Energy Conservation and Pomeron Loops in High Energy Evolution

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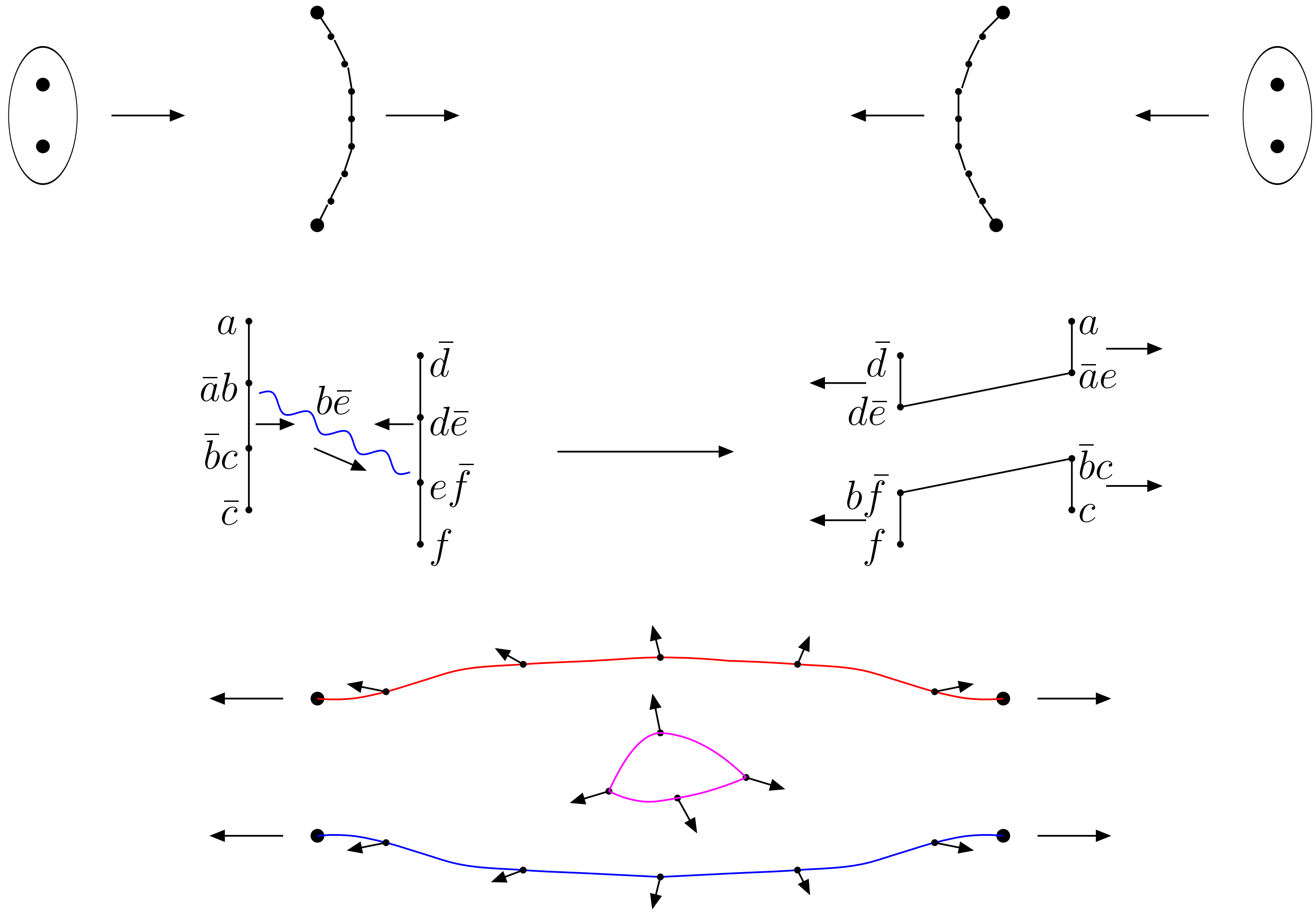
Outline

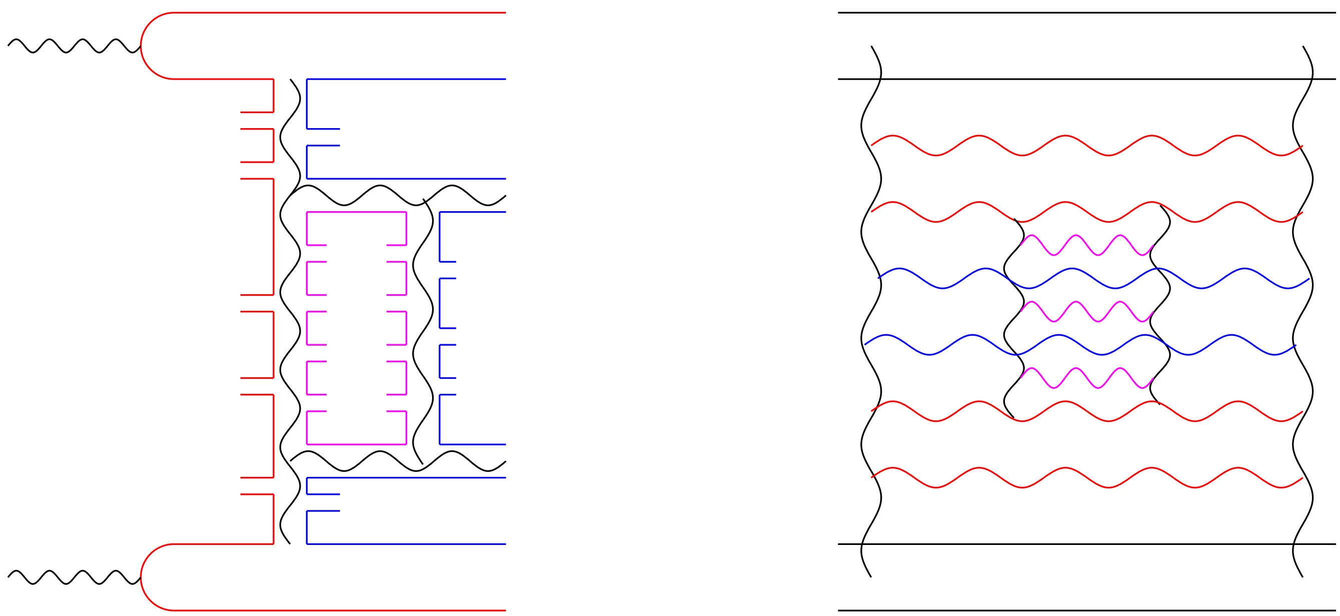
- Dipoles in High Energy QCD.
- Improving Mueller's Dipole Model:
  - Energy-Momentum Conservation.
  - Colour Suppressed Effects.
- DIS at HERA.
- pp at the Tevatron.
- Summary and Outlook.

Strings and Dipoles in HE Collisions



From Dipoles to Pomerons

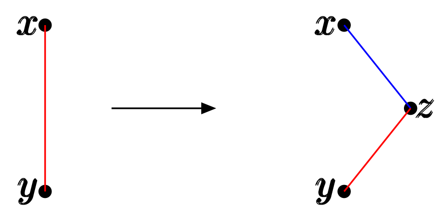
- Multiple interactions will generate colour loops. The colour loops in the inelastic amplitude, when squared, give rise to pomeron loops in the elastic amplitude.



Mueller's Dipole Model

- In the dipole model the splitting kernel is given by

$$\mathcal{M}(\boldsymbol{x},\boldsymbol{y},\boldsymbol{z}) = \frac{\bar{\alpha}_s}{2\pi}\frac{(\boldsymbol{x}-\boldsymbol{y})^2}{(\boldsymbol{x}-\boldsymbol{z})^2(\boldsymbol{z}-\boldsymbol{y})^2}$$



- This expression diverges when integrated over $d^2\boldsymbol{z}$. A cutoff, $\rho^2 \leq (\boldsymbol{x}-\boldsymbol{z})^2, (\boldsymbol{y}-\boldsymbol{z})^2$, is needed to regulate the divergence.
- Even though the divergence cancels against virtual emissions, the cut off, ρ, has to be kept in a MC.

Conserving Energy-Momentum

- A small dipole corresponds to two well localized gluons.

  $\Longrightarrow$ large $p_T \sim 1/r$ for these gluons. The emission of such gluons violates EM conservation.

- These emissions are compensated by virtual emissions.

  $\Longrightarrow$ σ_{tot} is determined by real emissions. Keeping only these we get a closer correspondence between the cascade and exclusive final states.

- Effects of EM conservation: hep-ph/0503181, JHEP 2005.

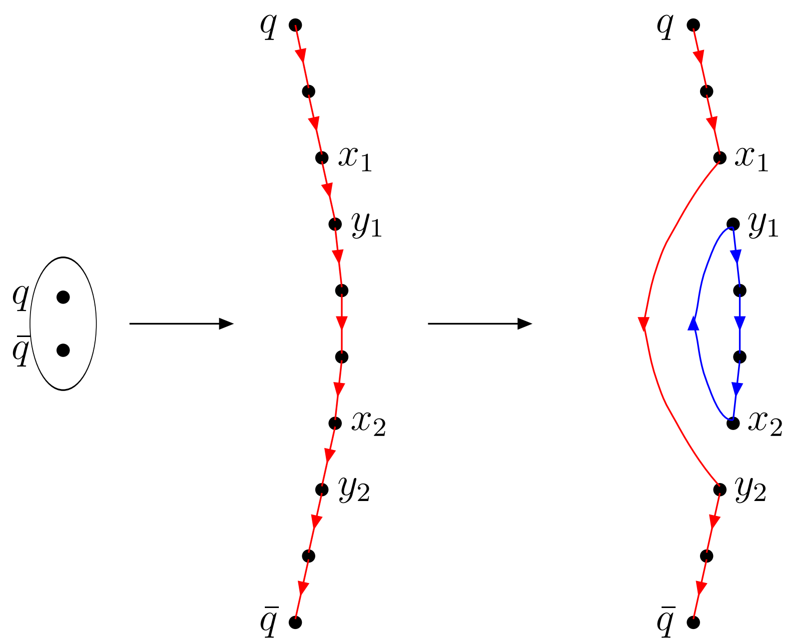
Beyond Large N_c

- Beyond large N_c, higher order multipoles are formed, such as quadrupoles.
- Try to approximate a quadrupole by two dipoles
  - Necessary to include a “dipole swing”.
- Multiple Interactions supressed by N_c^2 while evolution leading in N_c

  $\Longrightarrow$ Formalism not frame independent.

Dipole Swing

- Include a $2 \to 2$ transition (suppressed by N_c^2). This can be seen as a dipole swing (or a colour recoupling):$(x_1, y_1), (x_2, y_2) \to (x_1, y_2), (x_2, y_1)$.



- Result essentially frame independent.

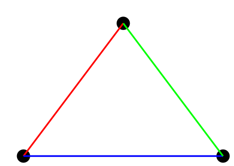
The γ^*p Cross Section

- To simulate DIS events we picture the γ^* fluctuate into a $q\bar{q}$ pair which initiates the dipole cascade.
- The $\gamma^* \to q\bar{q}$ vertex is given by the wavefunctions $\psi_T(z,\boldsymbol{r})$ and $\psi_L(z,\boldsymbol{r})$.

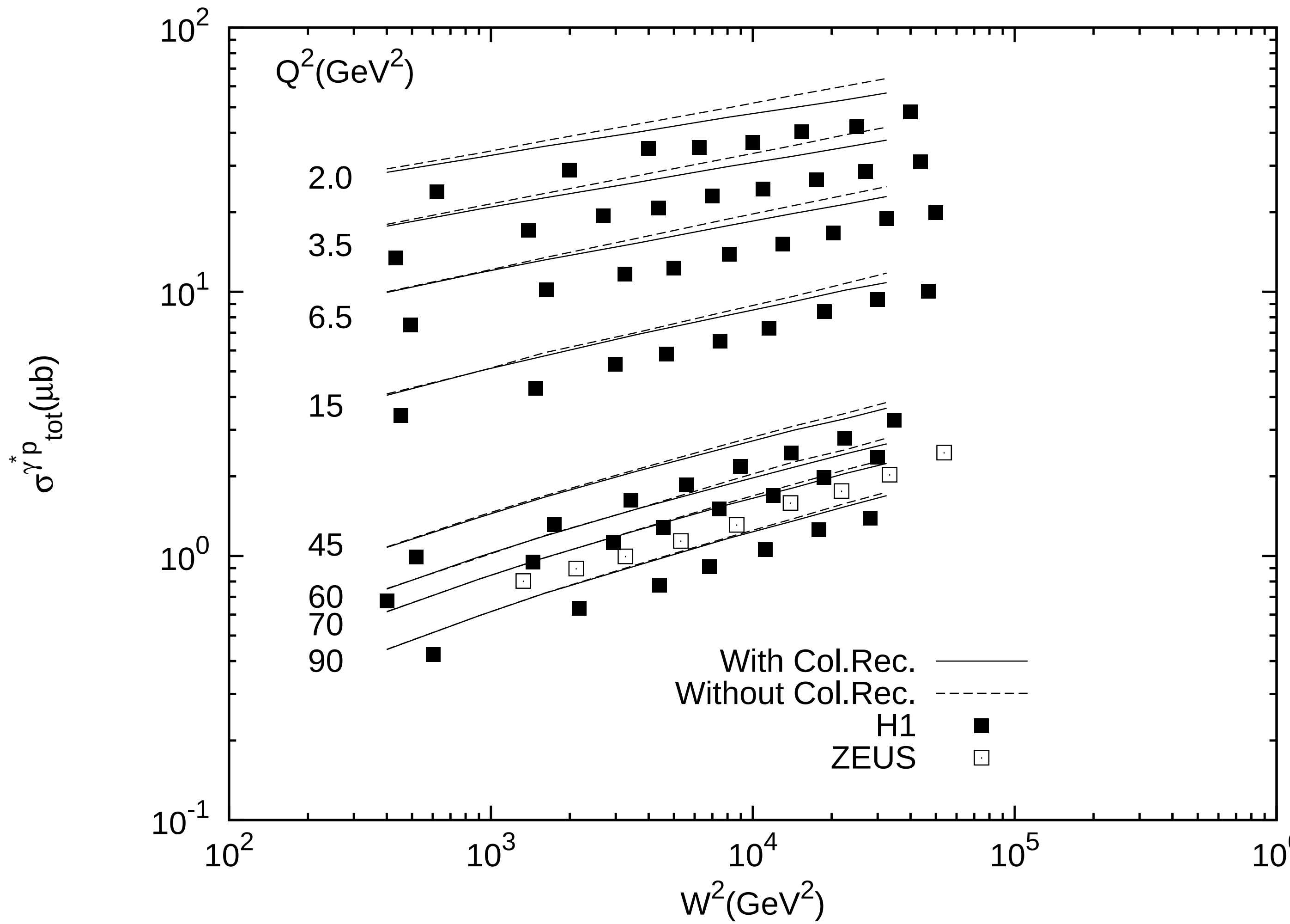
$$
\begin{aligned}
\sigma^{tot}_{\gamma^* p} = \sigma_T + \sigma_L &= \int d^2\boldsymbol{r} \int_0^1 dz (|\psi_T|^2 + |\psi_L|^2)\sigma(z,\boldsymbol{r}) \\
\sigma(z,\boldsymbol{r}) &= 2\int d^2\boldsymbol{b} \langle 1 - \exp(-\sum_{ij} \mathcal{T}_{ij}) \rangle \\
\mathcal{T}_{ij} &= \frac{\alpha_s^2}{8} \log^2 \{ \frac{(\boldsymbol{x}_i - \boldsymbol{y}_j)^2 (\boldsymbol{y}_i - \boldsymbol{x}_j)^2}{(\boldsymbol{x}_i - \boldsymbol{x}_j)^2 (\boldsymbol{y}_i - \boldsymbol{y}_j)^2} \}
\end{aligned}
$$

The Proton

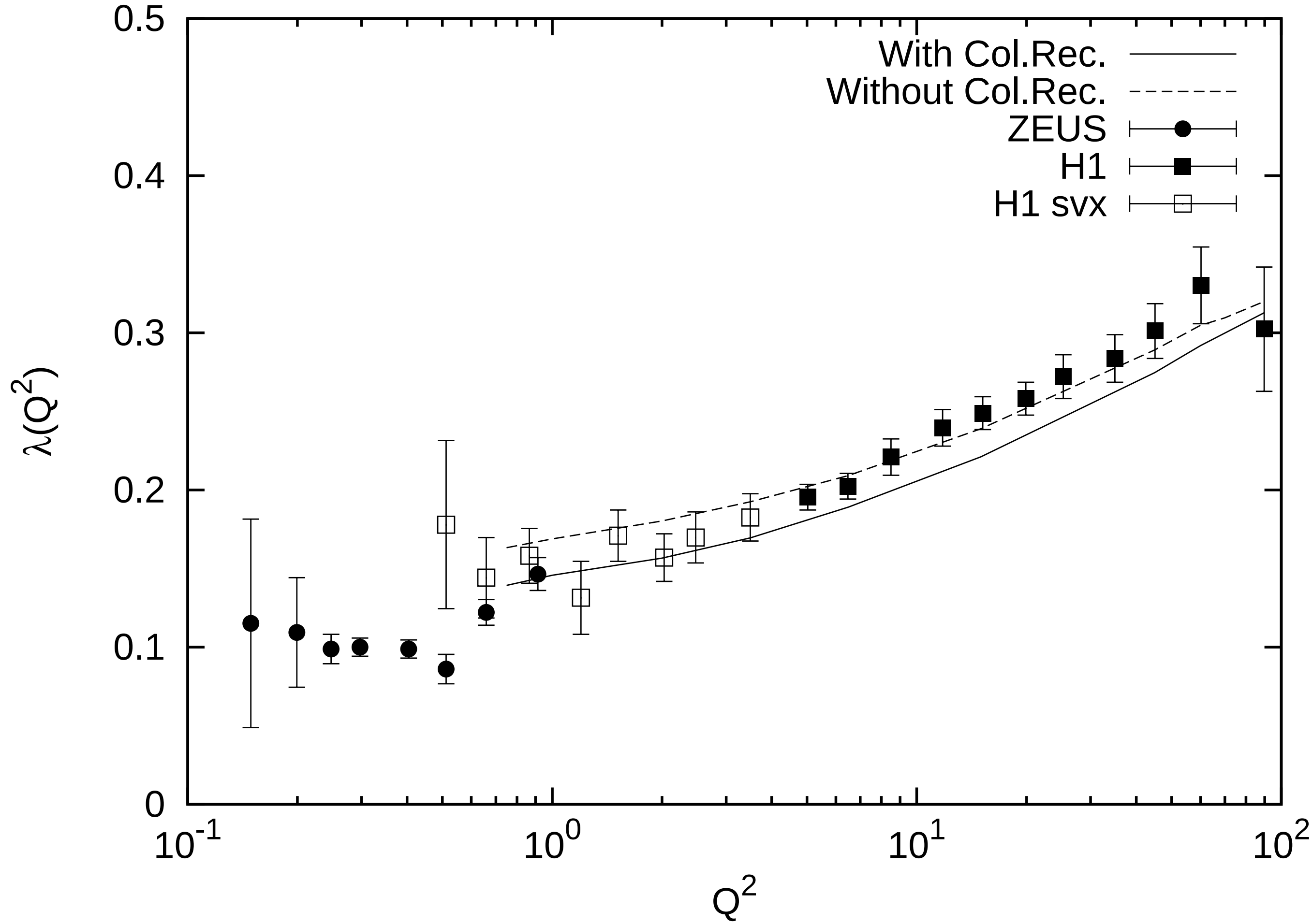
- Soft physics involved, cannot be fully described by PQCD.
- High energy pp collision $\Longrightarrow$ scattering dominated by minijets = hard subcollisions.
- For the first gluon emission the proton appears as 3 dipoles.
  - However, no factorization, even in large N_c limit.
- As an approximation we use a Δ shaped topology consisting of 3 colour dipoles.



Results for DIS



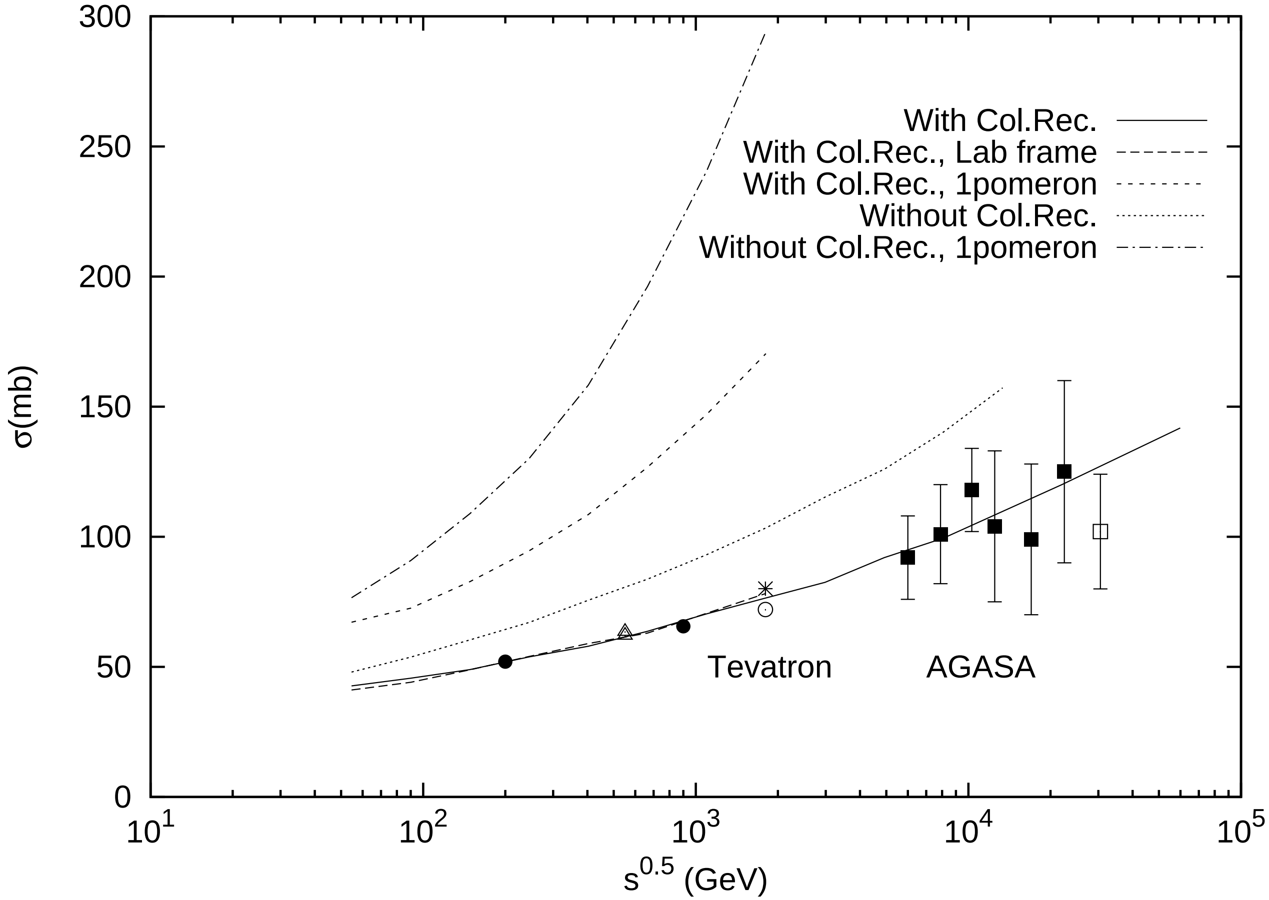
F_2 slope at HERA



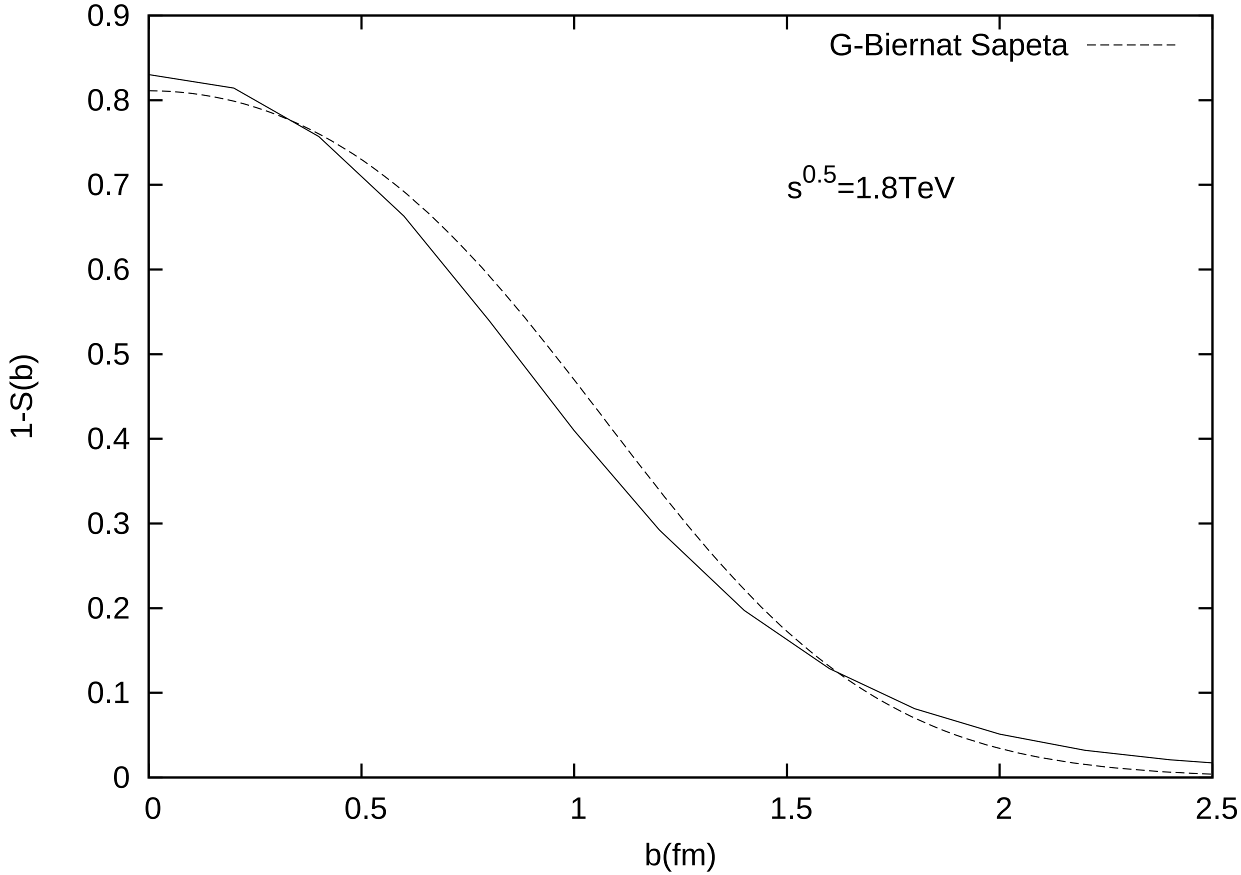
pp Total Cross Section

Saturation very important (small effect at HERA).

Dipole swing $\Longrightarrow$ Near frame independence.



pp Impact Parameter Profile



$S =$exp$(-\sum_{ij} \mathcal{T}_{ij})$. GB-S = two parameter fit to data.

Summary and Outlook

- Including EM conservation in the Dipole Model we get a good agreement with data for DIS at HERA.
- We have included some effects beyond leading N_c
  - These are seen to be very important for pp collisions.
  - Gives good agreement with data up to Tevatron energies.

- Obtain an explicitely frame independent formalism for subleading N_c effects in dipole language.
- Obtain results for exclusive final states.