Connection between DIS at small $x$

and high energy pp collisions

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hh-coll.: Conventional collinear factorization.

$\rightarrow$ High $p_T$ jets

But; Minijet cross section diverges

$\sigma_{\text{jet}} \sim \frac{1}{p_T}$

Also total $E_T$ diverges.

Cut off needed: Pythia fit to data $\Rightarrow$

$\Rightarrow p_{T0} \sim 2$ GeV growing with energy.

Difficult to extrapolate to the high energies at LHC.
\( k_1 = \text{factorization} \)

\[ k_1 < k_{11}, k_{12} \Rightarrow \]

Off shell ME does not blow up when \( k_1 \to 0 \).

\( k_1 \) does not determine jet \( q \perp \).

\[ \text{jet } q \perp \text{ total } E_\perp \text{ finite} \]

\( \sigma_{\text{jet}} > \sigma_{\text{tot}} \Rightarrow \) Several hard subcollisions in each event.

\( \Rightarrow \) correlations important

Pedestal effect \( \Rightarrow \) hard coll. not indep

Impact parameter dependence:

central coll.: many mini jets
peripheral coll.: few
How can DIS data improve predictions for hadronic collisions?

Small $x$: BEKLM: Non-$k_T$-ordered parton chains important.

Local max $\rightarrow$ Resolved photon interaction.

Several local maxima $\Rightarrow$ Correlated hard subcoll.
BFKL integral eq. only inclusive

soft emissions compensated by virtual corrections
Do not contribute to parton distr.
But do in final state properties

Added with Sudakov form factors.

CCFM-model interpolates between BFKL & DGLAP

some soft emissions included in initial state rad. ⇒
Extra suppression from non-eikonal form factors

Linked Dipole Chain (LDC) model (Lund)
Reformulation and generalization of CCFM

Separation ISR - FSR more similar to BFKL formal

$q_f$ final state, if $q_f < k_f$
ISR chain in LDC is symmetric photon end - proton end.

Leading order in $\ln \frac{1}{x}$:

$$F \sim \sum_{\text{i}} \mathcal{A} \cdot \frac{3 \alpha_s}{\pi} \frac{dZ_i}{Z_i} \frac{dQ_{2i}}{Q_{2i}} \times \Theta(q_{2i} - \min(k_{2i}, k_{2i-1}))$$

$$q_{2i} \equiv \max(k_{2i}, k_{2i-1})$$

$$\Rightarrow \frac{dQ_{2i}}{Q_{2i}} \approx \frac{dk_{2i}}{k_{2i}} \text{ except local max. or min.}$$

- Local max. $k_{2i} \Rightarrow \frac{dk_{2i}}{k_{2i}}$ hard subcell,
- Local min. $k_{2i} \Rightarrow \frac{dk_{2i}}{k_{2i}}$ no divergence

Symmetry $\Rightarrow$ Also applicable to hh cell.

Fit to DIS $\Rightarrow$ cross section for a chain in pp cell.
(possibly more than one hard subcell)
Integrated gluon distributions

LÖNBLAD-MIU-GG IHEP '02
Potential problem

Fit to DIS: Running $\Lambda_S$ =>

$\Rightarrow$ Soft cutoff $Q_0$ needed.

Good fits to DIS data possible with different cuts if input distrib. $f_0(x, Q_0^2)$ is adjusted accordingly.

PP

$Q_0^2 \Rightarrow$

hard chain $q_1 > Q_0$

soft chain $q_1 < Q_0$
Linked Dipole Chain model for hadronic coll.

![Graph showing cross section per chain as a function of the cutoff, $k_{10}$. The full line is the cross section for chains with at least one emission above the cutoff, the dotted line is for chains without emissions above the cutoff, and the dashed line is the sum of the two. Note that the input parton densities have been refitted for each value of $k_{10}$.

Cross section for hard scat chain

*soft* chain
Total cross section for a chain independent of the soft cutoff

\[ C_{\text{chain}} = C_{\text{hard chain}} + C_{\text{soft chain}} \]

fixed from DIS

Strong connection DIS - pp scatt.
Multiple interactions from 2 hard scatterings in the same chain and from more than one chain in a single event.

Uncorrelated chains: Poisson distrib.
Pythia: b-dep. double Gaussian \sim Geometric distrib.
but tail reduced by energy conserv.

\left\langle \mu \right\rangle \sim 14 \Rightarrow \sim 7
Prel. results, hadronic not included
(dep. on colour connection)
\(\sqrt{s} = 1.8 \text{ TeV}\)

\# minijets in \(|\eta| < 2.5\) in events with \(E_{\text{miss}} > 10 \text{ GeV}\)
Cutoff dependence

Pedestal effect: # jets in minimum azim.

1.8 TeV \( \eta < 2.5 \)

\[
\langle N_j \rangle
\]

- LDCG
- PYT4
- LDC7
- PYT (CDF-A)

E_{\text{max}} (GeV)

LDCMC \( k_{\perp 0} \):
0.99 GeV → 1.3 GeV

PYTHIA:
Default → CDF-A
\( ^{\uparrow} \) CDF tune

Leif Lönnblad
LHC?

LDCMC $k_{\perp 0}$:

$0.99 \rightarrow 1.3$ GeV
Unitarization and saturation

\[ \sigma_{\text{chain}} \propto s^1 \]
\[ \langle n_{\text{chain}} \rangle \propto \frac{s^1}{\sigma_{\text{tot}}} \]

The chains join at one end at the same rate as they multiply at the other.

Work on saturation and diffraction in progress.
Conclusions

- New way of describing final states in hadronic collisions
  uses $k_{1}$-factorization (LDC)

- Cutoff independent underlying event and pedestal effect

- Everything predicted from fit to DIS $F_{2}$

Future:

- Colour connections between mult. chains must be improved

- Studies of correlations, saturation and diffraction in progress