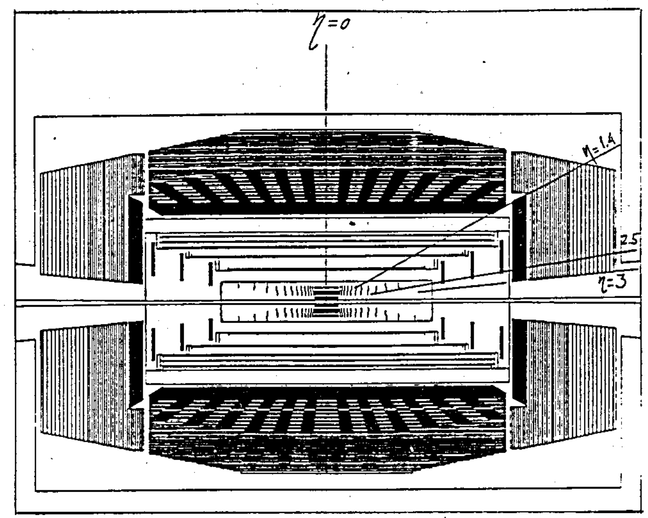

Figure 1. The general view of the SDC set-up. The direction with η = 0., 1.4 and 2.5 are shown.

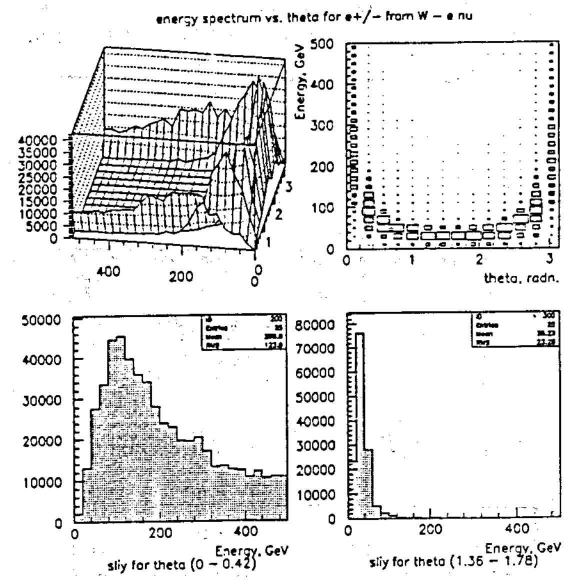

Figure 2. The upper pictures represent the energy spectrum against the θ angle for $e^{\pm}$ from $W \to e\nu$ decays. The lower pictures show slices from upper plot for (0. - 0.42) and (1.36 - 1.78) θ ranges.

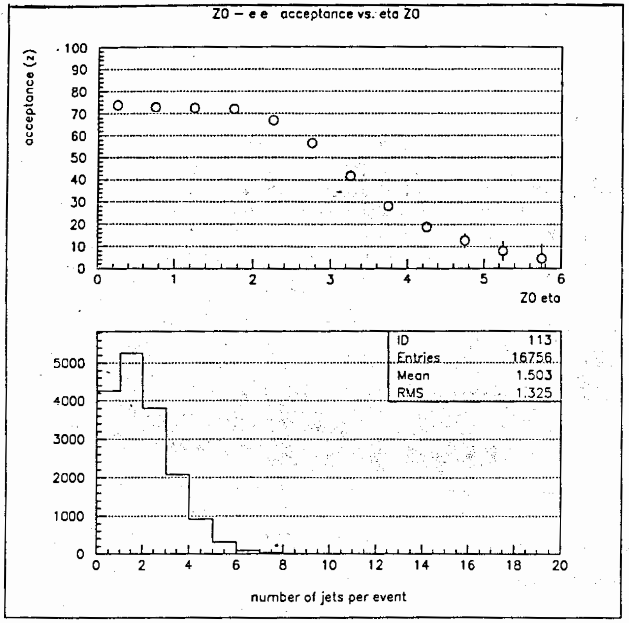

Figure 3. a) $Z^0 \to e^+e^-$ acceptance versus η_{Z^0}. b) Number of jets per event.

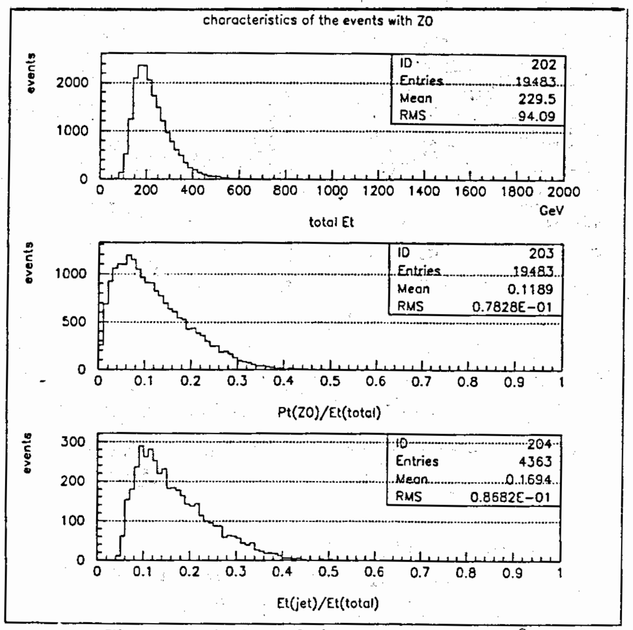

Figure 4. Characteristics of the events with Z^0. Total E_t is E_t for the calorimeter acceptance region i.e. $|\eta| < 6$.

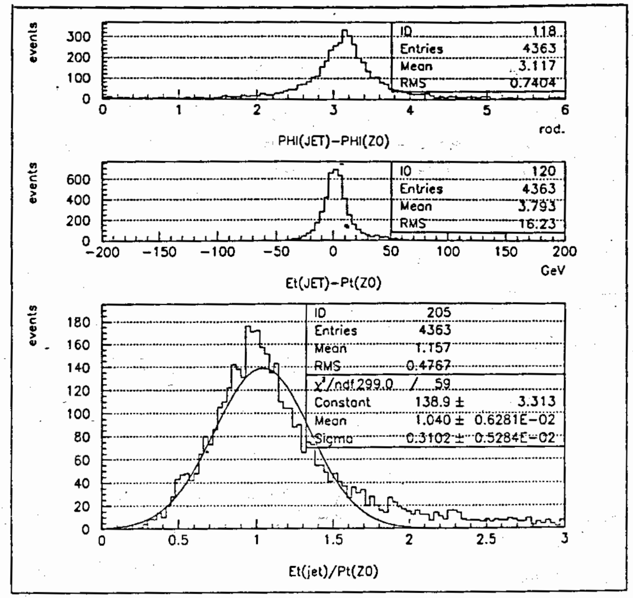

Figure 5. The angle and energy accuracy obtained for the jet opposite to the Z^0.

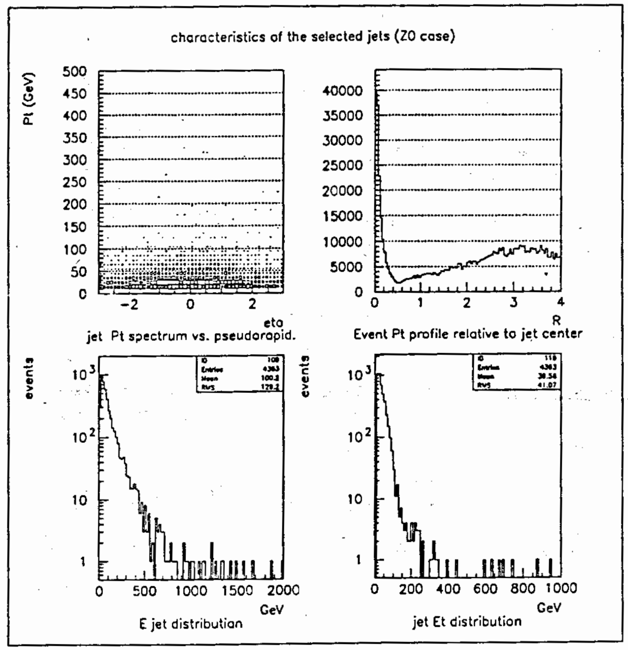

Figure 6. Characteristics of the selected jets (Z^0 case).

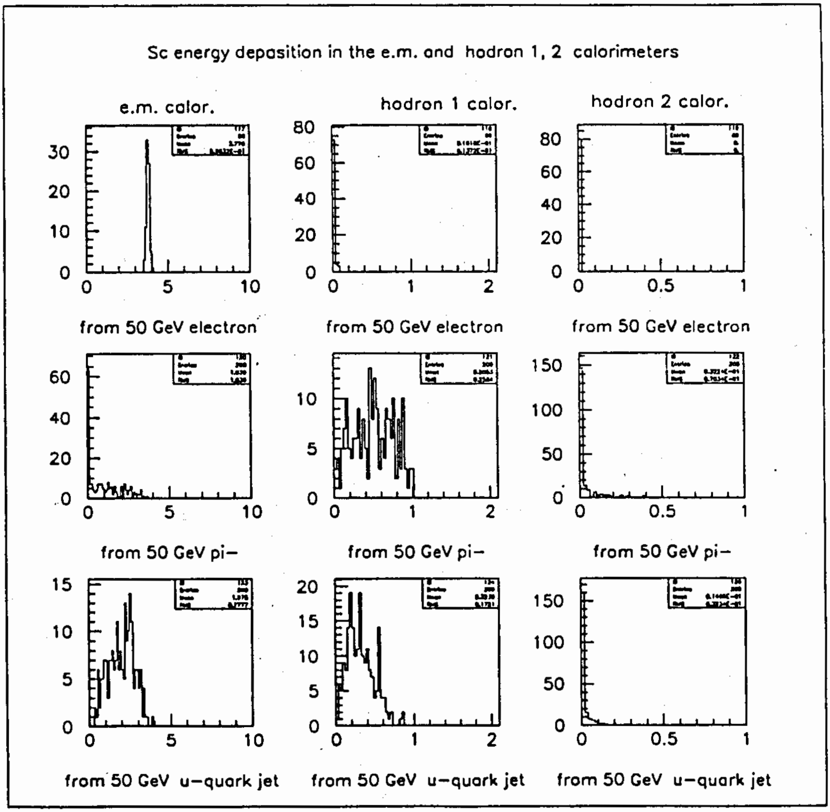

Figure 7. Energy deposition in the scintillator of the e.m and hadronic calorimeters for 50 GeV e^-, π^- and jets.

References

[1] ECFA Large Hadron Collider Workshop *AACHEN Vol.2 CERN 90-10*

[2] Review of Particle Properties *Physical Review D Vol.45 1 June 1992*

[3] Technical Design Report *1 April 1992 SDC-92-201, SSCL-SR-1215*

[4] Vl.Glagolev, W.Li, D.Schmid and M.Turcotte *SDC-Note, SDC-93-565*

Received by Publishing Department
on March 5, 1994.