($\propto \exp(2\alpha'_R t \ln(s/s_0))$, where $\alpha'_R \approx 1$ GeV^{-2}. It is predicted that with increase of Q^2, $\alpha'_R(eff)$ will decrease similar to the case of the vacuum channel where this effect was predicted for the vector meson production [41] and observed at HERA [51]

Currently such studies are performed with HERMES detector where they are building a special recoil detector for these purposes. These are also a focus of the ELFE proposal. However these will be able to study only significantly smaller Q^2 or larger x where nonperturbative dynamics may dominate. This is because $E^e_{inc} \leq 30$ GeV. It is a challenging problem to use a recoil detector with a polarized target. On the other hand fixed target detectors (if specially designed) may operate at a high luminosity - probably up to 10^{36} and can compensate for lower energies to some extent.

Chiral Dynamics Connection: The fact that the DES amplitudes factorize into three blocks opens a new field for the application and investigation of chiral dynamics. This includes production of the $\pi^+\pi^-$ system near the threshold $(M_{\pi^+\pi^-} < M_\rho)$ [52], producing a low mass $N\pi$ system [50]. The operators involved in this case are different from traditional low energy chiral dynamics and may involve gluonic operators.

3.1.3.2 Probing High-Energy Dynamics

At small x, the transition from soft nonperturbative Pomeron physics to hard perturbative high-energy physics by production of vector mesons is a the main focus. The shrinking of the transverse size of the longitudinal photon regulates this transition.

One of the most interesting interfaces of soft and hard dynamics is the high-energy interaction with nucleons/nuclei of systems of small size. These interactions grow with increase of energy much faster than the hadron-hadron interactions and may lead to a new perturbative regime of saturation discussed later. Exclusive production of vector mesons by longitudinally polarized photons, which is the dominant contribution to the $\gamma^* + N \to V + N$ processes at large Q^2, provides one of the cleanest ways to study such interactions. Studies at HERA revealed (on a semi quantitative level) several indicators of the transition to the hard regime, which is regulated by the shrinking of the transverse size of the longitudinal photon and increase of $\alpha^{eff}_{IP}(0)$ and decrease of α'_{IP} with increase of Q^2. However, to perform qualitative measurements requires a qualitative increase in the statistics, covered energy range, and the acceptance of the detectors.

A detailed study of the t-dependence of these cross-sections would lead to a study of the onset of the dynamics of saturation by the use of impact factor analysis of the scattering amplitudes [53]. Another interesting limit is the interaction of two small dipoles, which may be closer to the limit considered in the BFKL model of high-energy interactions [54]. To enhance this contribution one has to select special final states in the nucleon fragmentation region $p\pi^+\pi^-$ with large relative transverse momenta. This is just one example of the potential of double diffraction for studies of how and whether soft factorization in the diffraction will break with increase of Q^2 as the transverse size of the exchanged system becomes smaller and smaller.

3.1.3.3 New Nucleon Spectroscopy

Studies of DES processes will provide unique opportunities to look for new baryon states. At intermediate x the main advantage is the ability to select the isospin state of the baryonic system, as compared to the spectroscopy in the $\gamma + N \rightarrow$"*resonance*" processes.

The case of small x is especially interesting since the nucleon is interacting with the two-gluon ladder that is well localized in the transverse plane but extends over the whole nucleon in the longitudinal direction when viewed from the nucleon rest frame. Therefore, we can expect that this probe will effectively excite gluonic degrees of freedom in the nucleon and only in I = 1/2 state.

3.1.3.4 Experimental Considerations

The experimental requirements for a complete investigation of GPDs are formidable. Many different processes must be investigated at very high luminosity, at large enough Q^2, and with suitable energy resolution to determine reliably the final hadronic state. It is clear that one will need different accelerators to fulfill this ambitious task. EIC would be complementary to the fixed target experiments, both in kinematic range and with respect to the channels easily studied.

It is clear that measurement of DVCS is one of the cleanest processes for obtaining experimental information on GPDs. It is highly desirable to have data over a large kinematic range in x and Q^2 and low momentum transfer to the proton. Further, the measurements must be carried out in a manner to guarantee exclusivity, i.e., that the proton is intact in the final state.

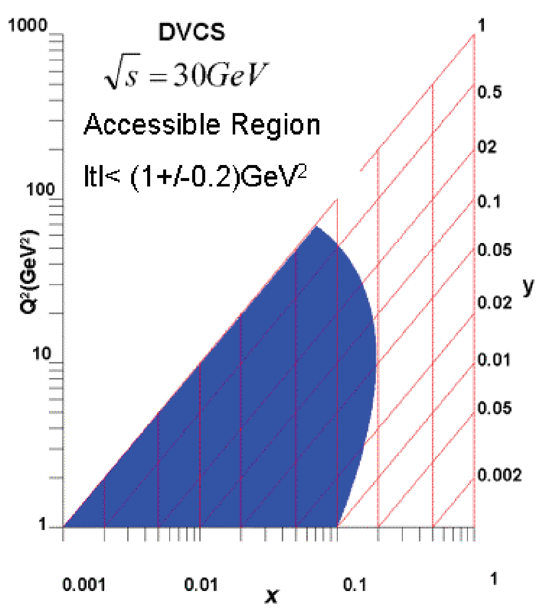

Figure 3.11: x vs. Q^2 Range of DVCS Measurable at the EIC ($\sqrt{s} = 30$ GeV)

Beam energies corresponding to $\sqrt{s}$ ~30 GeV are possible with the EIC. The lines are lines of constant y indicated on the right hand side.

At the EIC, measurement of DVCS would be accomplished by detecting the scattered electron and final-state photon at angles of about 30^0, and ensuring that no particles other than the forward-going fast protons are emitted in the final state. This technique has been used successfully in ZEUS and H1 experiments at DESY to measure DVCS at low x and high Q^2. Figure 3.11 shows the expected kinematic range for DVCS accessible at the EIC $(\sqrt{s} = 30 GeV)$.

3.1.4 Fragmentation: Hadronization and Spin Fragmentation

A fundamental question in hadronic physics is how quarks or gluons from high-energy scattering evolve into hadrons. This process is known as *hadronization*, often termed *fragmentation* in Deep Inelastic Scattering reactions. It is a clear manifestation of color confinement: the asymptotic physical states detected in the experiment must be color-neutral hadrons. Hadronization also appears in an astrophysical context as part of the transition from a deconfined state of free quarks and gluons in the Big Bang, into nucleons that provide the seeds for nuclear synthesis. Important areas of future study include:

- Understanding fragmentation in spin-dependent processes.
- Using fragmentation as a tool for hadron structure studies.
- Probing the global structure of the hadronic final state.

Inclusive scattering experiments give precise information on single-quark probability densities. However, much more precise data is needed to isolate the effects of particular quark flavors and helicities in order to explore fully the partonic substructure of matter. This additional data will enable an understanding of the process by which quarks in high-energy processes neutralize their color in the transitions leading to the colorless mesons and baryons detected in DIS reactions.

A polarized electron ion collider in the $\sqrt{s}$ ~30 GeV energy regime would enable studies of a number of interesting phenomena in quark-nuclear physics. One such phenomenon is the fragmentation of quarks into hadrons. In these studies, a quark makes a transition into a final hadron, which is then detected. The most commonly studied process is that of current fragmentation, shown schematically in Figure 3.12 (a).

There also is the process of target fragmentation in which a quark is struck by a virtual photon in a lepton-induced reaction, and one observes the subsequent decay of the remnants of the nucleon. The kinematic situation for target fragmentation is shown schematically in Figure 3.12 (b).

Target fragmentation is a largely unexplored regime of QCD. Observing such processes requires a detector capable of measuring decay fragments separated from the current jet by a large interval in rapidity. As a result, the collider geometry is essential for studies of