Selected results in hadronic final state in DIS at HERA

Stathes Paganis
Columbia Univ., Nevis Labs
on behalf of H1 and ZEUS collaborations
Recontres de Moriond - March 23 2003

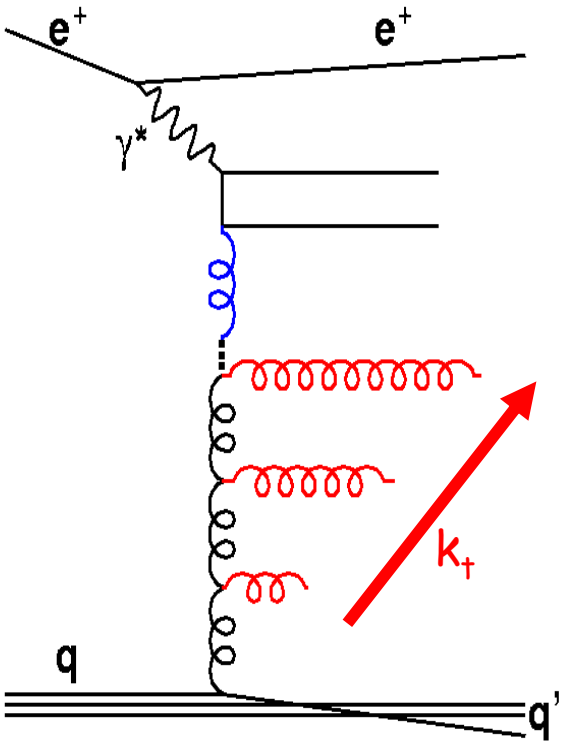
Outline

- Forward jet and π^0 production in DIS
- First observation of $K_s K_s$ resonances in DIS

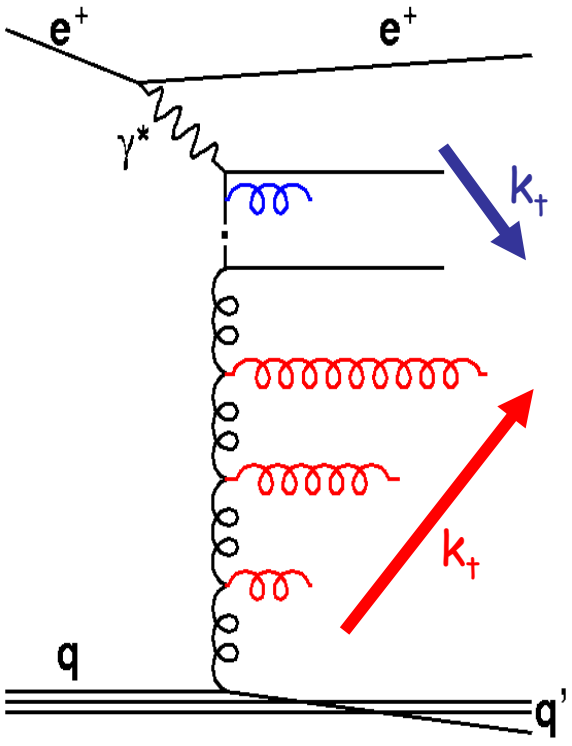
Multi-parton dynamics at low x

- Multi-parton emissions are described only by approximations
- Everything beyond $O(a_s a_s)$ is put into Evolution Equations
- DGLAP, BFKL, CCFM evolution schemes.

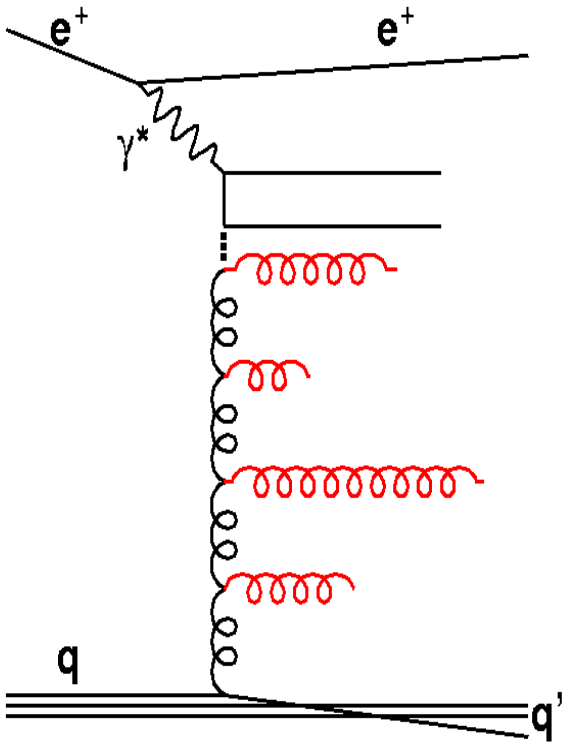
DGLAP: ordered in k_t



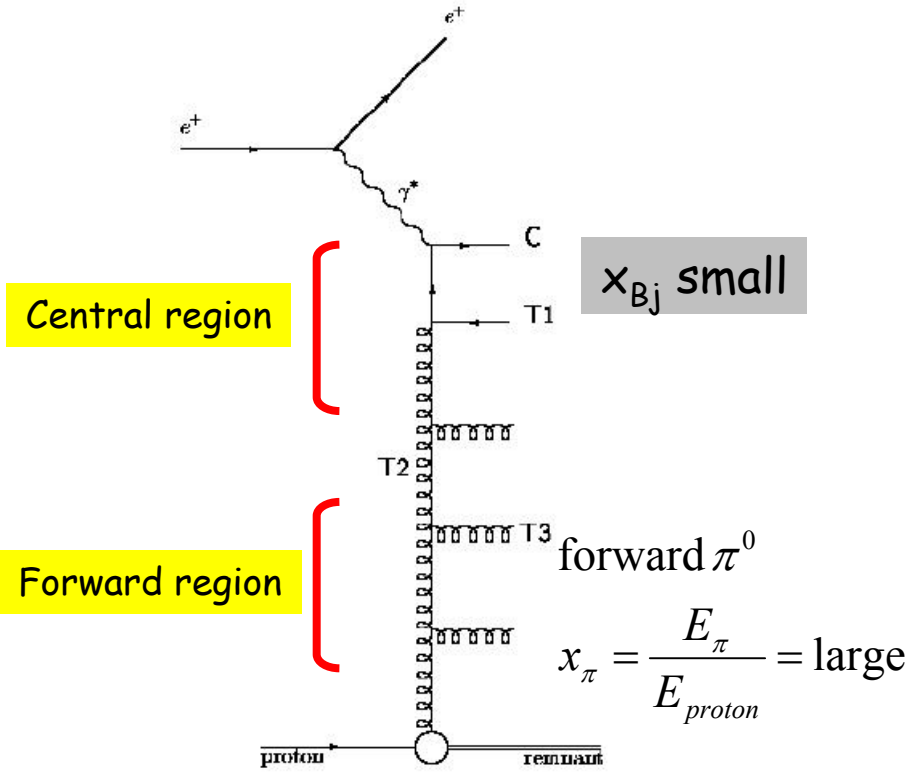
DGLAP+resolved photon: 2 ladders ordered in k_t



CCFM BFKL: not ordered in k_t



Parton dynamics at small x: forward jets and forward π^0



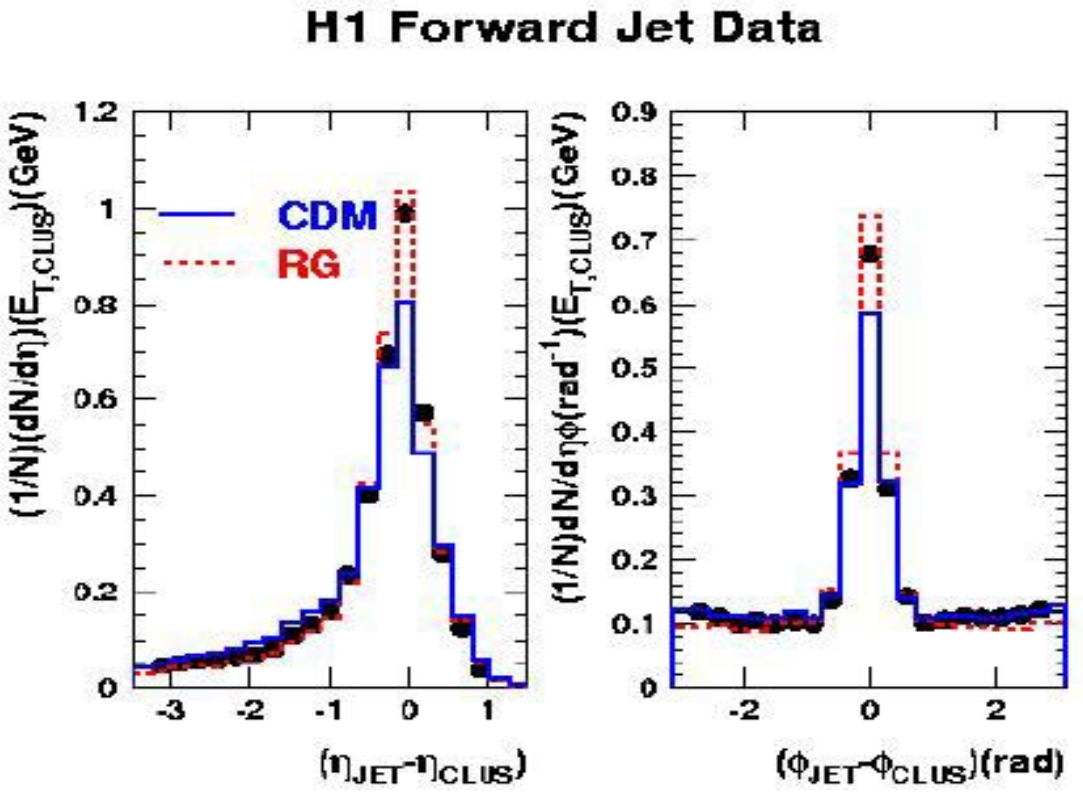
- An extended parton ladder at low x leads to high k_T partonic emission in the forward region
- A forward parton can be tagged by a jet OR by a single forward particle (like a π^0)

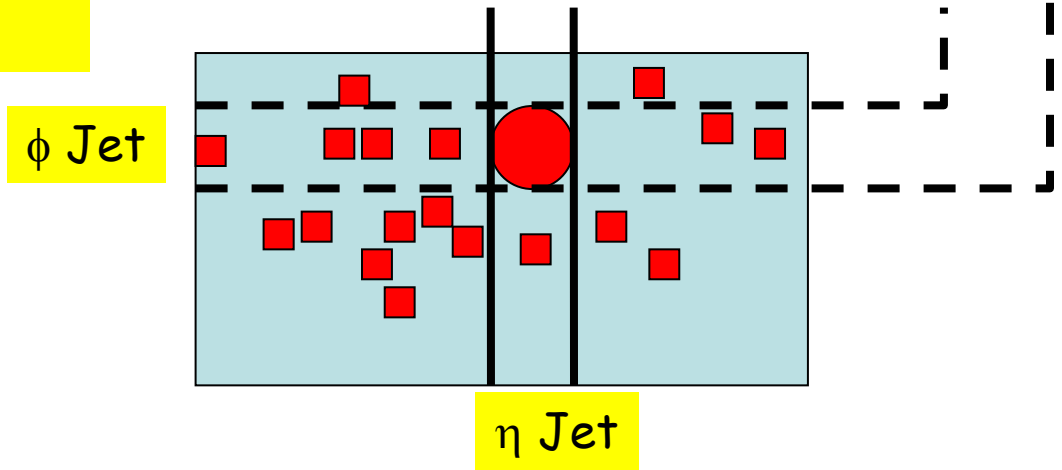
- DGLAP (strictly increasing gluon virtuality from proton to γ^*) works very well in the central rapidity region
- How about the forward region (small x)? Can we see any evidence for BFKL? (in BFKL the parton propagator virtualities perform a "random walk")

Forward Jet production: E_T flow

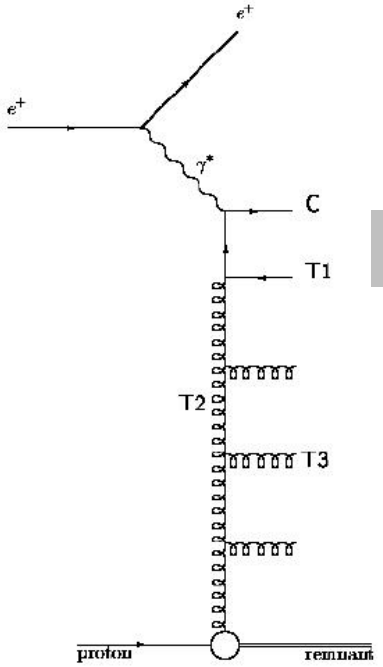
- Transverse energy flow around the selected forward jet as a function of $\Delta\eta$ and $\Delta\phi$

- DGLAP + resolved photon describes the Et flow better than CDM which simulates higher order QCD radiation without strong ordering in kt of emitted partons (similar to BFKL)





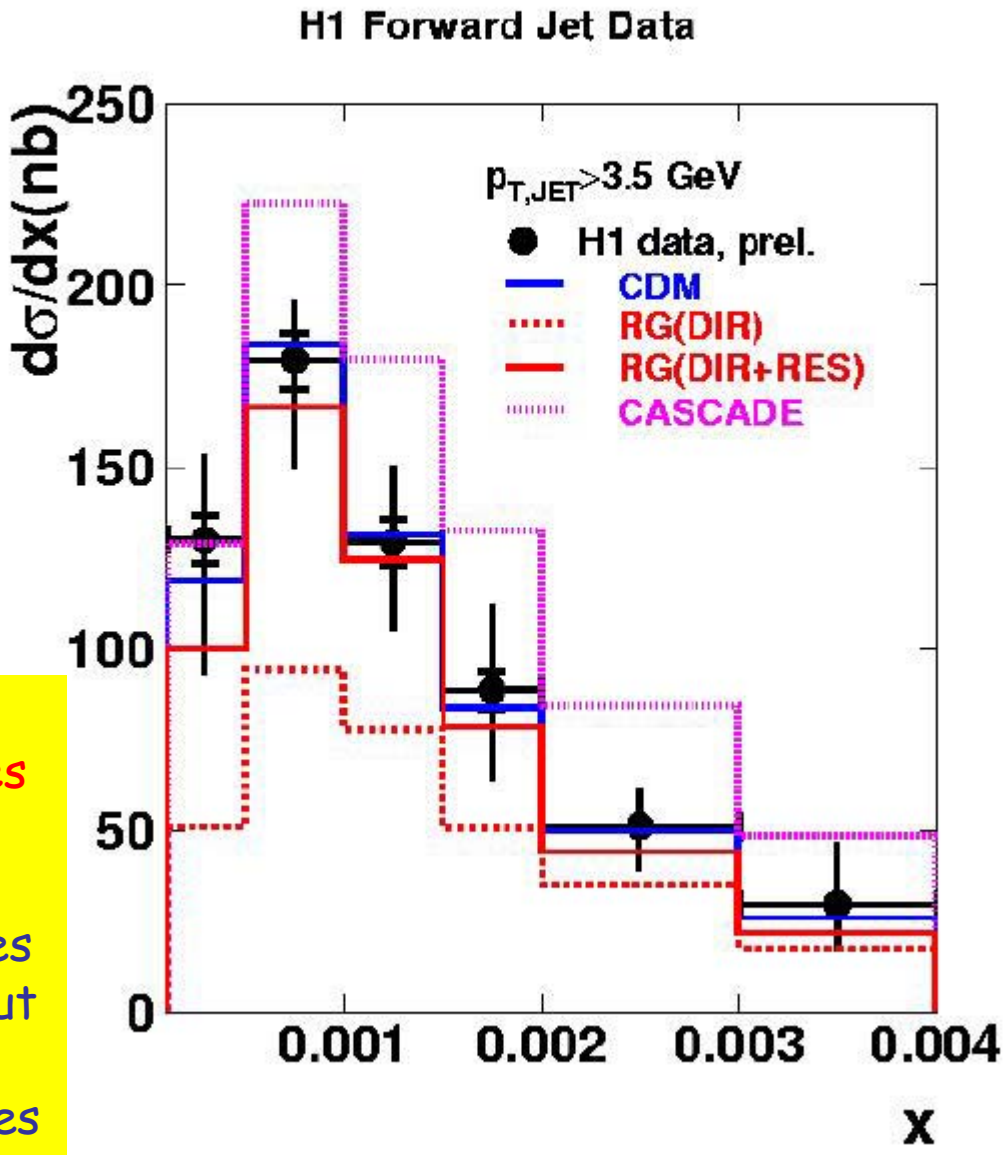
Forward jet production



x_{Bj} small

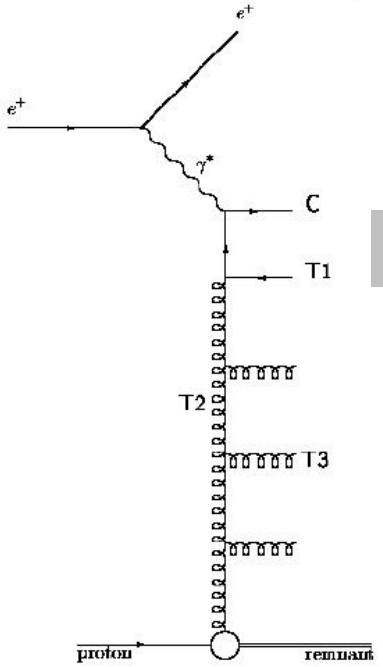
forward jet

$$x_{jet} = \frac{E_{jet}}{E_{proton}} = \text{large}$$



- DGLAP (dashed) too small
- DGLAP + resolved photon describes well the data
- CCFM (CASCADE) too large
- Color Dipole Model (CDM) simulates higher order QCD radiation without strong ordering in kt of emitted partons (similar to BFKL): describes well the data

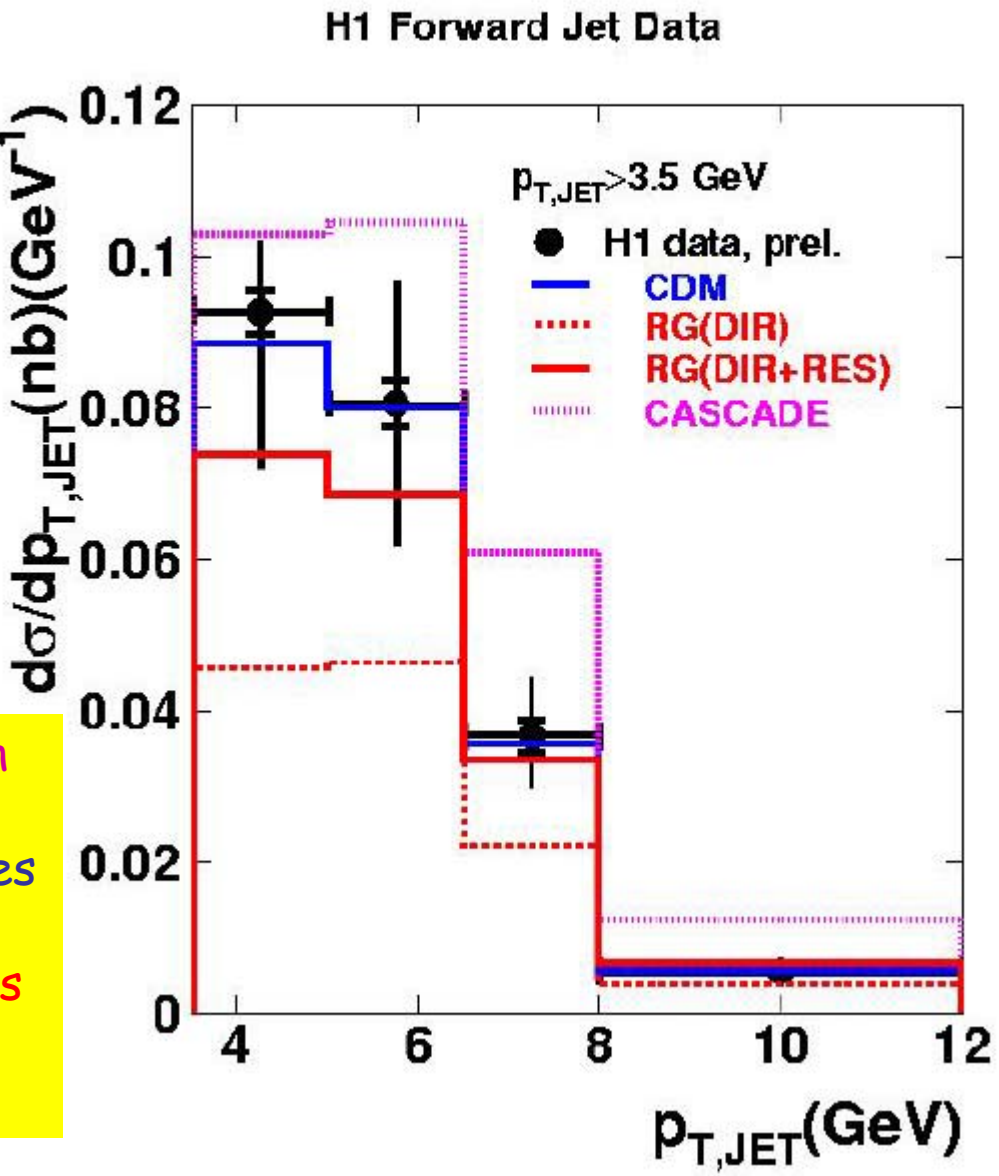
Fwd jet production: p_T dependence



x_{Bj} small

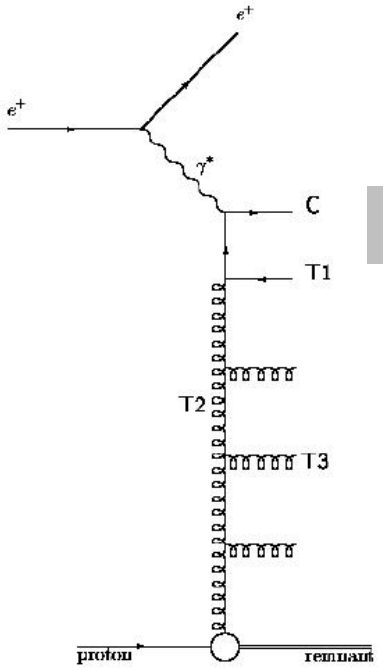
forward jet

$$x_{jet} = \frac{E_{jet}}{E_{proton}} = \text{large}$$



- CCFM (CASCADE) gets larger with increasing p_T
- Color Dipole Model (CDM) describes better the data
- DGLAP + resolved photon describes well the data
- DGLAP (dashed) too small

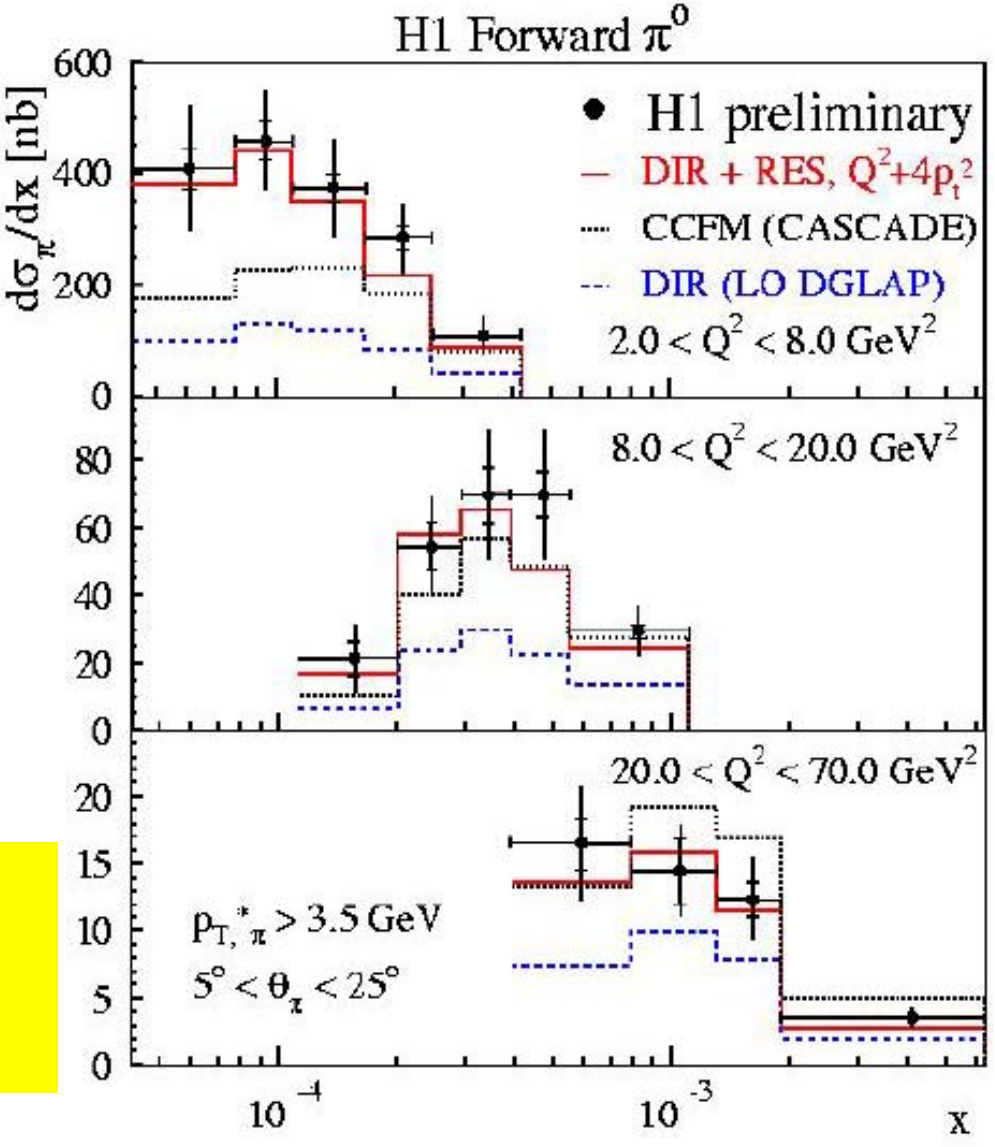
Forward π^0 production



x_{Bj} small

forward π^0

$$x_\pi = \frac{E_\pi}{E_{proton}} = \text{large}$$



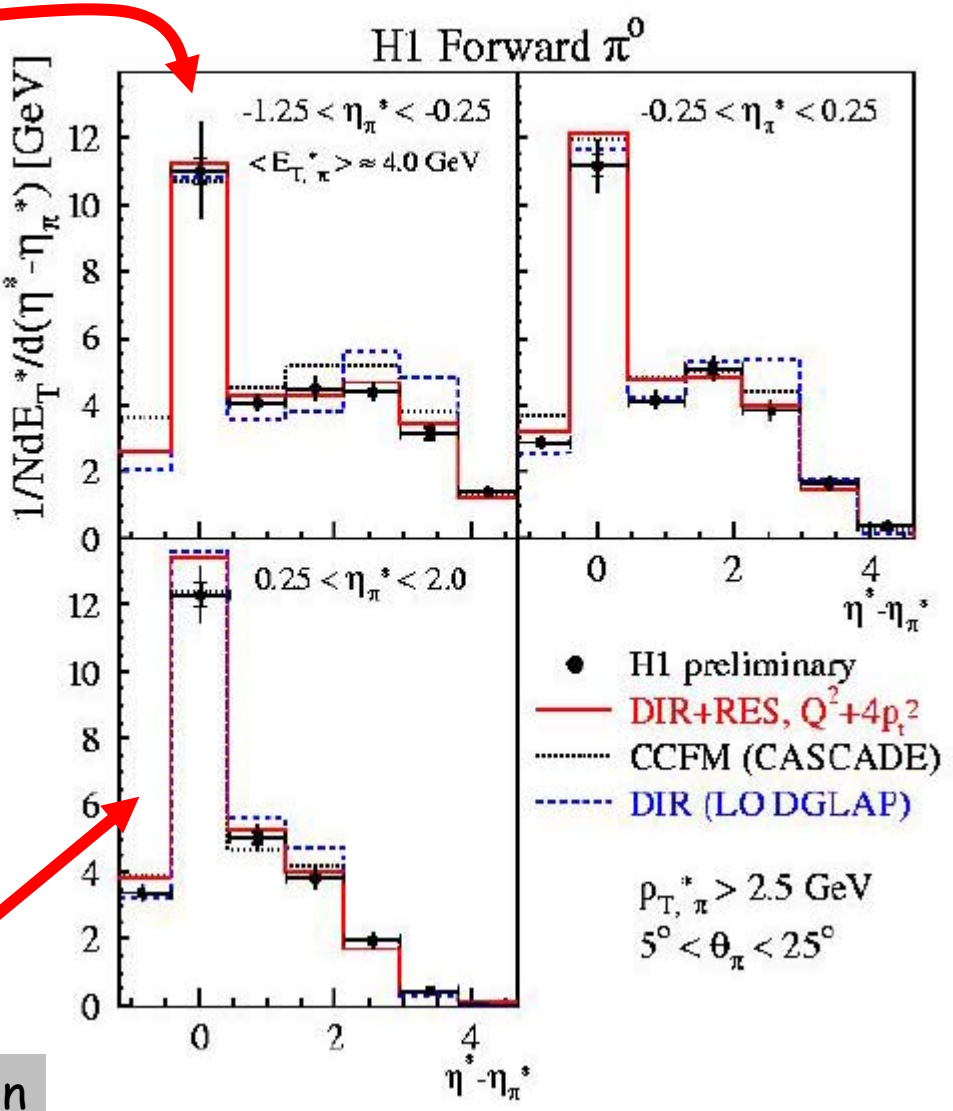
- DGLAP (dashed) too small
- DGLAP + resolved photon describes well the data
- CCFM too small at small x

Forward π^0: E_T-flow around π in γ^*p CMS

π^0 close to proton

η^*: p-rapidity in the γ^*p CMS frame

- Energy flow is highly collimated around the direction of the π
- Large amounts of transverse energy are also produced away from the π
- Transverse Energy flow around the π reflects how the transverse momentum of the jet is compensated along the ladder
- DGLAP+resolved photon describes better the E_t flow when p is close to the proton

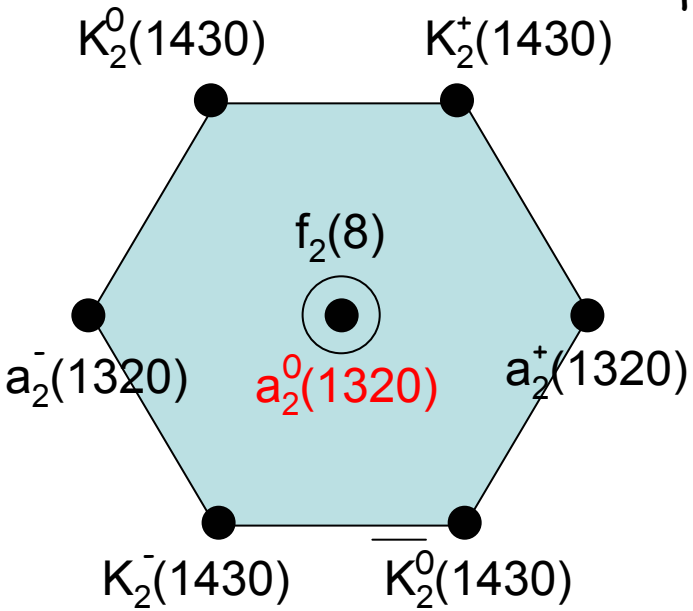


π^0 towards photon

K_sK_s final state in DIS

- K_sK_s couples to meson states with $J^{CP}=(even)^{++}$
- Scalar meson sector is not fully understood: there are too many candidates for the two I=0 available positions in the nonet
- Lattice QCD predicts the existence of hadrons made up by gluons (glueballs): the lightest glueball has $J^{CP}=0^{++}$ with a mass 1730+/-100MeV
- ep is gluon rich

Tensor $J^{CP}=2^{++}$ Nonet



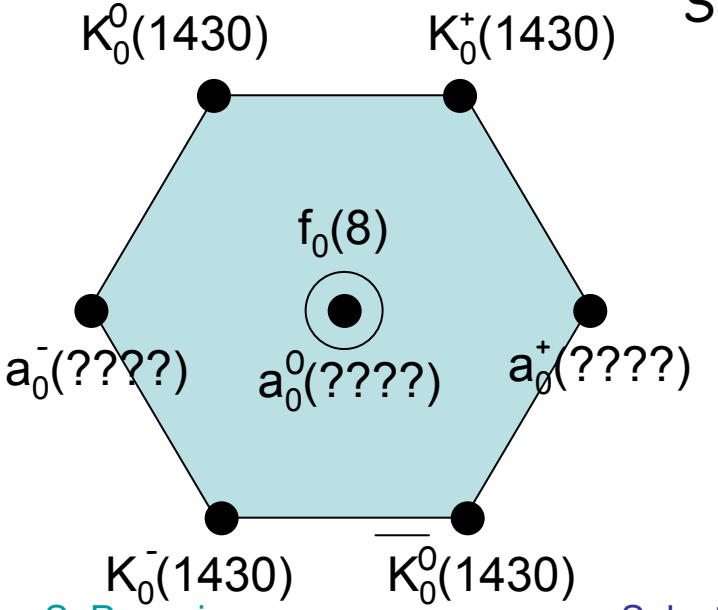
$f_2(1)$

$f_2(8)$ → $f_2(1270) \sim u\bar{u}+d\bar{d}$

$f_2(1)$ → $f_2(1525) \sim s\bar{s}$

$$a_2^0(1320) \sim u\bar{u} - d\bar{d}$$

Scalar $J^{CP}=0^{++}$ Nonet



$f_0(1)$

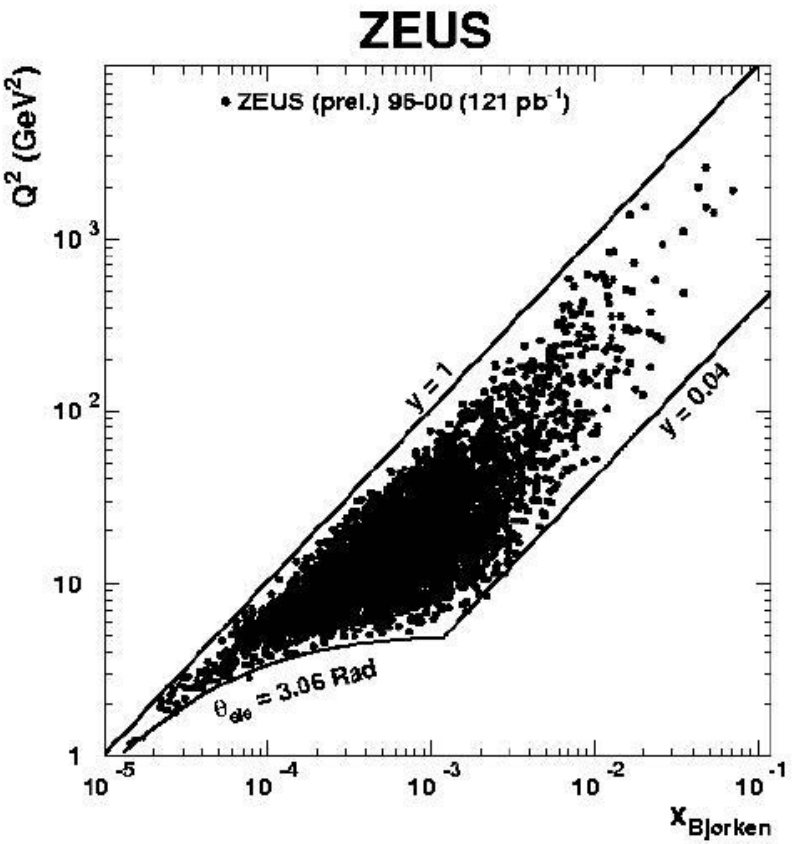
$f_0(8)$ → $f_0(1370) \sim u\bar{u}+d\bar{d}$

$f_0(1)$ → $f_0(1500) \sim$??

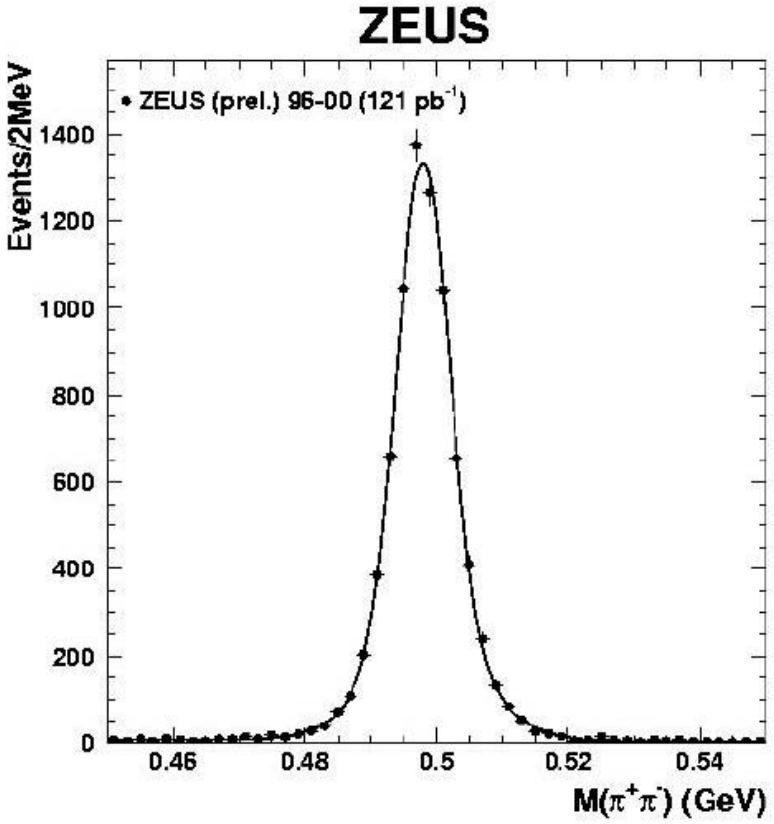
$f_0(1710) \sim s\bar{s}$

J=0 glueball can mix with the I=0 scalar mesons!

x vs Q^2 and K_s mass

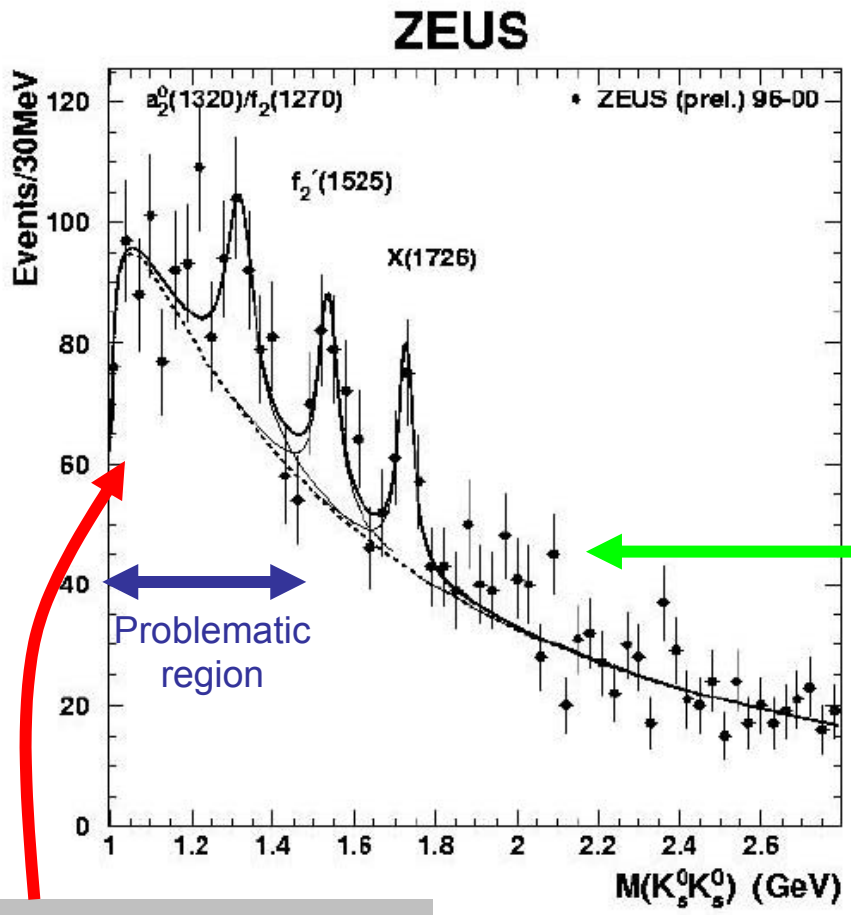


DIS events with at least 2 K_s were selected



Very clean Ks sample

First observation of $J^{CP}=(even)^{++}$ in DIS: two states are observed: a state consistent with $f_2'(1525)$ and X(1726) (is this the $f_0(1710)$?)

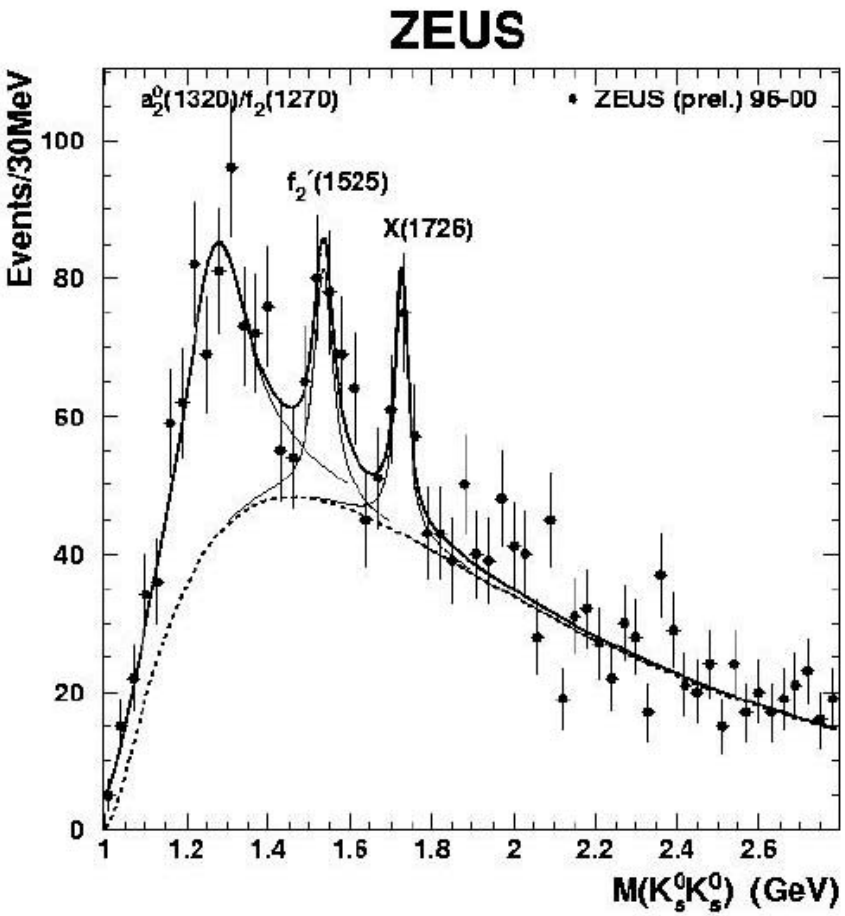


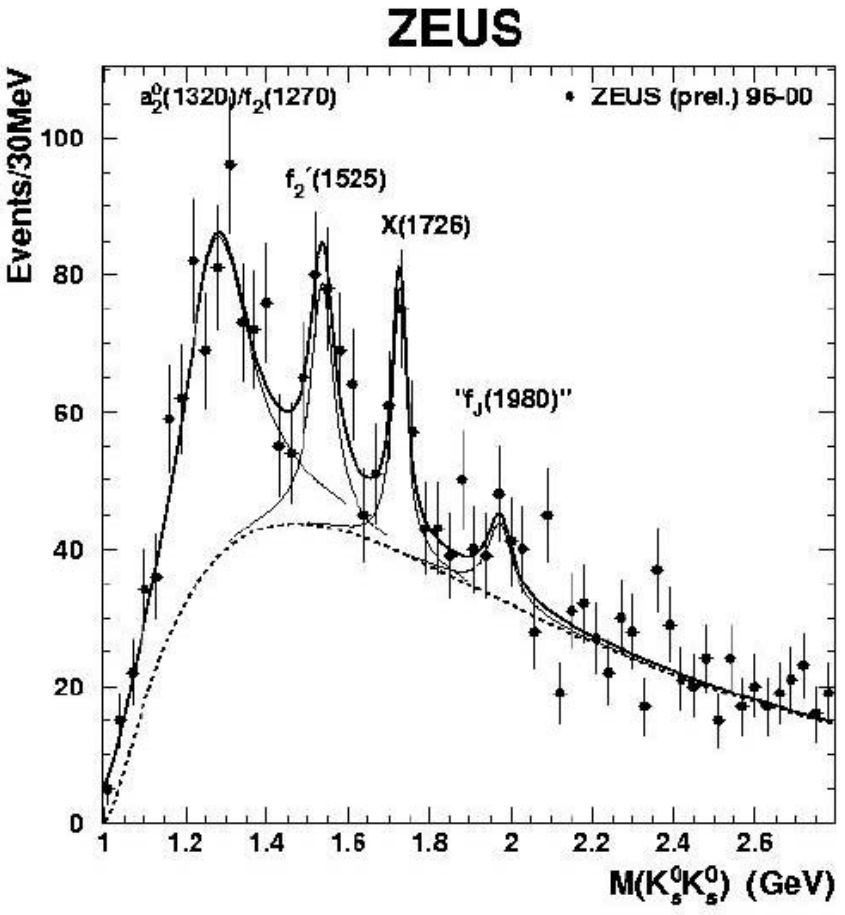
$$F(M)=\frac{dN}{dM}=\sum_{i=1}^{3}\left(\frac{N_i}{2\pi}\frac{\Gamma_i}{(M-M_{0,i})^2+\Gamma_i^2/4}\right)+A\left(M-2m_{K_s}\right)^B e^{-C\sqrt{M-2m_{K_s}}}$$

Several states have been observed in the 2GeV region (see PDG02)

$f_0(980)/a_0(980)$ gives K_s pair with very small opening angle in the lab. We would like to remove collinear K_s pairs and then fit the spectrum.

Observation of K_sK_s resonances in DIS





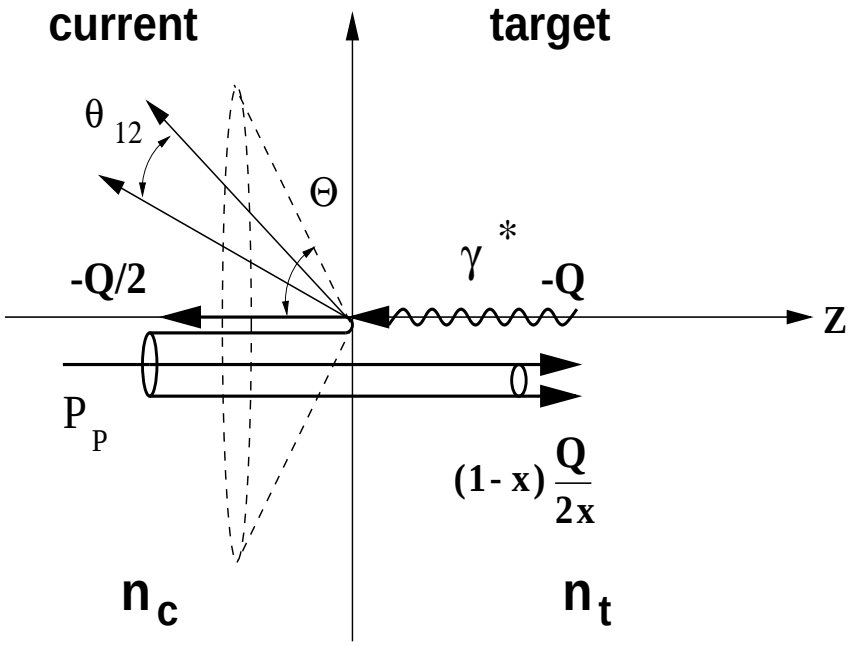
Applied cut: $\cos K_sK_s < 0.92$ to remove threshold enhancement

Attempt to fit with 4 Breit-Wigner

K_sK_s in the Breit Frame

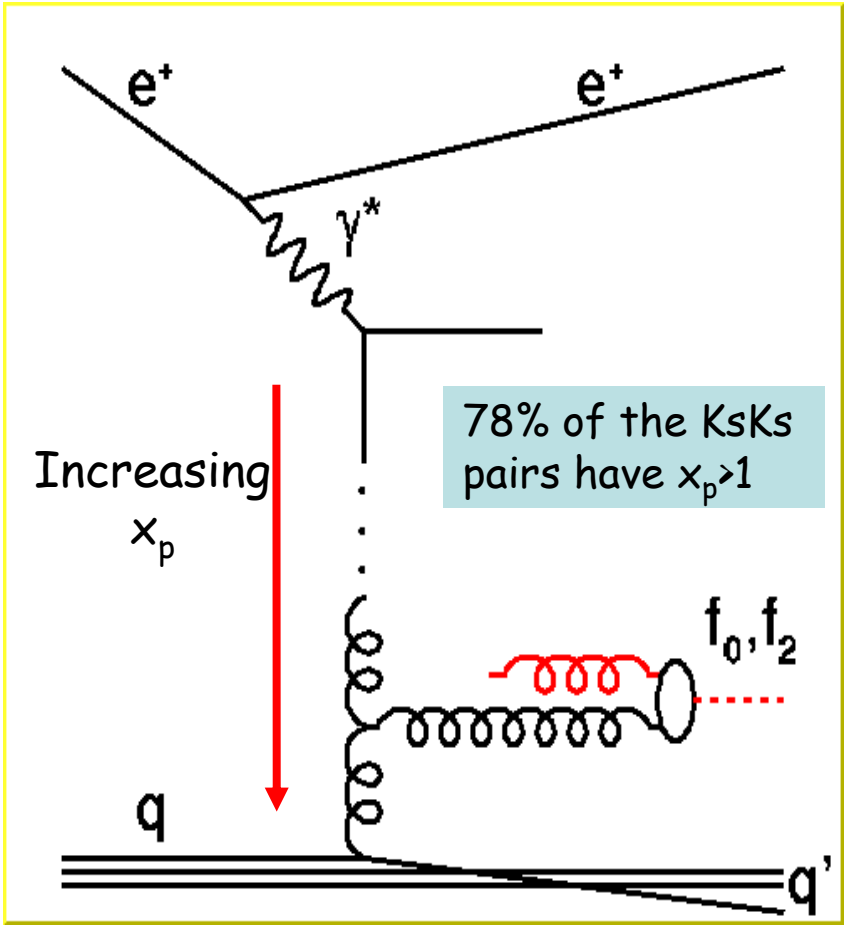
Current region in DIS is equivalent to an e^+e^- hemisphere

$$2x\vec{p} + \vec{q} = 0$$



$P_z(KsKs)<0$ (7%) $P_z(KsKs)>0$ (93%)

$$P_q = \frac{Q}{2} \quad , \quad x_p^{MAX} = \frac{P_{K_sK_s}^{MAX}}{P_q} = \frac{1-x}{x}$$



Summary

- New high statistics measurement of forward jets and pions performed
  - Data discriminate between different models
  - Cross sections much larger than standard DGLAP but DGLAP including the partonic substructure of the virtual photon describes the data
- First observation of J^{PC}=even^{++} resonances in K_sK_s final state in inclusive DIS
  - $a_2(1320)/f_2(1270)$ and $f_2'(1525)$ observed
  - X(1726) is observed, this is probably the $f_0(1710)$ (glueball candidate)