SEARCH FOR QCD-INSTANTONS AT HERA

E.A. DE WOLF

CERN, European Organisation for Nuclear Research, CH-1211 Geneva 23, Switzerland and Universitaire Instelling Antwerpen, Universiteitsplein 1, B-2610 Antwerpen

E-mail: e.de.wolf@cern.ch

FOR THE H1 COLLABORATION

Signals of QCD instanton induced processes are searched for in deep-inelastic ep scattering a HERA in a kinematic region defined by the Bjorken scaling variables $x > 10^{-3}$, $0.1 < y < 0.6$ and polar angle of the scattered positron $\theta_{el} > 156°$. Upper limits are derived from the expected instanton-induced final state properties based on the QCDINS Monte Carlo model.

1 Instantons in DIS

After initial work by Balitsky and Braun[1], theoretical and phenomenological studies of the rôle of instantons in deep inelastic scattering (DIS) at HERA have been vigorously pursued[a] by Ringwald, Schrempp and collaborators[2].

Instanton induced processes (I-events) in DIS arise predominantly from photon gluon fusion in an instanton background (see Fig. 1) via the reaction

$$\gamma^* + g \to \sum_{n_{\rm flavours}} (\bar{q}_R + q_R) + n_g\, g,$$

where q_R ($\bar{q}_R$) denotes right handed quarks[b] and g gluons. The cross section is calculated[3] to be in the range 10–100 pb for $0.1 < y < 0.9$ and $x > 10^{-3}$, which is sizable but three orders of magnitude smaller than that of "normal" DIS events.

The final states in I-events are characterized by: a current-quark jet (q'', Fig. 1), a partonic final state from I-decay consisting of $2n_f - 1$ right-handed quarks and anti-quarks. In every I-induced event, one quark anti-quark pair of all $n_f (= 3)$ flavours is simultaneously produced. In addition, on average $\langle n_g \rangle^{(I)} \sim \mathcal{O}(1/\alpha_s) \sim 3$ gluons are isotropically emitted in the I-process. I-events are thus expected to show a pseudo-rapidity (η) region (with a width of about 1.1 units) densely populated with particles of high transverse momentum and uniformly distributed in azimuth. This, together with the high density of partons emitted in the I-process leads to a high particle multiplicity and large transverse energy. To simulate QCD-instanton induced scattering processes in DIS and their characteristic final states, the QCDINS Monte Carlo generator was developed.[4] It is based on instanton perturbation theory and imbedded in HERWIG.[5]

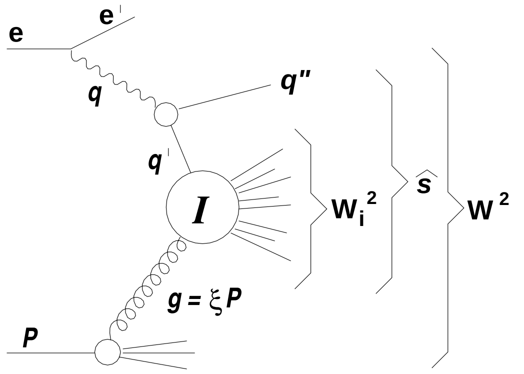

Figure 1. Dominant graph for the instanton-induced contribution to deep-inelastic ep scattering with the relevant kinematic variables as indicated: $Q'^2 = -q'^2 = -(q - q')^2$, $x' = Q'^2/2(g \cdot q')$, $W_i^2 = (q' + g)^2 = Q'^2(1 - x')/x'$.

[a] See papers 250–252, 254, 255 submitted to this Conference.

[b] Right handed quarks are produced in instanton processes, left-handed ones in anti-instanton processes.

2 H1 results

The preliminary H1 results presented here use data taken in 1997 with the H1 detector, corresponding to an integrated luminosity of $\mathcal{L} = 15.78\ \mathrm{pb}^{-1}$. The analysis is performed in the DIS kinematic region $0.1 < y_{el} < 0.6$, $x_{el} > 10^{-3}$ and $\theta_{el} > 156^{\circ}$. The total DIS sample comprises ~ 280K events.

The search strategies aim to enrich a data sample in I-induced events using cuts on selected observables while optimizing the separation power, defined as the ratio of the detection efficiencies, for I-induced and DIS-events.

The following observables[c] have been used: (1) Et_{jet}, the jet with highest E_T (cone algorithm with radius $R = 0.5$). This jet is associated with the current quark (q") in Fig. 1. (2) The virtuality of the quark entering the I-process $Q'^2 = -(q - q")^2$ where the photon (4-momentum q) is reconstructed from the scattered electron. (3) The number of charged particles n_B in the so-called "instanton band".[d] (4) The sphericity SPH calculated in the rest system of the particles outside the current jet. (5) Et_b the total transverse energy in the instanton band calculated as the scalar sum of the transverse energies and (6) Δ_b,[e] a quantity measuring the E_T weighted Φ event isotropy.

Among many studied, three scenarios are chosen based on the following criteria: (A) The highest instanton efficiency ($\epsilon_{ins} \approx 30\%$), (B) high ϵ_{ins} with reasonable background reduction and (C) highest background reduction ($\epsilon_{dis} \approx 0.13 - 0.16\%$) with $\epsilon_{DIS} \approx 10\%$.

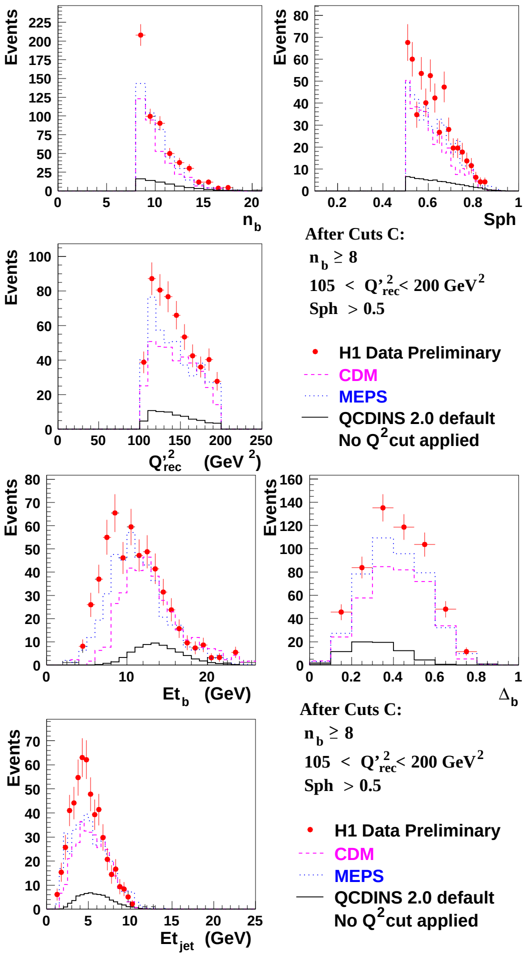

Figure 2. The distributions of kinematic variables in cut-scenario C, compared with the Color Dipole Model (CDM)[6], MEPS[7] and QCDINS.

Table 1 summarizes the number of events in data and expected in the standard DIS Monte Carlo simulations after applying cuts A)–C). Distributions after cuts C are shown in Fig. 2. An excess of events over DIS Monte Carlos is observed. However, the size of this signal is comparable with the difference between CDM and MEPS. Also, the excess in transverse energy Et_b in the instanton band differs from the QCDINS expectation. Nevertheless, given the uncertainties in the I-event cross section calculation and the modelling

[c]All observables, except sphericity, are calculated in the hadronic CMS ($\vec{q} + \vec{P} = \vec{0}$).

[d]Particles belonging to the jet q" are removed from the final state and the E_T-weighted mean pseudorapidity $\bar{\eta}$ is recalculated with the remaining ones. The instanton band is defined as $\bar{\eta} \pm 1.1$.

[e]Δ_b is defined as $\Delta_b = \frac{E_{in} - E_{out}}{E_{in}}$ where E_{in} (E_{out}) is the maximal (minimal) value of the sum of the projections on all possible axis $\vec{i}$ of all energy depositions in the band (i.e. $E_{in} = max \sum_n |\vec{p_n}\vec{i}|$). For isotropic events (jet-like events) Δ_b is expected to be small (large).

Table 1. Measured numbers of events and expected background for 3 cut scenario's. The errors are systematics dominated.

(A) DATA: 3000		(B) DATA: 1332		(C) DATA: 549	
CDM	MEPS	CDM	MEPS	CDM	MEPS
2469^{+242}_{-238}	2572^{+237}_{-222}	1005^{+82}_{-70}	1084^{+75}_{-46}	363^{+22}_{-26}	435^{+36}_{-22}

of the hadronic final state, an I-signal of the form predicted by QCDINS cannot be excluded at this stage of the analysis.

H1 has derived cross section upper limits (95% CL) by comparing the QCDINS predicted cross section, data and CDM/MEPS expectations. Results are shown in Fig. 3. Regions above the curves are excluded[f]. Instanton cross sections between 100 and 1000 pb are excluded.

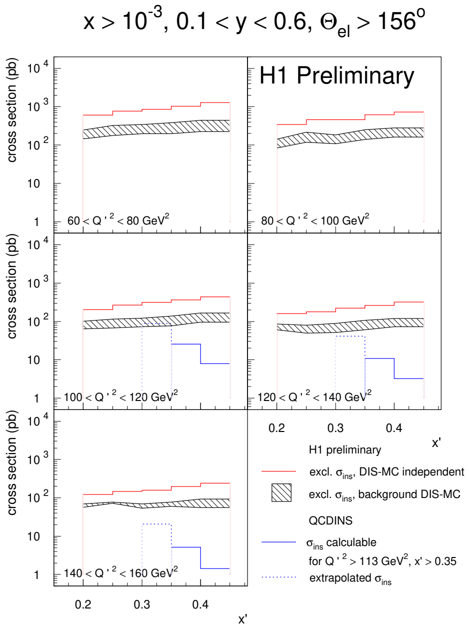

Figure 3. Upper limit on the cross section for instanton induced events as modelled by QCDINS as a function of x' in bins of Q'^2 . Regions above the curves are excluded. Also shown is the instanton cross section predicted in the fiducial region $x' > 0.35$ and $Q'^2 > 113$ GeV^2.

Acknowledgements

I am grateful to T. Carli, S. Mikocki, A. Ringwald and F. Schrempp for help and valuable comments.

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[f] For a detailed description of the methods used, the reader should consult the original H1 paper. [8].