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QCD + simulation

- check list: PROGRAMS
- QCD test
- → hadronic final state
- conclusion

check list : PROGRAMS

- standard DIS:
  - ARIADNE ✓
  - LEPTO pb with bo evolution
  - RAPGAP ✓
  - PYTHIA ✓
  - HERWIG ✓
  - SMALLX ✓
  - CASCADE ✓
- electroweak corr: HERACLES (parameter corrections)
- NLO jet:
  - DISENT, DISASTER++ } no Z-exchange, no CC
  - MEPJET disagrees at HERA
- heavy quarks:
  - AROMA NO CC !
  - PYTHIA ✓
  - HERWIG ✓
  - RAPGAP ✓
  - CASCADE ✓
- PDFLIB: most pdf's stop at $x = 10^{-5}$
  use GRV or 99 parameterisations

QCD tests:

- structure functions → talk by W. van Neerven

at large Q^2 → THE way to test QCD
→ everything is well-behaved
→ just wait for further calculations
→ easy to measure: electron detectors!

CAN ONLY MEASURED IN EP! (nowhere else!)

- hadronic final states:

- more complicated in theory + experiment
- challenge to understand
- ONLY well measureable in ep!
- needed for any other collider

TOPICS:

- α_s nothing really new, not studied in detail
  not a question of lumi, s.
  larger theor. uncertainties.

- charged current:
  x-section ~ 5 * HERA
  single t-prod nearly impossible!

- azimuth assymetries: (calc. by. T. Gehrmann)
  ~ 5% effect, at HERA and THERA
  shifted to larger p_t values
  ⇒ easier to measure
- inclusive cross-sections → structure fcts.
- small x processes:
  - jet cross sections → resolved virtual γ^*
  - heavy quarks
  - forward jets
  - diffraction

Dijet Virtual Photoproduction

- Cuts: $Q^2 \in [.25, 6]$ GeV^2, $|\eta| < 2$, $y > 0.1$
asymmetric jet cuts $E_{T_1}, E_{T_2} > 7, 5$ GeV
Scales: $\mu^2 = Q^2 + E_T^2$, SaS1D PDFs for virtual photon

- Sum: full line. Direct: dotted. Resolved: dash-dotted.

- THERA resolved dominant over whole Q^2 range whereas direct dominant for larger Q^2 at HERA.

- THERA gives excellent opportunity to study virtual photon structure (also at larger p_T), especially Q^2 dependence.

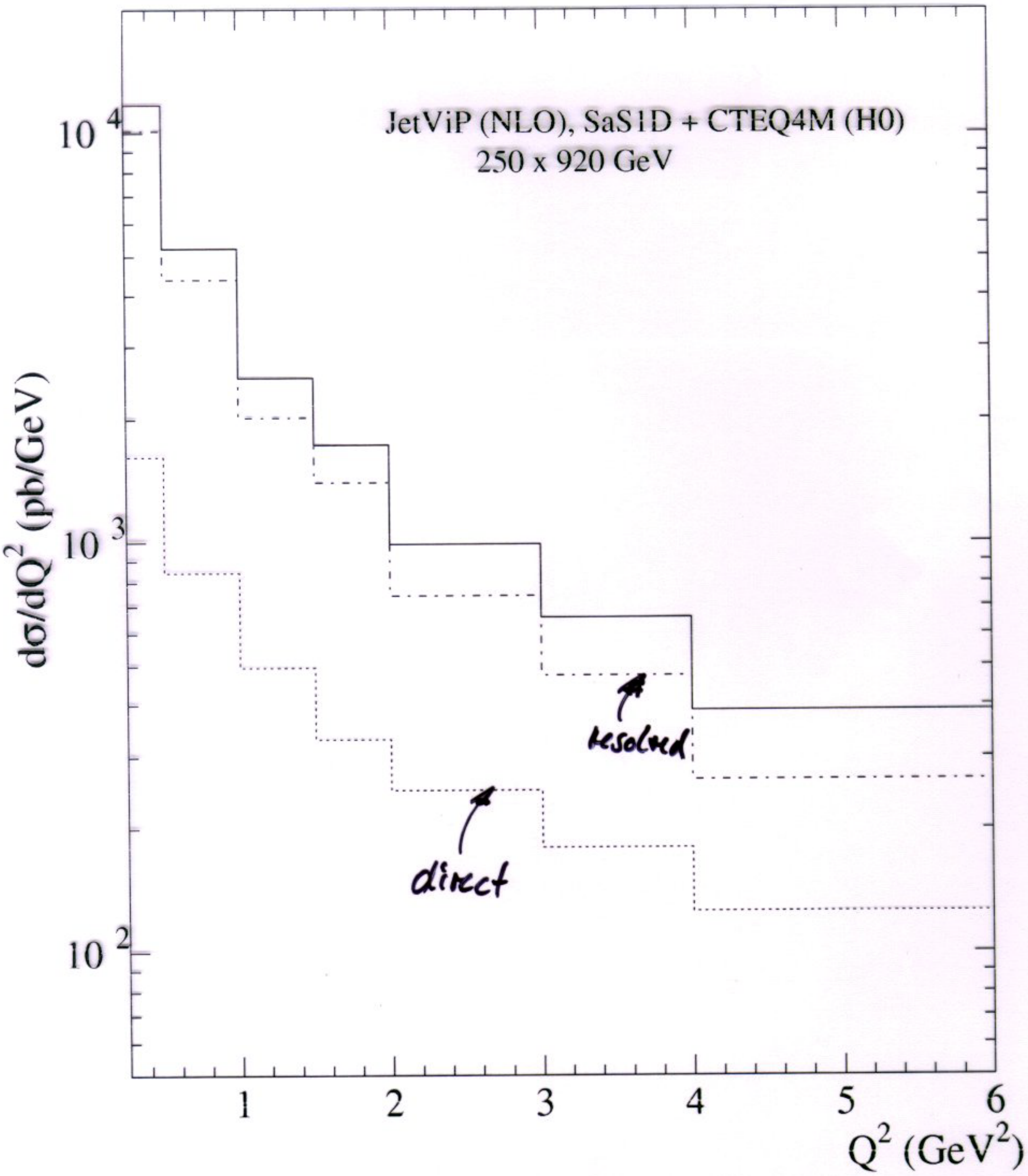


Figure 3: Virtual Photoproduction $eP \to$ dijets at THERA with $.25 < Q^2 < 6$ GeV^2, $|\eta| < 2$, $E_{T_1}, E_{T_2} > 7,5$ GeV, $y > 0.1$.

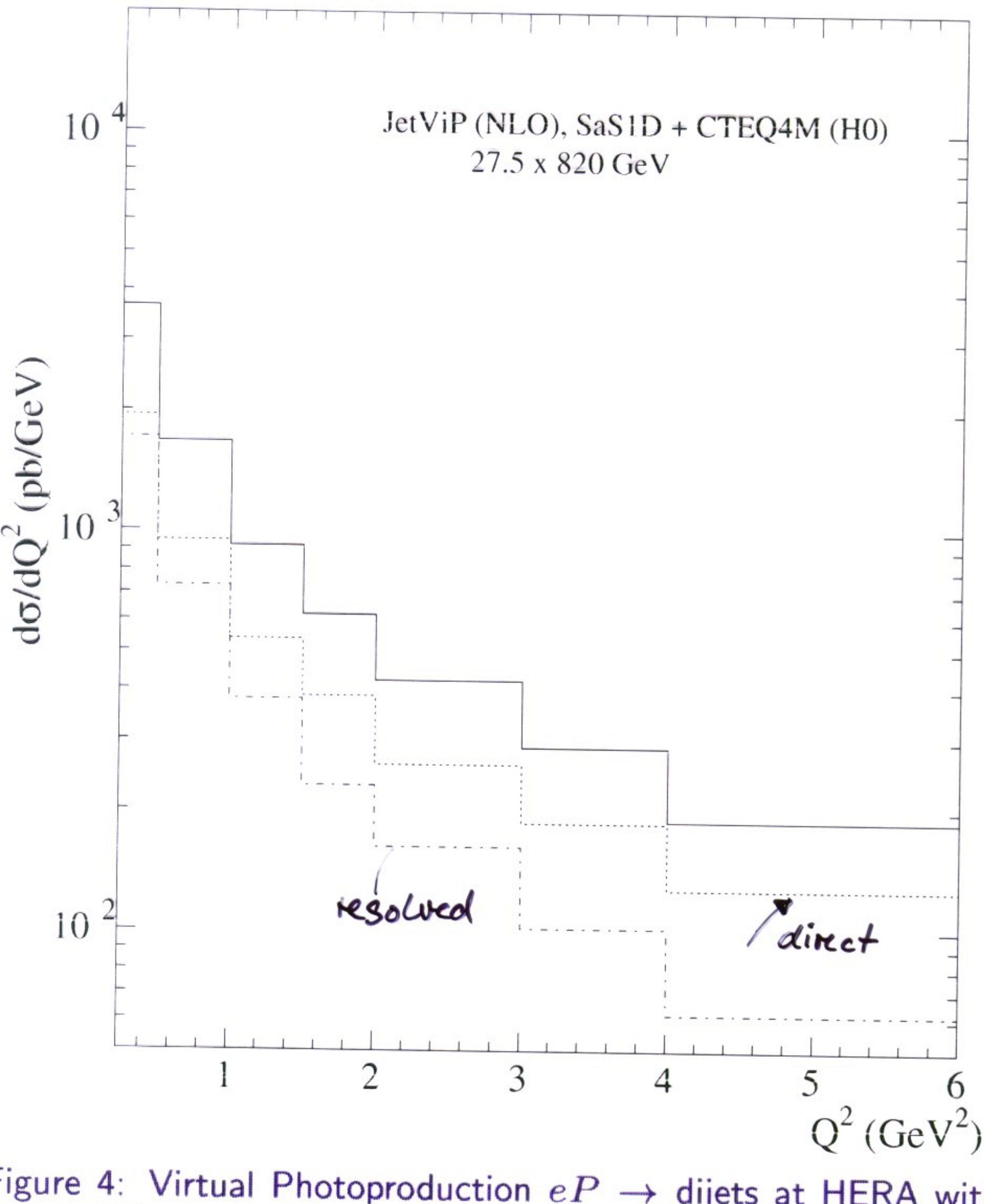


Figure 4: Virtual Photoproduction $eP \rightarrow$ dijets at HERA with $.25 < Q^2 < 6$ GeV^2, $|\eta| < 2$, $E_{T_1}, E_{T_2} > 7,5$ GeV, $y > 0.1$.

dijet virtual γ-production

- at **HERA**:

in LO → resolved γ^* ~ direct γ^*

in NLO → only small res. γ^* needed / calculated

→ in fwd jets res γ^* are important in NLO

at THERA

in NLO → resolved γ^* > direct γ^*

in NNLO → ?

in fwd jets ?

at THERA NLO ~ LO at HERA

can we continue to get

NNLO

NNNLO

⋮

?

small x : understood ?

- small x processes:
  - F_2
  - fwd jets, fwd π's
  - particle spectra, E-flow
  - charm
  - J/ψ
  - jet's
- why important ?
  - understanding QCD
  - transition perturbative → non perturb. region
  - if saturation from high parton density
    → understand evolution of parton density
  - new region in QCD, HERA is exploring
  - necessary for anything in future !
- approches to small x:
  - BFKL; problem with large NLO corr. !
    matching with DGLAP ?
  - resolved virtual γ:
    1st order approximation, problem with scale
  - CCFM !

present picture of DIS

- if relevant scale of hard subprocess is $\sim p_\perp^2$

→ 3 different contributions needed for DIS:

$$\text{DIS} = \underset{(E_\perp^2 \ll Q^2)}{\text{direct } \gamma\text{'s}} + \underset{(E_\perp^2 \sim Q^2)}{\text{BFKL}} + \underset{(E_\perp^2 \gg Q^2)}{\text{resolved } \gamma\text{'s}}$$

→ what about intermediate regions ?

$E_\perp^2 \to Q^2$?

→ adding further contributions ?

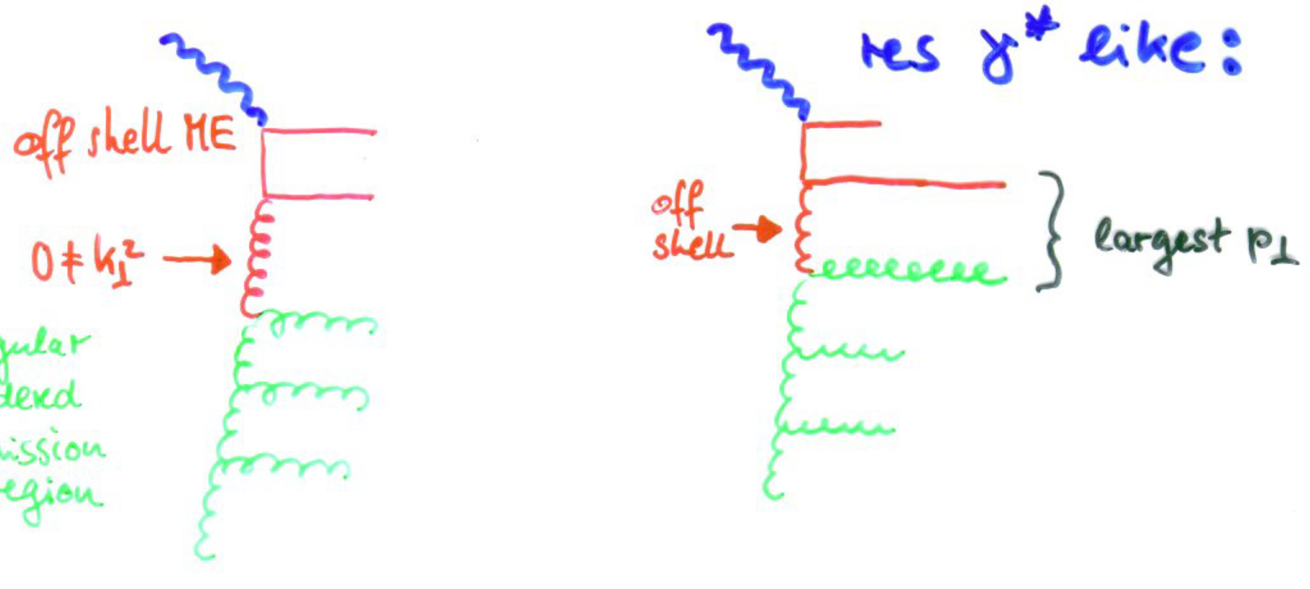
→ double counting ?

→ too complicated !

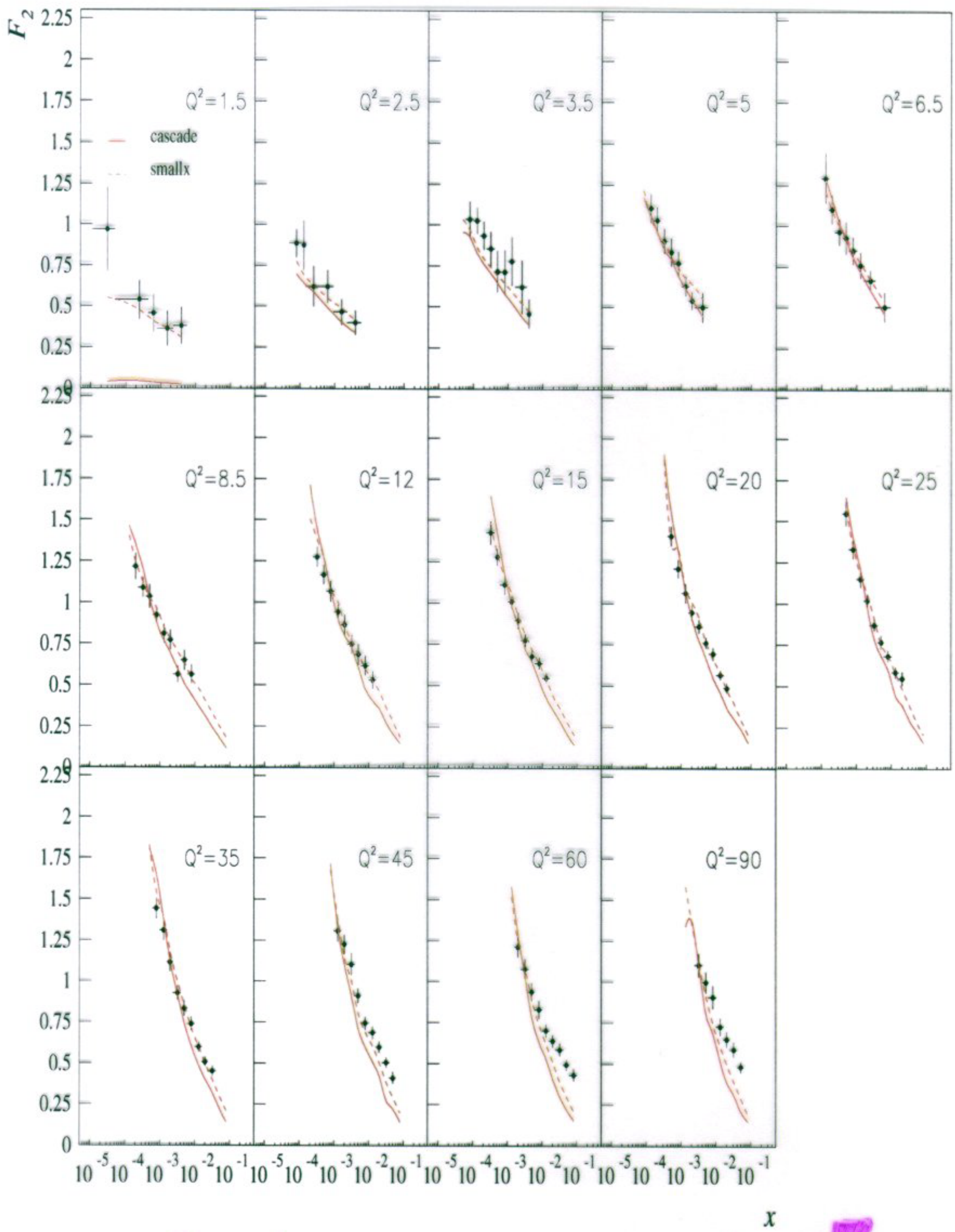
→ $\boxed{\text{Unification needed !}}$

$k_\perp$-factorisation + CCFM parton evolution !

→ reproduces BFKL $x \to 0$, DGLAP for large x !



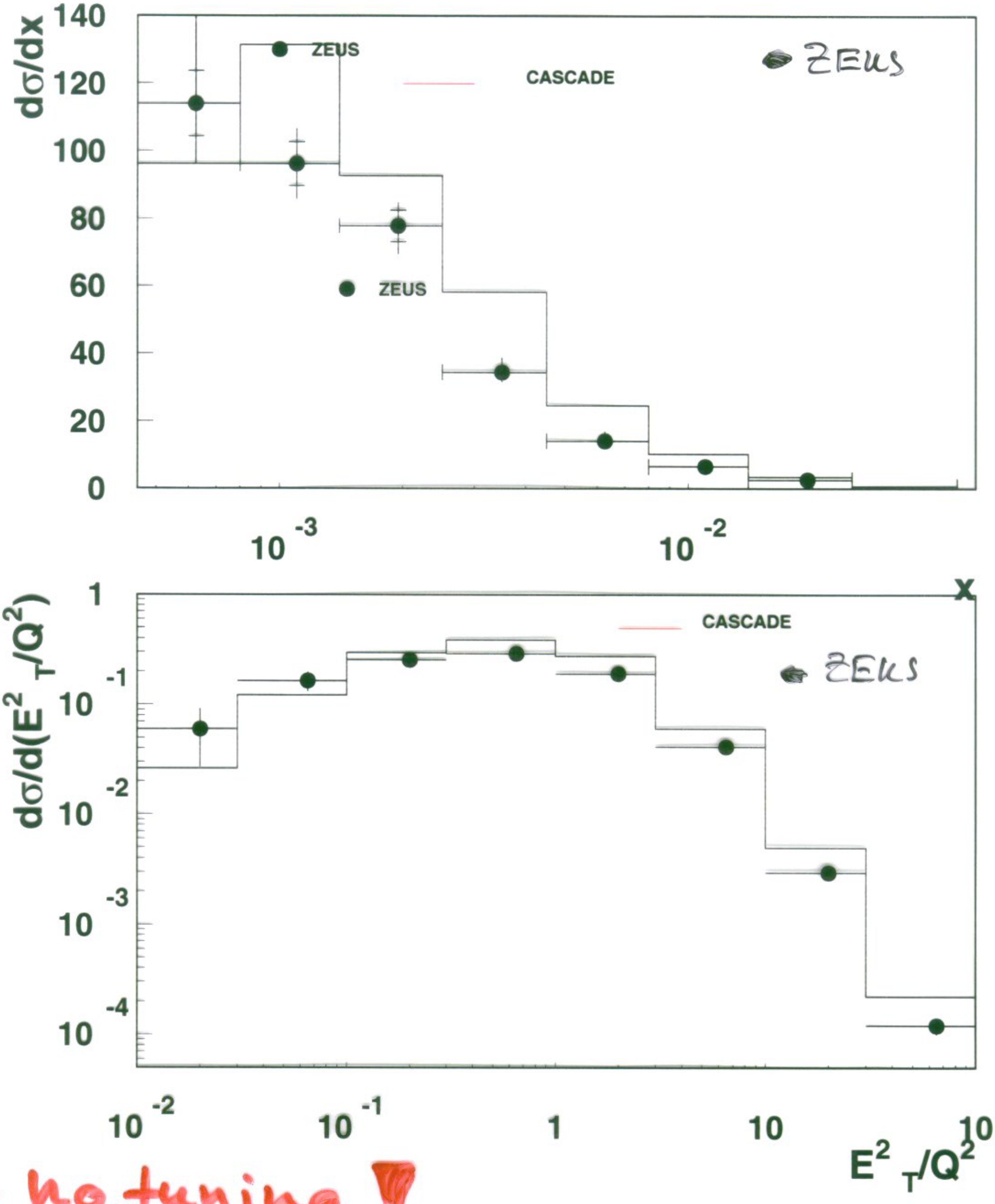
F_2 from SMALLX (fwd evolution) and CASCADE (bwd evol.)



→ perfect agreement!

unintegrated gluon determined!

forward jets : CASCADE



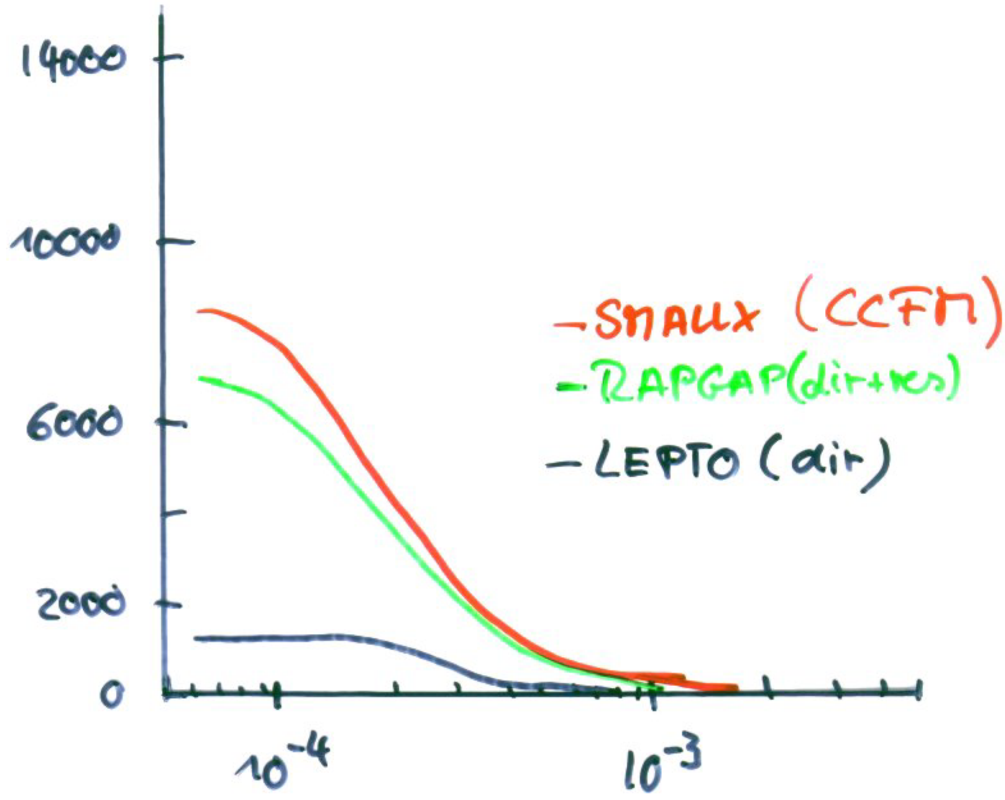
→ no tuning !

→ consistent description !
full range $E_\perp^2/Q^2$!

fwd jet x section

angular cut: 1^0

e: 250 x 920
$0.5 < p_\perp^2/Q^2 < 2$
ZEUS cuts

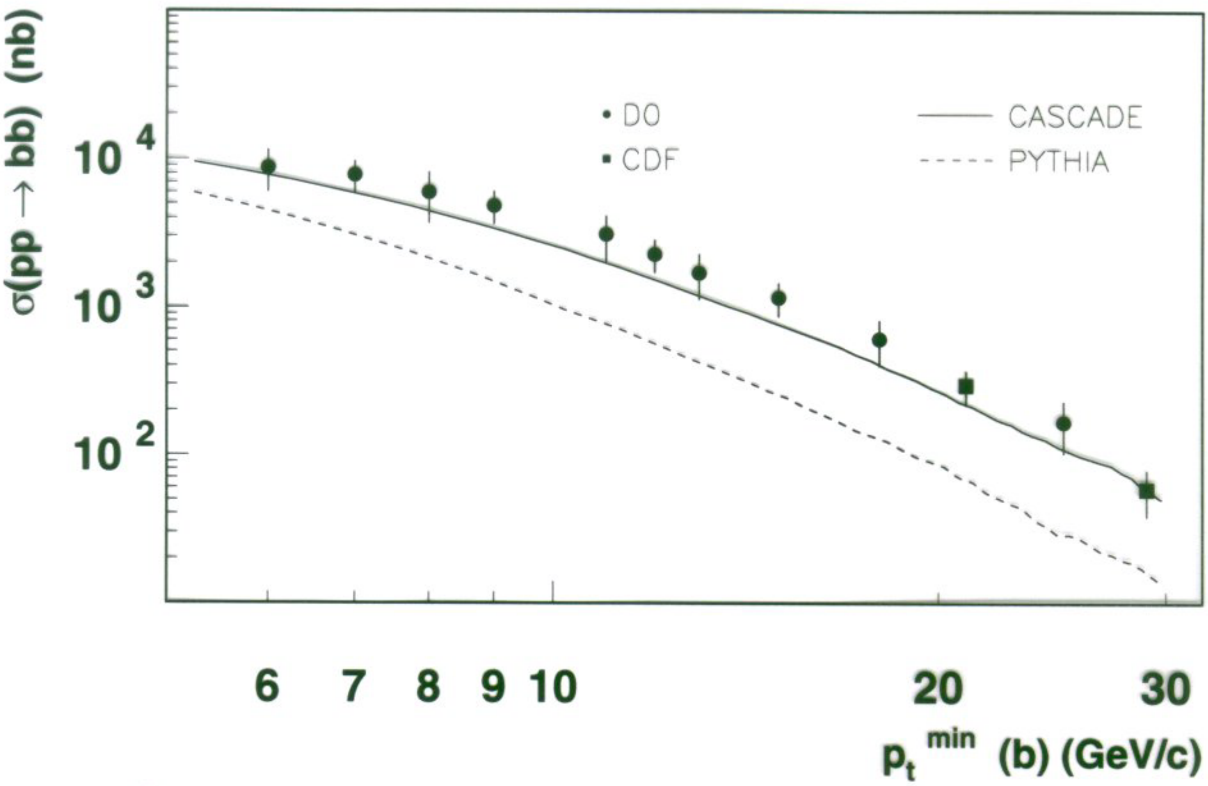


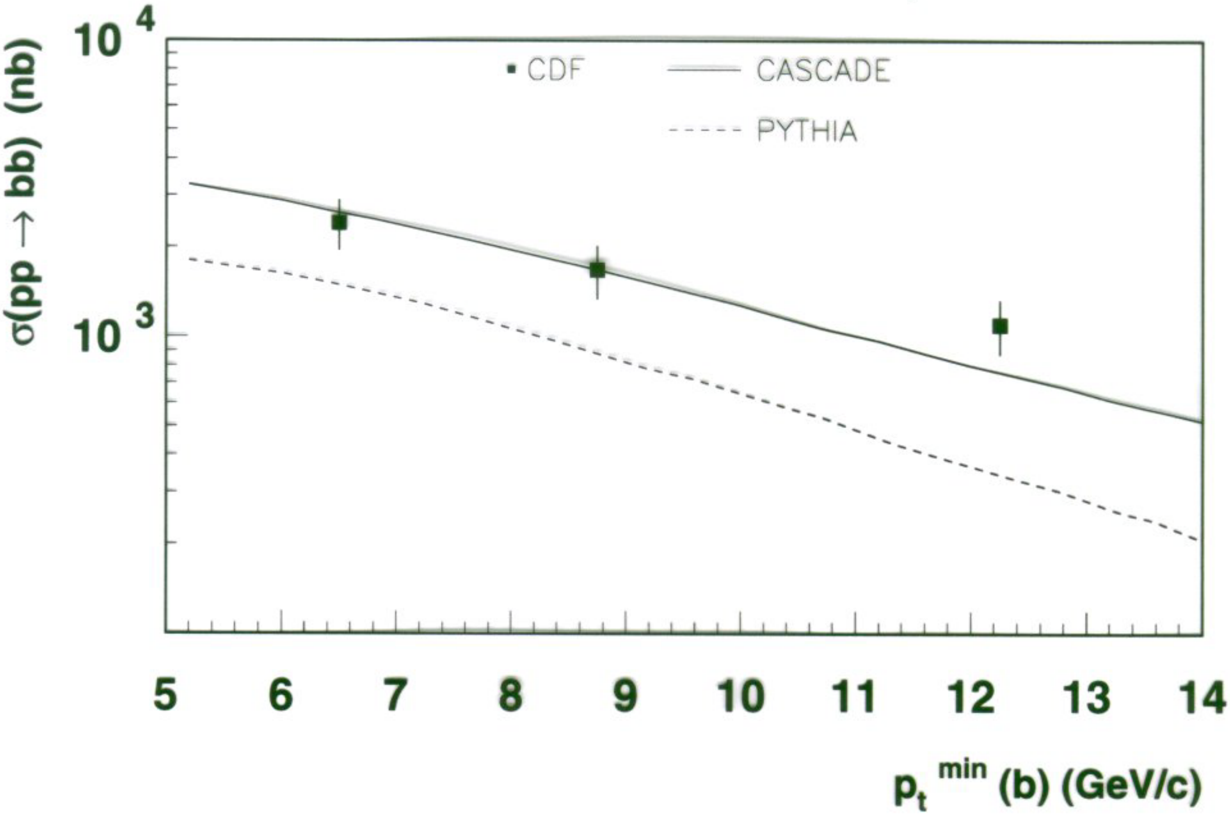
→ huge effect.
(at HERA ~ factor 2 ~ data/LEPTO)

→ measure in detail parton dynam

→ ordering / non-ordering

$b\bar{b}$-production at TEVATRON

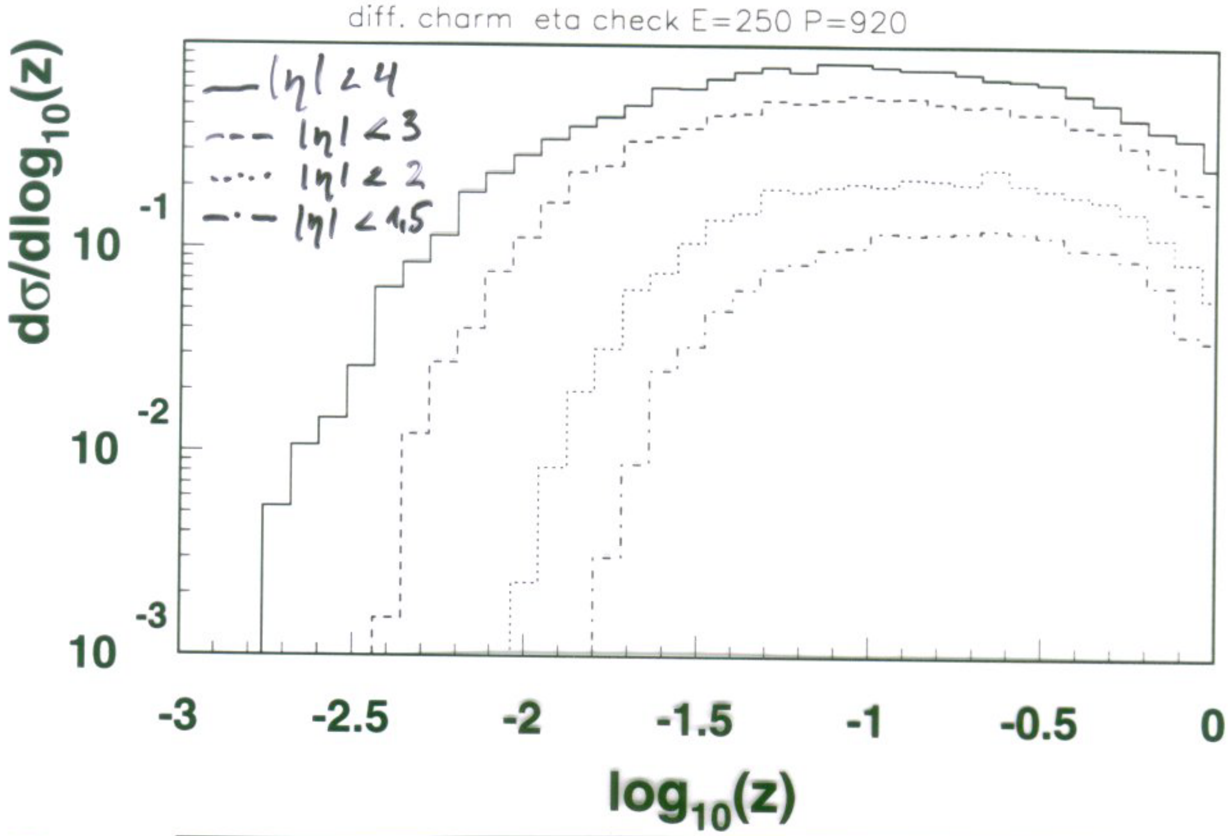


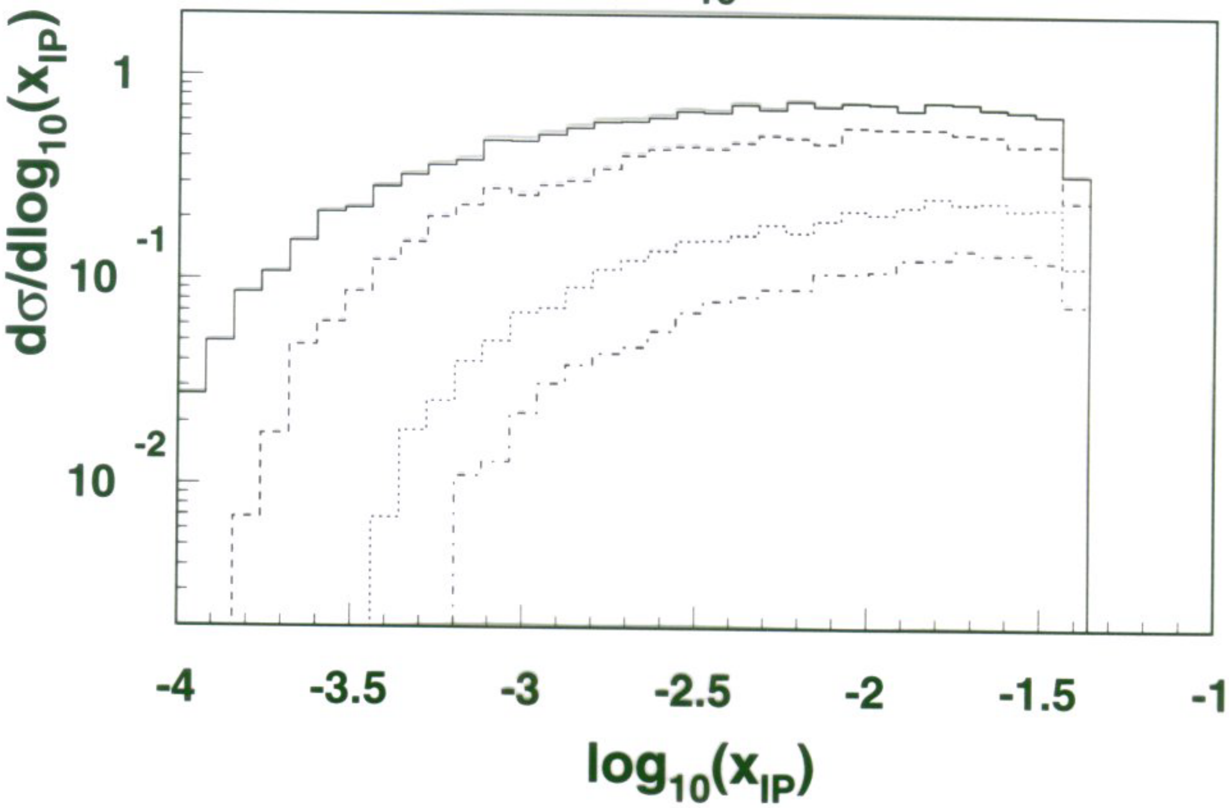


→ perfect description

D* in diffraction

THERA $|\eta|_{D^*}$ check





towards TDR

- QCD tests : inclusive quantities
  only possible in ep !
  QCD calculable quantities !
  structure functions !

- QCD tests: hadronic final state
  THE ONLY way for detailed understanding
  of high energy interactions:
  - most challenging : still unsolved small$x$ region
  - cleanest way to look at parton dynamics
  - all what only is touched at HERA
    can be well measured at THERA
    - contribution of res. virt. γ's
    - forward jets
    - heavy quark production
    - diffraction

towards TDR:

- hadr. final state (cont'd)
  - obtain consistent picture of DIS
    (not QPM + BFKL + res γ + ...)

→ one solution → $k_\perp$ factorisation → CCFM !?!

- describe F_2, fwd jets, heavy quarks, ...
- including "res. virtual γ's"
- measurement of unintegrated gluon!

HERA → TEVATRON
THERA → LHC

- other solutions ?

- more theoretical work is needed and is being done ....

→ on the way to describe lot of measurements

→ further tests = measurements needed!