Parton dynamics and identified particles at HERA

on behalf of the H1 and ZEUS collaborations

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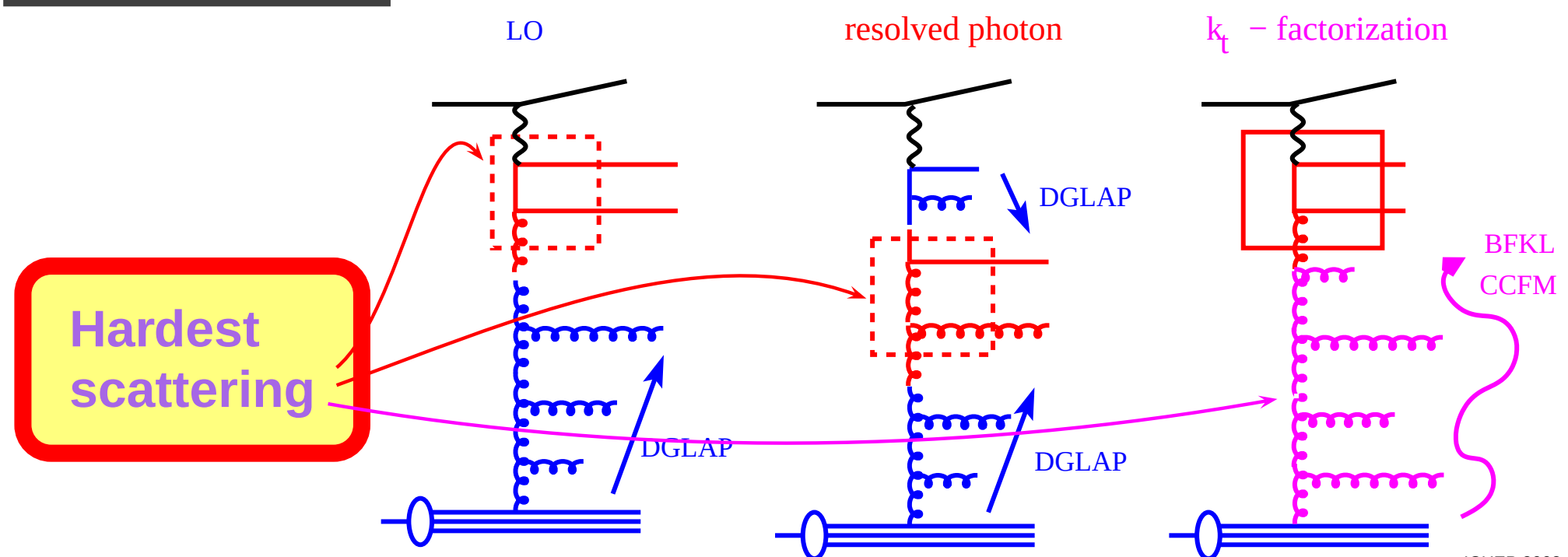
- Parton dynamics at high energies
- central region
  - ➤ single particle production
- From central to forward (proton) direction:
  - forward jet production
  - forward π^0 production
- From forward back to central rapidities:
  - ➤ instantons
- Conclusion

Multi parton dynamics at small x

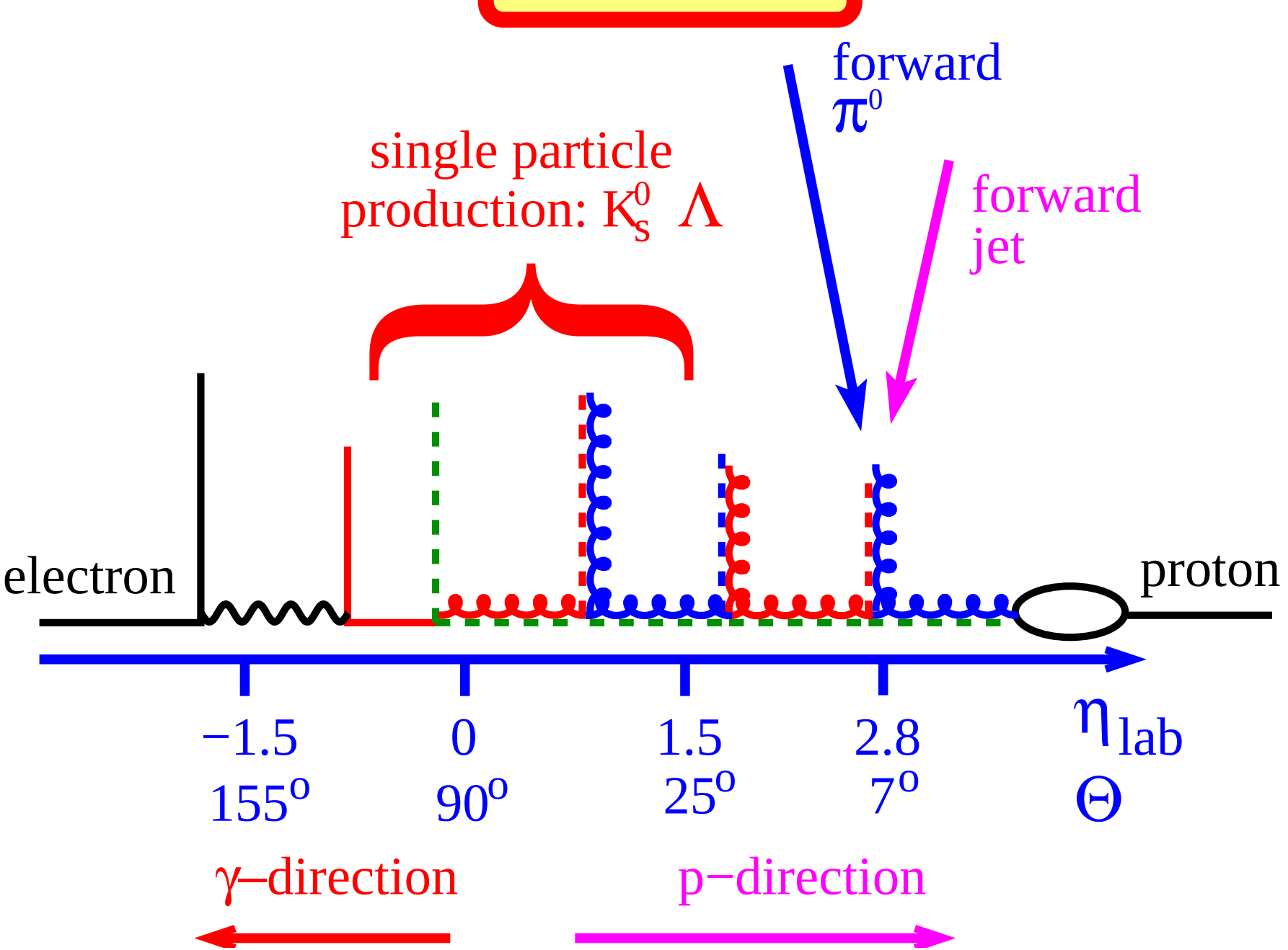
- describe multiparton emissions only in approximations
- put everything beyond $\mathcal{O}(\alpha_s^2)$ into **Evolution Equations**

BUT which use when ?

DGLAP		BFKL CCFM
single ladder	2 ladders	ordered in
ordered in p_t	each ordered in p_t	energy/angle

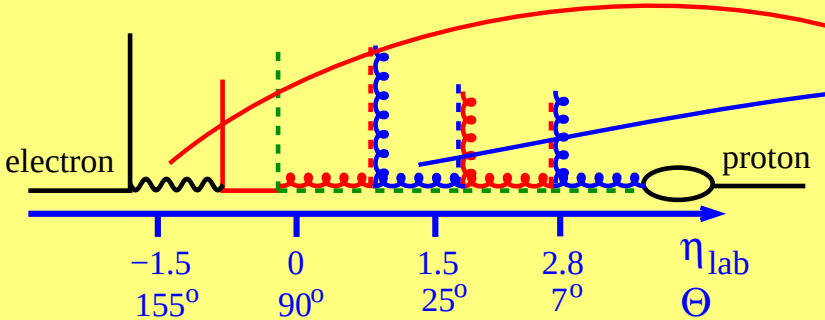


Overview


forward
π^0
single particle
production: K^0_s Λ
forward
jet
electron
proton
−1.5
155°
0
90°
1.5
25°
2.8
7°
η_{lab}
Θ
γ–direction
p−direction

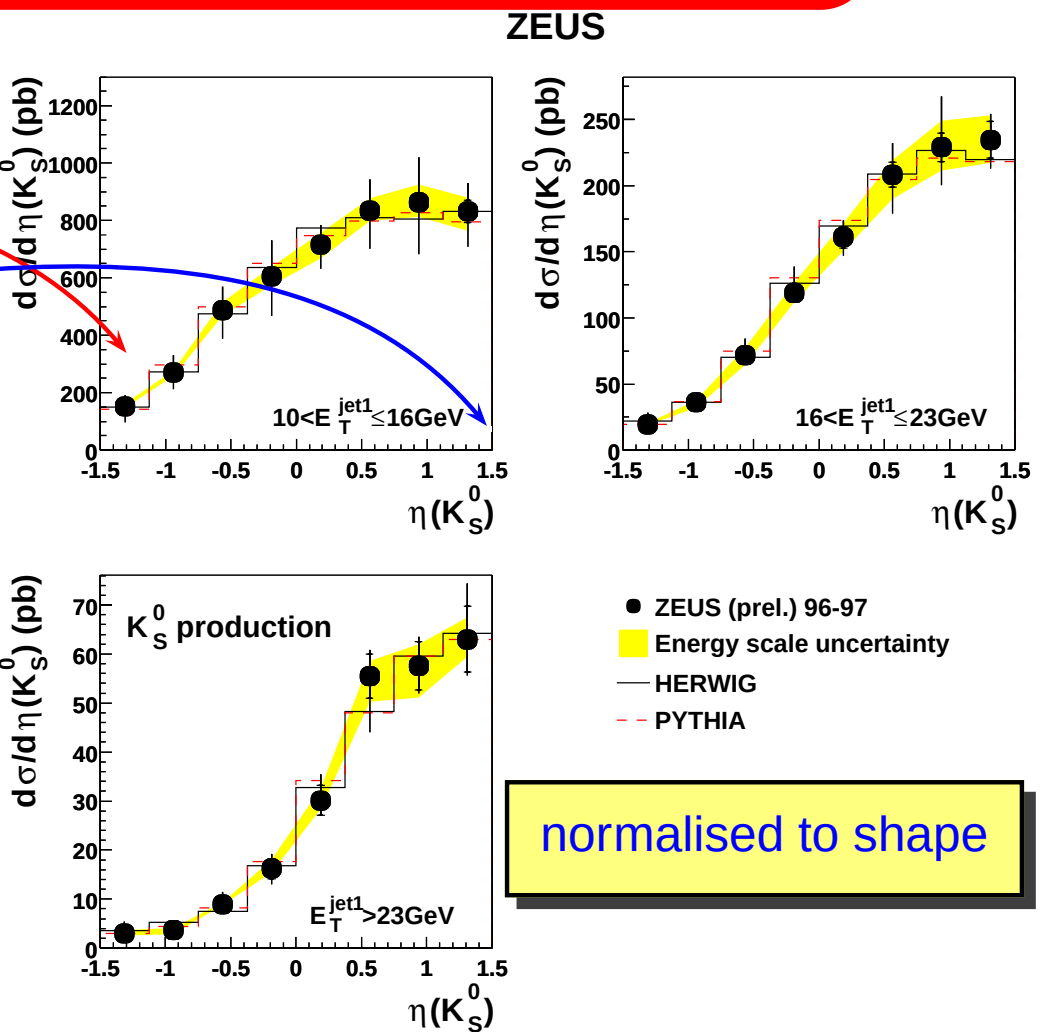
Particle production in central region e.g. K_s in photoproduction

photoproduction of jets with $K_0 \to \pi^+\pi^-$



large E_T central η_{lab} region
well described by:

- LO Monte Carlo PYTHIA/HERWIG
- based on DGLAP
- including fragmentation



normalised to shape

Particle Production well understood !!!

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

DGLAP works fine in central region !

Investigate forward region

Anything new there ?

Observe deviations from DGLAP ?

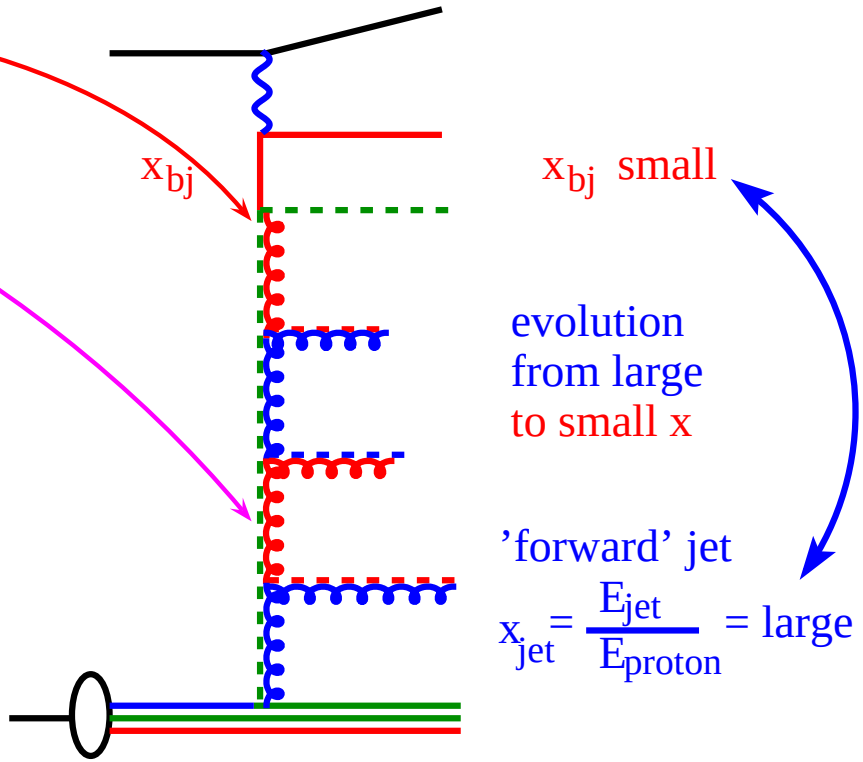
☛ evidence for BFKL ?

or

☛ CCFM ?

or

☛ no approximation is good ?

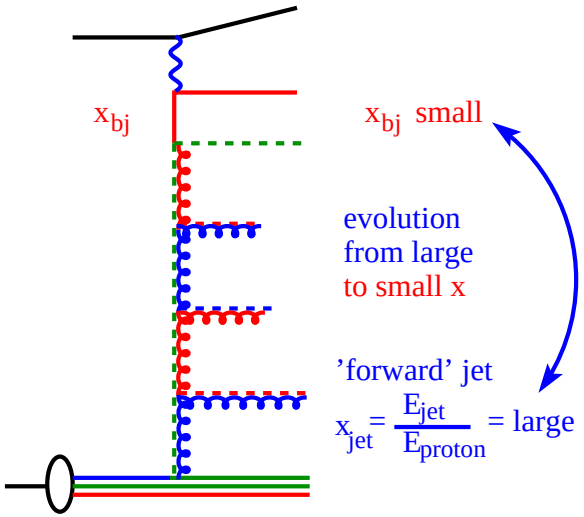


Mueller - Navelet jets in DIS: Jet (π^0) in p - direction with

$p_t^2 \sim Q^2$, x_{jet} large, BUT small x_{bj}

☛ suppress DGLAP (Q^2) evolution allow evolution in x (BFKL)

Parton dynamics at small x: Forward Jets I



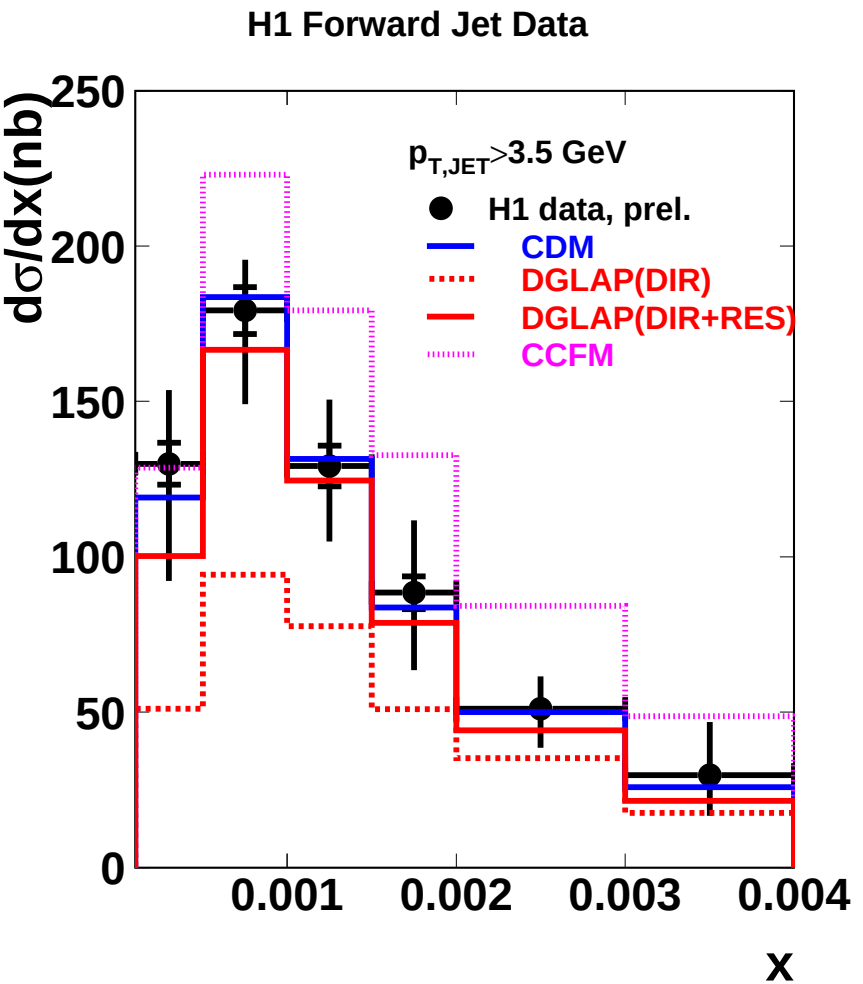
DIS : $5\ \text{GeV}^2 < Q^2 < 75\ \text{GeV}^2$

forward jet (incl. k_t algorithm)

$7.03^o < \theta_{jet} < 20.0^o$

$x_{jet} > 0.035$

$0.5 < \frac{p_{t\ jet}^2}{Q^2} < 2$

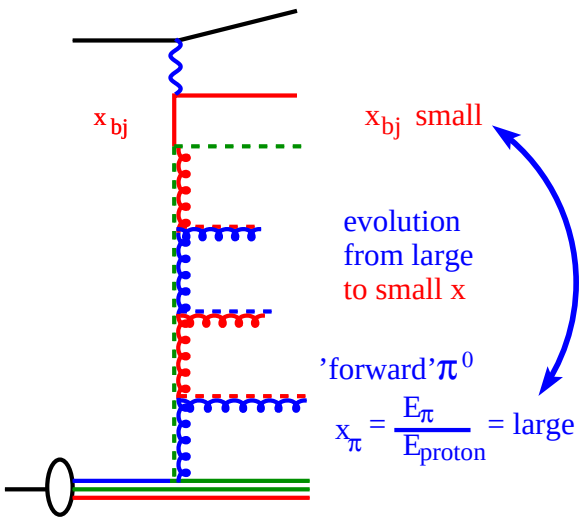


DGLAP too small, need resolved virtual photons ?!?

or Color Dipole Model (CDM)

or k_t factorisation with BFKL or CCFM

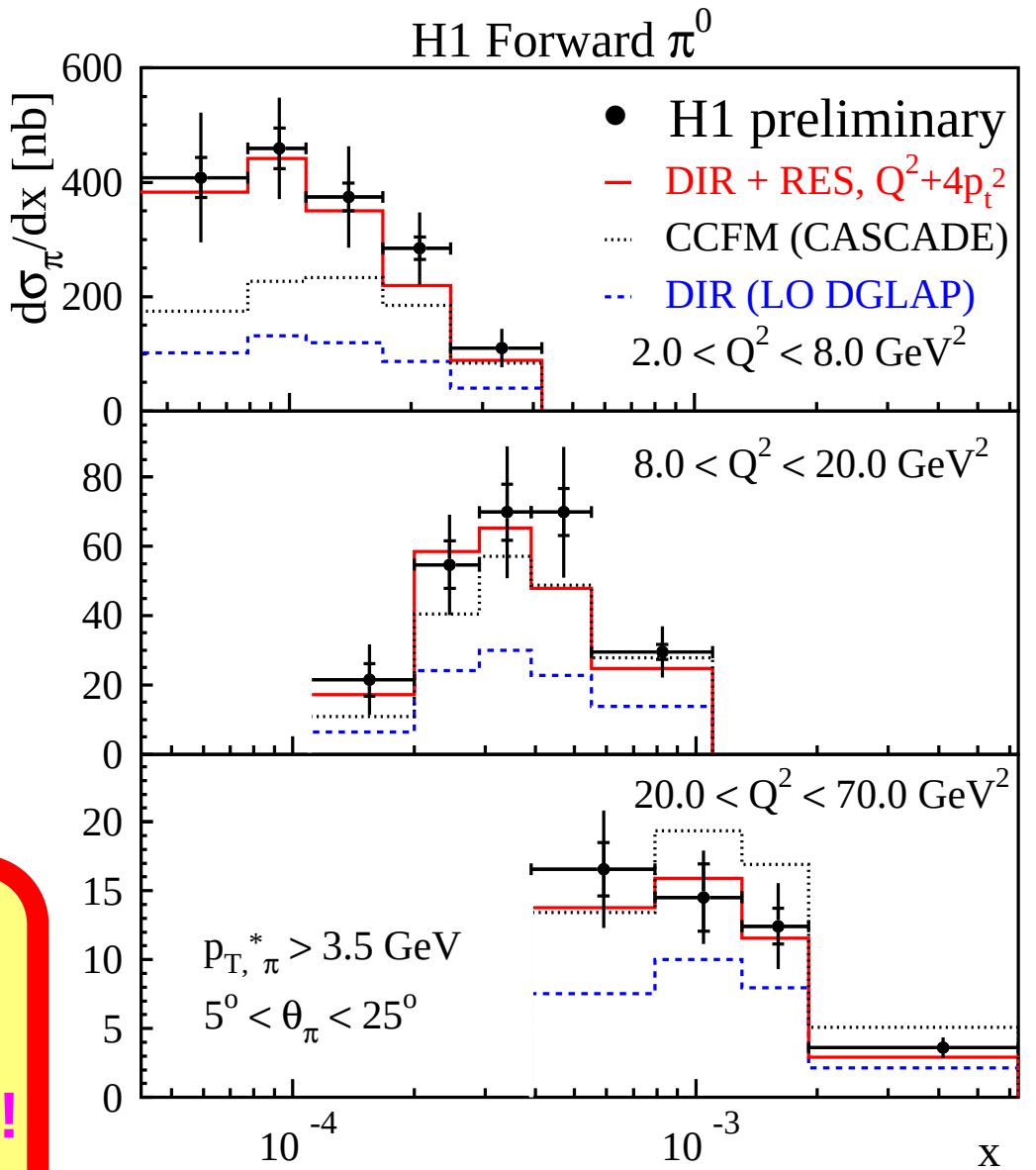
Parton dynamics at small x: Forward π^0 I



DIS : forward π^0 (instead of jet)

$5^o < \theta_\pi < 25.0^o$

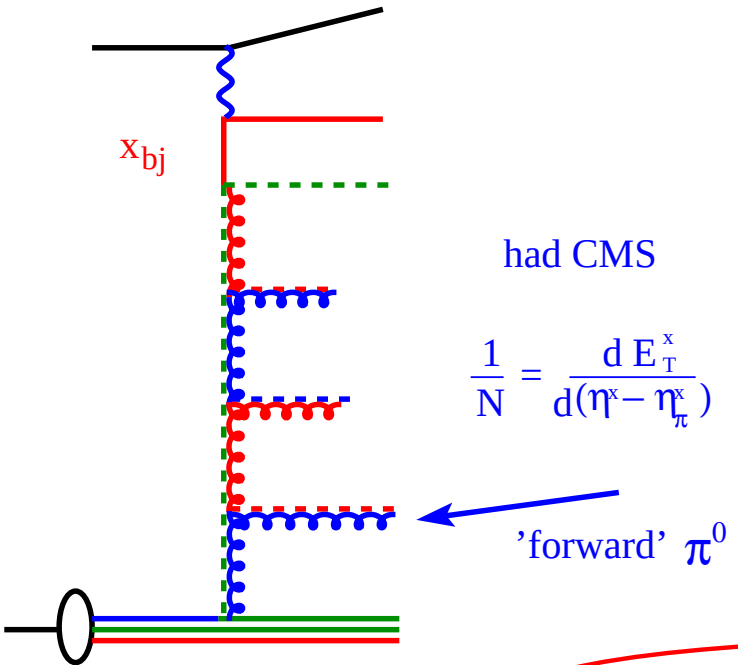
$x_\pi > 0.01$

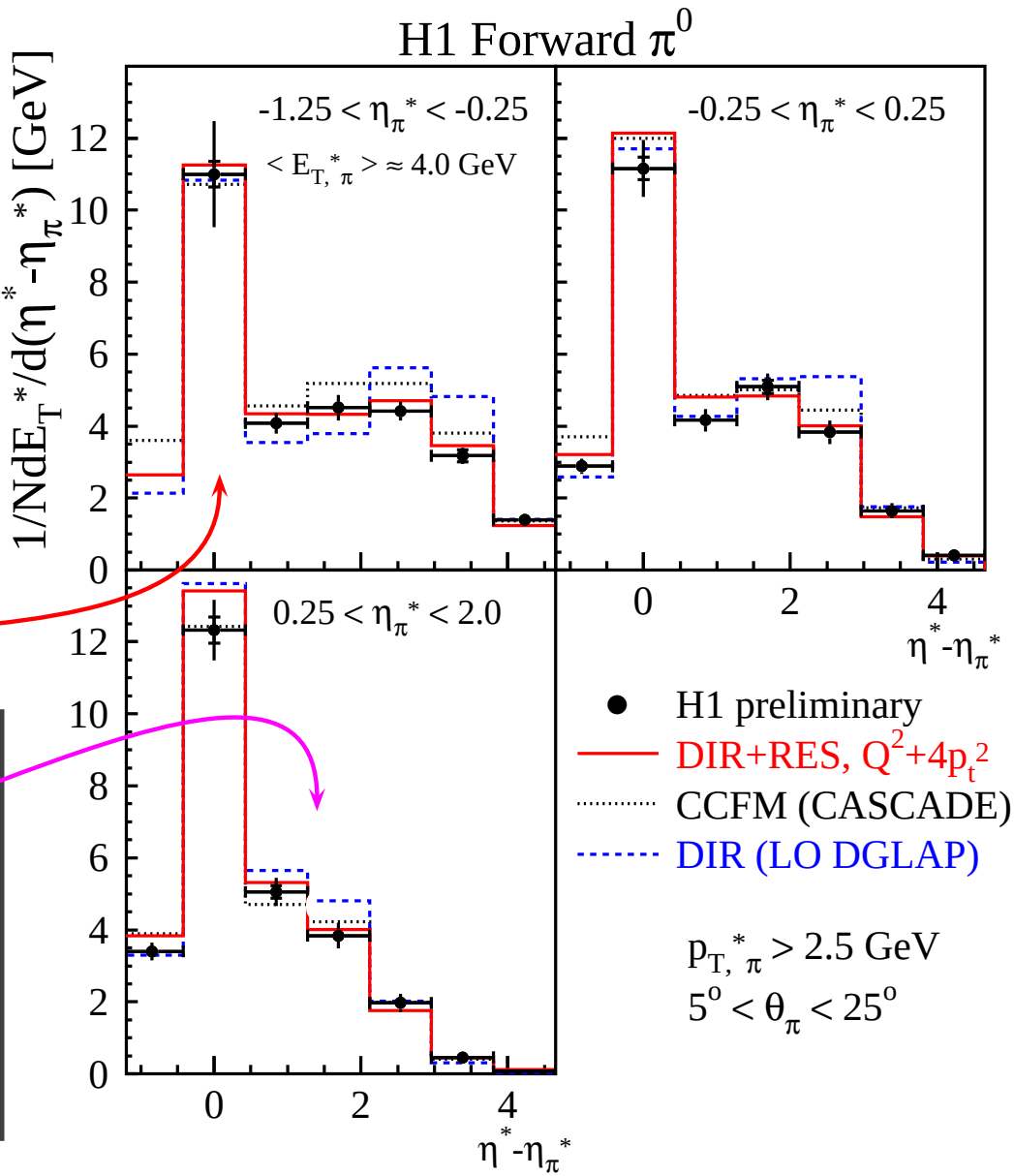


DGLAP too small, need:

- **resolved virtual photons ?!?**
- **CCFM too small at small x !?!**
- **WHY ?!?**

Parton dynamics at small x: Forward π^0 II





in hadronic CMS

- π^0 close to proton
- π^0 towards photon
- E_T-flow around π: transverse momentum compensation along ladder

Back to the central

significant deviations from DGLAP

- related to small x QCD
- related to $g \to gg$ vertex
- related to non-abelian structure of QCD

vacuum structure of QCD ?

Instantons ?

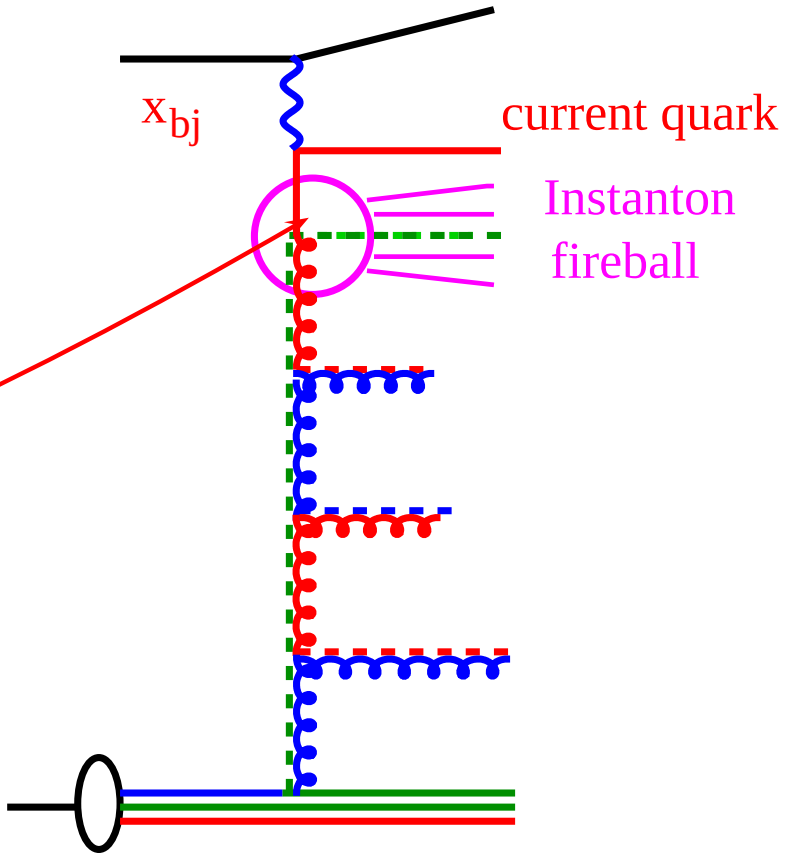
Investigate again central region in DIS

Anything new there ?

Observe deviations from known ?

- high multiplicity events
- evidence for Instantons ?

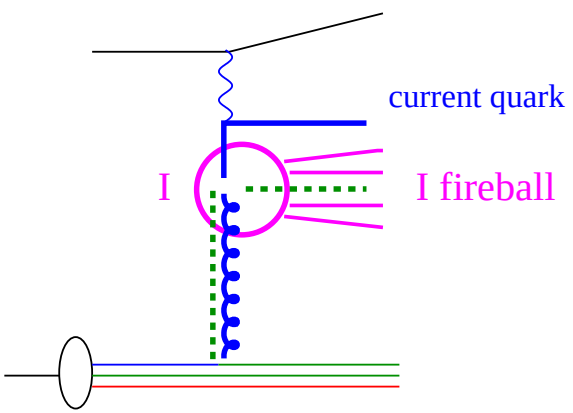
or ?



Particle production: Instantons I

Instantons are:

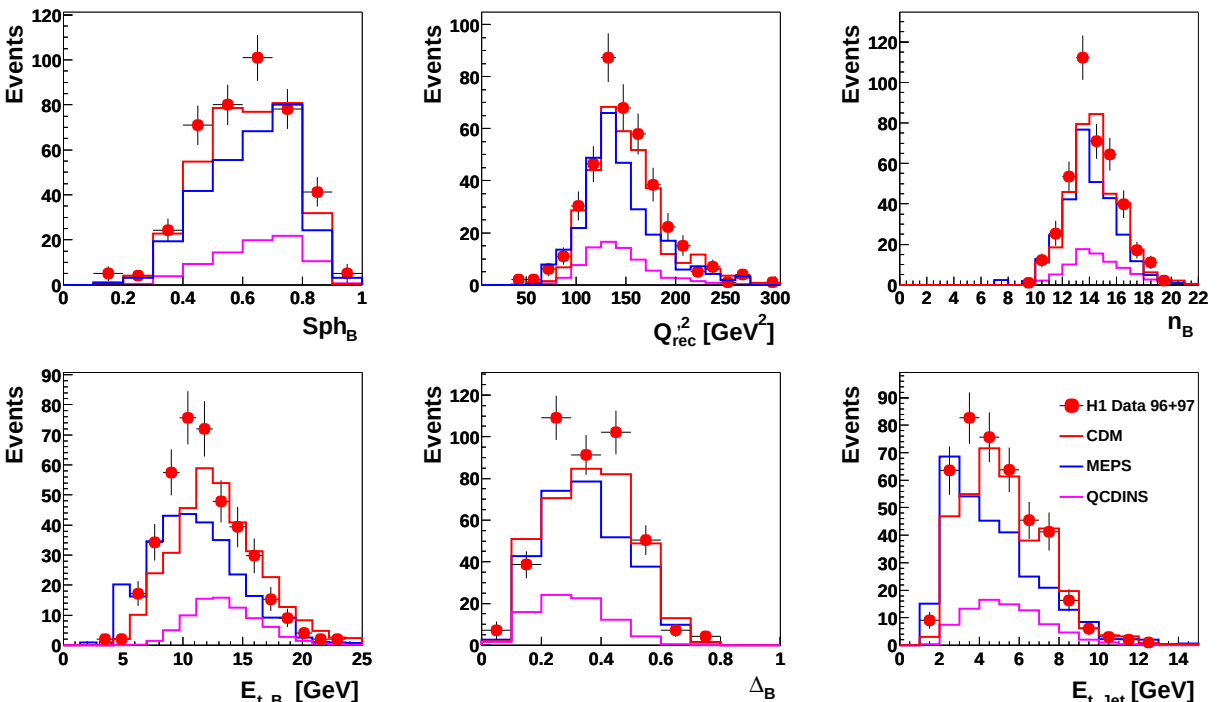
- non-perturbative fluctuations of the gluon field !?!
- tunneling transitions between topologically non-equivalent vacua !?!



- multi particle production in η band

Theory - Phenomenology:
A. Ringwald F. Schrempp 1994 - 2001
Discrimination:

- standard DIS MC simulation
- Instanton MC QCDINS
- combination of different cuts

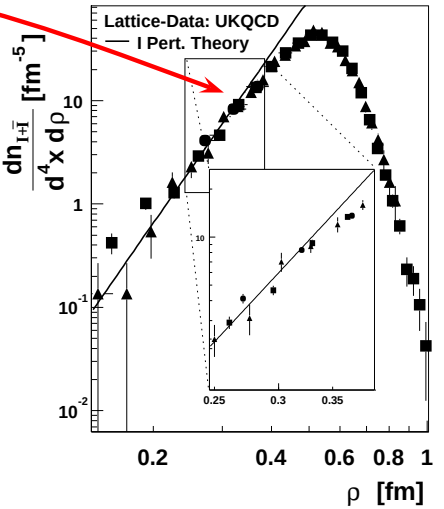


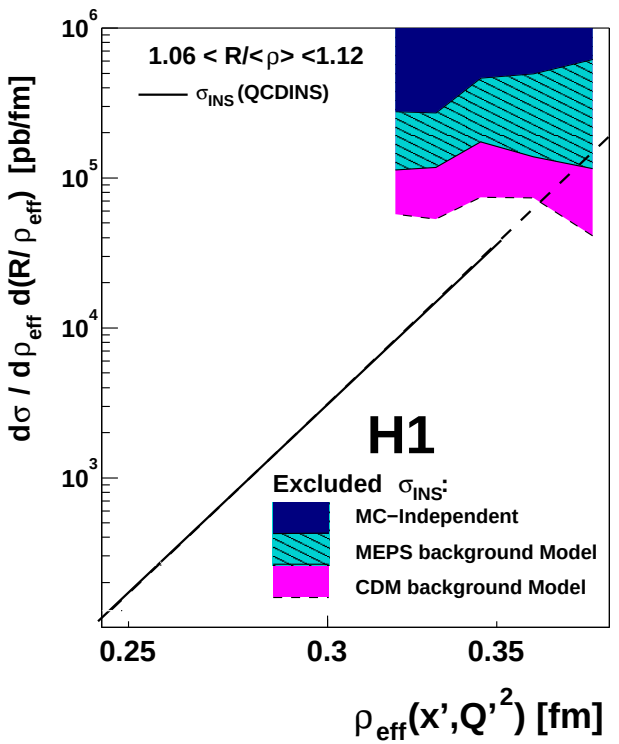
Particle production: Instanton results

	N
H1 Data	484
CDM	443^{+29}_{-35}
MEPS	304^{+21}_{-25}

- More events found than expected, really ???
- Large model dependence
- Probe instanton size in DIS
- resolution $Q'^2 \sim 1/\rho_{eff}$
- small ρ_{eff} calculated perturbatively

- Lattice meets Instanton perturbation theory
- turn result into limit on instanton size ρ_{eff}





Large size instanton excluded !?!

Conclusions and Summary

- Understanding high energy QCD parton dynamics is challenge !!!
- Single particle photoproduction in central region:
  - well described in standard DGLAP simulations
- New high statistics measurement of forward jets and forward pions performed
  - cross sections much larger than standard DGLAP predictions
  - need to go beyond DGLAP, BFKL ... CCFM ???
- Instanton search:
  large size instantons excluded
  challenge to understand better standard QCD background
- Future:
  - more data still to come
  - improvements in theory needed (NLO in k_t-factorisation etc...) !!!

Important steps towards understanding QCD at small x !!!