PHYSICS NOISE TO CALORIMETRY AT SSC

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SUMMARY

The effect of the unbiased events to calorimetry at the SSC was studied with a Monte-Carlo simulation.

INTRODUCTION

At the SSC we expect the luminosity of $L=10^{33}$ cm^2/sec and the inelastic cross section of σ=100mb. With these conditions an event rate is 10^8 per second, which corresponds to 1.6 events per beam crossing , assuming 60MHz beam crossing cycle. Most of these events are uninteresting from a 'new physics' viewpoint.They constitute the background- or noise- against the signal events.

These background events are often called unbiased events, whose trigger condition is only that they come from beam-beam crossings. When data acquisition is triggered with a certain condition, the signal of the unbiased events may accidentally overlap on that of the triggered event, since detectors or electronics generally have a finite response time. Consideration of such overap effect is important for designing calorimeters, electronics and triggerring[1].

In this note, we report a Monte-Carlo simulation study on the noise introduced to calorimetry by unbiased events in various pesudo-rapidity ranges. Events were generated by ISAJET V5.2 generator and simulated with a simlified shower simulation program. The program includes longitudinal and lateral development of hadronic and electromagnetic showers. Using the information on shower development, the leackage from adjacent towers was also included in the noise , because a typical tower size in proposed SSC calorimeters is comparable with the shower size.

EVENT GENERATION

As physics processes, we chose (a) minimum bias events, and (b) two-jet events with small transverse momentum Pt (4<Pt<10GeV/c). A total of 10000 events were generated for each process. At the SSC energy ($\sqrt{s}$=40 TeV), the cross section of the low Pt two-jet events is comparable to that of the minimum bias events. In fact, we obtained 124mb for two-jet and 137mb for the minimum bias cross sections with the ISAJET generator. We mixed these two kinds of events randomly in order but keeping event frequency proportional to the cross section of each process. To get time sequence of the 'observed' events, we distributed these events over beam crossings according to the Poisson distribution with a mean value of 1.6 events/crossing.

DETECTOR SIMULATION

Calorimeter

Parameters of the calorimeters assumed in this work are shown in Table 1. All parameter values are based on 'Model A' in 'The Conceptual Design of SSC Detectors'. In Model A , each of the electromagnetic and hadronic calorimeter sections is devided longitudinally into two segments. The hadronic part consists of the front (precision) and the rear (hadron catcher) parts. The shower radiators in the precision and the catcher parts are Uranium and Iron, rspectively. We ignore for the present analysis the effect of material difference between the front and back segments to the energy resolution , and assume that the energy resolution for hadrons is 35% as determined by the front part . We also ignore the effects of the magnetic field , crack of the calorimeters and particle conversions in material in front of the calorimeter. Parameters which define geometry are shown in Table 1 and 2.

Table 1

η	1	2	4	5
$\Delta\eta=\Delta\phi$ (em)	0.03	0.03	0.03	0.1
(had)	0.06	0.06	0.06	0.2
distance from collision point	3m	3m	16m	16m

Table 2

	EM	HAD
material	U	U+Fe
energy resolution (%/$\sqrt{E(GeV)}$)	15	35
layer thickness (x_0)	1	3.39
(λ)	0.03	0.1
no. of layers	9+16	62+50

Shower Simulation

Electromagnetic and hadronic showers were simulated with shower models being used in CDF simulation package[2]. Materials used in CDF calorimeters are different from those used in Model A. The Central CDF Electromagnetic (Hadronic) calorimeter is constructed with lead-scintillator (iron-scintillator) sandwitches, while Model A calorimeters consist of Uranium-Argon sandwiches. We ignore the effects of this difference to the shower development except that we use the radiation length, the interaction length, material density, and the critical energy of Uranium and Argon in the shower parametrization.

Energy deposit to a typical tower was calculated as follows;

1. We define a tower with a given value of η , and find the electromagnetic and hadronic particles hitting the given and neighboring towers,
2. The total energy deposit of each of these particles in each layer was calculated according to the longitudinal shower profile,
3. The energy deposit in the given tower was obtained by considering the transverse profile of the shower produced by individual particles and integrating the energy deposit over the tower area.

Electromagnetic Shower In this study, we assume that the longitudinal shape of the electromagnetic shower is given by a function,

$$dE/ds= k\, s^{(a-1)}\exp(-bs), \qquad (1)$$

where K is a normarization factor , and s is the depth , measured in radiation lengths, from the starting point. The constants a and b are parameters which determine slopes of the shower in its rise and fall. The numerical values for a and b obtained from the beam test of the CDF Central calorimeters are

$$a=2.4+0.56(e)+da, \qquad (2)$$
$$b=0.5+db.$$

The fluctuations da and db obey the Gaussian distributions with sigmas 0.5 and 0.049 respectively. The numerical values are empirical ones and they should be detector dependent. Here we assume the same values for SSC calorimeters just for simplicity.

The transverse profile of the electromagnetic shower is expressed as a sum of two Gaussian distributions,

$$dE/dR=k[a\exp(-r^2/(2\sigma_{nar}^2)+(1-a)\exp(-r^2/2\sigma_{wid}^2)], \qquad (3)$$

where parameters which represent the lateral shower size are

$$\sigma_{nar} = (a_n + b_n s)x_{eff}/\varepsilon), \quad (4)$$
$$\sigma_{wid} = (a_w + b_w s)x_{eff}/\varepsilon),$$

with numerical values a_n=0.0, b_n=0.039±0.055, a_w=8.19, b_w=0.0 and a=0.6. In the above expression, x_{eff} is the effective radiation lengths of the showering material, and ε is the critical energy of the material.

Hadronic Showers The longitudinal profile of hadronic shower has the same form as the electromagnetic one,

$$dE/dz = kz^{(a-1)}\exp(-bz), \quad (5)$$

where z is the depth, measured in the unit of interaction lengths, from the starting point of the shower. The starting point z_0 is assumed to fluctuate according to a function $\exp(-z_0/\lambda)$. Until a hadronic shower starts, a particle is treated as a minimum-ionizationizing particle. The numerical values of parameters are

$$a = 1.0 + 0.036E, \quad \text{for} \quad E<10\text{GeV}, \quad (6)$$
$$a = 0.62 + 0.31\ln(E), \quad \text{for} \quad E>10\text{GeV},$$
$$b = 0.81 + 0.024\ln(E).$$

The longitudinal profile is fluctuated by multiplying the depth z by a random scale factor, SCALE. The variable 1/SCALE is assumed to distribute according to a truncated Gaussian between 0.01 and infinity. It has a Gaussian distribution with a mean of 0.6 and a sigma of 0.45 . The SCALE factor is forced to be in the range from 0.2 to 1.5 .

The transverse profile of the hadronic shower is assumed to be a single component Gaussian function with sigma linearly glowing with the number of grams/cm2 traversed. The numerical value of sighad is given empirically (from CDF beam test) by

$$\sigma_{had} = a_h + b_h * (\text{grams/cm}^2)$$

with

$$a_h = 6.45 \quad (7)$$
$$b_h = 0.07 \pm 0.02$$

WAVE FORM FROM AMPLIFIER/SHAPER AND R.M.S. NOISE FROM UNBIASED EVENTS

The instantaneous noise amlitude f(t) is given by

$$f(t) = \sum_k H_k f_k(t) \quad (8)$$

where H_k is the energy deposit by the k-th event , and $f_k(t)$ is a wave form of the output of amplifier/shaper. In the present analysis , we assumed it to be a simple 'one-shot sine wave' with sampling time of τ=400ns, 1μs and 10μs [3]. If the k-th event occurs at a beam crossing time T_k, $f_k(t)$ is given by

$$f_k(t) = \sin[\omega(t - T_k)], \quad \text{for } T_k < t < T_k + \tau \quad (9)$$
$$= 0, \quad \text{otherwise}$$

where

$$\omega = 2\pi/\tau.$$

The r.m.s noise is calculated from Eq(7) to be

$$n = \sqrt{\frac{\tau}{T}\sum_{k=1}^{N}\sum_{l=1}^{N} H_k H_l F_{kl}} \quad (10)$$

where correlation factor F_{kl} for one-shot sine wave is given by

$$F_{kl} = 0, \quad \text{for } x_d \geq 1$$
$$F_{kl} = (1-x_d)\cos 2\pi x_d + \frac{1}{2\pi}\sin 2\pi x_d, \quad \text{for } x_d < 1 \quad (11)$$

with $x_d = \dfrac{|T_k - T_l|}{\tau}$.

RESULTS AND DISCUSSIONS

The simulation for the unbiased events was done with a procedure as described in the previous section. The total number of particles hitting a given tower was about 10 per 10000 beam crossings, which is consistent with the particle multiplicity

$$dN/d\eta = 6 \quad (12)$$

at 40TeV.

The enegy deposit in typical tower segments are shown as a function of time in Figs.1. The average energy deposit per tower is shown in Fig.2. Figures 3 show examples of the distribution of the instantaneous noise level as given by Eqs.(8) and (9) and sampled every 16ns. One notices that the distributions are far from Gaussians exept in some hadron tower segments where the shower size is larger than tower sizes.The r.m.s noise per tower segment is summarized in Figures 4. From this result one may conclude that the physics noise caused by the unbiased events are negligible compared to energies of individual particles interesting at the SSC.

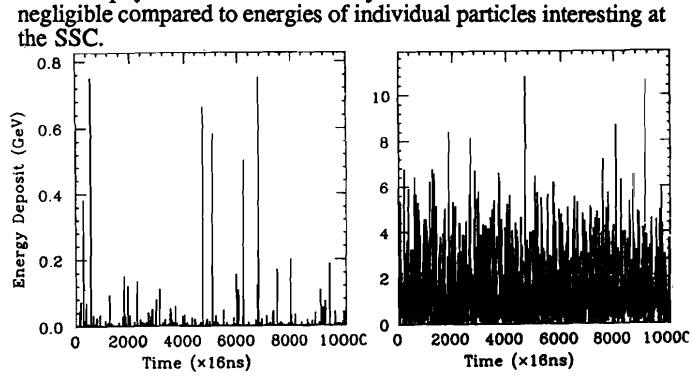

Fig.1 Examples of energy deposit in a tower segment as a function of time.η=0 1st segment (electromagnetic part ,left) η=5 3rd segment (hadronic part , right)

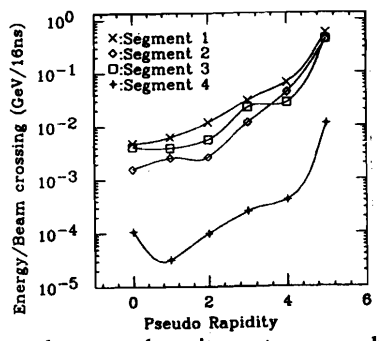

Fig.2 Averaged energy deposit per tower per beam crossing (16ns) as functions of pseudo rapidity and segment.

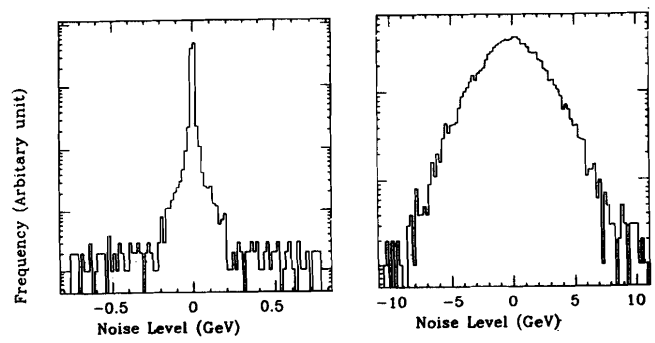

Fig.3 Examples of Distribution of noise level sampled each beam crossing time (16ns). Time constant was taken as τ=400ns. η=0 1st. segment (left). η=5 3rd segment (right).

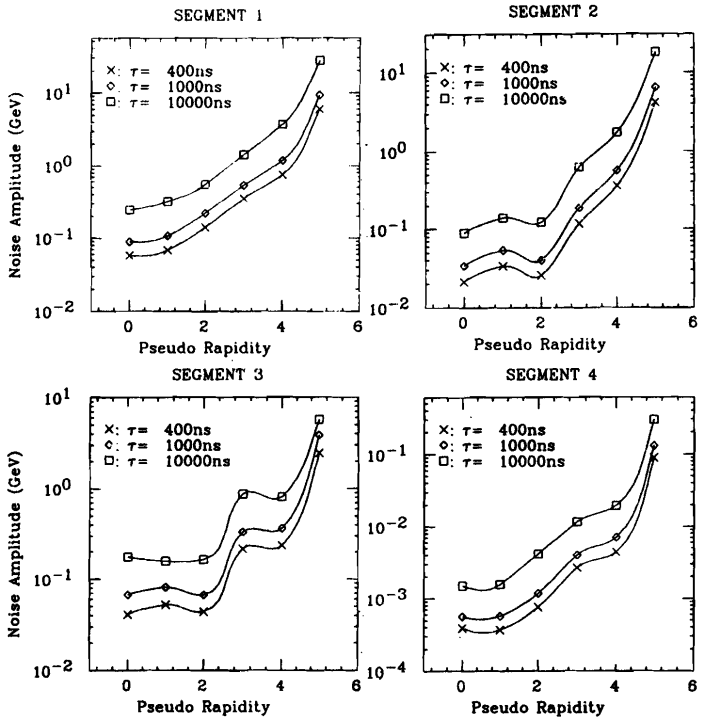

Fig.4 Summary of R.M.S. values of each segment at each time constant.

At hadron collider experiments , however , the total energy transverse to the beam axis, E_t^{tot}, is a useful quantity in characterizing the events. The missing transverse energy E_t^{miss} is also a crutial quantity in search for particles whose decay products contain neutral evading particles as neutrinos or photinos. To measure these quantities signals are summed, in scaler and vectorially, over the whole region of η and ϕ.

The total r.m.s. noise in a given η_k is given by

$$\Delta E_t^{sum}(\eta_k) = \sqrt{N_\phi}\,\Delta E(\eta_k)\sin\theta \qquad (13)$$

where $\Delta E(\eta)$ is the r.m.s noise per tower and N_ϕ is the number of ϕ bins in the calorimeter towers. The integrated r.m.s. noise over η_k is given by

$$\Delta E_t^{tot} = \sqrt{N_\phi}\sqrt{\sum_k \left[\frac{\Delta E(\eta_k)}{\cosh\eta_k}\right]^2 \Delta\eta_k} \qquad (14)$$

Numerically, ΔE_t^{tot}=3.4GeV for τ=400ns, 5.3GeV for 1μs, and 15GeV for 10μs.

The error in the measurement of the missing transverse energy E_t^{miss} is

$$\Delta E_t^{miss} = \Delta E_t^{tot}/\sqrt{2} \qquad (15)$$

corresponding to the average value of $\cos^2\phi$ of 1/2.

The results show that , with the sampling time of 400ns and 1μs, the r.m.s noise is acceptable for the Et_t^{ot} and E_t^{miss} measurements. It should be noted,however, that we ignored noise correlation between towers, so that the estimation gives the lower limit of the noise. If the correlated number of towers are N_c, the r.m.s. noise is $\sqrt{N_c}$ times larger. Thus, the physics noise is sizable and worth paying attention to for the design of experiments at the SSC.

CONCLUSION

A simulation study on physics noise to calorimetry at SSC was done. The estimated r.m.s. noise is negligible to the measurements of energies of individual particles. The error introduced to the E_t^{tot} or E_t^{miss} measurement amounts to a few GeV with sampling time of 400ns, and more than 10 GeV with a sampling time of 10μs. The effect is worth considering for the design of experiments at SSC.

ACKNOWLEDGEMENT

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REFERENCES

[1] As a previous work, Franzini made a 'first order' estimate of minimum bias signal and their variance. He assumed simple Poisson distributions and very long decay time (100 μsec) of ampilifier. (Proceedings of the workshop on triggering, data acquisition, and offline computiing for high energy/high luminosity hadron-hadron colliders p.93 Fermilab Nov.1985)

[2] J.Freeman and M.Eaton Description of CDFcalorimetry simulation May 1985 (not published) .
Bock et al., CERN-EP/80-206
Bertani and DelFabbro , CDFnote-102 (not published)

[3] V.Radeka , talk at this workshop.