Study of DIS events containing a leading proton at HERA

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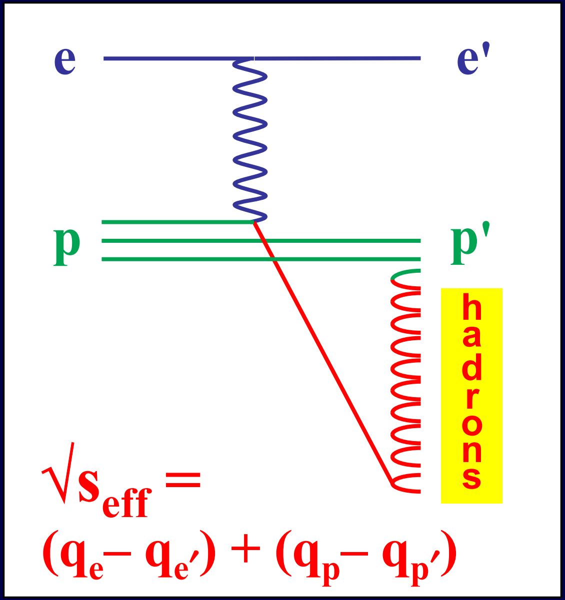
Try to compare the leading proton production as measured in ZEUS and in previous experiments to DJANGOH (LEPTO + MEPS or Ariadne) and HERWIG MC generators

Leading protons

By leading proton we mean $x_L = p'/p_{beam} < 0.95$, i.e. non-diffractive production.

We believe a correct simulation of the leading protons is important since they carry away a large fraction of the beam-proton momentum,

$\Rightarrow$ they determine the effective energy available for hadronisation



Introduction

Aim: high-statistics study of production of leading protons in ep collisions in the kinematic range:

$Q^2 > 3$ GeV^2

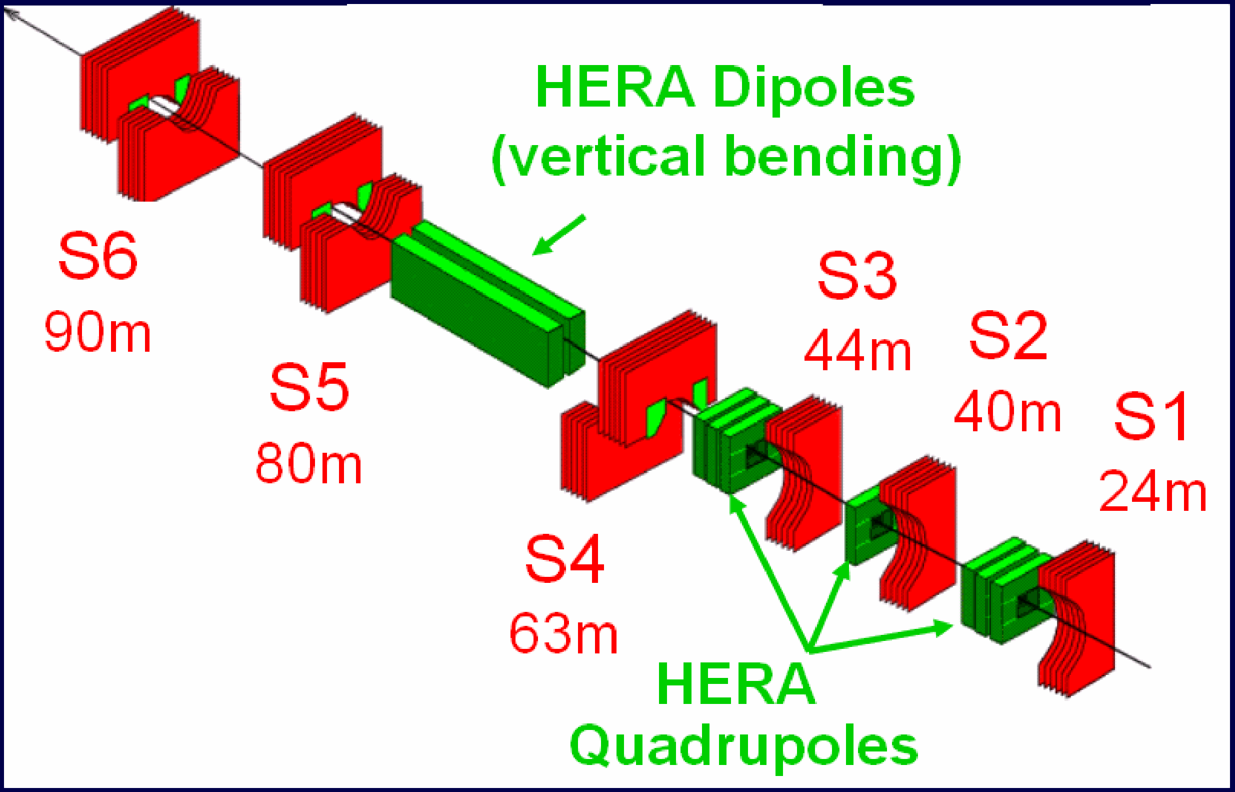
$45 < W < 225$ GeV

$0 < p_T^2 < 0.5$ GeV^2

$x_L > 0.35$

- **Cross sections vs. x_L and p_T^2, p_T^2 slopes**
- **Final states vs. Effective Energy available for hadronisation**
  - to compare with pp and e^+e^-
- **Cross sections in bins of Q^2**
  - to test factorisation of vertices
- **Fracture functions**
  - never measured

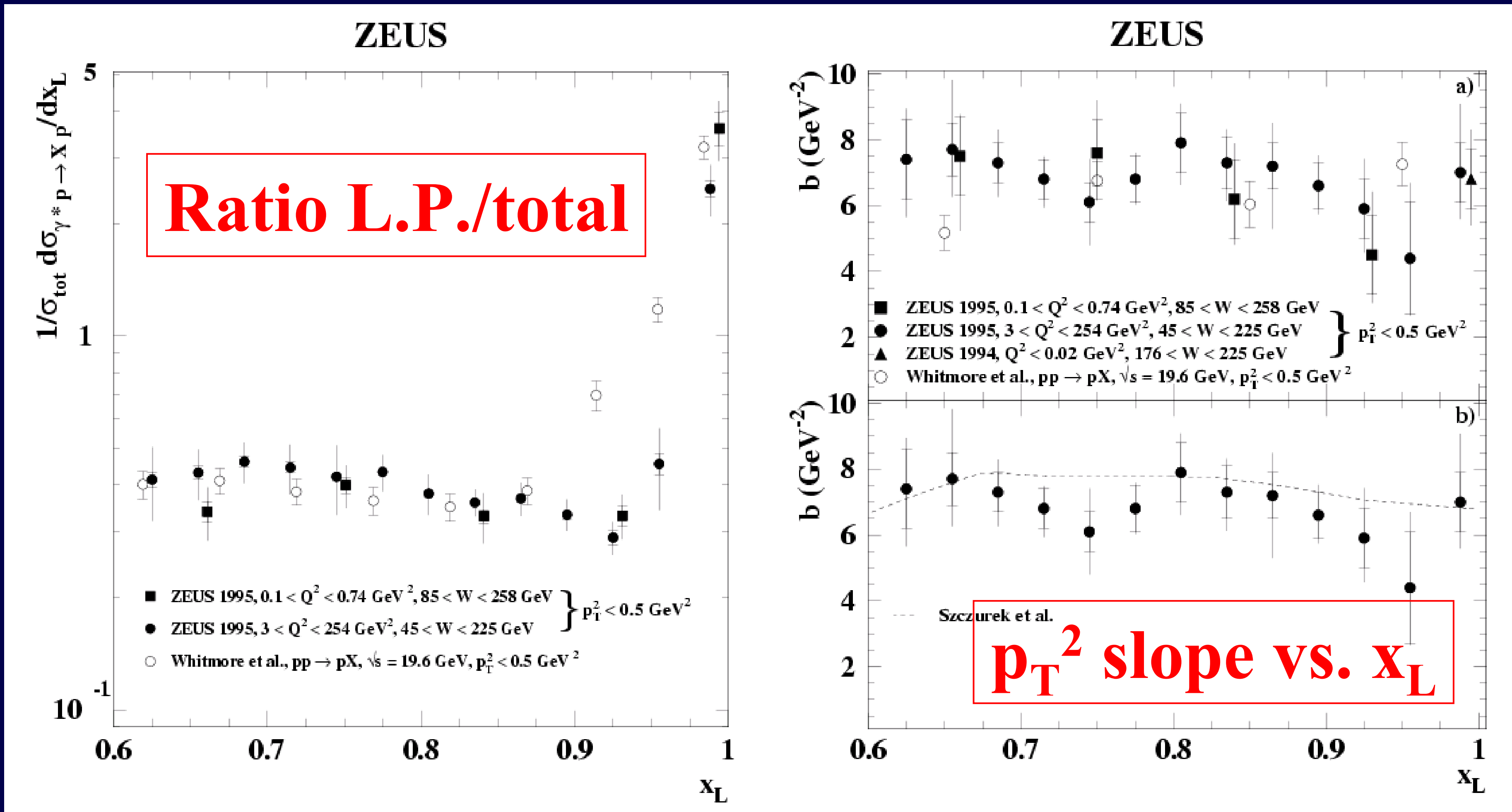
The ZEUS Leading Proton Spectrometer



- 6 stations each made by 6 Si-detector planes,
- positioned between 24 and 90m from IP,
- inserted to 10σ from the proton beam during data taking.
- very high resolution in x_L.

The ZEUS publication

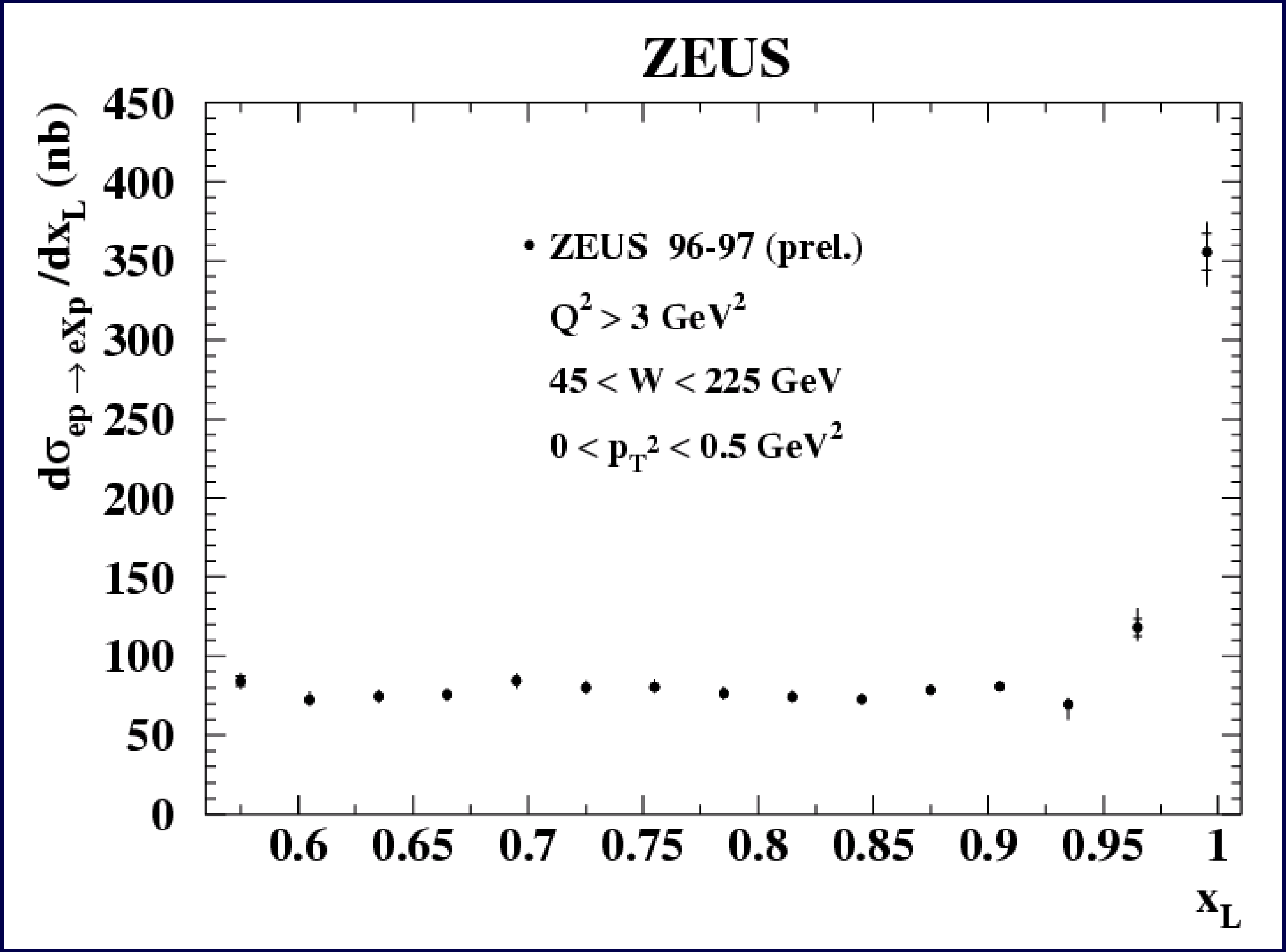
Nucl. Phys. B 658 (2003) 3-46 **3.4 pb^{-1}, $x_L > 0.6$, $p_T^2 < 0.5\ GeV^2$**



more in the talk by M. Arneodo in the diffractive WG

The ZEUS prel. results: $d\sigma/dx_L$

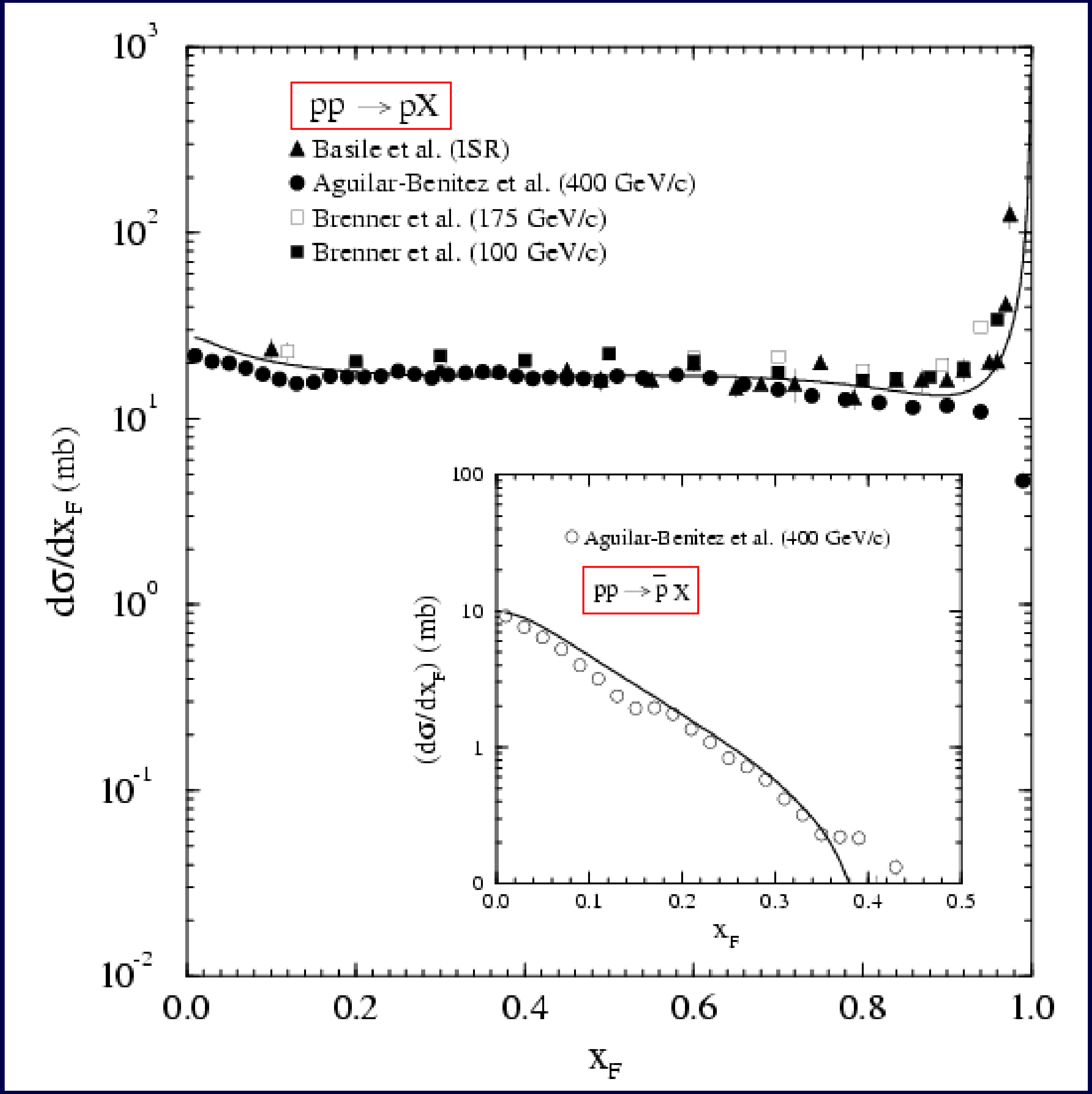
Based on **12.8 pb^{-1}**, **x_L > 0.56** (0.35-0.40, eventually), still **preliminary**:



Abstract # 544 of EPS03

Cross sections measured: $d\sigma/dx_L \approx$ flat below the diffractive peak, where it grows by a factor of ~5

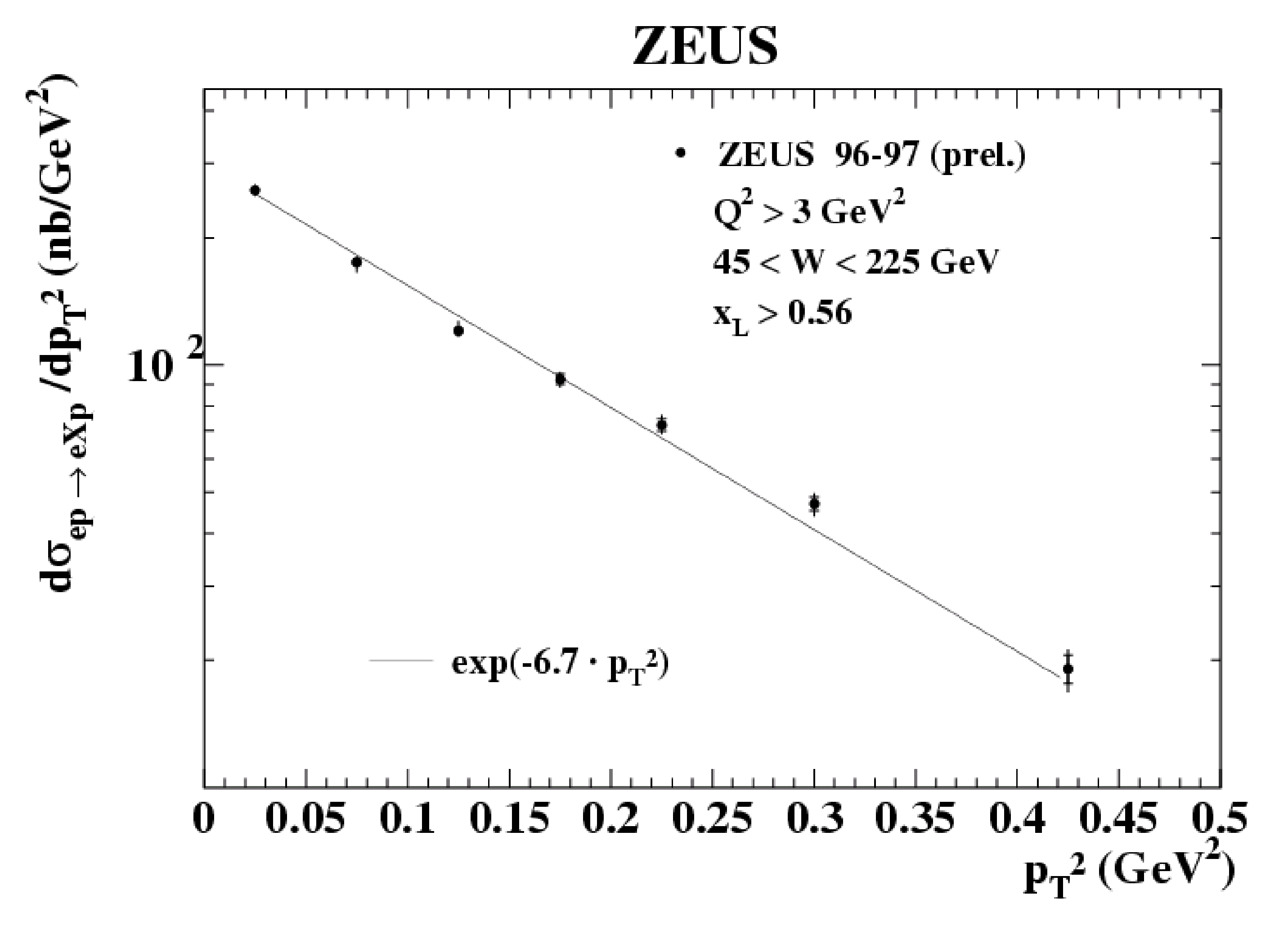
Previous $d\sigma/dx_L$ measurements



Compilation from Batista, Covolan (hep-ph/9811425):

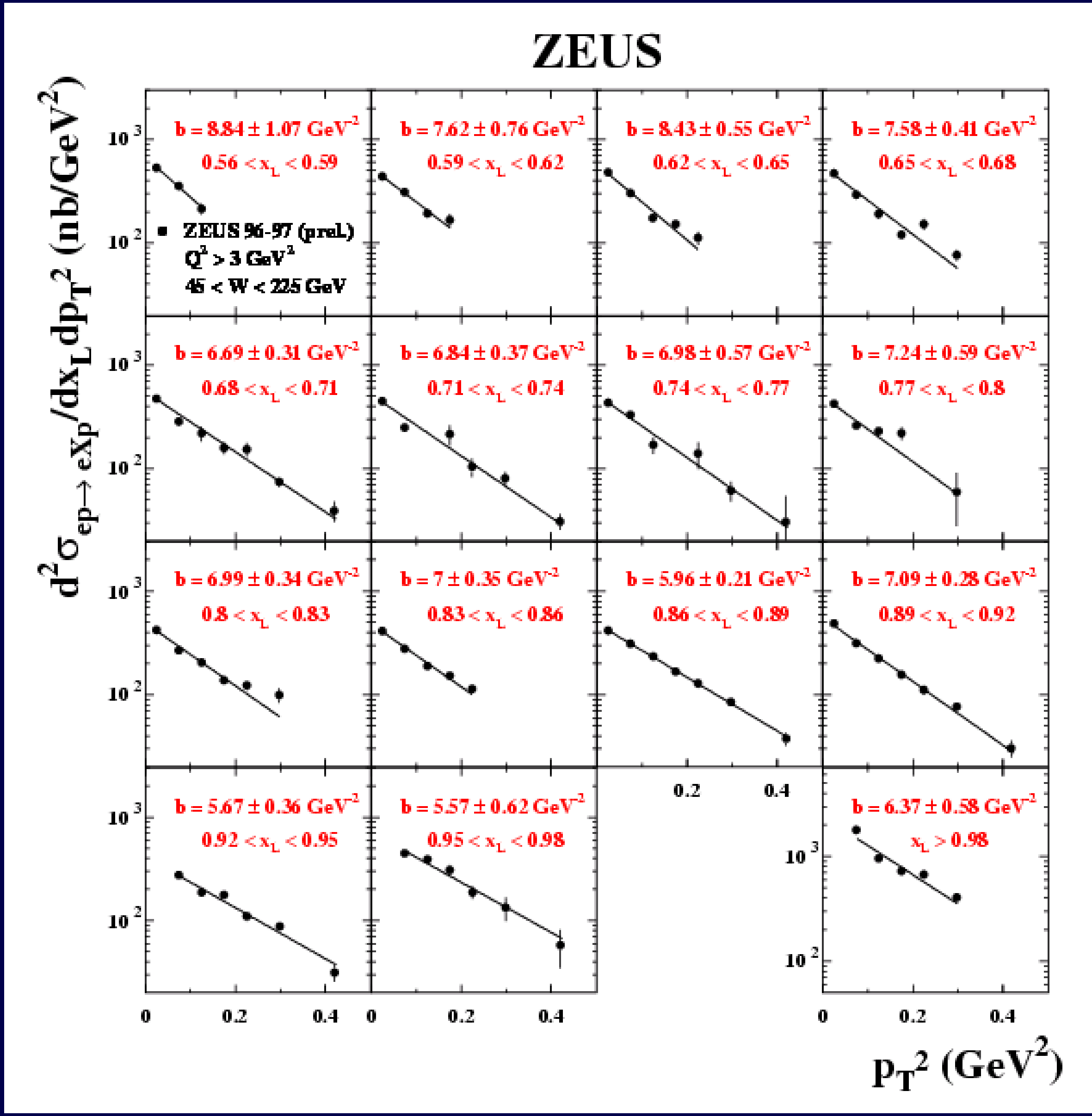
⇒ $d\sigma/dx_L$ flat for protons.

The ZEUS prel. results: $d\sigma/dp_T^2$

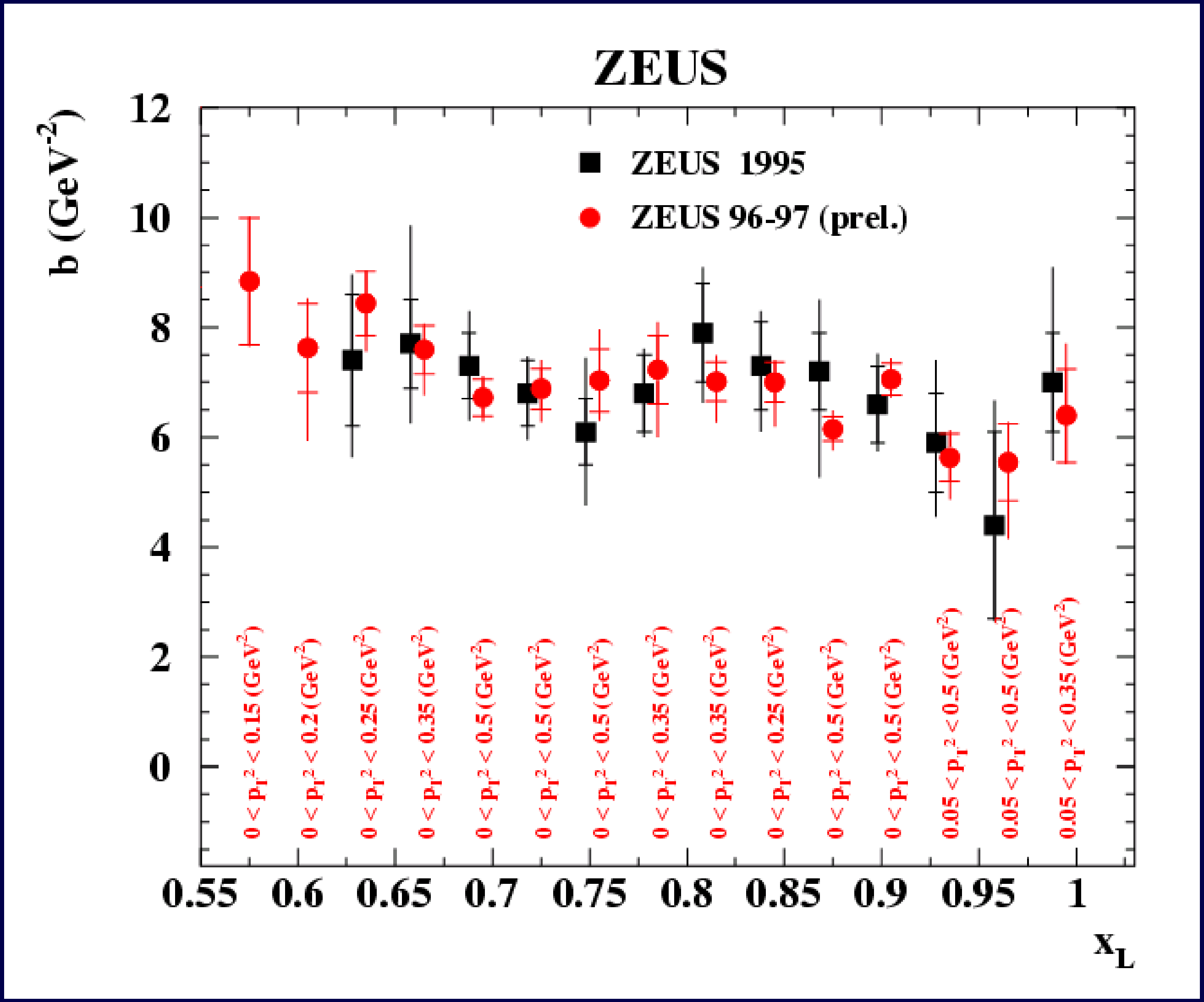


Slope of $d\sigma/dp_T^2$: b ~ 7 GeV^{-2}

The ZEUS prel. results: $d\sigma/dp_T^2$



The ZEUS prel. results: $d\sigma/dp_T^2$

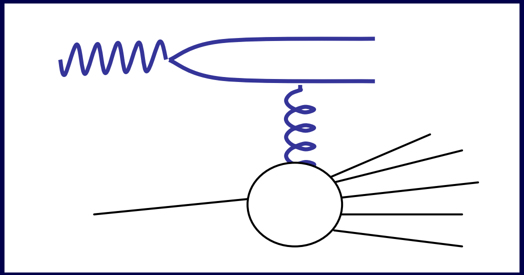
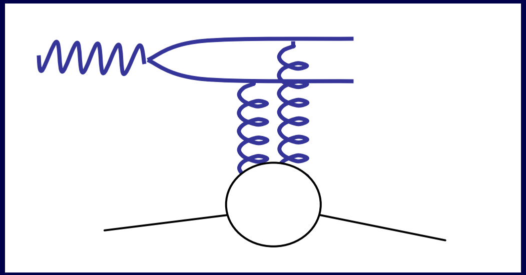
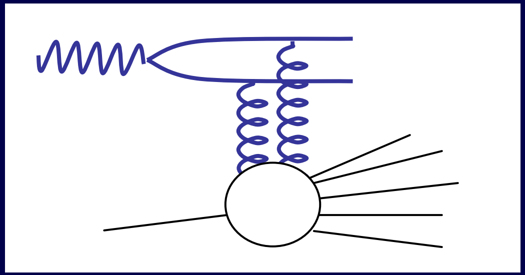


The slope of $d\sigma/dp_T^2$ does not vary too much in the x_L range measured

The Montecarlo samples

- Djangoh (LEPTO-MEPS, CTEQ5D)
- Djangoh (LEPTO-Ariadne,CTEQ5L)
- Herwig + Pomwig + Sang

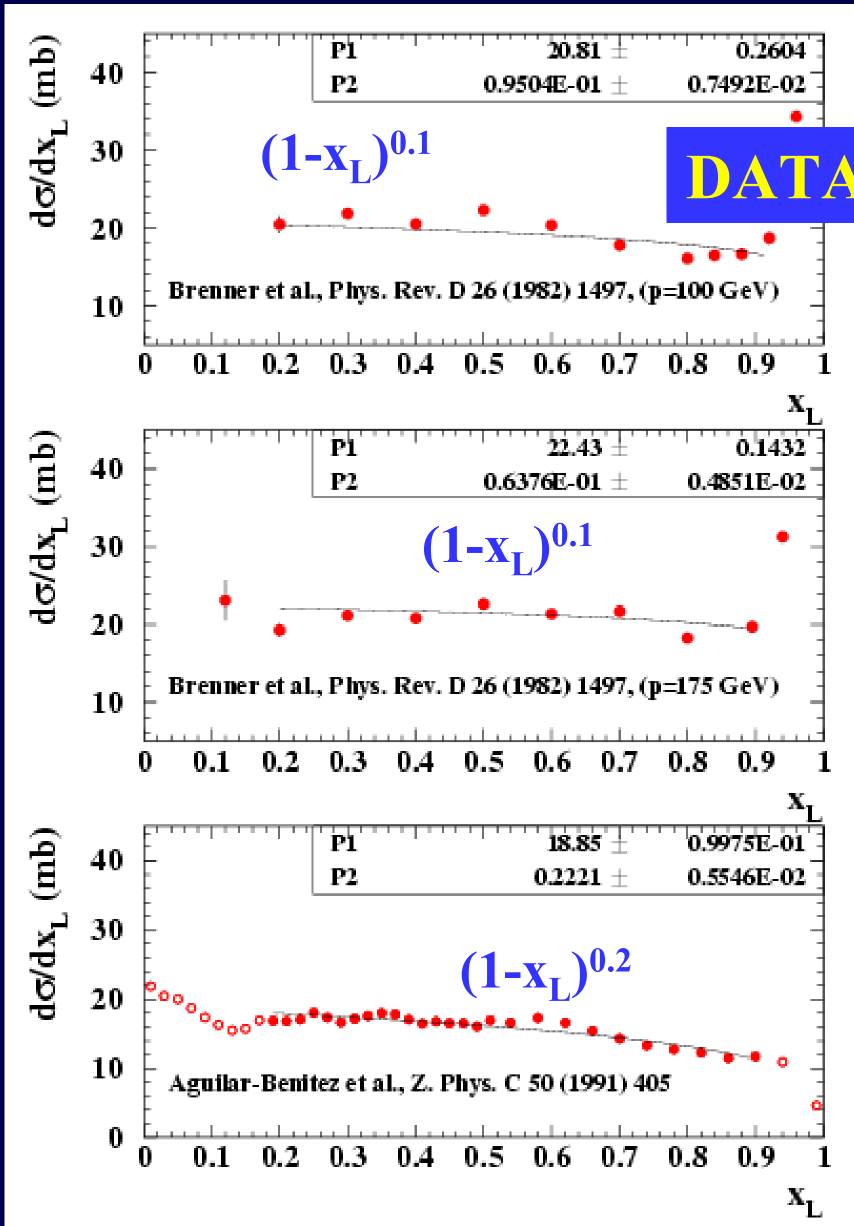
non diffr. single diffr. double diffr.

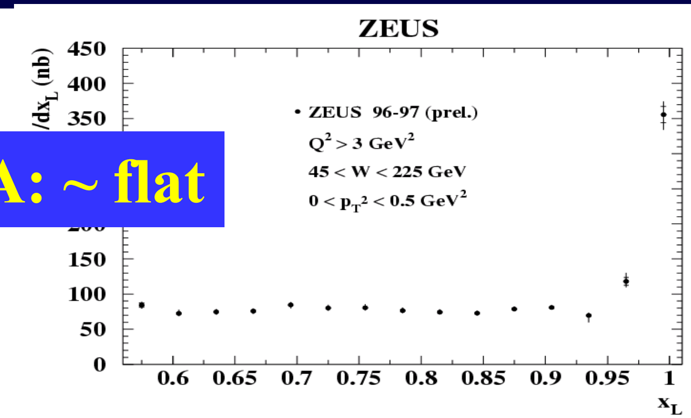




Need to reweight:
- leading proton x_L and p_T^2
- diffractive component

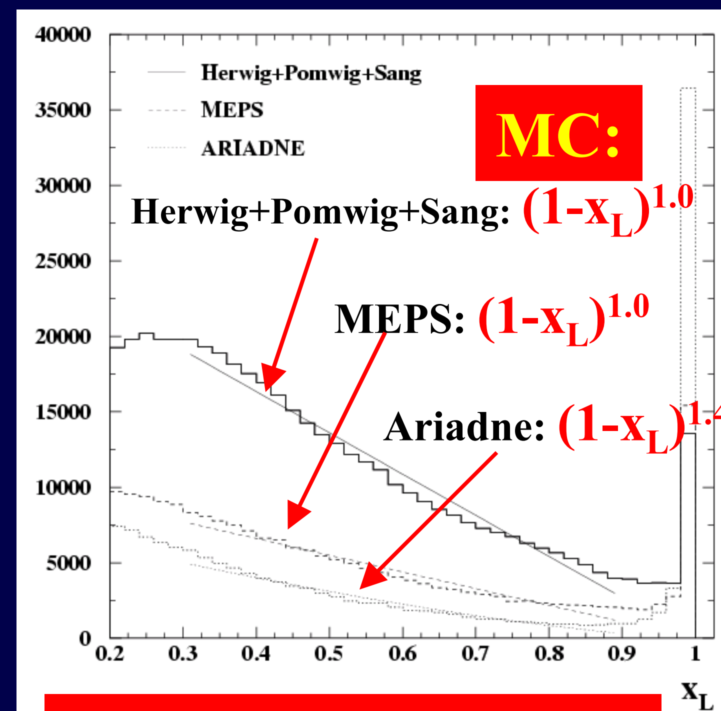
x_L distribution: DATA vs. MC

My own fits below the diffractive peak:



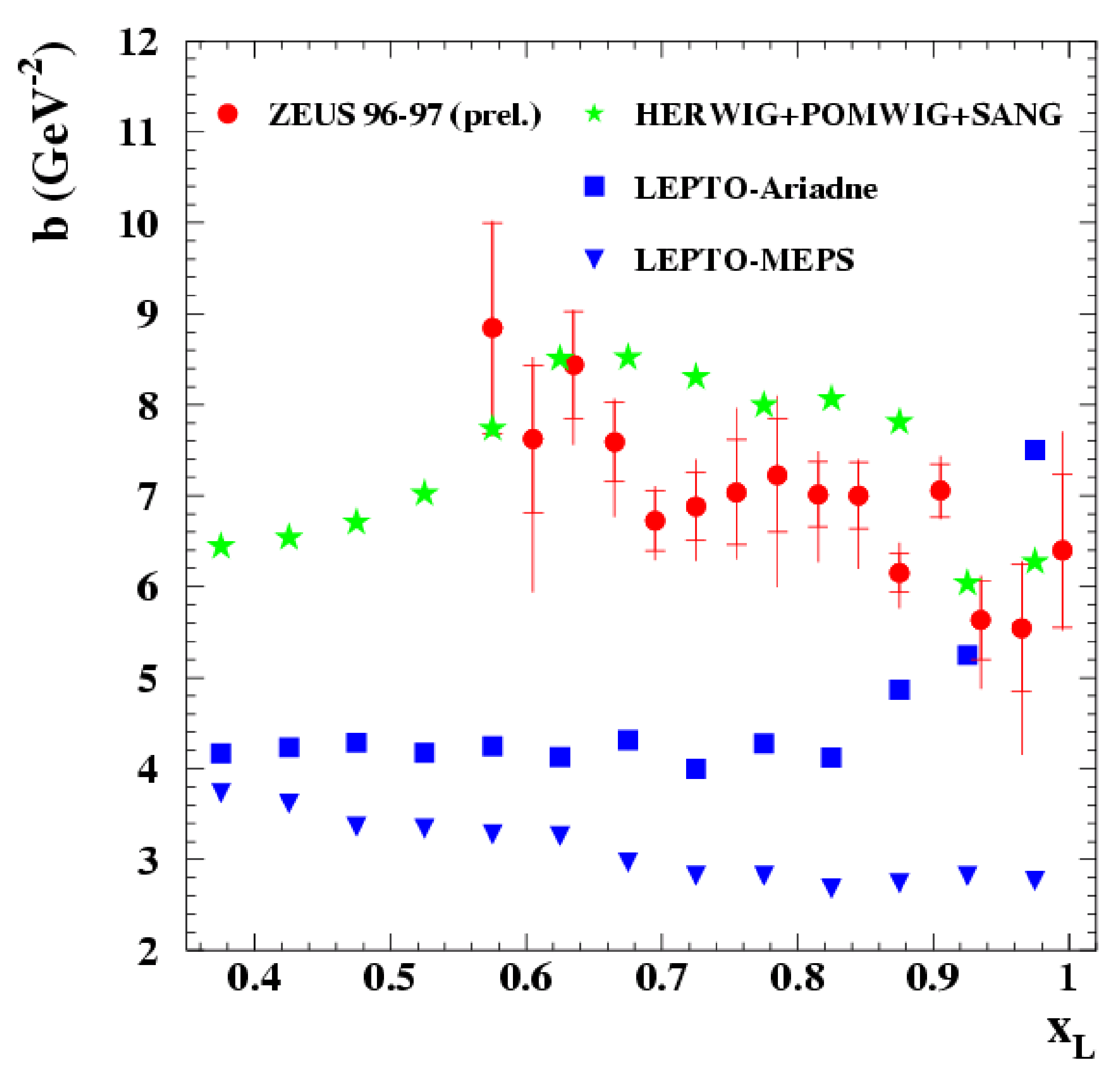


DATA: ~ flat



⇒ quite different!

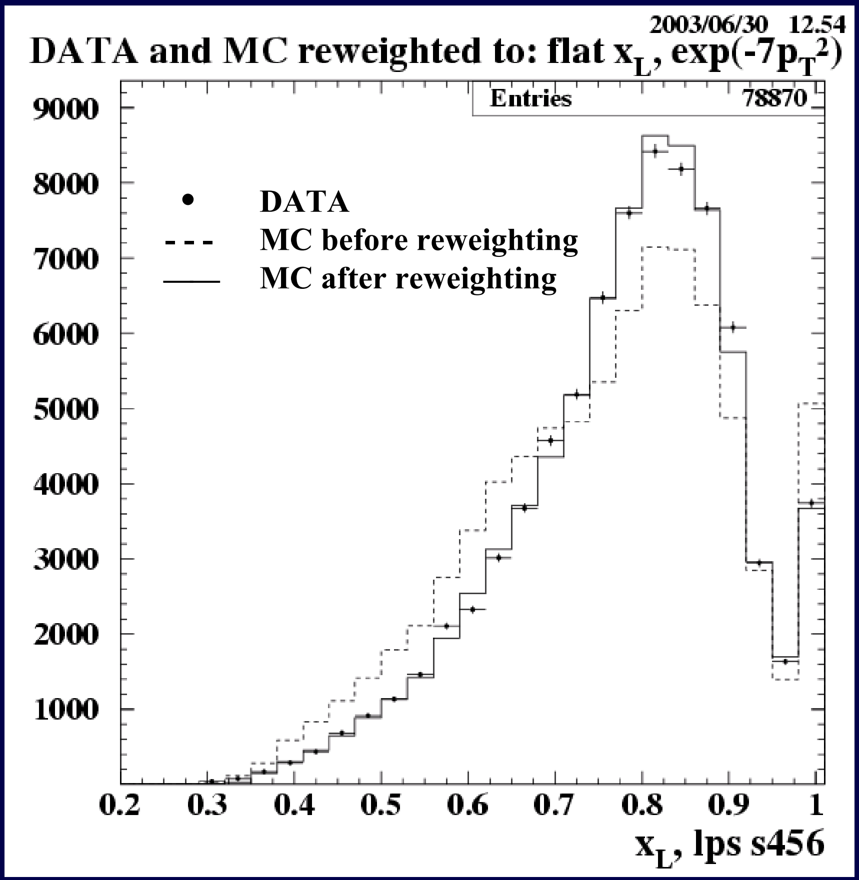
p_T^2 distribution: DATA vs. MC

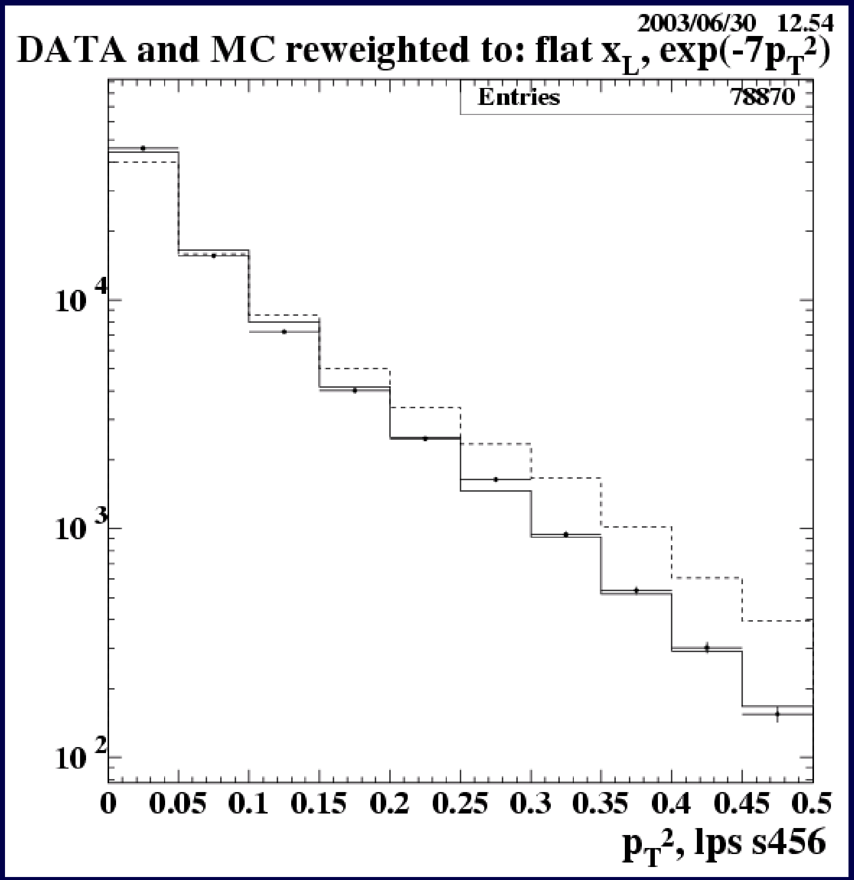


Fit $d\sigma/dp_T^2$ to $e^{-bp_T^2}$ in the range $p_T^2 < 0.5$ GeV^2

- **HERWIG ≈ ok**
- **LEPTO too low: the primordial p_T (“k_T parton” card) needs to be tuned.**

Reweighting of MC: p_T^2 and x_L

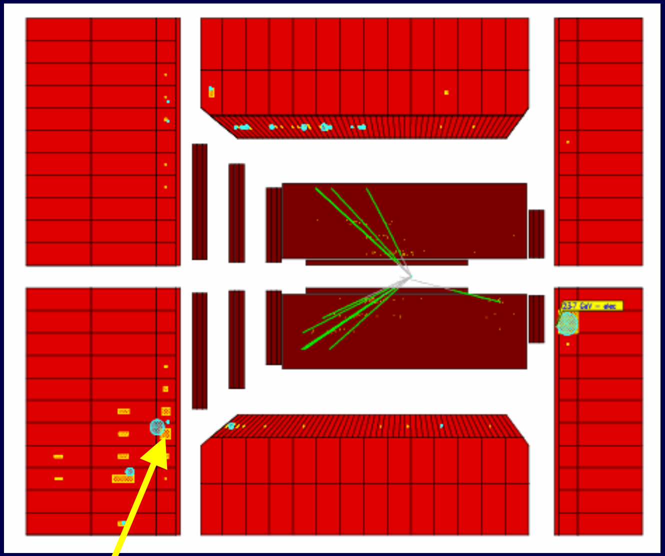




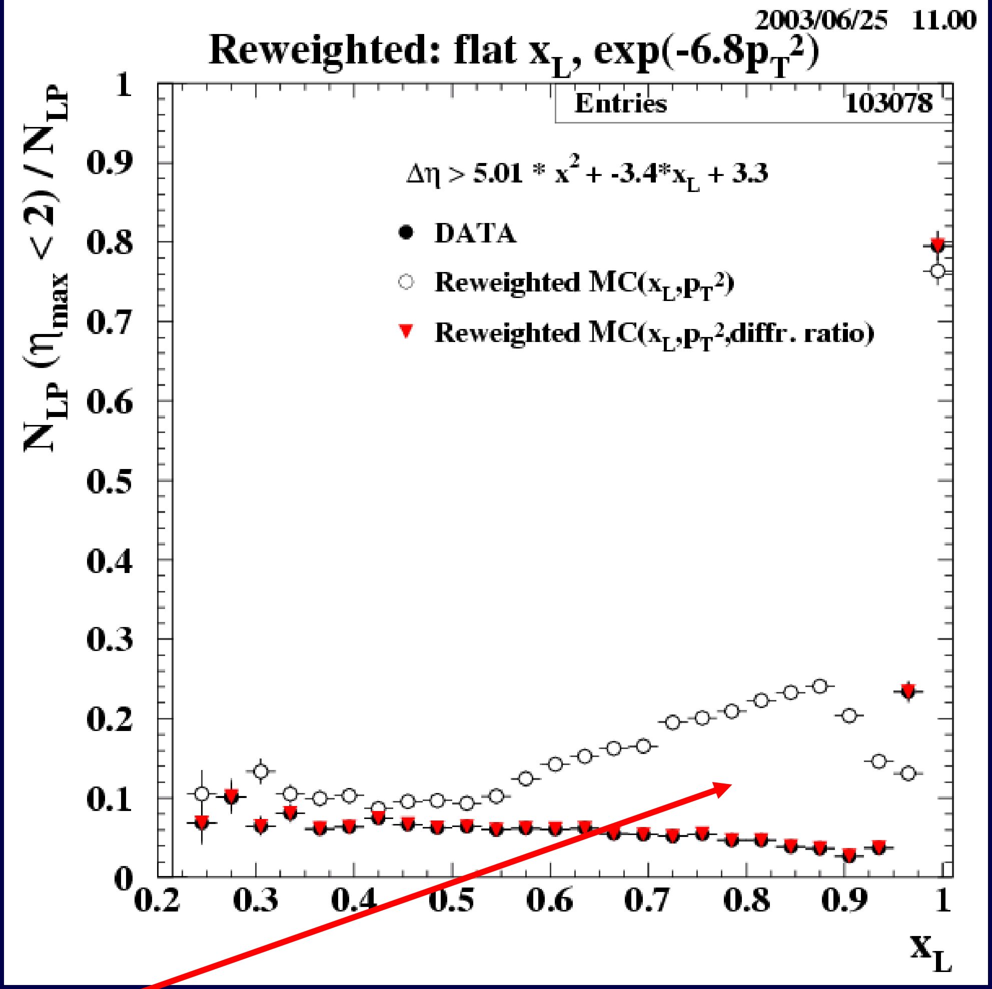
Good agreement at detector level after reweighting

Reweighting of MC: diffractive

Diffraction at HERA often identified by $\eta_{max} < 2$,

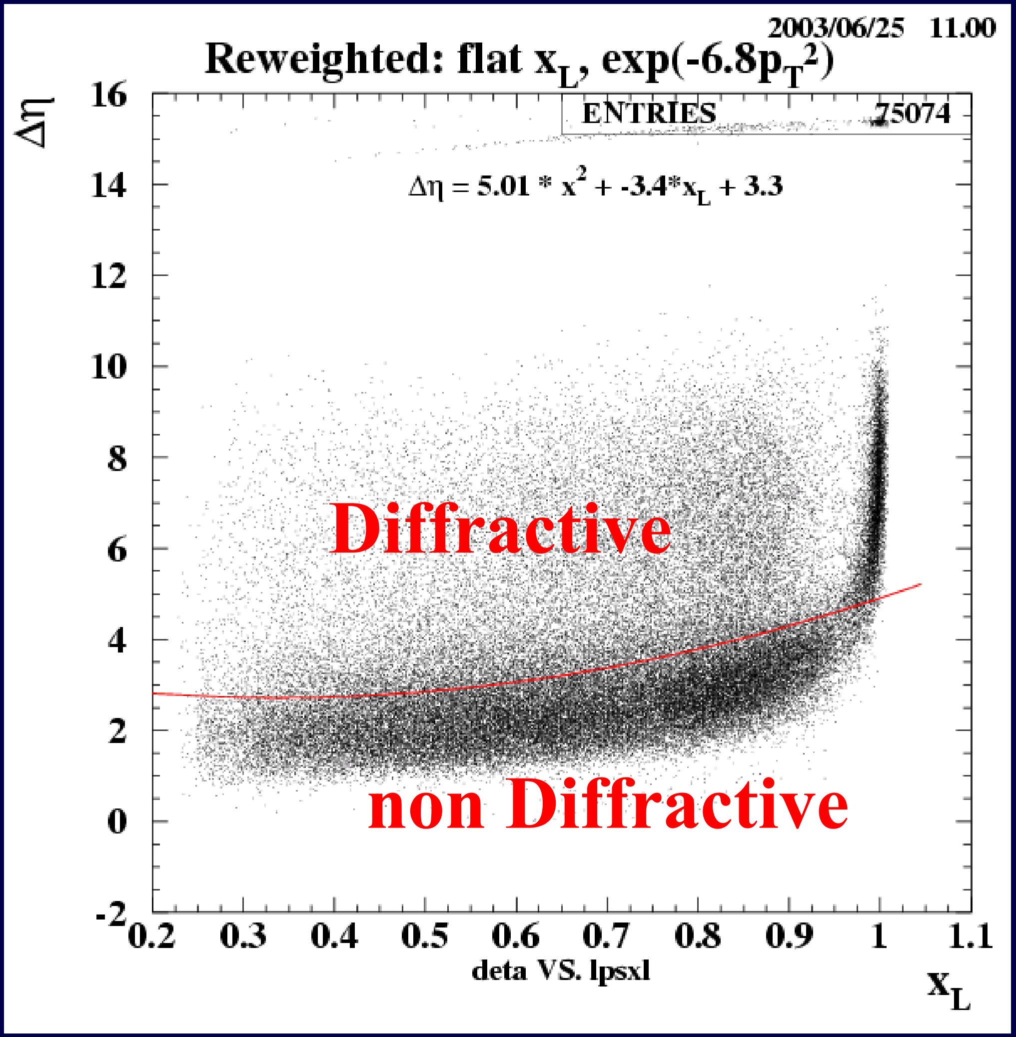


where η_{max} is the pseudorapidity of the most forward energy deposit.



Too much diffraction (SCI) in LEPTO-MEPS.

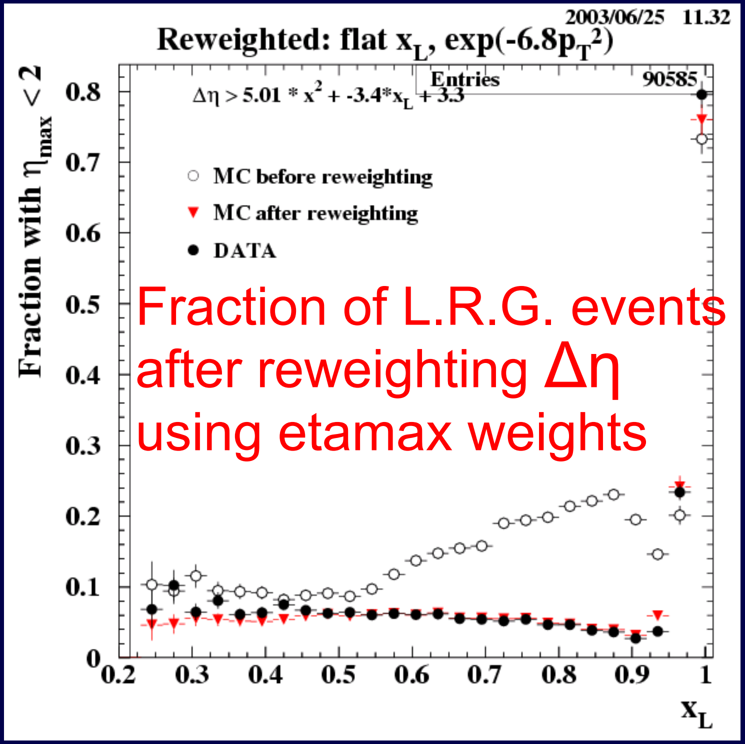
Reweighting of MC: diffractive



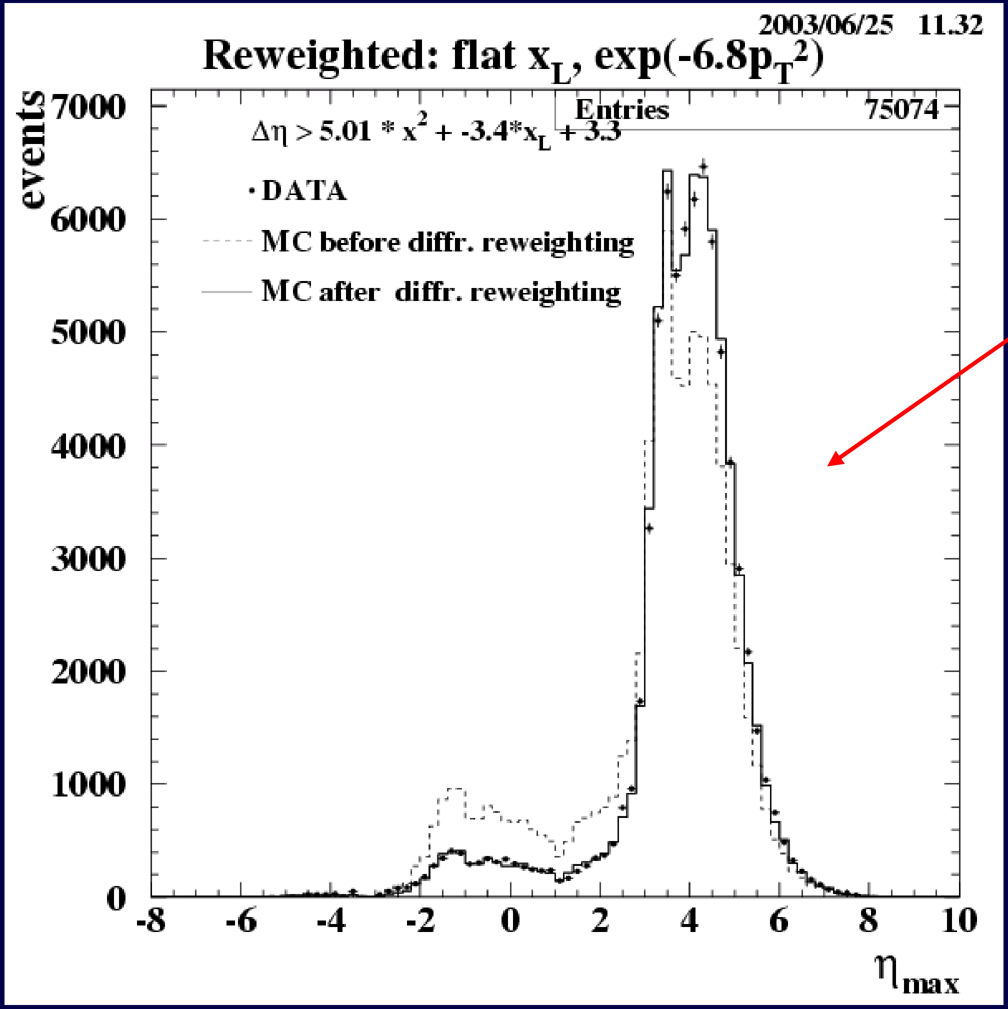
Problem: no flag to identify diffractive events in LEPTO.

Solved defining:

$\Delta\eta$ = largest rapidity gap in the event (at the generator level)



Reweighting of MC: diffractive

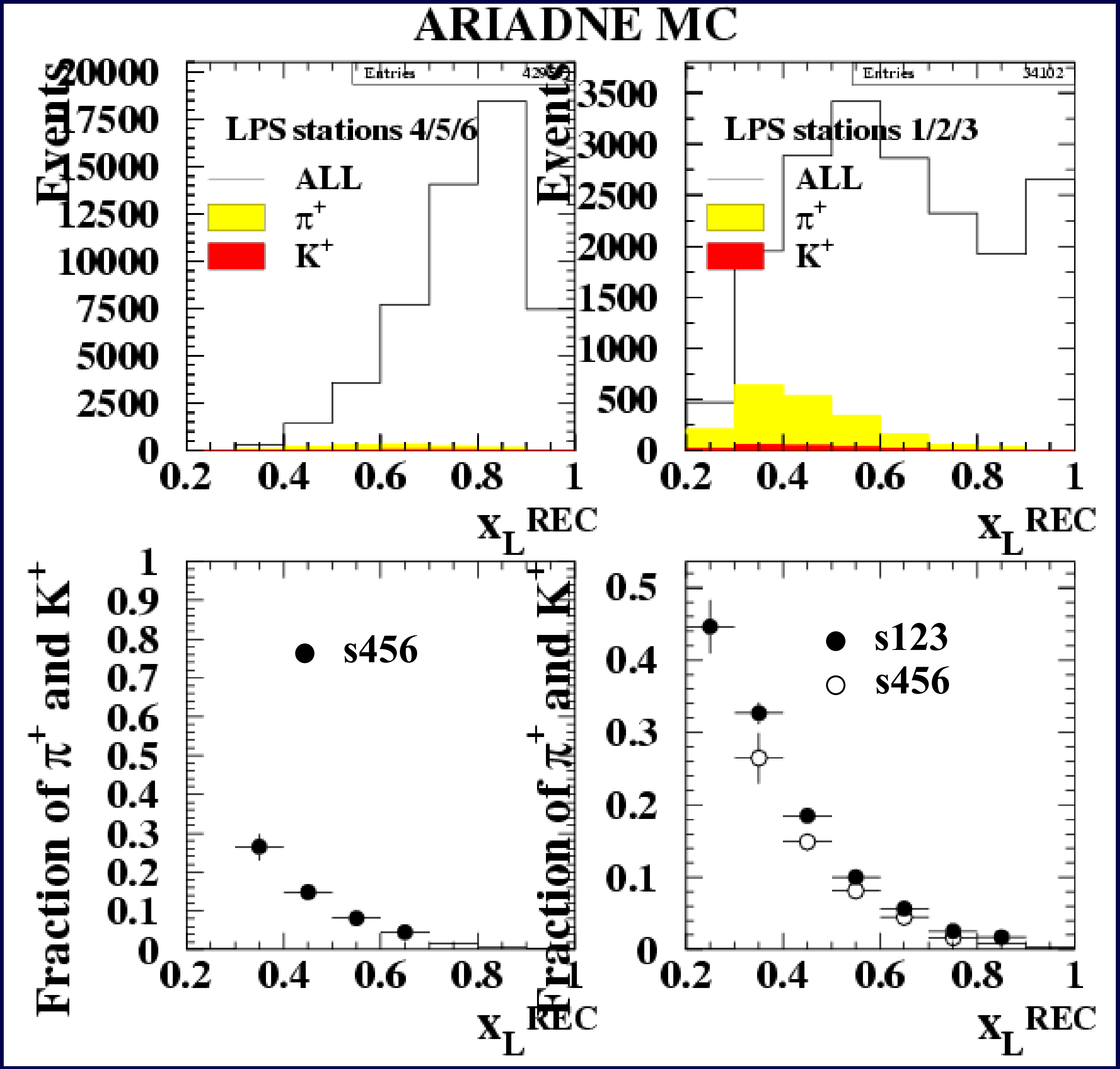


The η_{max} distribution is a good tool to check the DATA-based reweighting of the diffractive component

Good agreement of η_{max} distribution after reweighting

Much better would be to have a flag to tag diffractive events

Backgrounds: π^+ and K^+



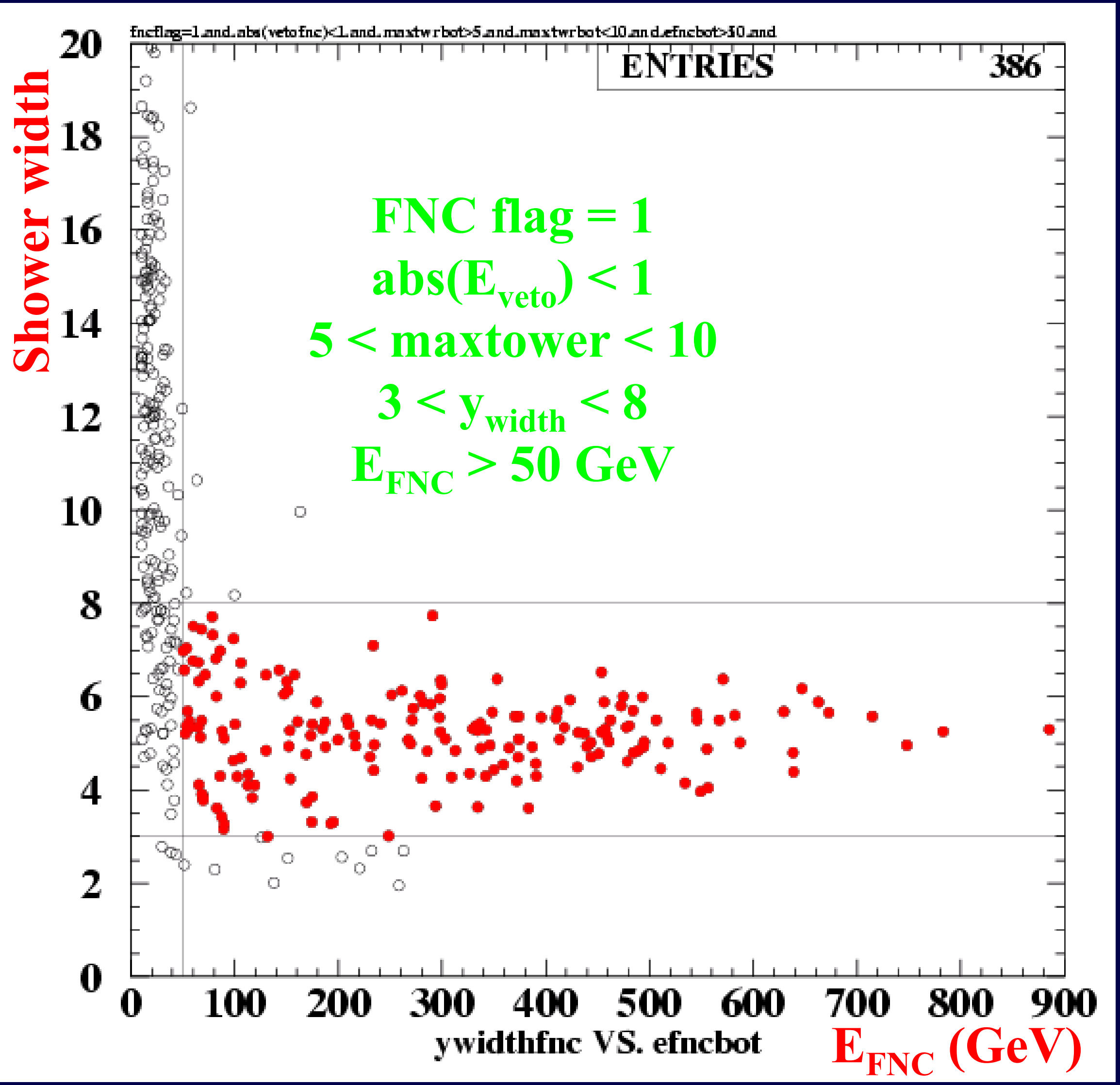
π^+, K^+ contamination increasing with decreasing x_L:

~ 30% at x_L = 0.3

Subtraction done using MC, but after checking the

FNC-LPS double coincidences ⟶

Double coincidences LPS*FNC



FNC: Forward Neutron Calorimeter

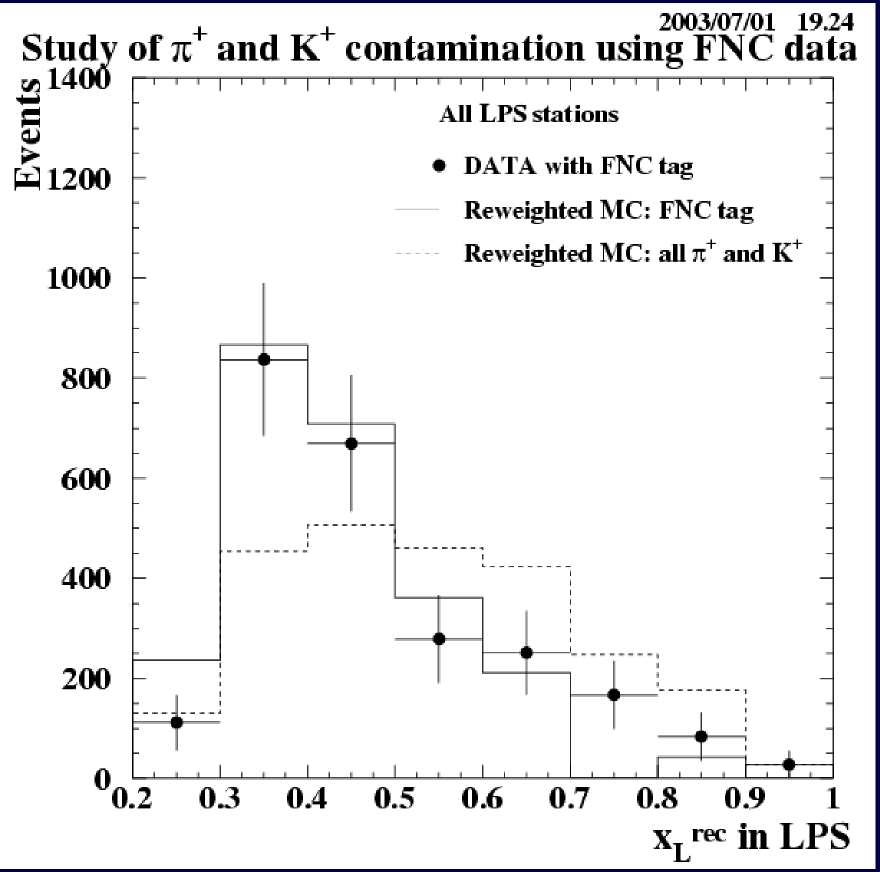
179 double coincidences of clean neutrons in the FNC and positive charged track in the LPS

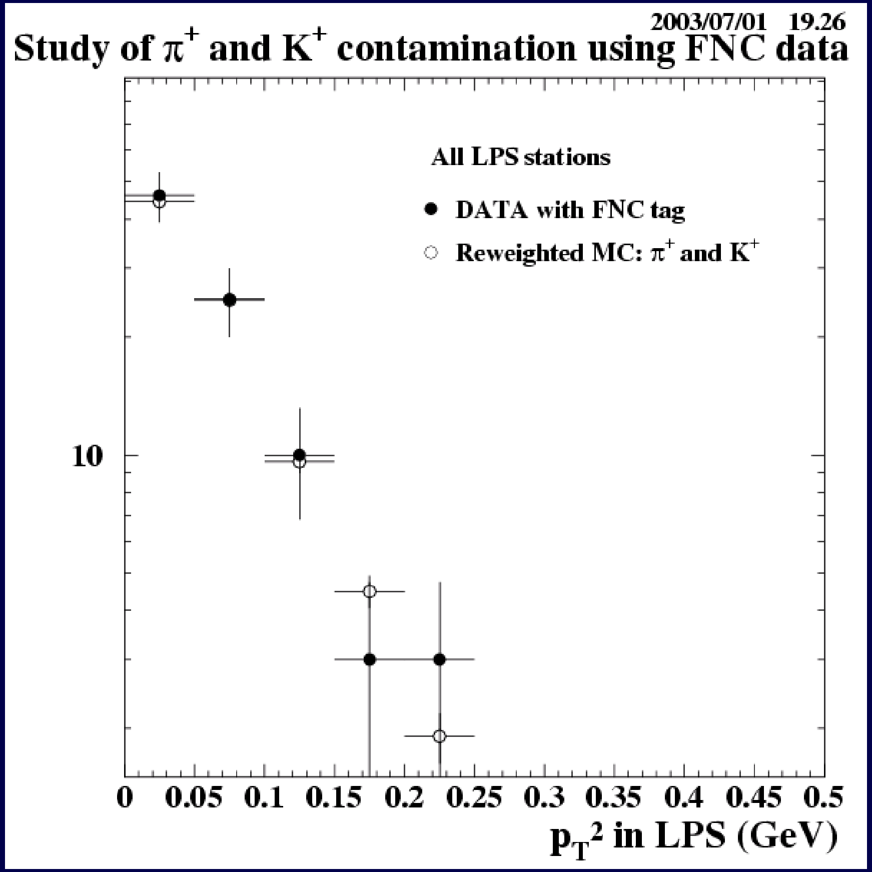
If good neutron in FNC

⇓

either π^+ or K^+ in LPS

Double coincidences LPS*FNC





- After reweighting the diffractive fraction in MC: good agreement between the double coincidences FNC * LPS in DATA and in MC both in x_L and p_T^2 ⇒ reliable simulation of π^+ and K^+

Summary

We had to do lots of reweighting for our measurement:

- ❑ x_L spectrum of leading protons generated in MC's differ from measurements
- ❑ b slopes of p_T^2 distributions too small in LEPTO; may be fixed by tuning primordial k_T
- ❑ too many diffractive events in LEPTO-MEPS (SCI) : reweighting more difficult, since there is no flag to identify diffractive events
- ❑ Fraction of π^+ and K^+ w.r.t. protons in MC seems ok

Leading proton production in MC's needs tuning

The selection cuts

$|V_z| < 50$ cm

$38 < E\text{-}P_z < 65$ GeV

Sinistra cand's > 0

E'_e(Sin.) > 10 GeV

Econe (R=0.8) < 5 GeV

H-box cut on RCAL

Q^2_{DA}(ZUFO) > 3 GeV^2

$45 < W_{DA} > 225$ GeV

$y_{JB} > 0.03$

LPStag = 1 (all ok)

$\Delta_{pipe} > 0.04$ cm

$\Delta_{pot} > 0.02$ cm

$E+P_z < 1655$ GeV

$p_T^2 < 0.5$ GeV^2

$0.35 < x_L < 1.02$

Selected events: 71937 in s456

Migrations and backgrounds

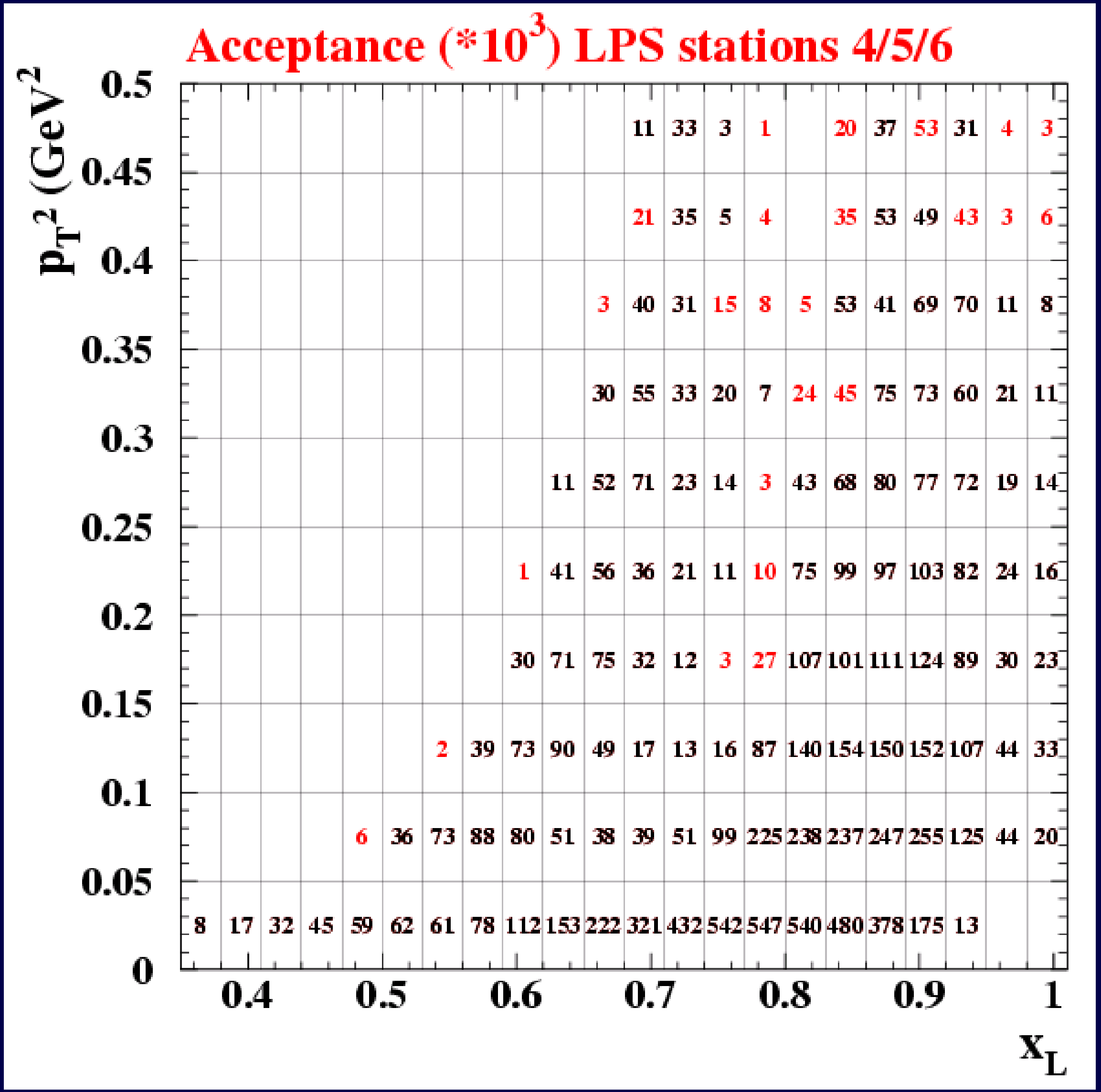
Three sources:

- **Migrations from low Q^2**: studied using MC samples of photoproduction and $0.5 < Q^2 < 2$ GeV^2
- **Overlay events**: accidental coincidences of DIS events with halo-protons or proton-gas collisions
- **π^+ and K^+** reconstructed in the LPS

p_T^2, x_L acceptance for s456

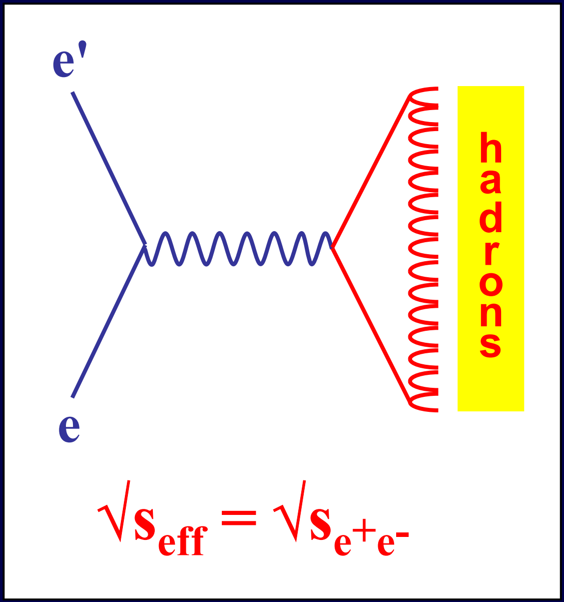
The bins rejected (the red cells in the plot) are those where the acceptance varies wildly, and therefore are difficult to simulate

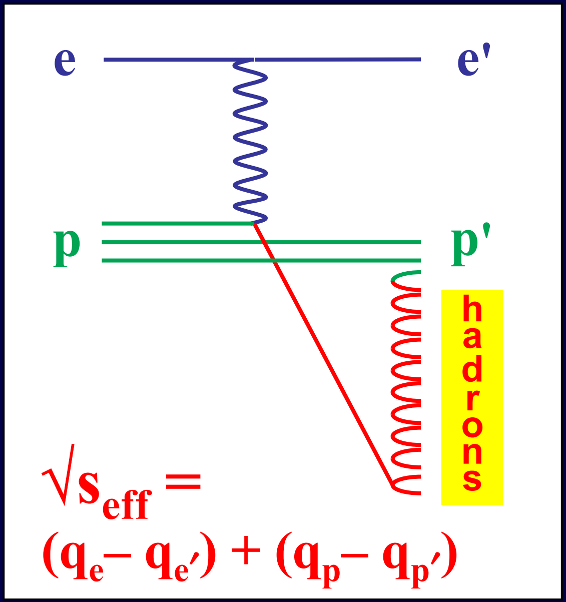
As a systematic check, will use a different selection criteria to reject bins.

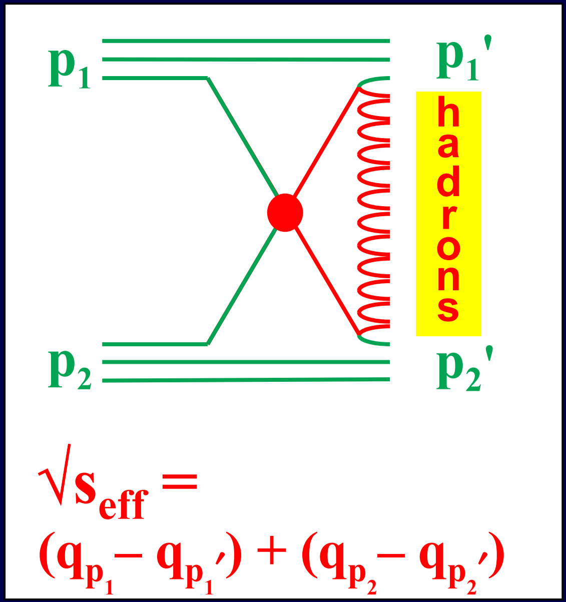


Study of hadronic final states with the LPS

The proton (and γ) hemisphere can be studied using the LPS in the LAB frame and compared to e^+e^- and pp data if we use the **energy available for hadron production** in each case:
i.e. subtract the four momenta of the scattered beam particles

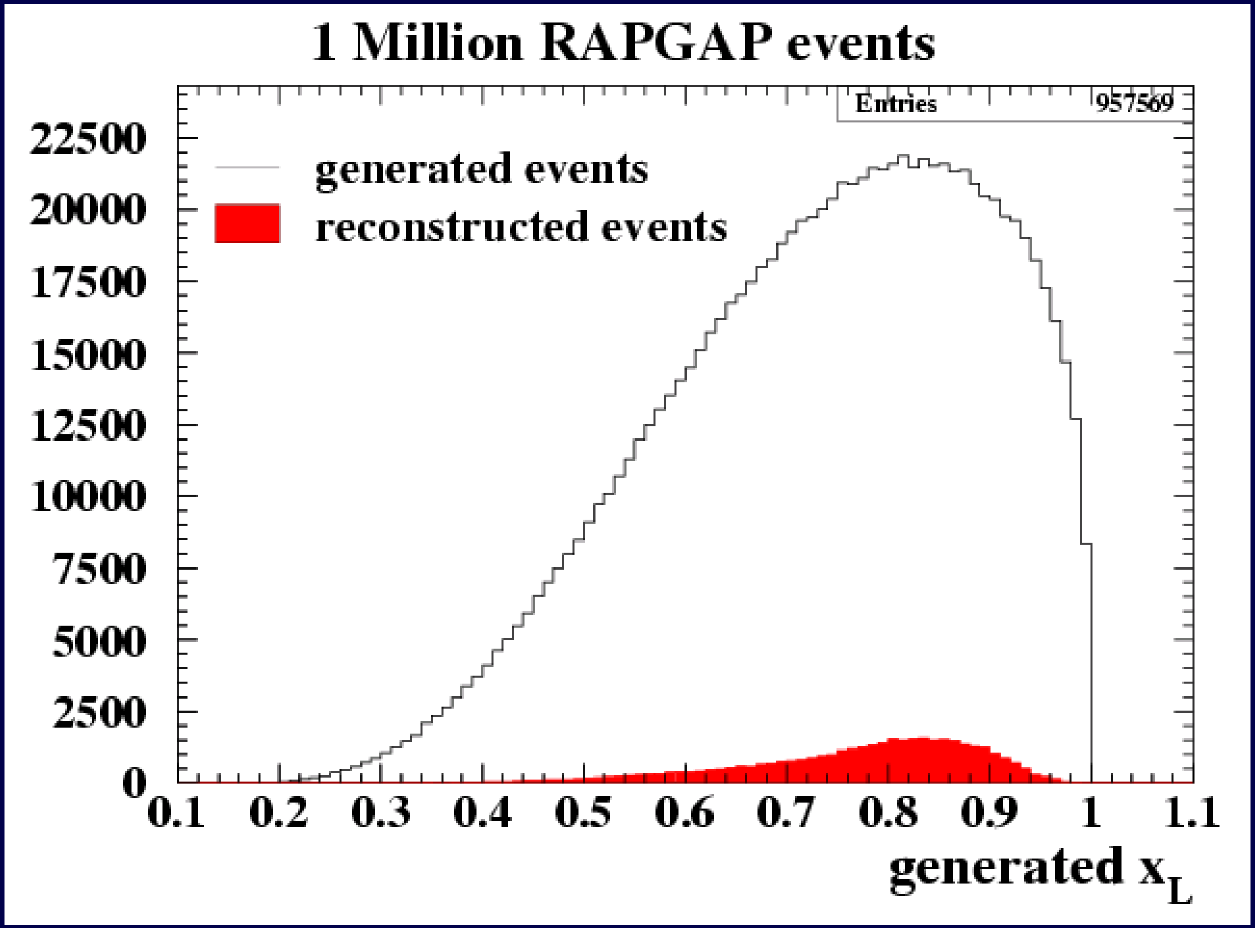






($\sqrt{s_{eff}}$ is also called $\hat{s}$, q^{had}_{tot} or qht in the literature)

RAPGAP Reggeon-exchange:



Not enough MC statistics at low x_L, due both to the RAPGAP generated x_L distribution and the LPS acceptance.