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On Vertex Determination in $H \rightarrow \gamma\gamma$ Searches Response to Dr.D.Froidevaux

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1 Introduction

In GEM's recent physics report to the PAC (GEM-92-126), we pointed out that based upon our analysis using PYTHIA program the primary Higgs event vertex for H$\rightarrow \gamma\gamma$ searches at the SSC can be determined by using underlying event topology with a probability of 85%.

A question was raised by Dr. D. Froidevaux concerning the reliability of this analysis, and specially the Monte Carlo program used in this analysis. Dr. D. Froidevaux's question was based on experimental data that the W production is not much different from the minimum bias event.

After a brief study on this issue, we conclude:

- The W production data published by UA1, UA2 and CDF agree well with PYTHIA predictions;
- The higher p_T of Higgs production, compared with W production, predicted by PYTHIA, has solid theoretical backup: while W is produced through $q\bar{q}'$ annihilation, the Higgs is produced through gluon-gluon fusion or W/Z-W/Z fusion. Here, gluon-gluon coupling is larger than quark-gluon coupling, so Higgs gets more recoil than W, and W/Z mass in the propagator produces high p_T.
- Theoretical calculations including high order corrections predict that the p_T of Higgs at the SSC energy is over 50 GeV, and the PYTHIA's prediction is consistent with this result.

In this note, we discuss the facts and analysis, which leads to above conclusions.

2 PYTHIA vs Experiment Data

PYTHIA's predictions for the W production has been compared with the UA1 and UA2 data. The comparison is published in **Z. Phys. C32 67** (1986), which shows PYTHIA's predictions agree with data.

We compared PYTHIA with the CDF data (for the W-boson mass measurement) published in **PR D43 2070** (1991). Figure 1 shows this comparison. While Figure (a) and (b) are the transverse energy of the W boson and the scalar E_T sum of the underlying event measured by CDF, Figure 1(c) and (d) are corresponding predictions calculated with PYTHIA 5.6.

Since we do not know the exact experimental cuts used in CDF data analysis, Figure 1(c) plots the p_T of W's without any event selection cut, and Figure 1(d) plots the scalar sum of E_T (Σ E_T) of all partons produced in the rapidity range of ± 3.5. It is clear from Figure 1 that the data agree reasonablly well with PYTHIA's predictions. Also, PYTHIA tends to give softer distributions, which may be explained by data selection cuts and/or detector effects.

The detailed comparison between PYTHIA and minimum bias events are given in **CERN 90-10 (LHC Workshop) 155**.

3 W vs 80 GeV Higgs

Figure 2 shows the p_T distributions of W and 80 GeV Higgs produced at three center of mass energies of 1.8 TeV, 16 TeV and 40 TeV. This is a measure of the transverse motion of the underlying event. Figure 3 shows the Σ E_T of partons in the rapidity range ± 3.5 for the same sets of events. This is a measure of the multiplicity of hadrons of the underlying event. In each plot the average value is also listed.

As one can see from the average values in these plots, the $< p_T >$ and $< \Sigma\ E_T >$ in the Higgs events are larger than that in the W production at the same center of mass energy. This difference can be easily understood by diffrent production mechanism of W and Higgs. While W is produced by q-$\overline{q'}$ annihilation, the Higgs is produced by either gluon-gluon fusion or W/Z-W/Z fusion processes. In corresponding figures of

Fig.2 and Fig.3, the contributions from gluon-gluon fusion process are shown in gray area, and their corresponding average values ($< p_T >_{gg}$ and $< \Sigma\ E_T >_{gg}$) are also listed.

The $< p_T >_{gg}$ and $< \Sigma\ E_T >_{gg}$ for the Higgs production are around a factor of two larger than those in the W production. This can be understood by the difference of gluon-gluon and quark-gluon coupling, where the average number of partons radiated from the incident partons is different by a factor of 9/4.

The cross section of W/Z-W/Z fusion in Higgs production is around 25% of the total production cross sections at the SSC energy. The W/Z fusion process tends to give a higher $< p_T >$ and $< \Sigma\ E_T >$ because p_T in this process is determined by the W and Z mass which appears in a form of propagator.

4 Energy Dependence

The $< p_T >$ and $< \Sigma\ E_T >$ show a mild energy dependence. This is determined by perturbative QCD, which everyone relies on to predict phenomena at SSC energy.

5 Conclusion

In this note, we have shown that a big difference exists between the W production at Tevatron energy and the Higgs production at SSC energy. The reasons are:

1. The number of partons in the Higgs production by gluon-gluon fusion is twice larger than that in the W production;
2. The p_T of Higgs from W/Z-W/Z fusion is larger than the typical p_T produced by QCD radiation;
3. The mild energy dependence is predicted by the perturbative QCD.

The theoretical calculations (calculations done analytically, not by thousands of lines of Monte Carlo codes) predicts that the p_T of Higgs at SSC energy is over 50 GeV, which is consistent with or larger than the prediction of PYTHIA.

In summary, we believe that the difference between Fig.2(a) and (f) and/or Fig.3(a) and (f) are understandable, and the prediction is as reliable as other physics

quantities at the SSC energies predicted by perturbative QCD based Monte Carlo programs.

Note, we used the default mode for the Higgs production (MSTP(82) = 1) of PYTHIA in our analysis. According to Sjostrand, this prediction is conservative. We also used MINBIAS event of ISEJET to generate minimum bias events, so our estimation by using ISAJET might be a under estimation. The result obtained by using PYTHIA (85%) thus is more appropriate to use.

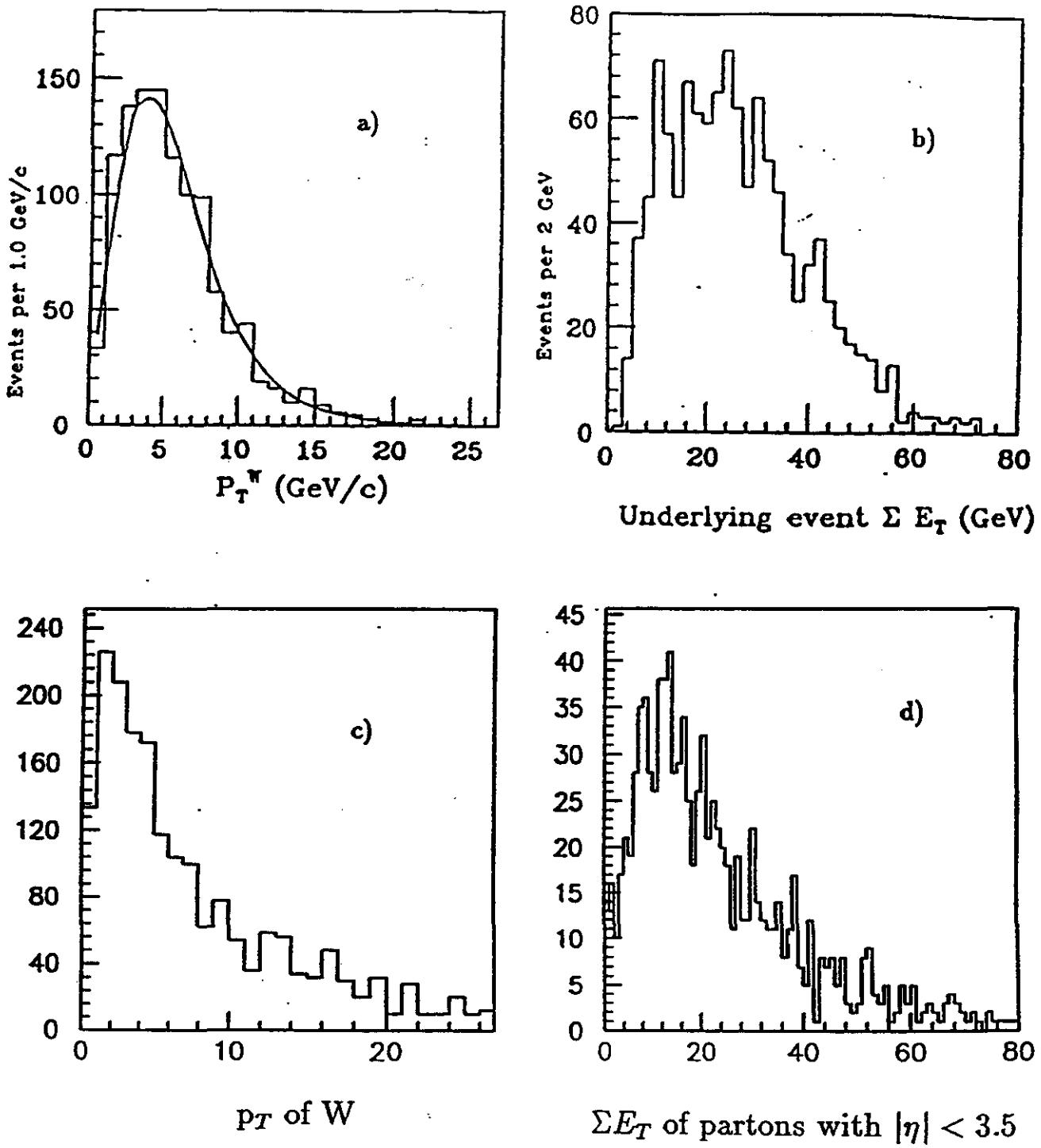

Fig.1 CDF W production data vs PYTHIA prediction

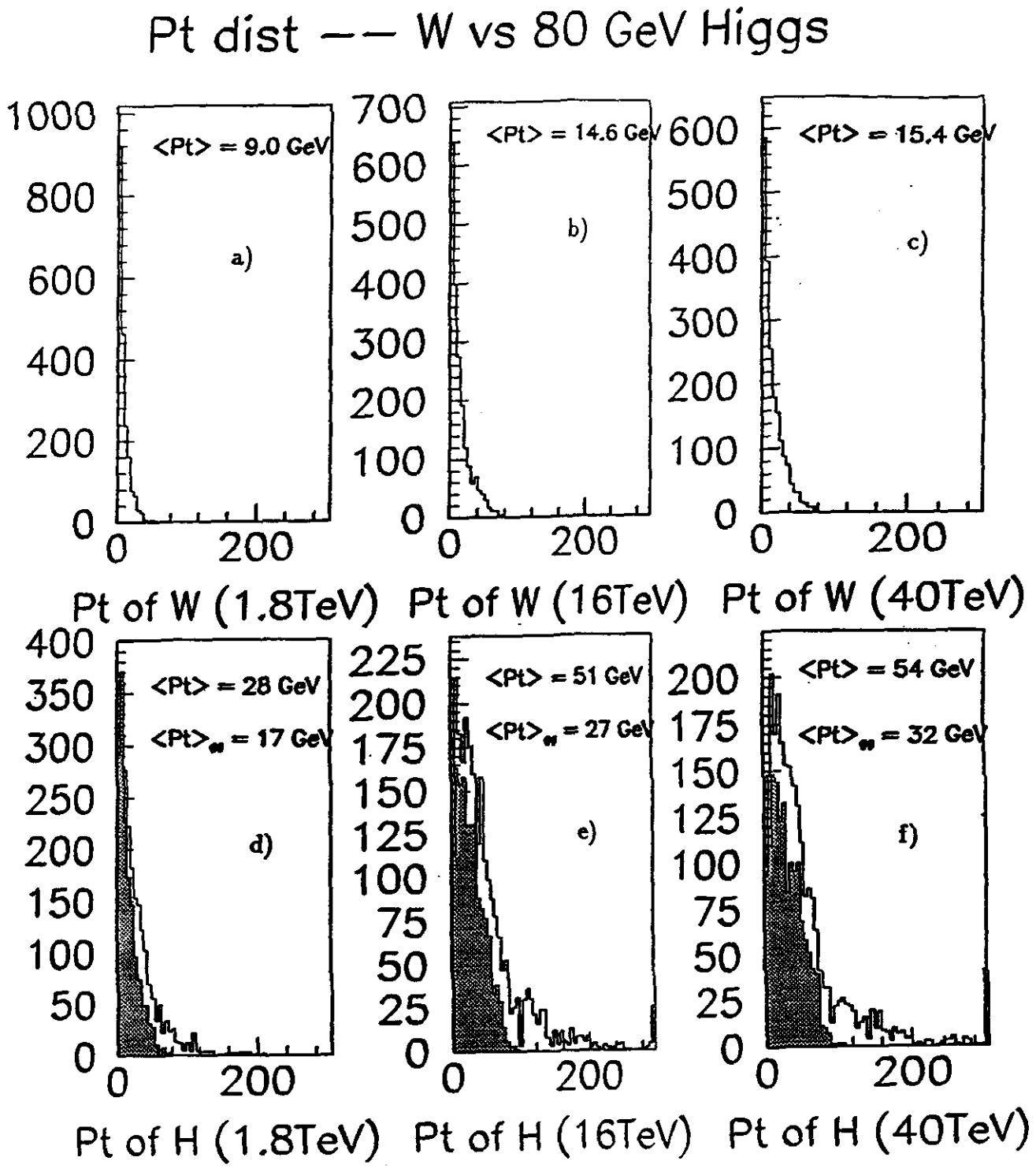

Fig.2 P_t distribution of W and 80 GeV Higgs

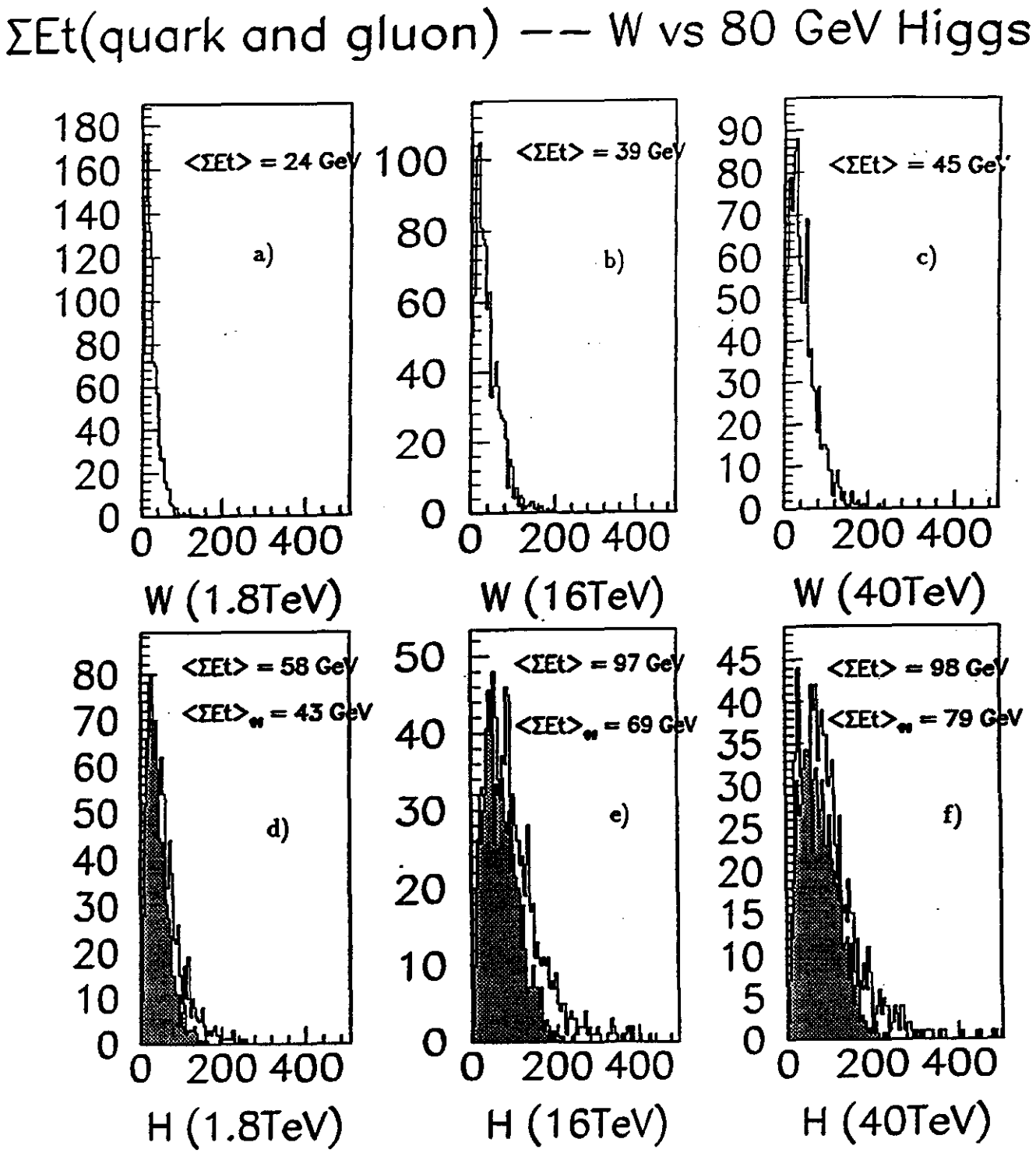

Fig.3 ΣE_t(q and g) in W and Higgs production