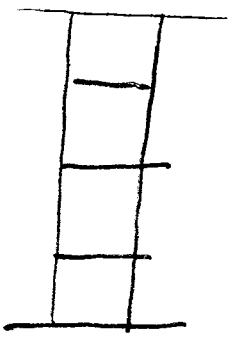
S-channel picture: space-time sequence

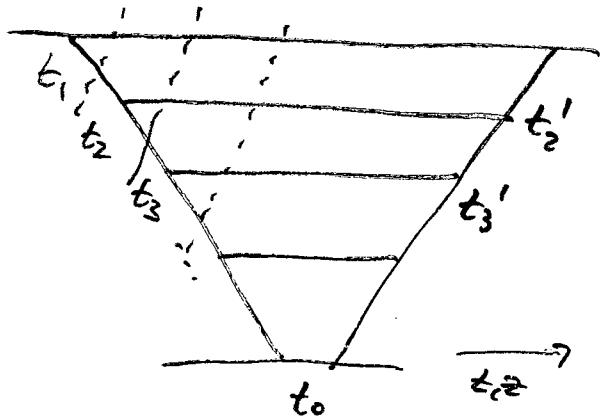
scalar theory:



$T \sim is\, g^2 s^{\alpha(t)}$

$\alpha(t) = -1 + (t - m^2)$

covariant p.th.

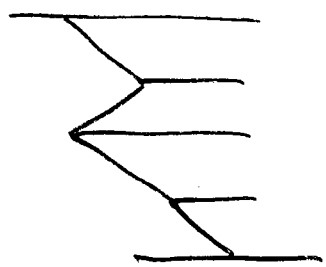


noncovariant p.th.

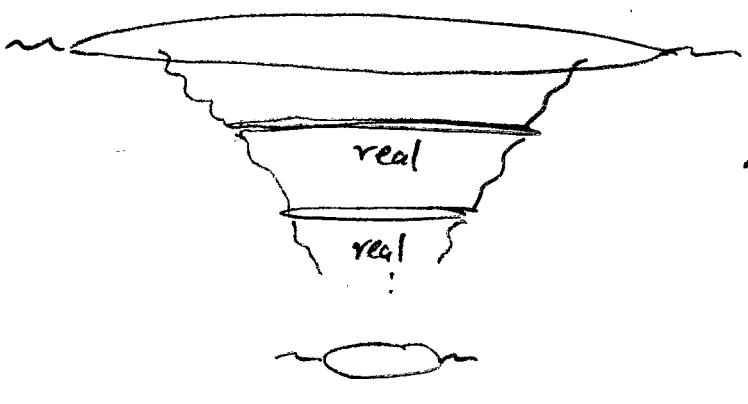
time sequence:

$t_1 < t_2 < \dots t_0 < \dots < t_2' < t_1'$

suppressed:

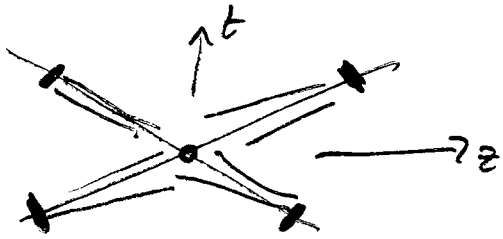


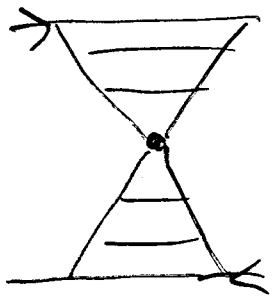
BFKL:



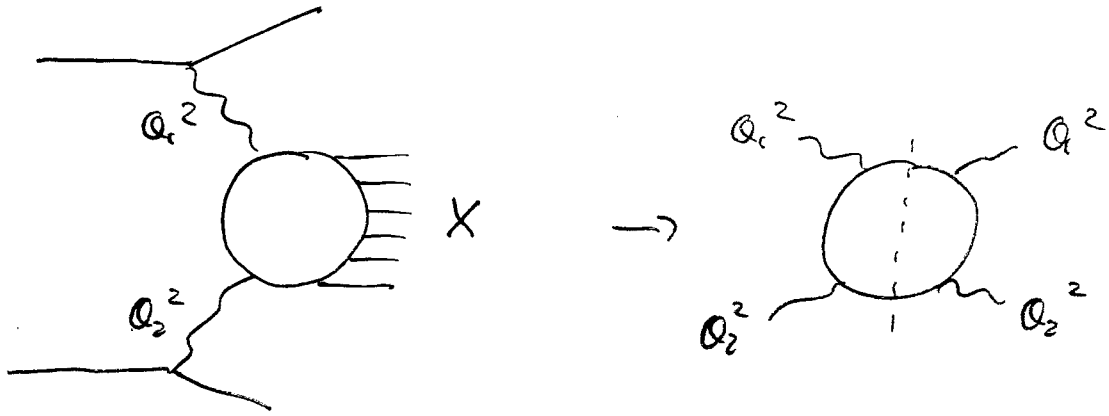
reggeization:

light-cone:

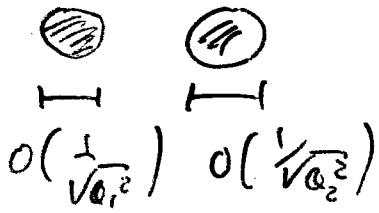




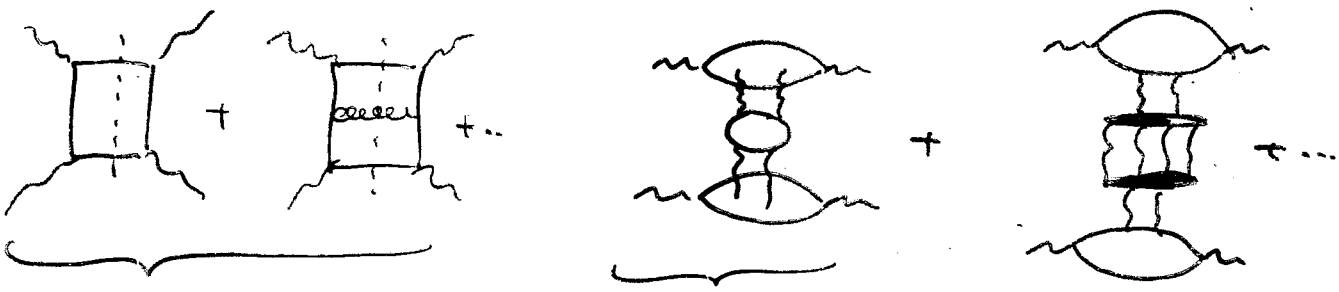
III. $\gamma^*\gamma^*$-scattering in e^+e^-



Scattering of small size projectiles:



in pQCD: LO



$O(\frac{1}{s}) \cdot \log^l s$

double log

$s^{-1+\omega_{DL}}$

$\omega_{DL} \sim \sqrt{\alpha_s}$

~ 0.5

flavor nonsinglet:

"secondary" exchange

singlet exchange ?

$O(1) \cdot \log^l s$

single-log

$s^{\omega_{BFKL}}$

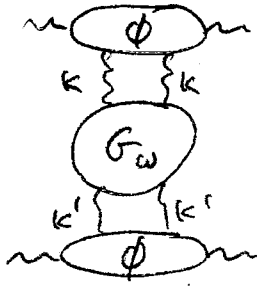
$\omega_{BFKL} \sim 0.3 .. 0.5$

$- \alpha_s^4 \, s^{2\omega_{BFKL} + \delta}$

NLO: Green's function + impact factor

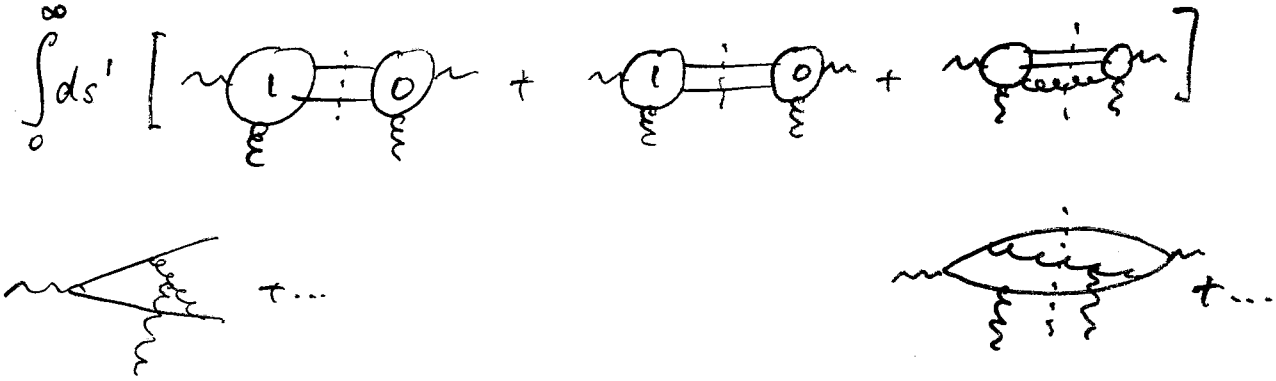
- Green's function ✓ Fadin, Lipatov
- impact factor ✓ JB, Gieseke, Qiao, Kyrielis, Chachamis
- combine to get $\sigma_{\gamma^*\gamma^*}$: in progress

Status of NLO impact factor:



$$\sigma = \int \frac{d\omega}{2\pi i} \int d^2k\, d^2k'\, \phi(k)\, G_\omega(k,k')\, \phi(k') \left(\frac{s}{kk'}\right)^\omega$$

NLO:



- UV-renormalization
- IR cancellations (collinear, soft)
- computer code for remaining finite pieces
- energy scale: remove LO

$$\phi = \phi^{Born}\left[1 - \beta_0 \ln \frac{Q^2}{\mu^2}\right] + \Delta\phi(Q^2, r^2, s_0)$$

Change s_0 ("scheme"):

$$\int \frac{d\omega}{2\pi i} \int d^2k\, d^2k' \left(\frac{s}{kk'}\right)^{\omega} \phi \quad G_\omega \quad \phi$$

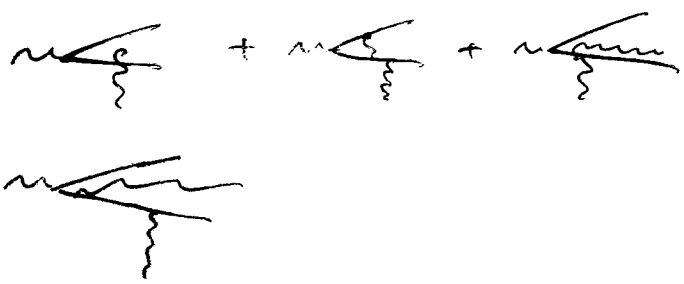
$$= \int \frac{d\omega}{2\pi i} \int d^2k\, d^2k' \left(\frac{s}{\sqrt{Q_1^2 Q_2^2}}\right)^{\omega} \underbrace{\phi \cdot \left(\frac{\sqrt{Q_1^2}}{k}\right)^{\omega}}_{\tilde{\phi}} \quad G_\omega \quad \underbrace{\left(\frac{\sqrt{Q_2^2}}{k'}\right)^{\omega} \phi}_{\tilde{\phi}}$$

Results: corrections are

- large
- negative
- resummation needed?
- improving computer code for 'virtual' + 'real'

Open issues:

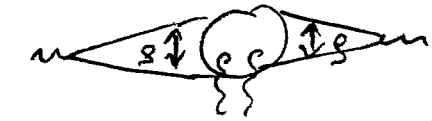
- wave function interpretation:



$\}$ $q\bar{q}$ component

$q\bar{q}g$-component

- color dipole picture:



ρ is "frozen"

'off-diagonal'

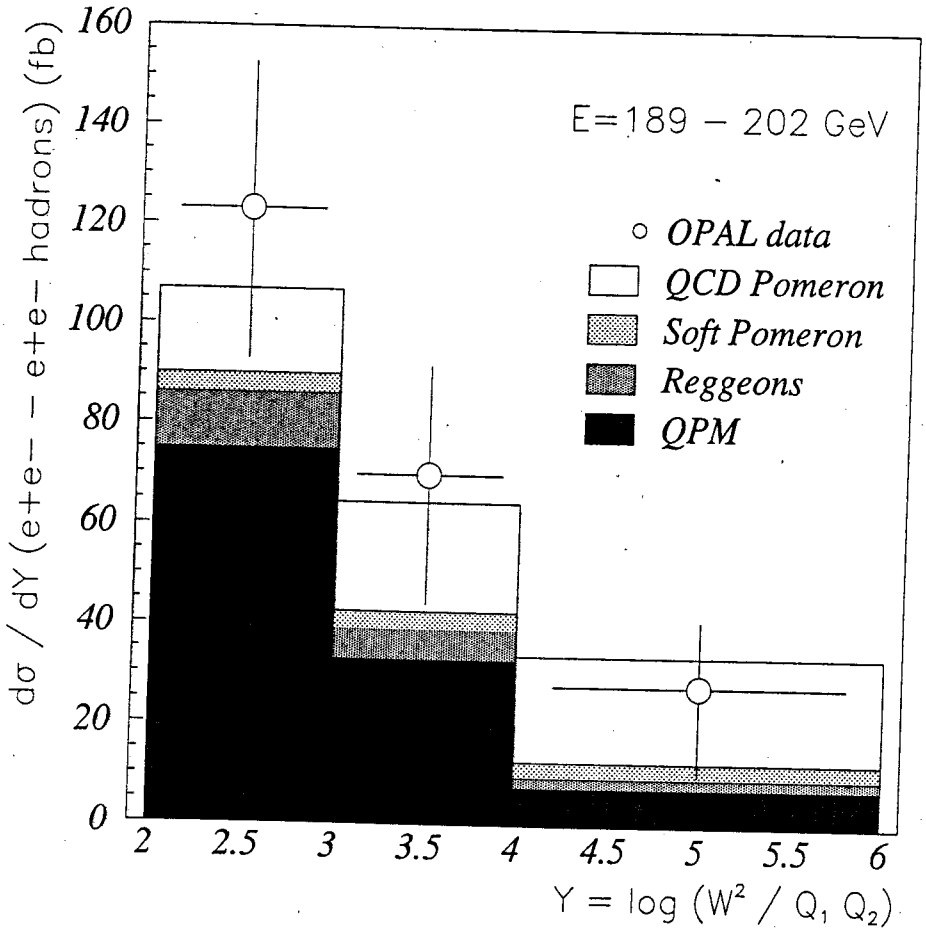


Figure 3: Comparison of the OPAL preliminary data [20] on the differential cross-section for doubly tagged events $d\sigma(e^+e^- \to e^+e^- + hadrons)/dY$ with our predictions plotted as function of Y for the e^+e^- collision energies between 189 and 202 GeV.

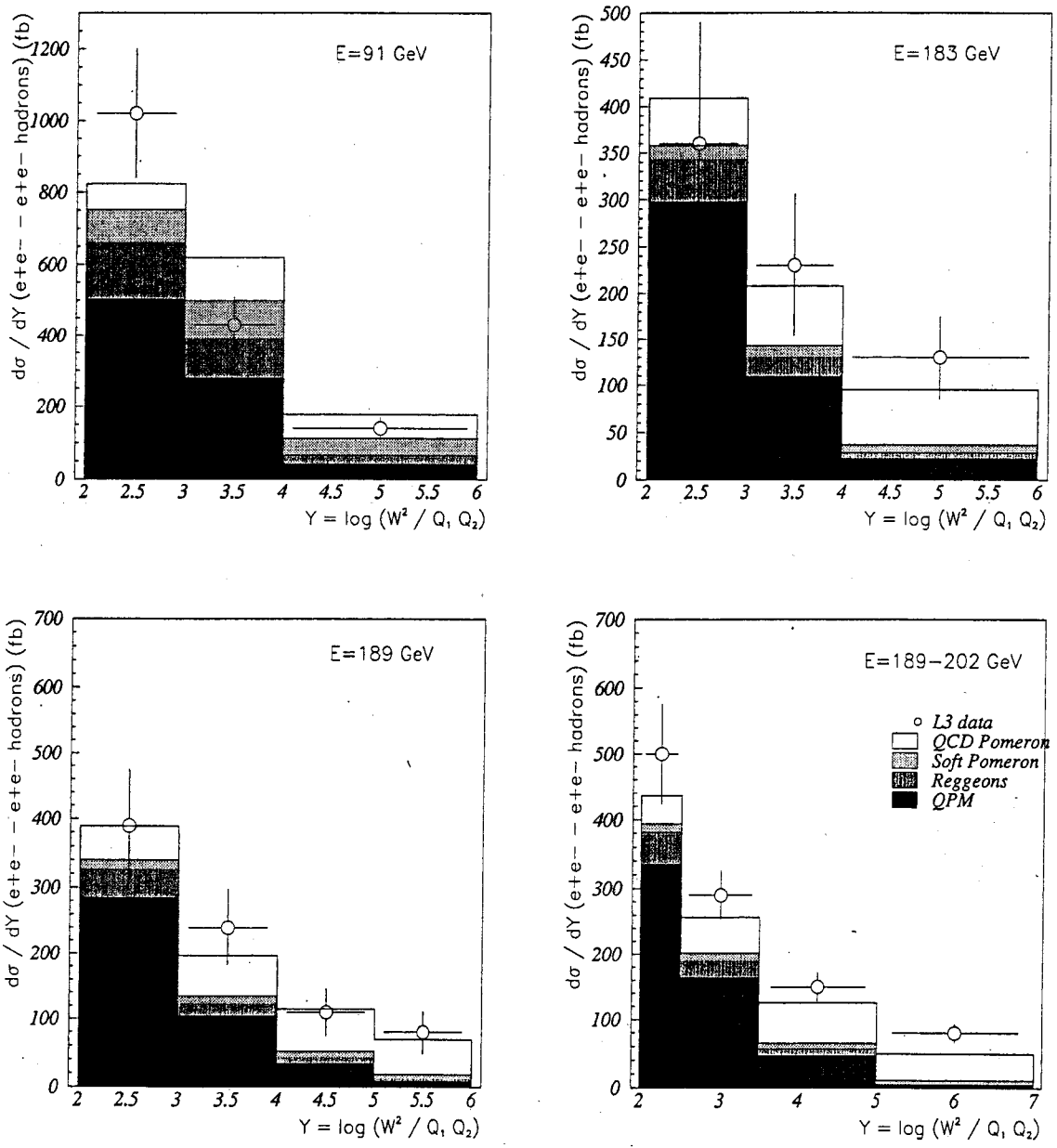


Figure 2: Comparison of the L3 data [19] on the differential cross-section for doubly tagged events $d\sigma(e^+e^- \to e^+e^- + hadrons)/dY$ with our predictions plotted as function of Y for different e^+e^- collision energies, corresponding to the measurements by the L3 collaboration. Four different mechanisms contributing to $d\sigma/dY$ are described in the text.

Comparison with LEP data

- naive LO BFKL above the data
- phenomenological fit: large contribution from quark box + secondary
- Next: NLO-fit!

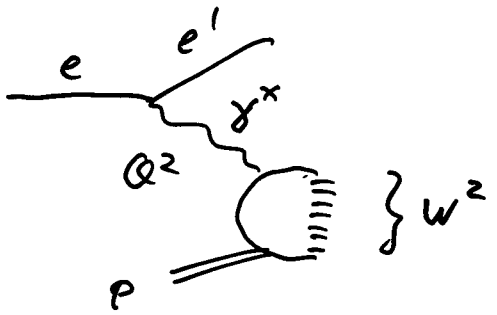
Conclusion for $\gamma^*\gamma^*$ in e^+e^-:

- clean testing laboratory
- wait for NLO, wait for ILC

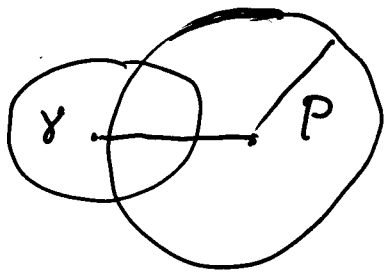
IV. Diffraction in $\gamma^* p$ (DIS at HERA)

Outline:

1. Elastic, total cross section
2. Vectorproduction
3. Saturation
4. Diffractive structure function
5. Diffraction and F_2

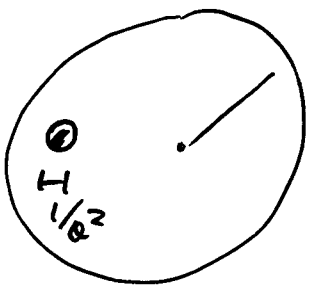


$$W^2 = Q^2\left(\frac{1}{x} - 1\right)$$



$Q^2 = 0$

"big photon"



$Q^2 \neq 0$

"pointlike photon"

Interpolation between "small" and "large"

nonperturbative

(partly) pQCD