Low-x and Diffraction :

a few questions addressed at HERA which have not been answered

'Future Physics with HERA Data for Current and Planned Experiments',
DESY, 11 -13 November 2014

J.Bartels, Hamburg

- Structure function at low x and small Q^2
- Diffractive parton densities
- A global lesson on high energy scattering (for theorists)

Structure functions at low x and low Q^2:

Talks of A.Levy, A.Cooper-Sarkar

Question:
how far down in x and Q^2 does DGLAP work?

Low x problem, not answered

Originally belief: not below 10 GeV ^{2}

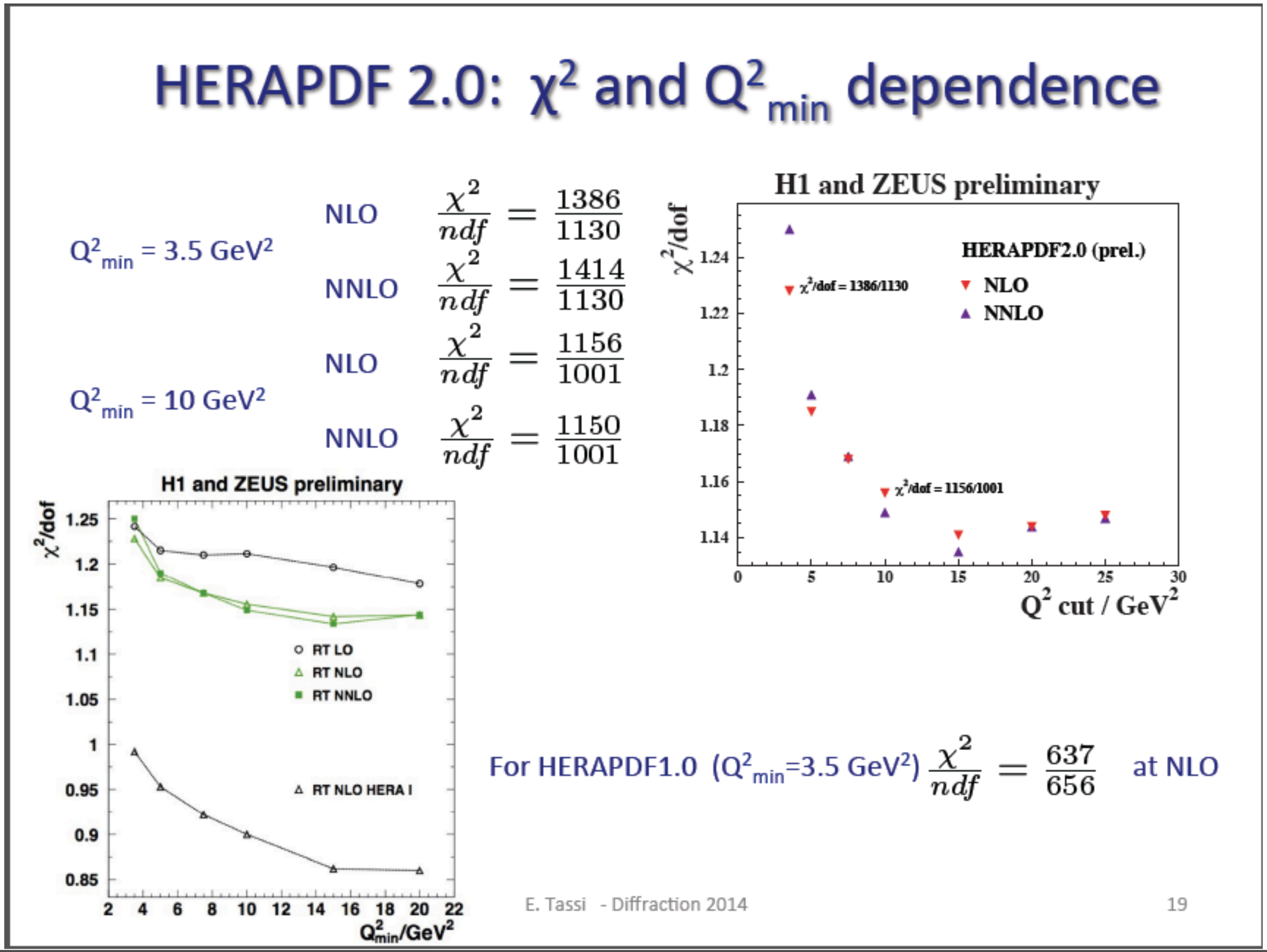
But at HERA time: DGLAP was applied at lower values (theory, PDF fits), various strange features

Consensus:
DGLAP must fail somewhere. Different views:

- don't ask for physics of initial conditions concentrate on evolution, predictive power
- what is the physics, can one learn learn from the transition and extend the QCD description?

Recent message:
use data from larger and extrapolate down Q^2 with DGLAP

Question:
unfold x-dependence



What should be done:

find out which theory, when evolving to low Q^2, provides best description

(Linear) DGLAP:

- NLO vs NNLO
- flavor scheme → Moch, Blümlein
- higher twist corrections

BFKL:

BFKL-improved DGLAP (Altarelli, Ball Forte; Ciafaloni,Colferai, Salam,Stasto): fit to data?

Perform NLO analysis: NLO impact factor (Balitsky, Chirilli)

pure BFKL (Kowalski, Lipatov, Ross)

Nonlinear evolution (saturation): (inclusive sfr not the best test for saturation)

saturation models (G-BW, BG-BK,Kowalski,Luszczak):

matching with NLO DGLAP, quark contributions

use of BK equations (Albacete, Armesto,Milhano,Salgado,)

Wish: do not stop, try to find answers

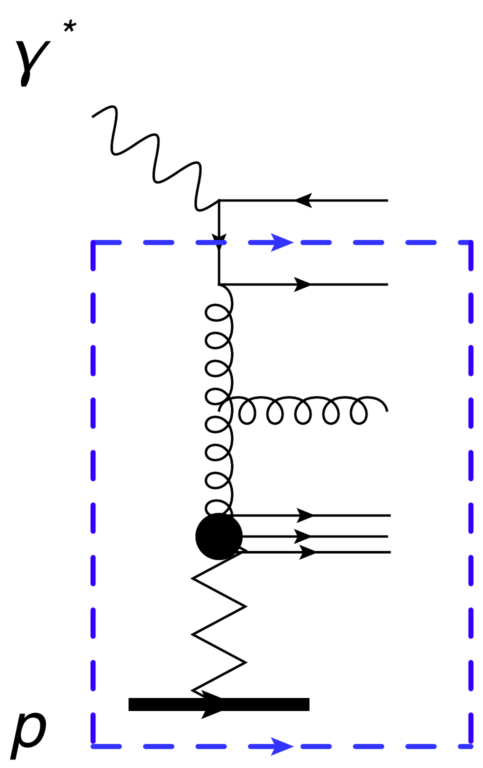
HERA: diffractive parton densities

Two important applications at the LHC:

1) HERA diffractive pdfs cannot be transported to LHC, survival probabilities: understanding is vital for any diffractive/rapidity gap final state at the LHC, multiparton interactions
2) Diffractive final states in LHC Monte Carlo: full event structure needs diffraction. HERA results are indispensable ingredient

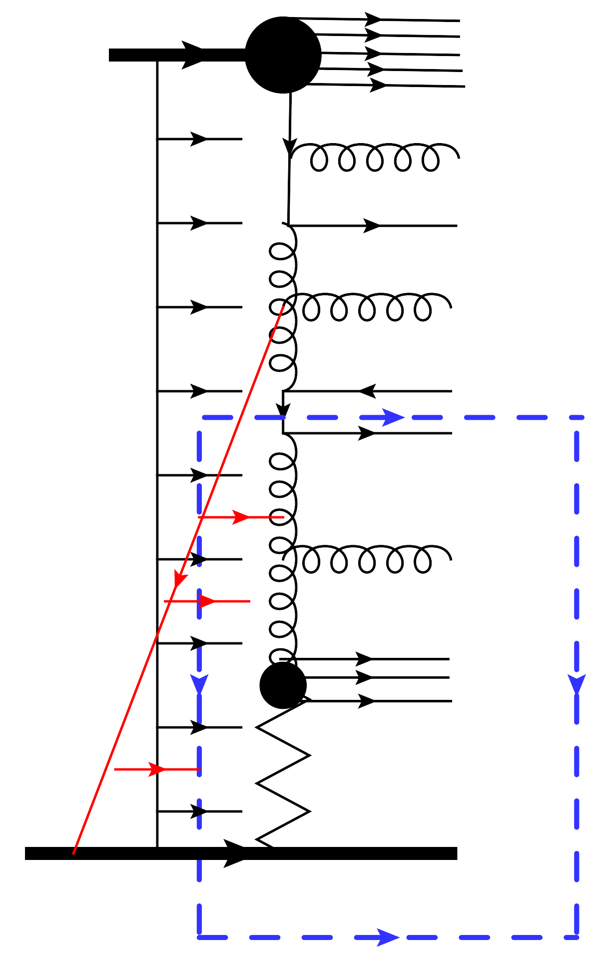
ad 1):

HERA



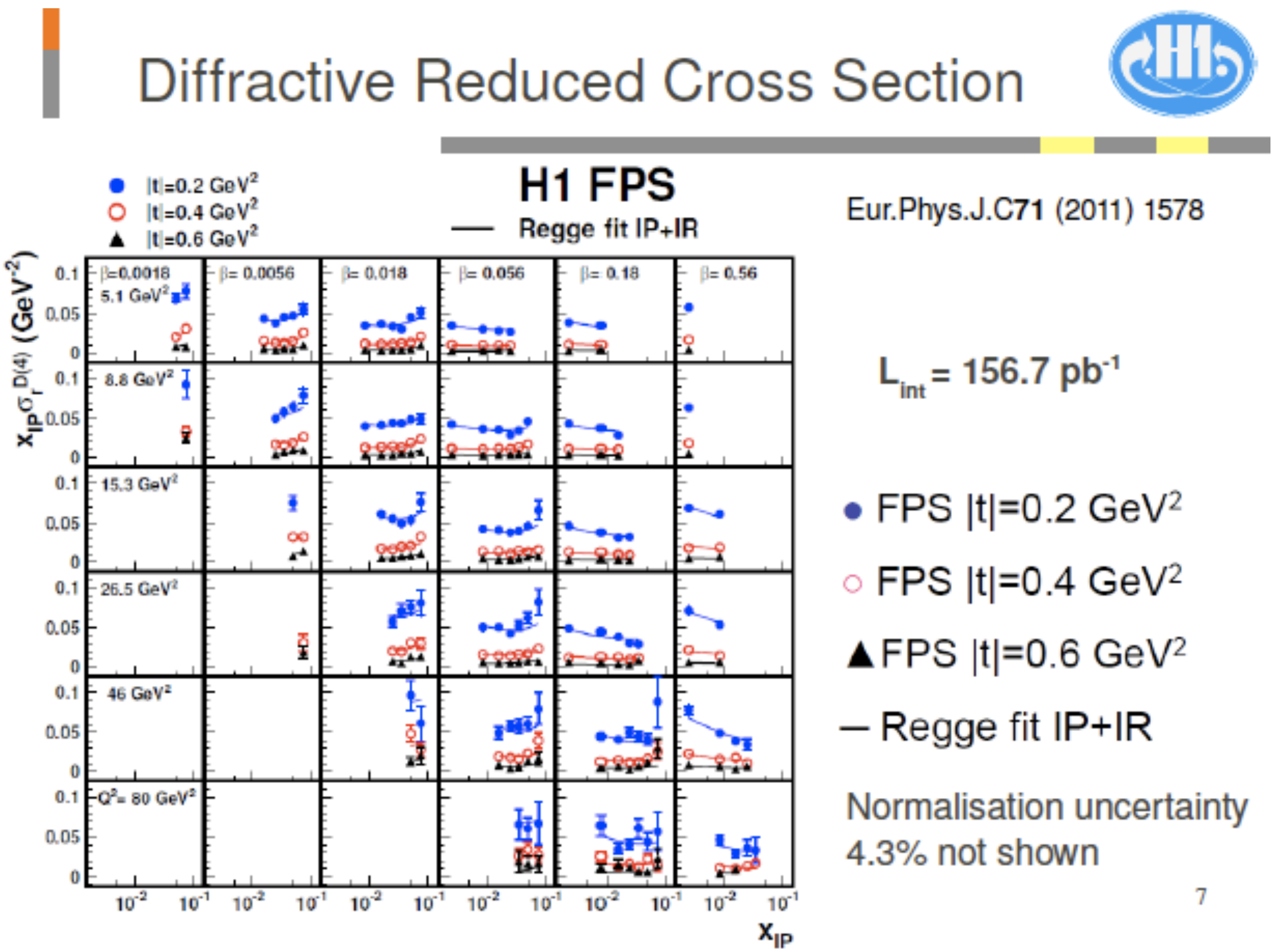
solid theoretical basis

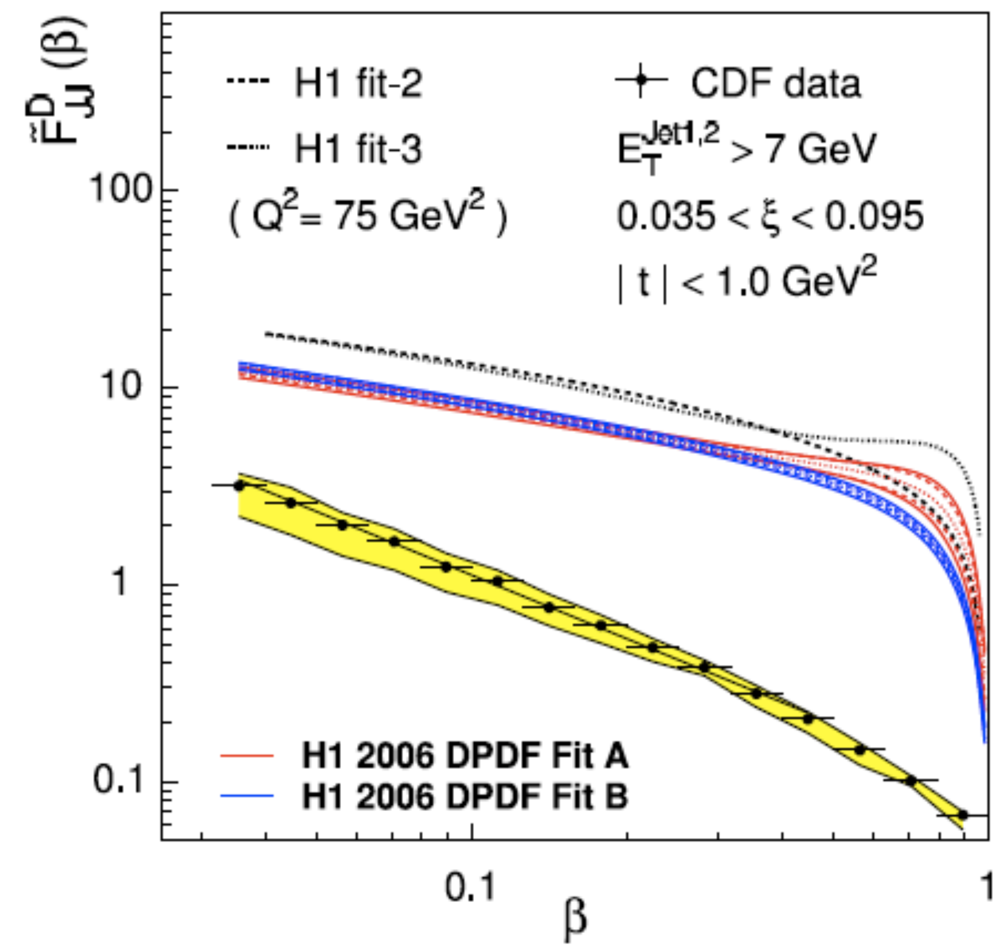
LHC



'survival probability' S^2 : simple factor, related to MPI, no theory, needs to be measured

What is needed:





need more differential measurements!

Differential measurements at LHC, compare with HERA:

S^2 is not a constant

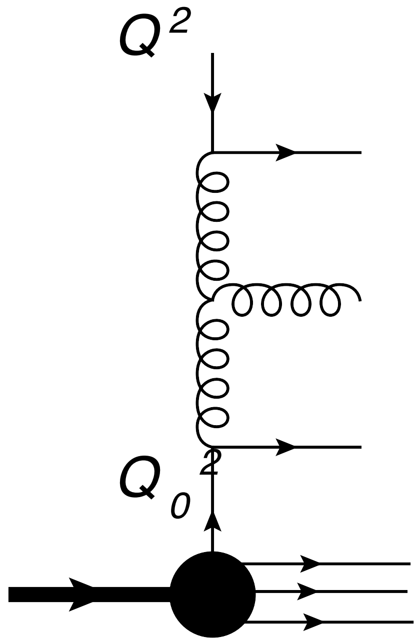
Wish: model the survival probability S^2 .

Difficulty: implement diffraction

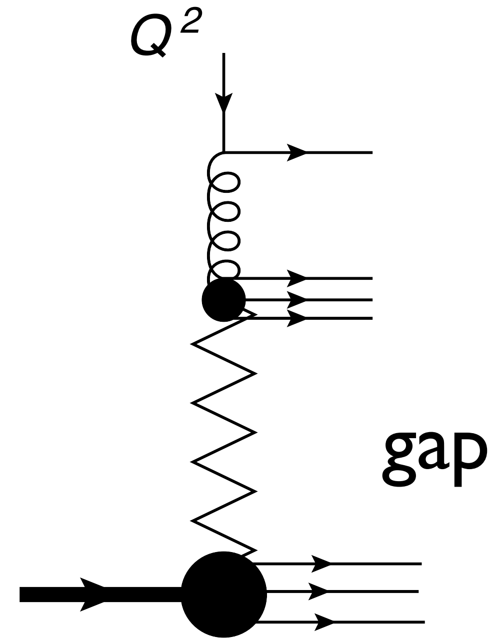
(JB,Diehl,Plätzer}

ad 2): Rapidity gaps in Monte Carlo needed for UE at LHC

'normal' evolution
has no rapidity gaps

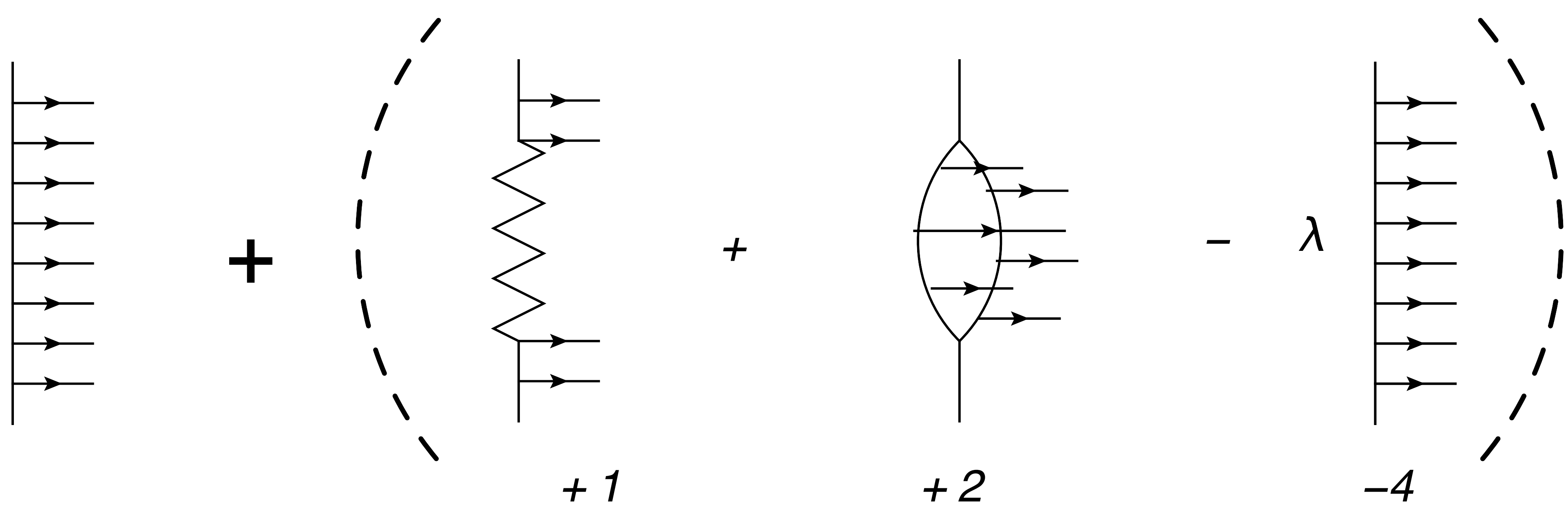


cannot simply add
a 'new' component:



AGK

Abramovsky,Gribov,Kanchelli

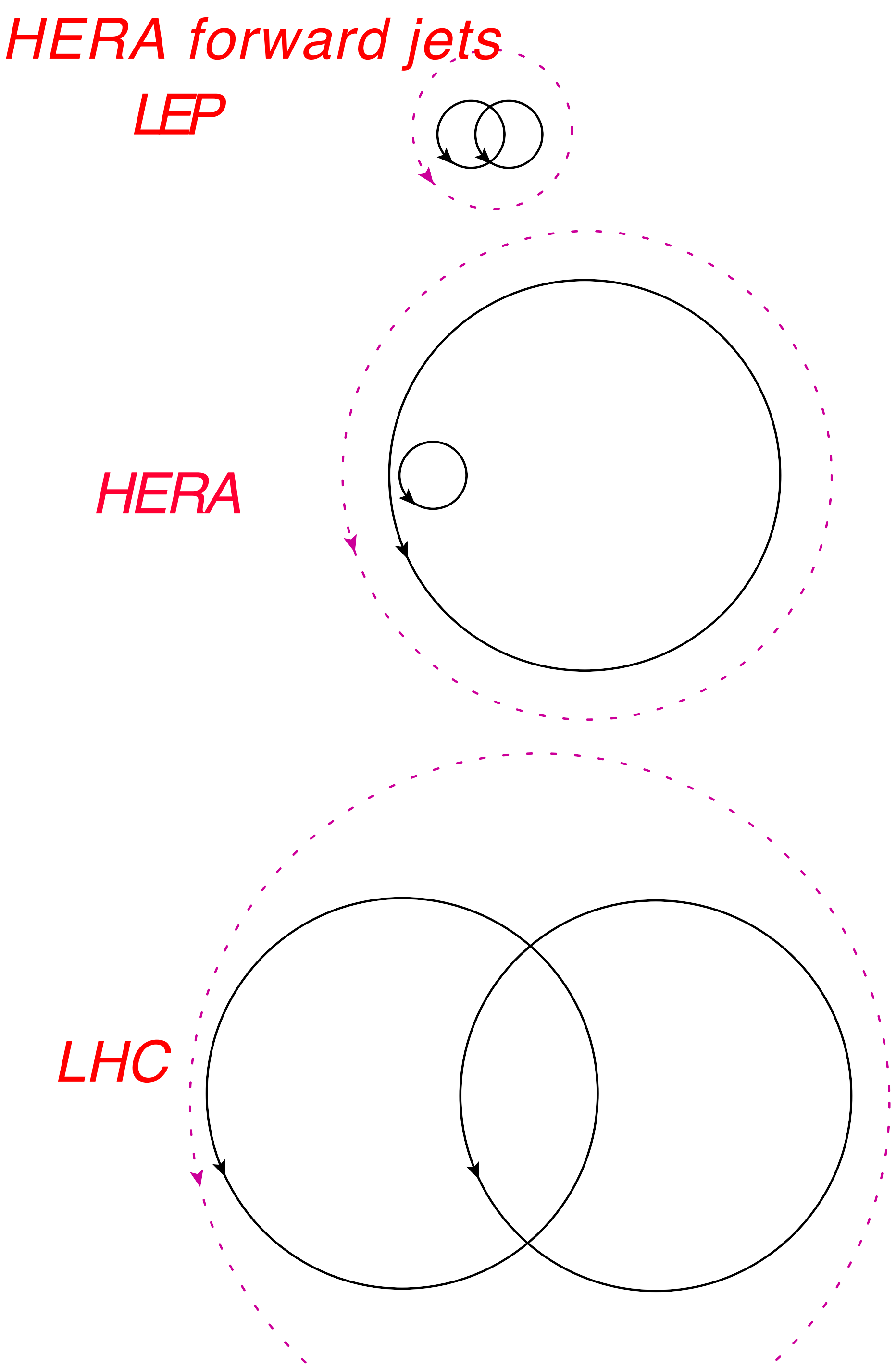


Contributions are related in magnitude: use HERA data

Conclusion for this part:

- HERA diffractive pdf are important for rapidity gaps, underlying events at the LHC
- but to make fulls use needs some work

A theoretical HERA lesson on high energy scattering: energy dependence changes with transverse size



$\gamma^* \gamma^* \quad \sigma_{tot} \approx s^{\omega_{BFKL}}$

$\gamma^* p \quad \sigma_{tot} \approx (W^2)^{\lambda}$

$p\, p \quad \sigma_{tot} \approx s^{0.08}$

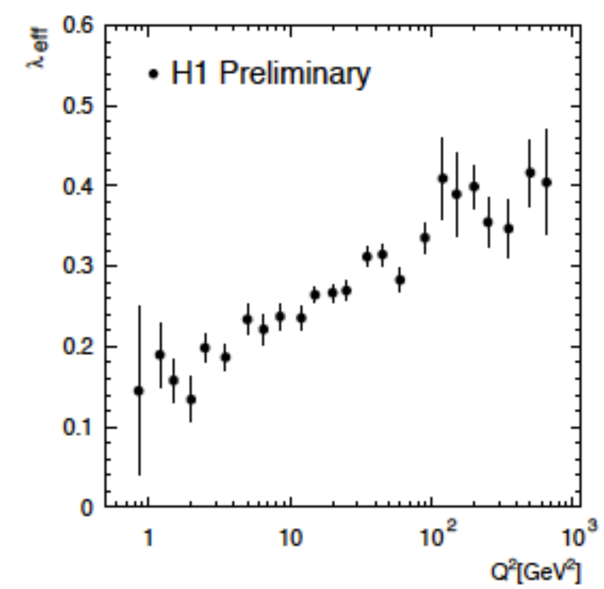


Figure 6: The slope λ_{eff} of F_2 as a function of Q^2 .

Small: strong rise ---- large: slow rise

Global picture:

Short distance/hard scale: $\gamma^*\gamma^*$

pQCD - BFKL, Pomeron loops,...

Regge, intercept clearly above one

large distance/hadronic scale: pp

npQCD - Donnachie/Landshoff,
semihard -Durham/Tel Aviv

Regge, intercept little above one

$$\text{distance, rapidity} \to \infty$$

$$\text{momenta,energy: } k \to 0$$

Question:
is it possible to find a description of a continuous transition?
(not obvious: DL need two Regge poles, hard and soft)

Attempt:

Renormalization group approach: flow equations

(JB, G.P.Vacca,C.Contreras, preliminary)

Ansatz:

$$\mathcal{L} = (\tfrac{1}{2}\psi^\dagger \overset{\leftrightarrow}{\partial_y}\psi - \alpha' \psi^\dagger \nabla^2 \psi) + V(\psi, \psi^\dagger)$$

$$V(\psi,\psi^\dagger) = -\mu\psi^\dagger\psi + i\lambda\psi^\dagger(\psi^\dagger + \psi)\psi$$
$$+ g(\psi^\dagger\psi)^2 + g'\psi^\dagger({\psi^\dagger}^2 + \psi^2)\psi + \cdots$$

Search for IR fixed point
in the space of theories: exists

First indication for a possible scenario:

- in the soft region
  (but: energy, transverse extension not infinite)
  there is a Pomeron with intercept slightly above one
- at infinite energies intercept goes to one, no obvious violation of unitarity
- Bridge to BFKL still not understood

Seems to support DL, but phenomenology needed

Conclusions

1) Wish: understand the low-x, low Q^2 region of structure functions;
transition to nonperturbative QCD

2) More subtle: HERA diffraction has applications at LHC

3) Hope that theorists will take up the challenge: smooth connection between hard and soft physics, e.g. $\sigma_{pp}^{tot}, \sigma_{\gamma^* p}^{tot}, \sigma_{\gamma^* \gamma^*}^{tot}$