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ELECTROWEAK MULTI-PARTICLE-PRODUCTION AT TeV ENERGIES?

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Abstract

At very high energies the mean particle multiplicity in electroweak scattering processes should become high, associated with slowly raising total inelastic cross sections. I speculate that this nonperturbative phenomenon may already occur for energies above a few TeV.

GEOMETRICAL FLAVOUR INTERACTIONS AT VERY HIGH ENERGIES

The similar structure of QCD and QFD suggests that at very high energies weak and strong interactions should behave similarly. The weak scattering of leptons and quarks (or W,Z bosons) should show similar properties as the strong scattering of quarks (or gluons). This analogy refers not only to the production of a few particles with large transverse momenta which is well described by (parton model) perturbation theory. It also applies to the large, almost constant total inelastic cross section which presumably cannot be computed in perturbation theory [1]. The total weak inelastic cross section as well as suitable total multiparticle cross sections (for producing a number of weakly interacting particles greater than a certain minimal number n_o) become approximately energy independent at very high energies, with a size determined by the W-boson mass m_W

$$\sigma_W = 4\pi c_W m_W^{-2}. \qquad (1)$$

The quantity c_W typically increases with logarithms or small powers of energy. By analogy with QCD it was speculated [1] that

- typical multiparticle cross sections are in the range 1nb-10μb for high parton-parton cm energies $\sqrt{\hat{s}}$;
- the mean multiplicity becomes large, typically of order $1/\alpha_W \approx 30$, multiplied with a slowly increasing function of $\hat{s}/m_W^2$;
- the inclusive differential cross sections decrease rapidly for transverse momenta p_t exceeding a characteristic value of order m_W, with typical $p_t \approx$ 20-60 GeV;
- this behaviour may set in rather rapidly above a certain threshold energy of the order of a few TeV to about 20 TeV.

In a simple picture these processes arise from the scattering of the clouds of weak gauge bosons and scalars carried along by colliding quarks or leptons. Both the almost constant multiparticle cross sections $\sigma \sim m_W^{-2}$ and the characteristic transverse momenta $p_t \sim m_W$ directly reflect the finite size of these clouds ($\sim m_W^{-1}$) which is, of course, related to the finite range of the underlying interactions. Processes with the above characteristics may be called Geometric Flavour Interactions (GFI).

Intuitively, a GFI event is described by the scattering of two wave packets with transversal extension $\sim m_W^{-1}$. One expects a change in shape and phase of the wavepackets as a result ot the scattering. When expressed in particle number eigenstates the outgoing waves are typically a superposition of multi-particle states, in contrast to the incoming waves which are one particle eigenstates. At very high energies there seems to be no apparent reason why one particle states should dominate in the outgoing waves - one rather expects a high mean multiplicity.

Perturbation theory naively suggests that the production of any additional weakly interacting particle is suppressed by the weak fine structure constant α_W. I expect that naive perturbation theory breaks down for large multiplicities n ,namely that for $n\alpha_W \ln(s/m_W^2) = O(1)$ the perturbative production of n and n+1 particles are of similar size. For $n\alpha_W = O(1)$ one even encounters strong fields which presumably cause a breakdown even for appropriately resummed perturbative series. An example of possible nonperturbative effects has been given [3] by the exponential rise of B+L violating cross sections, $\sigma_{\Delta(B+L)} \sim \exp[(s/M_o^2)^\gamma]$. Unfortunately it remains still unclear if the instanton [4] approximation underlying these calculations remains qualitatively valid at energy scales near the sphaleron [5] energy where B+L violation could become substantial. A breakdown of (tree approximation) perturbation theory has also been observed in a pure scalar theory for high energy scattering with high multiplicity [6].

The lessons from these examples indicate that classical configurations other than the vacuum may play an important role in high energy scattering. This seems reasonable since the classical configuration serving as a starting point for an expansion should correspond to the classical scattering of two appropriate wave packets. Such a configuration has certainly a smaller symmetry than the vacuum. For example, the Lorentz symmetry reduces to the two dimensional rotations in the plane transversal to the scattering axis. For low energies the multiplicities must be small. The "scattered wave" configuration should be "near" the vacuum configuration such that perturbation theory around the vacuum can be applied. There seems to be no good reason why this should also hold for high energies and multiplicities.

To summarize, I expect the breakdown of perturbation theory to be mainly a classical effect, showing up already in the tree approximation. (An expansion in the number of quantum loops (instead of powers of α) may give reliable results as long as $n\alpha_W \lesssim 1$). New methods, incorporating the scattered fields from the beginning of an expansion may have to be developed. In the meanwhile, I will try in this talk to learn some qualitative features of weak interactions at very high energies from the observed high energy behaviour of QCD.

THE QCD-QFD ANALOGY

Let me compare QCD and QFD at very high energies. I neglect for simplicity electromagnetism. This corresponds to the limit $\sin^2\vartheta_w = 0$ in the standard model. One immediately sees three basic similarities:

- Both theories are nonabelian gauge theories based on simple groups. The difference between SU(3) and SU(2) should mainly show up quantitatively by different values of the Casimir operators.

- At high energies both gauge couplings are in the perturbative range. (The numerical difference between $\alpha_s(\sqrt{s})$ and $\alpha_w(\sqrt{s})$ disappears for $\sqrt{s}$ somewhat below the Planck scale, $\sqrt{s} \approx 10^{15}$ GeV).

- The topological features (e.g. instantons) of SU(3) and SU(2) gauge theories are very similar.

The main difference between QCD and QFD concerns the different physical infrared cutoff. For vanishing gauge boson masses both theories have strong infrared divergences. In QCD the infrared behaviour is regulated by confinement which turns this model into a massive theory at a scale $\Lambda_s \approx 1$ GeV. Spontaneous symmetry breaking in QFD gives the gauge bosons a mass $m_w \approx 80$ GeV and therefore provides an effective infrared cutoff. Although the difference between confinement and spontaneous symmetry breaking is crucial in many respects, I emphasize here that it can only show up in quantities which are infrared divergent for $\Lambda_s \to 0$ or $m_w \to 0$!

More precisely, in QFD a quantity is called infrared finite (or stable) if it becomes independent of m_w in the limit $m_w \to 0$. Here the limit is taken by changing the mass term in the scalar potential, leaving all dimensionless couplings at a given energy scale fixed. (Actually, one should consider the m_w dependence of a given quantity for small but finite values of $m_w/\sqrt{s}$, such that m_w is above the weak confinement scale $m_w > \Lambda_w = 10^{-23}$ GeV.) In QCD, infrared stable quantities are independent of details of confinement, hadronization etc. Although the intuitive meaning of an infrared finite quantity is obvious, its precise definition requires a little thought since the limit $\Lambda_s \to 0$ cannot be taken without changing the dimensionless coupling $\alpha_s(\sqrt{s})$. For one possible definition one may give the gluons a mass m_s by spontaneous breaking of SU(3). An infrared finite quantity is independent of m_s for m_s in the range between zero and a few GeV (say $m_s < 5$ GeV). I will denote the IR cutoff scale (m_w or m_s) by μ.

Let me now formulate my <u>first conjecture:</u> <u>Infrared finite quantities</u> defined similarly in QCD and QFD show only "minor" quantitative differences in scattering processes at very high energies. Two related infrared stable quantities in QCD and QFD, 0_s and 0_w, can always be expressed as functions of the dimensionless couplings at the scale $\sqrt{s}$

$$0_s = h_s(\alpha_s(\sqrt{s}))s^{D/2}$$
$$0_w = h_w(\alpha_w(\sqrt{s}))s^{D/2} \qquad (2)$$

with D corresponding to their canonical dimension. The above conjecture states that the qualitative behaviour of the functions $h_s(\alpha)$ and $h_w(\alpha)$ is similar.

Two comments are in order:

- I have implicitely assumed that the dimensionless couplings other than the gauge coupling (e.g. Yukawa couplings) do not play an important role. This is, of course, not true for all infrared finite quantities. Also, the analogy should be restricted to quantities for which the existence of scalar fields and the chiral structure in QFD are not crucial.

- The conjecture is trivially true for quantities which can be reliably calculated in perturbation theory where h_s and h_w are power series in α_s and α_w, respectively. It should extend to situations where appropriate partial resummations of the perturbative series are applicable. An even more interesting application concerns quantities which cannot be computed in perturbation theory even for small values of the gauge coupling. This may happen for processes involving many particles ($n \gtrsim \alpha^{-1}$), high densities, high temperatures or strong fields. We could use (2) to obtain the qualitative behaviour of QFD quanties 0_w from the <u>measured</u> s-dependence of corresponding QCD quantities 0_s and vice versa, once infrared finiteness is established. Unfortunately the direct analogy for scattering processes relates to parton scattering in QCD. This weakens the practical use of phenomenological data from hadron scattering.

Let me next turn to "infrared divergent" quantities which may depend, for example, on logarithms or inverse powers of the IR scale μ. (Strictly speaking there is no divergence for $\mu \to 0$ since the IR behaviour is regulated by confinement, for $\mu < \Lambda_{s(w)}$.) For QCD and μ at the physical cutoff scale $\mu \approx \Lambda_s$ confinement plays a crucial role and no direct comparison with QFD quantities for $\mu = m_w$ is possible. For $\mu \gg \Lambda_s$, however, α_s is again a small coupling and no important qualitative differences between QCD and QFD remain. Infrared divergent quantities will depend in addition on the scale ratio μ^2/s

$$0_{s(w)} = h_{s(w)}\left(\frac{\mu^2}{s}; \alpha_{s(w)}(\sqrt{s})\right)s^{D/2} \qquad (3)$$

The structure of infrared divergences in QCD and QFD is exactly the same. This leads to my <u>second conjecture</u>: For $\mu \gg \Lambda_s(\Lambda_w)$, the <u>infrared divergent quantities</u> defined similarly in QCD and QFD show qualitatively the same dependence on μ^2/s and $\alpha(\sqrt{s})$. In particular, the "degree of divergence"

$$p = -\mu \frac{\partial}{\partial\mu} \ln 0_{s(w)} \qquad (4)$$

should behave similarly in both theories.

TOTAL INELASTIC MULTIPARTICLE CROSS SECTIONS

Let me define $\sigma_w^{(n_0)}$ as the total weak inelastic multiparticle cross section for the production of more than n_0 weakly interacting particles - leptons, quarks, W and Z bosons and Higgs scalars. The analogous multiparticle cross section $\sigma_s^{(n_0)}(s)$ raises slowly for high energies

$$\sigma_s^{(n_0)} = \frac{4\pi}{\Lambda_s^2}\, c_s^{(n_0)}(s/\Lambda_s^2) \qquad (5)$$

$$c_s = A + C \ln^2 \frac{s}{\Lambda_s^2} + D \ln \frac{s}{\Lambda_s^2} \qquad (6)$$

The numerical values of the constants A,C... depend on the choice of the strong interaction scale Λ_s and are typically [7] (for $n_o = 3$)

$$A = (3 - 12)(\Lambda_s/1\ \text{GeV})^2$$

$$C = (0.03 - 0.1)(\Lambda_s/1\ \text{GeV})^2 \qquad (7)$$

The behaviour (5) is valid above a threshold energy of a few GeV. Details depend on n_o which should be choosen below the average multiplicity at $\sqrt{s}$.

For very high energies $\sqrt{s}$ and an IR cutoff scale $\mu \gg \Lambda_s$ (with $\alpha_s(\sqrt{s}) \ln \frac{s}{\mu^2} \leq 1$) one obtains in a leading log perturbative calculation [2] (both for QCD and QFD) the total inelastic parton cross section ($n_o = 2$)

$$\sigma_{s(w)} = \frac{4\pi \hat{c}_{s(w)}}{\mu^2}\, \alpha_{s(w)}^{2+\delta} \ln^{\delta}\left(\frac{s}{\mu^2}\right) \left(\frac{s}{\mu^2}\right)^{\frac{\hat{\alpha}}{2}} \qquad (8)$$

(For QFD one has $\delta = -1.5$, $\hat{\alpha} = 16 \ln 2\, \pi^{-1} \alpha_w$.) This value (for $\alpha = \alpha(\sqrt{s})$) should be at least an approximative lower bound. One therefore finds the leading behaviour $\sigma_s \sim \mu^{-2}$ both for high μ and for low $\mu \approx \Lambda_s$. This qualitative behaviour obtains already in the tree approximation where $\sigma_s \sim \alpha_s^2 \mu^{-2}$. I conclude from (5), (8) that σ_s (and more generally $\sigma_s^{(n_0)}$) is an <u>infrared divergent</u> quantity with degree of divergence near two. My second conjecture then implies for QFD that $\sigma_w^{(n_0)}$ must be of the form (1), $\sigma_w^{(n_0)} = 4\pi c_w^{(n_0)} m_w^{-2}$, with $c_w^{(n_0)}$ slowly increasing functions of s/m_w^2.

Although in QCD the gauge coupling is small for very high s, the coefficients $c_s^{(n_0)}$ are not supressed by their naive perturbative values $c_s^{(n_0)} \sim \alpha_s^{n_0}(\sqrt{s})$. Indeed, a strongly infrared divergent cross section $\sigma \sim \mu^{-2}$ must be dominated by modes with momenta $p_\mu p^\mu \approx \mu^2$. The effective interactions between modes with $p_\mu p^\mu \ll s$ are presumably governed by effective couplings γ_i for some sort of effective (two dimensional?) long distance theory adapted to the specific scattering process. The running of γ_i as a function of μ (for fixed $\sqrt{s}$) is described by new β functions. For μ near $\sqrt{s}$ the effective couplings should reflect perturbation theory. On the other hand there must be some <u>critical scale ratio</u> μ_c^2/s where the deviation of γ_i from their perturbative values becomes substantial. Depending on a slow or fast running of γ_i (and on their "initial values" determind by $\alpha_s(\sqrt{s})$) the scale μ_c will be much smaller than $\sqrt{s}$ or not very far below $\sqrt{s}$. This scale for the onset of nonperturbative behaviour will be crucial for the subsequent discussion. It can be higher than Λ_s but obviously not lower, since confinement certainly implies strong effective couplings for $\mu = \Lambda_s$.

Applying the QCD-QFD analogy to weak interactions at $\sqrt{s} = 10$ TeV I expect for $\mu_c \ll m_w$ (slow running) that σ_w is near the perturbative value, approximately given by (8)

$$\sigma_w \approx 8.5\, \hat{c}\ \text{nb}, \qquad (9)$$

or by the tree approximation for fermion-fermion scattering, $\sigma_w \approx 0.1$ nb. In contrast, for $\mu_c > m_w$ (fast running) it seems not impossible that c_w becomes of order unity as in QCD. The analogue of (5) with $\Lambda_s = 1$ GeV replaced by m_w and $c_w \approx c_s(s/m_w^2)$ yields

$$\sigma_w \approx 10\,\mu\text{b} \qquad (10)$$

I conclude that at high energies the total inelastic weak cross section is of order $\sigma_w \sim m_w^{-2}$ and presumably increases slowly for $s \to \infty$. It is much bigger than a typical weak cross section for the production of a few particles with large transverse momentum which obeys $\sigma \sim s^{-1}$. The magnitude of σ_w at realistic energies ($\sqrt{s} = 10$ TeV) crucially depends on the slow or fast transition from the perturbative to the nonperturbative regime.

AVERAGE MULTIPLICITY

Having established that σ_w is large and presumably slowly raising for high values of s/m_w^2, the next question concerns the average multiplicity $\bar{n}_w$. I will argue that $\bar{n}_w$ exceeds $\alpha_w^{-1}(m_w)$ for very high energies.

For an analogy, consider proton-proton scattering at very high energies. For $\sqrt{s} = 1$ TeV the measured mean multiplicity of charged hadrons is 31. A similar multiplicity $\bar{n}_s(\mu) \approx 30$ may be expected for quark-quark scattering in spontaneously broken QCD with $\mu \approx \Lambda_s \approx 1$ GeV. (I assume that neither σ_s nor $\bar{n}_s$ change drastically between the confining and spontaneously broken phase, as long as one stays in the immediate vicinity of the transition line ($\mu \approx \Lambda_s$). I also use a rough counting rule of one parton with mass Λ_s for one charged hadron.) For $\sqrt{s} \gg 1$ TeV one expects that multiplicities increase even further. On the other hand $\bar{n}_s(\mu)$ must be near two for μ^2 in the vicinity of s. There is simply not enough energy to produce many particles in this case and perturbation theory should apply.

Unfortunately, not much is known about the behaviour of $\bar{n}_s(\mu)$ for intermediate values of μ, except that there must be some transition from small multiplicity to large multiplicity as μ decreases to Λ_s. One may envisage three alternative possibilities for the behaviour of $\bar{n}_s$ with decreasing μ:

(i) The mean multiplicity increases only slowly until the immediate neighbourhood of Λ_s, where it jumps to the high nonperturbative value. (The "smoothness" assumption for the phase transition is questionable for this case.) In this scenario $\bar{n}_s(\mu)\alpha_s(\mu)$ remains smaller than one for all $\mu > \Lambda_s$ and $\bar{n}_s(\mu)$ can be described by perturbation theory except for the immediate vicinity of the confinement scale Λ_s. The QCD-QFD analogy would imply a small perturbative average multiplicity for weak interactions at all energies.

(ii) There may be a sizeable increase of $\bar{n}_s$ until a critical scale ratio μ_c^2/s (with $\mu_c \gg \Lambda_s$) where perturbation theory fails. Then for $\mu \ll \mu_c$ the average multiplicity remains constant and is therefore an infrared finite quantity. This would correspond to a complete saturation for high particle numbers. In this case the first assumption about the QCD-QFD analogy would apply: One could try to extrapolate from the observed behaviour of $\bar{n}_s(\alpha_s(\sqrt{s}))$ to QFD multiplicities at high energies ($m_w^2/s < \mu_c^2/s$). They should have a similar functional dependence on $\alpha_w(\sqrt{s}), \bar{n}_w(\alpha) \simeq \bar{n}_s(\alpha)$.

(iii) After a substantial increase $\bar{n}_s$ reaches the value $\alpha_s^{-1}(\mu_0)$ for a scale $\mu_0 \gg \Lambda_s$. Then a saturation effect may set in due to strong colour fields generated for $\bar{n}_s \alpha_s \approx 1$. A possible saturation is, however, not necessarily complete since for decreasing μ the available volume for particle production increases as well as the mean kinetic energy/particle in units of μ which is $\sim \sqrt{s}/\mu \, \bar{n}_s(\mu)$. A slow increase of $\bar{n}_s(\mu)$ for $\mu < \mu_0$ results and the mean multiplicity is "mildly" infrared divergent

$$\bar{n}_s(\mu) = \frac{1}{\alpha_s(\mu_0)} \nu_s\left(\frac{\mu_0^2}{\mu^2}\right) \qquad (11)$$

Here ν_s increases slowly for $\mu < \mu_0$, typically involving logarithms or small powers. Applying this scenario to weak interactions would predict large multiplicities $\bar{n}_w(m_w) > \alpha_w^{-1}(m_w)$ at very high energies.

The first scenario requires that for massive QCD (say $\mu = 5$ GeV) the mean multiplicity remains bounded as $s \to \infty$. In view of the increasing gluon density within a quark and the increasing mean virtuality of "primordially produced" quanta this seems rather unlikely. It is excluded if the exclusive cross section for the production of a given number of particles decreases for $s \to \infty$ whereas σ_s increases or remains constant. I conclude that for high enough s there is always a scale $\mu_0 \gg \Lambda_{s(w)}$ where $\bar{n}_{s(w)}(\mu_0) = \alpha_{s(w)}^{-1}(\mu_0)$! The production of many particles is not directly related to confinement!

The second scenario with an infrared finite mean multiplicity requires a complete saturation for small μ^2/s. This seems possible only as a consequence of an infrared fixpoint behaviour. It seems difficult, however, to understand why quantities determined by a true IR fixpoint should depend an the "initial values of couplings" which are determined by $\alpha(\sqrt{s})$. In view of the s dependence of the observed high mean multiplicity in proton-proton scattering this scenario appears improbable.

It remains the most likely third scenario: For high enough s there exists a scale $\mu_0 \gg \Lambda_{s(w)}$ where $\bar{n}_{s(w)}(\mu_0)\alpha_{s(w)}(\mu_0) = 1$, with a mild infrared divergence of $\bar{n}(\mu)$ for $\mu < \mu_0$. Such a qualitative behaviour could nicely account for the observed multiplicity increase in high energy p-p scattering which is somewhat stronger than logarithmic. (Note that the mean charged multiplicity in p-p scattering cannot be compared directly to e^+e^- scattering. The latter is characterized by the showering of highly virtual "primordial" quarks.) It is tempting to associate μ_0 with the critical scale μ_c where the nonperturbative behaviour sets in and $c_{s(w)} = \sigma_{s(w)}\mu^2/4\pi$ becomes large. In a geometrical scattering process is seems natural that a high "opacity" $c_{s(w)}$ is implied by a high multiplicity, unless the high value of $\bar{n}$ arises dominantly from the "decay" of virtual quanta.

In conclusion, I conjecture for the high energy behaviour of both QCD and QFD the existence of a critical scale $\mu_c \gg \Lambda_{s(w)}$ where $\bar{n}_{s(w)}$ becomes of order $\alpha_{s(w)}^{-1}(\mu_c)$ and $c_{s(w)}$ may become of order one. There is nonperturbative behaviour without strong gauge couplings!

THRESHOLD ENERGY

The appearance of nonperturbative phenomena in weak scattering processes at high energies is certainly theoretically interesting. Are these energies experimentally accessible at future colliders? The answer depends on the ratio μ_c^2/s. This can only be a function of $\alpha_w(\sqrt{s})$ and we need it for realistic energies, say $\sqrt{s} = 10$ TeV. For $\mu_c \ll m_w$ the perturbative regime covers all scales between m_w and $\sqrt{s}$ and I expect $c_w \sim \alpha_w^2$ and a mean multiplicity not very much above two. For $\mu_c \gtrsim m_w$, in contrast, many weakly interacting particles may be produced with a cross section above 1 nb!

Starting from perturbation theory, I can imagine two possible sources for the onset of a nonperturbative behaviour: The perturbative evaluation of σ_w may break down (independent of energy) for high multiplicity, $n_w \alpha_w \approx 1$. Then one would expect essentially a kinematic threshold since α_w^{-1} particles must be produced (without a strong phase space suppression)

$$\sqrt{s}/\mu_c \approx \alpha_w^{-1}(\mu_c) \qquad (12)$$

The threshold energy E_w^{crit} where such an effect could be observed experimentally obtains for $\mu_c = m_w$

$$E_w^{crit} \sim \alpha_w^{-1}(m_w)m_w \approx (2.5\text{-}4) \text{ TeV} \qquad (13)$$

Alternatively, the transition to the nonperturbative regime may only occur for

$$\alpha_w(\mu_c) \ln \frac{s}{\mu_c^2} = O(1) \qquad (14)$$

Then E_w^{crit} depends exponentially on α_w^{-1} and its value is very sensitive to details of the r.h.s.of (14). For $\sqrt{s} = 10$ TeV one has $\alpha_w \ln(s/m_w^2) \approx 1/3$. An experimentally observable threshold cannot be excluded at present, but there is no convincing argument for a low threshold in this case. I should mention that both scenarios are perfectly compatible with the observed onset of the asymptotic behaviour of QCD beyond a threshold energy of around 2 GeV.

Finally, it is also conceavable that the nonperturbative behaviour does not show up directly as a breakdown of the perturbative series. This may happen if it is due to classical configurations like instantons [8]. For example, if the nonperturbative behaviour in the electroweak theory is due to the sphaleron transition one expects a threshold enery in the vicinity of the sphaleron mass

$$E_w^{crit} \approx 10 \text{ TeV} . \qquad (15)$$

In my opinion the issue of the threshold energy is completely open so far. This makes it interesting to speculate that nonperturbative QFD could be observed at future colliders. The characteristic features of the nonperturbative geometrical flavour production would be striking [9]:

1) For parton energies near the threshold ($\sqrt{s} \approx E_W^{crit}$), the events look rather central, i.e. jets and charged leptons are distributed over the whole angular range. Only partons with energies much above E_W^{crit} produce more forward oriented events. For "threshold machines" like the LHC (or SSC) most of the activity will be in the central detector ($10^\circ < \vartheta < 170^\circ$). Even at $\sqrt{s}$ = 200 TeV one may expect on the average about one half of the produced particles in this central region.
2) The average transverse momentum per quark jet or lepton is estimated as $\langle p_t \rangle \approx 35$ GeV and the total transverse energy is huge, $\langle E_t^{tot} \rangle \approx 1.6 - 2.2$ TeV. (All numbers are given for $n_W = 30$.)
3) One expects on average at least 3.5 (more typically 5) "isolated" electrons or muons per event and hence, one may trigger on two isolated charged leptons in the central region.
4) A similar number of neutrinos is responsible for an average missing transverse energy $\langle \not{E}_t^{tot} \rangle \approx 260-320$ GeV.
5) More than 20 jets per event should be seen in the central detectors of the LHC and SSC.
6) In addition, one expects many events with a high charged hadron multiplicity ($n_h > 100$) in the forward and/or backward detectors ($|\eta| > 2.5$).

I conclude that there is essentially no background for these events. Even with a parton cross section $\hat{\sigma}_W \approx 1$ nb they should be detected if the threshold energy E_W^{crit} is below 11 GeV and 28 GeV for the LHC and SSC, respectively. For larger cross sections and lower E_W^{crit} these machines may turn into W, Higgs and top factories with possibly as much as 10^3 events per second!

REFERENCES

[1] A. Ringwald and C. Wetterich, DESY 90-067.
[2] V. Fadin, E. Kuraev and L.Lipatov, Phys. Lett. 60B(1975) 50; E. Kuraev, L. Lipatov and V. Fadin, Sov.Phys. JETP 44 (1976) 443; ibid 45 (1977) 199; Y. Balitsky and L. Lipatov, Sov. Journ. Nucl. Phys. 28 (1978) 822; JETP Lett. 30 (1979) 355; J. Bartels, Nucl. Phys. B151 (1979) 293; ibid B175 (1980) 365; Y. Balitsky, L. Lipatov and V. Fadin, in Materials of the 14th Winter School of Leningrad Institute of Nuclear Research (1979), p. 109, (in Russian); L. Lipatov, Sov. Phys. JETP 63 (1986) 904.
[3] H. Aoyama and H. Goldberg, Phys. Lett. 188B (1987) 506; A. Ringwald, Nucl. Phys. B330 (1990) 1; O. Espinosa, Calt.68-1586 (1989); L. McLerran, A. Vainshtein and M. Voloshin, TPI-MINN-89/36-T (1989); V.I. Zakharov, TPI-MINN-90/7-T (1990); S. Khlebnikov, V. Rubakov and P. Tinyakov, Instanton induced cross sections below the sphaleron, INR preprint (1990); M. Porrati, Pisa preprint, IFUP-TH 13/90 (1990).
[4] A. Belavin, A. Polyakov, A. Schwartz and Y. Tyupkin, Phys. Lett. 59B (1975) 85; G. 't Hooft, Phys. Rev. D14 (1976) 3432; Phys. Rev. D18 (1978) 2199; I. Affleck, Nucl. Phys. B191 (1981) 445.
[5] N. Manton, Phys. Rev. D28 (1983) 2019; F. Klinkhamer and N. Manton, Phys. Rev. D30 (1984) 2212.

[6] H. Goldberg, preprint NUB-2998 (1990)
[7] Particle Data Group, Phys. Lett. 204B (1988) 1.
[8] J.M. Cornwall, talk at workshop "Electroweak Baryon Number Violation up to 200 TeV", Erice 1990.
[9] A. Ringwald, F. Schrempp and C. Wetterich, preprint DESY-90-127