Leading neutrons and protons

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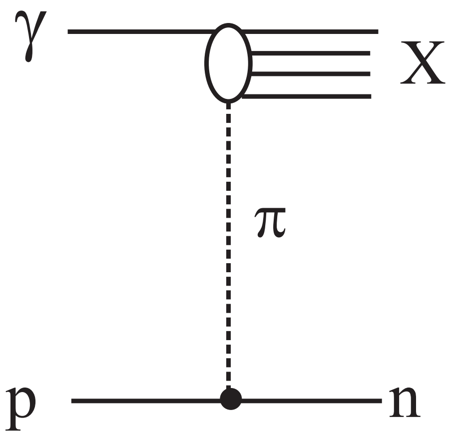
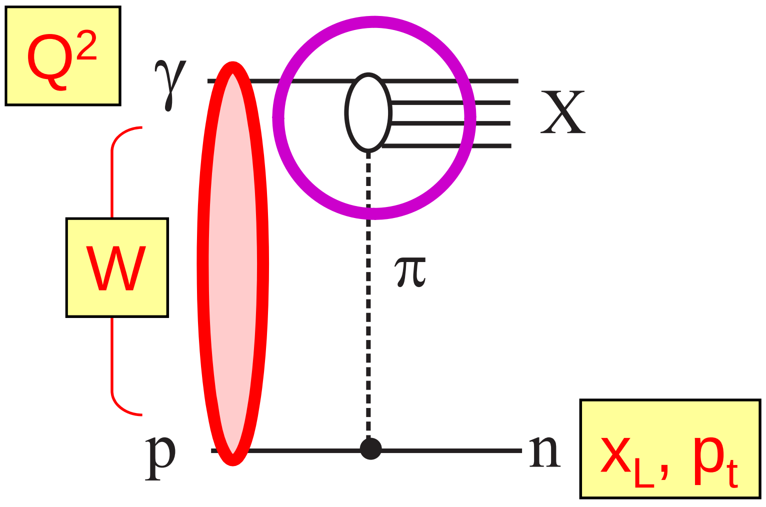
For Forward Physics at LHC it is useful to start with leading neutrons observed at HERA --- prelimin. ZEUS data
--- good example of problems to be faced.



Alan Martin (Durham)
Forward Physics Workshop
Manchester, Dec. 2006



π exchange dominates for $x_L > 0.6$,

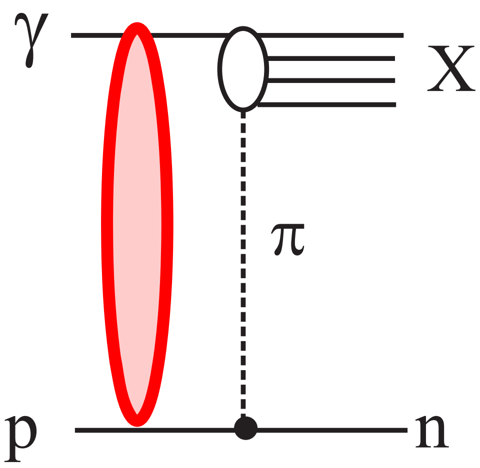
but absorptive effects

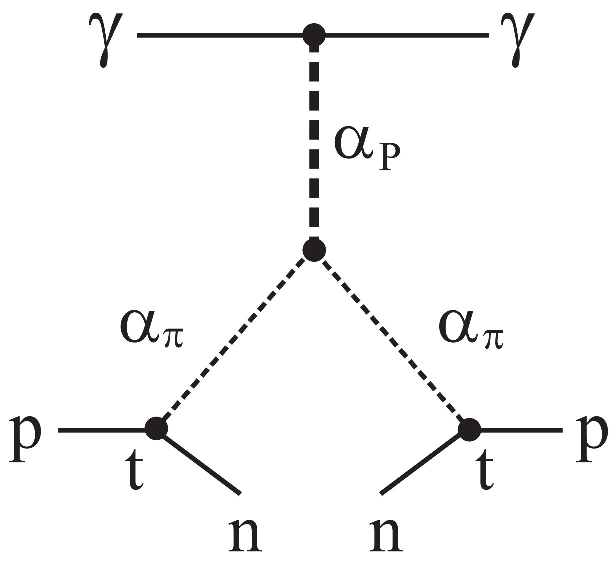
Leading neutron data (Q^2, x_L, p_t) →

π structure fn, $F_2^{\pi}(x,Q^2)$ at small x → $f^{\pi}_{q,g}$

Here, we study re-scatt. effects in photoprod:

$\sigma_{abs}(q\bar{q}\text{-}N)$ → check of S^2





$$\frac{d\sigma(\gamma p \to XN)}{dx_L dt} = S^2 \frac{G^2_{\pi^+ pn}}{16\pi^2} \frac{(-t)}{(t-m_\pi^2)^2} F^2(t)\,(1-x_L)^{1-2\alpha_\pi(t)}\,\sigma^{tot}_{\gamma\pi}(M^2)$$

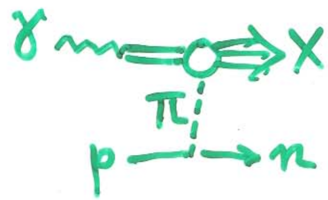
gap survival factor

$S^2 \sim 0.48$ for photoproduction

$$\sigma^{tot}_{\gamma\pi} = \frac{2}{3}\sigma^{tot}_{\gamma p}$$

Add^{ve}QM:

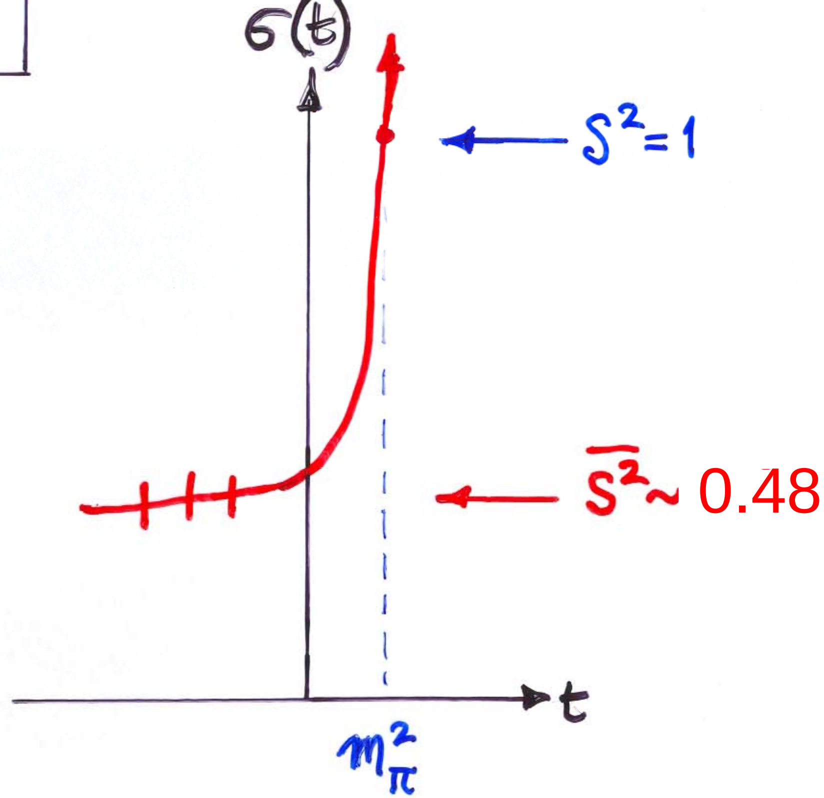
$$\overline{S^2} \sim \frac{\int e^{-\Omega(s,b)}\, d\sigma_0\, d^2b}{\int d\sigma_0\, d^2b}$$



$\sigma(q\bar{q}-N) \sim \sigma(\rho p) \sim \sigma(\pi p)$

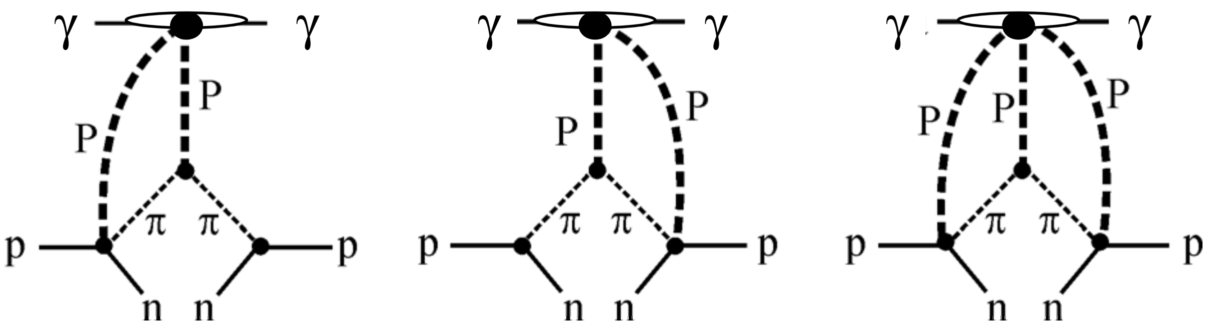
$$\Omega(s,b) = \frac{\sigma(s)}{4\pi B}\, e^{-b^2/4B}$$

$T_{el} \sim e^{Bt}$



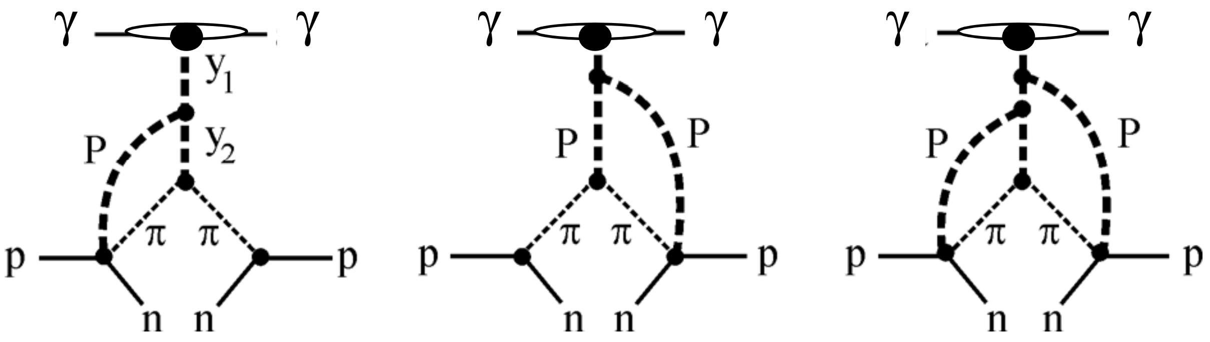
Calculation of survival factor, $S^2(x_L,p_t^2,Q^2)$

(a)



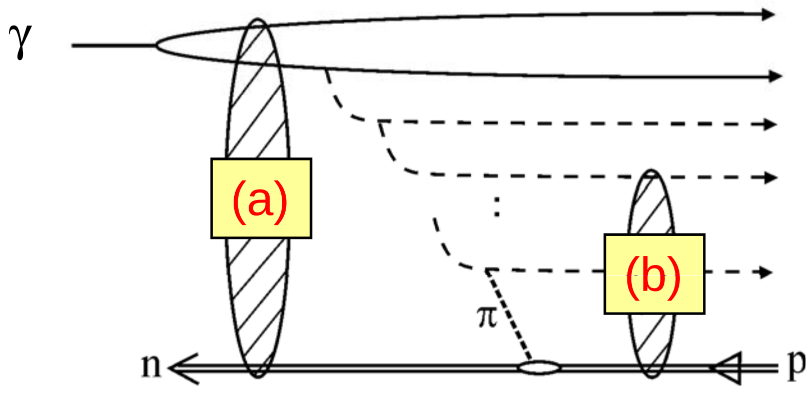
normal eikonal diagrams

(b)



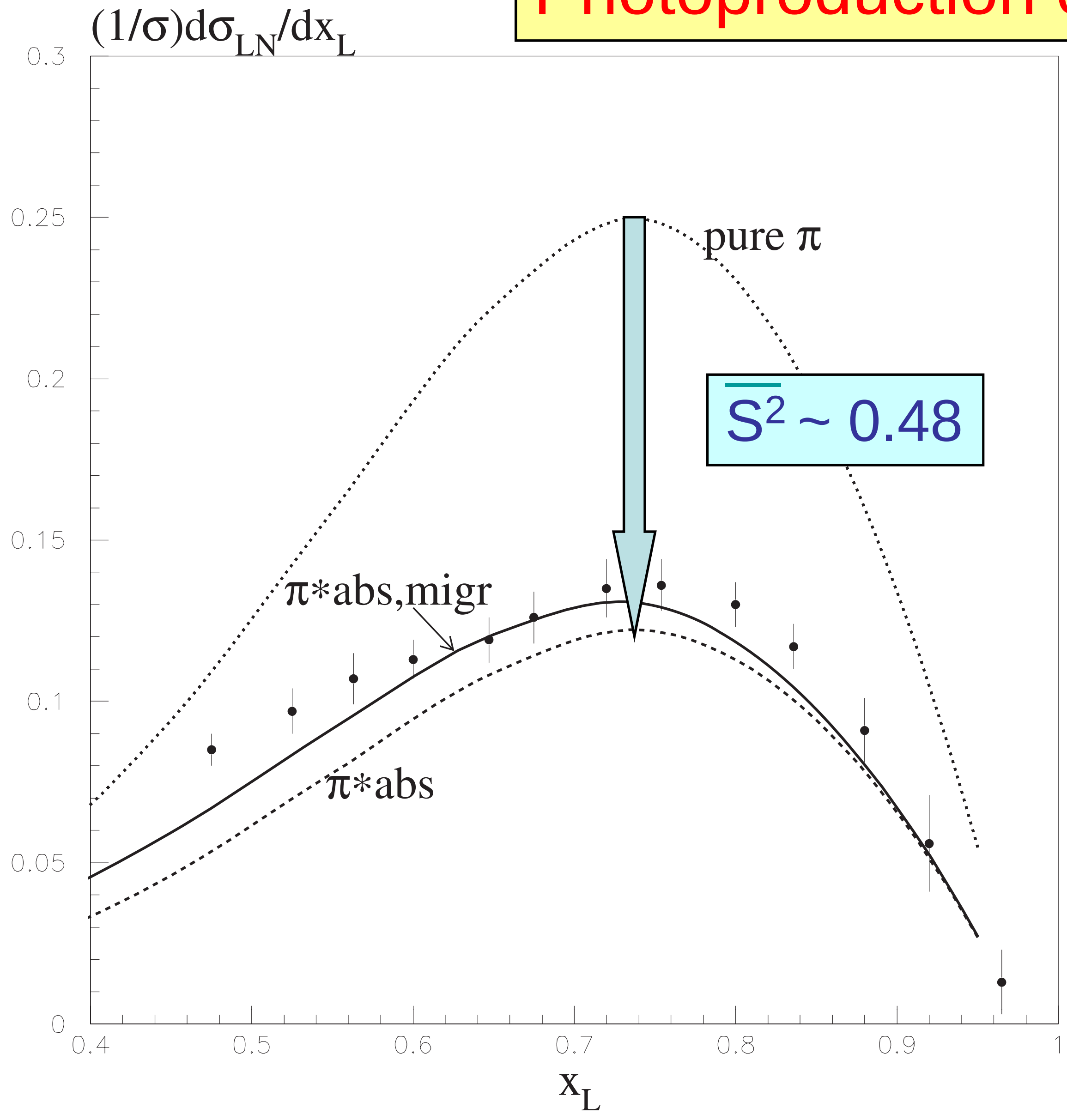
enhanced diag.
need y_i > 2-3:
result ~ 15%

space-time picture

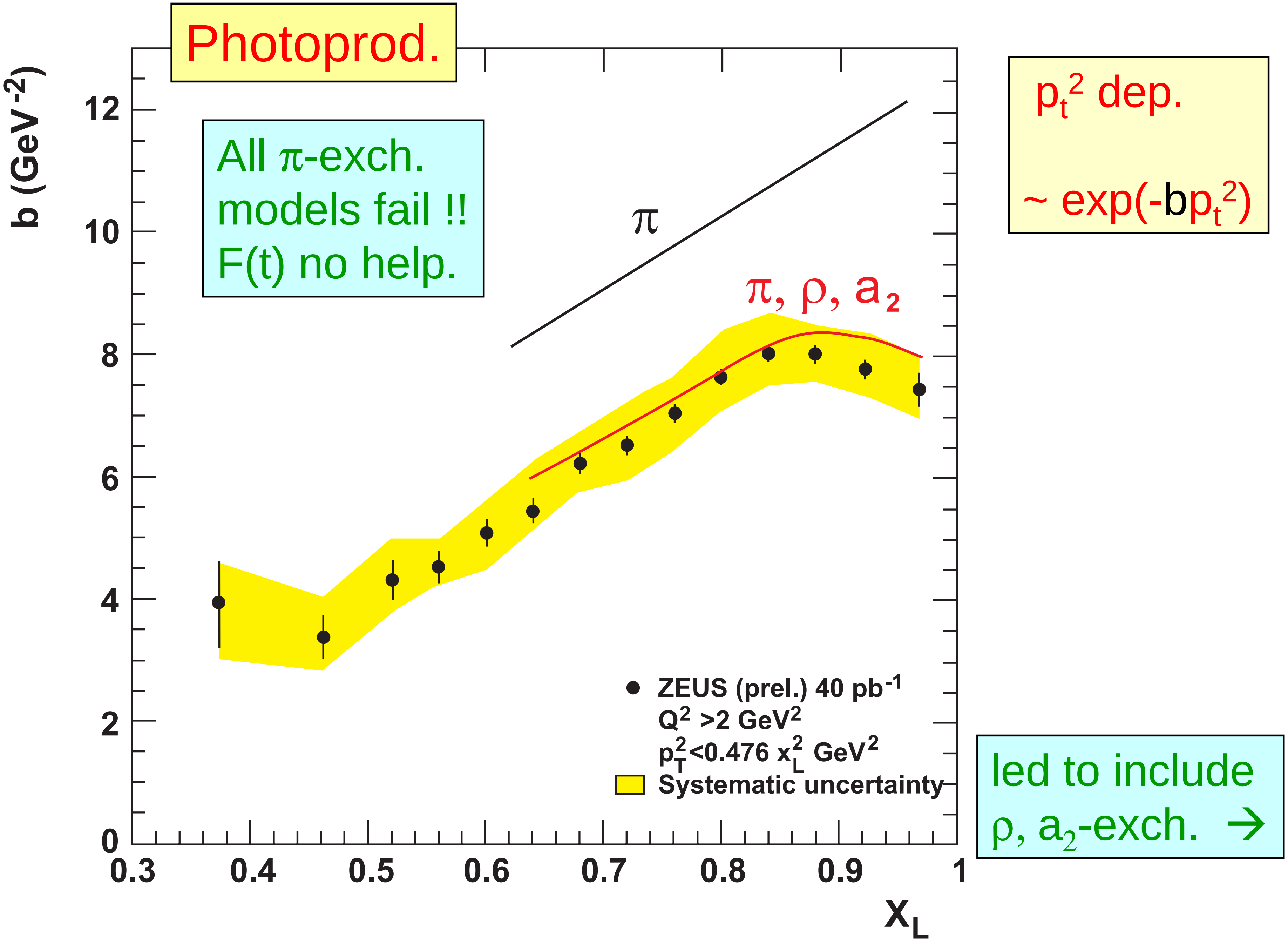


If enhanced diag were important, then n yield would be energy dep.
Not seen in data.

Photoproduction of leading n



Prelim. ZEUS data (DIS2006)

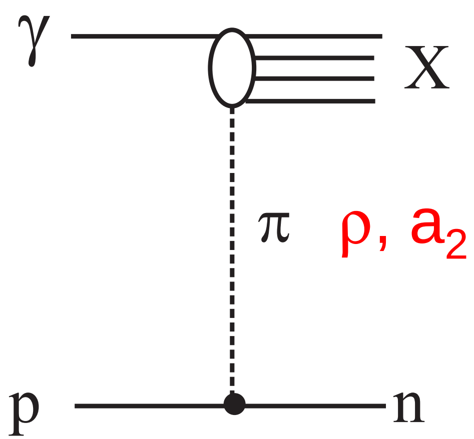


Photoprod.
All π-exch.
models fail !!
F(t) no help.
π
π, ρ, a₂
b (GeV⁻²)
12
10
8
6
4
2
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x_L
ZEUS (prel.) 40 pb⁻¹
Q² >2 GeV²
p_T²<0.476 x_L² GeV²
Systematic uncertainty
p_t² dep.
~ exp(-bp_t²)
led to include
ρ, a₂-exch. →

Including ρ and a_2 exchange

Irving, Worden

$$\frac{V_\rho^{\text{flip}}}{V_\rho^{\text{non-flip}}} \simeq s\, \frac{p_t}{2m_N}$$



large flip

enlarges σ, more at larger p_t
leading to smaller slope, b

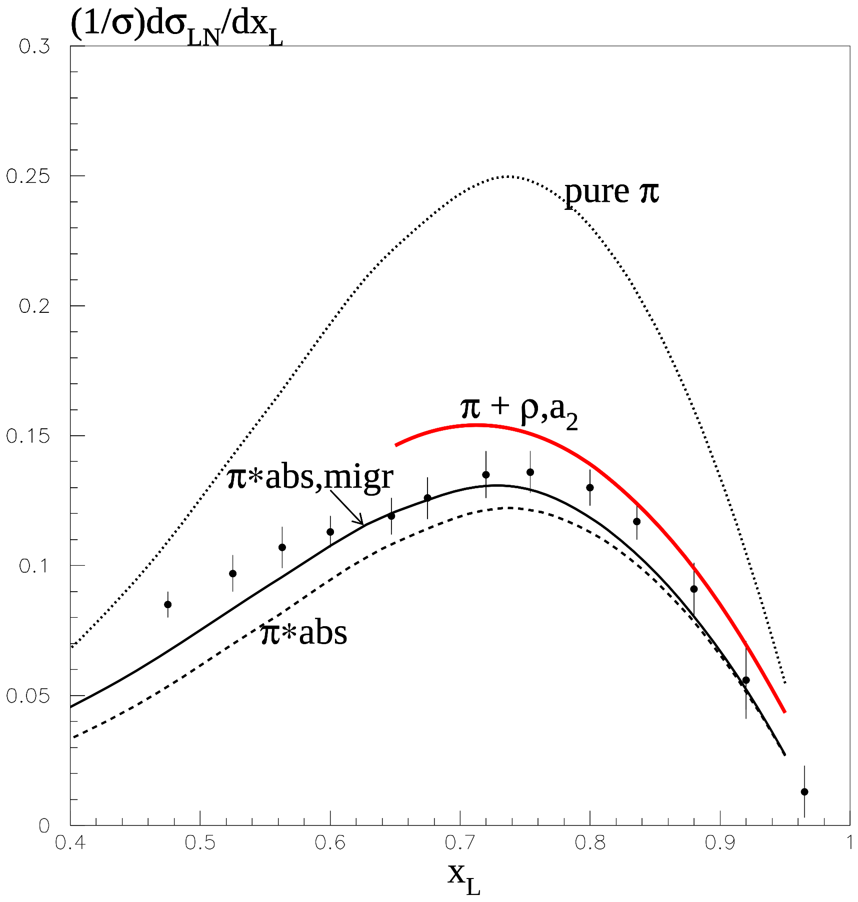
Use ρ, a_2 exch. degeneracy, additive QM

Slope b now OK --- σ too large --- adjust parameters to attempt to simultaneously describe σ and b

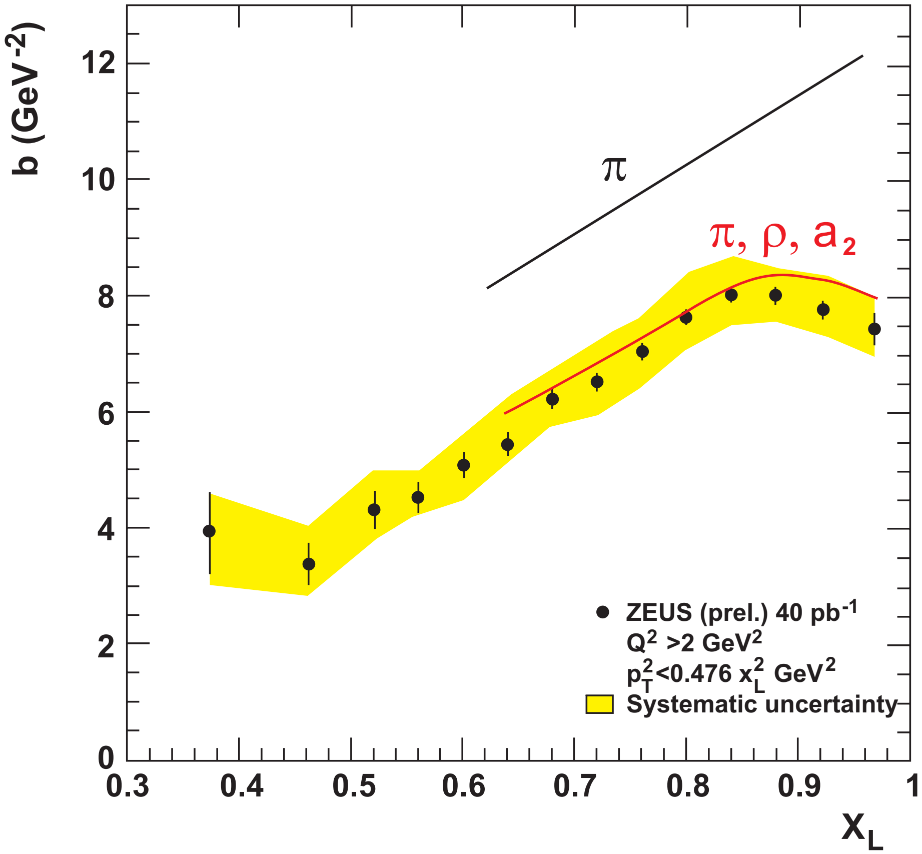
diff^ve. excit. → 1.3 $\left[\sigma(q\bar{q}\text{-}p) \sim \sigma(\rho p) \sim \sigma(\pi p) \sim 31\text{mb}\right]$ $\overline{S^2} \sim 0.48$

1.6 34mb now $\overline{S^2} \sim 0.4$

cross section



p_t^2 slope



now $\overline{S}^2 \sim 0.4$, instead of 0.48

Conclusions on leading neutrons at HERA

- Exploratory study of prelim. ZEUS data (Q^2, x_L, p_t, W) informative for forward physics at LHC

- π exch (with abs.) describes σ, but not p_t^2 slope b
  $\rightarrow$need also ρ, a_2 exchange

  turnover of slope as $x_L \rightarrow 1$ ($t_{min} \rightarrow 0$) may be used to determine ρ, a_2 versus π exchange contributions

- Absorptive corrections important $\overline{S}^2 \sim 0.4$
  Small contrib. from enhanced diagrams

  important for LHC

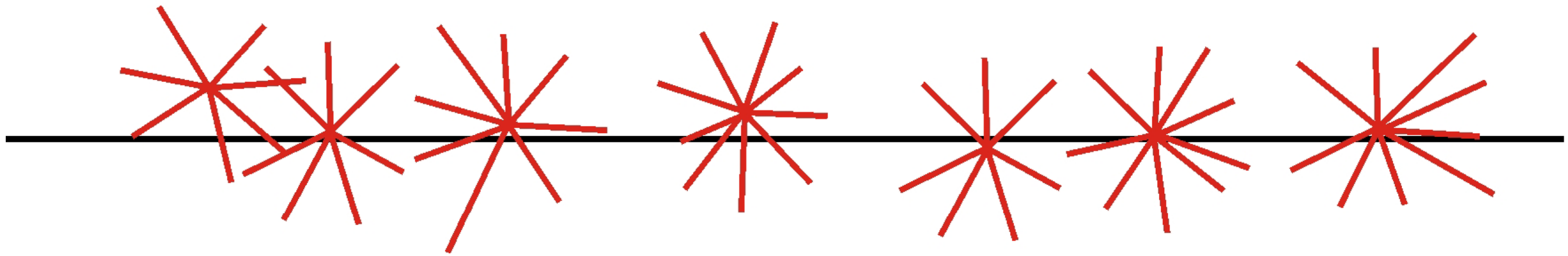
- Simultaneous description all data (Q^2, x_L, p_t dep.) difficult

- This is good. Precise LN data should determine $F_2^{\pi}(x,Q^2)$ at small x and $S^2(x_L,p_t,Q^2)$

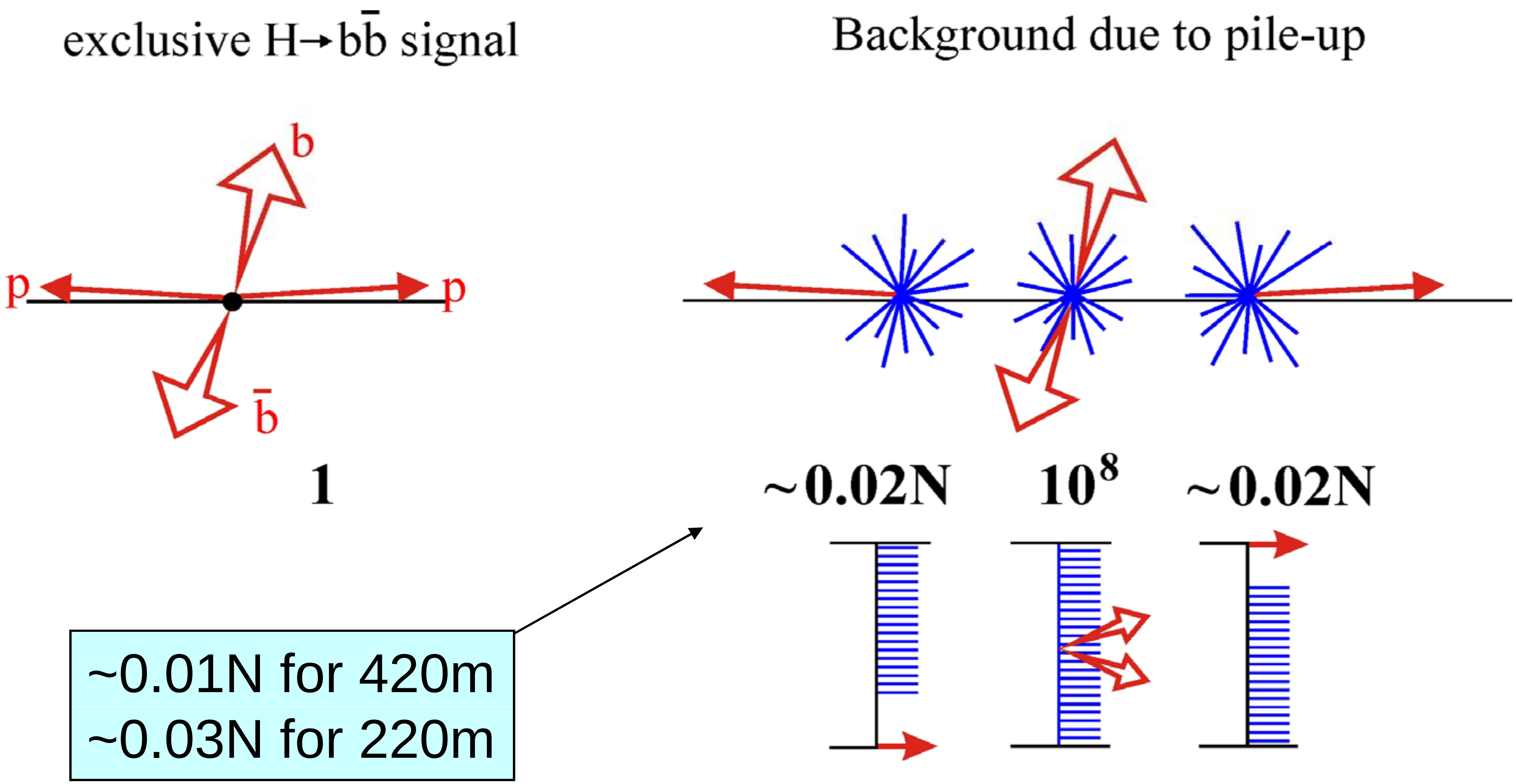
LHC

Pile-up $\mathscr{L} = 10^{33}$ cm^{-2} sec^{-1} N = 3.5

10^{34} N = 35



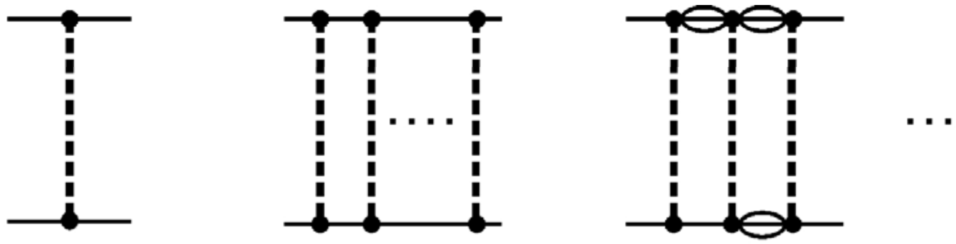
every bunch crossing !



need to predict SD….see Misha Ryskin's talk

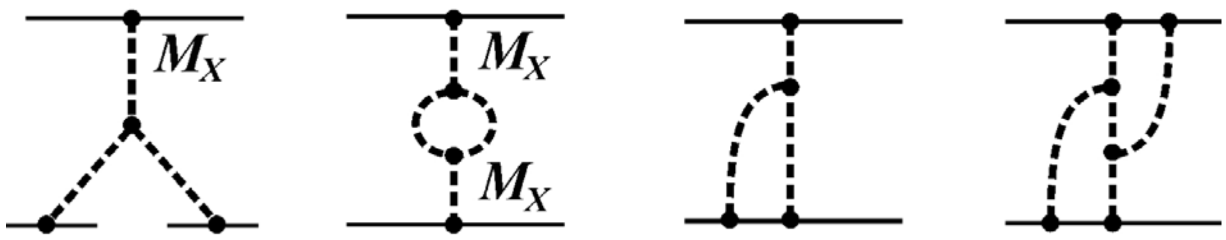
Forward physics at LHC needs predictions for leading protons

s-channel unitarity generates a whole sequence of multi-Pomeron diagrams: → (low-mass) SD, DD



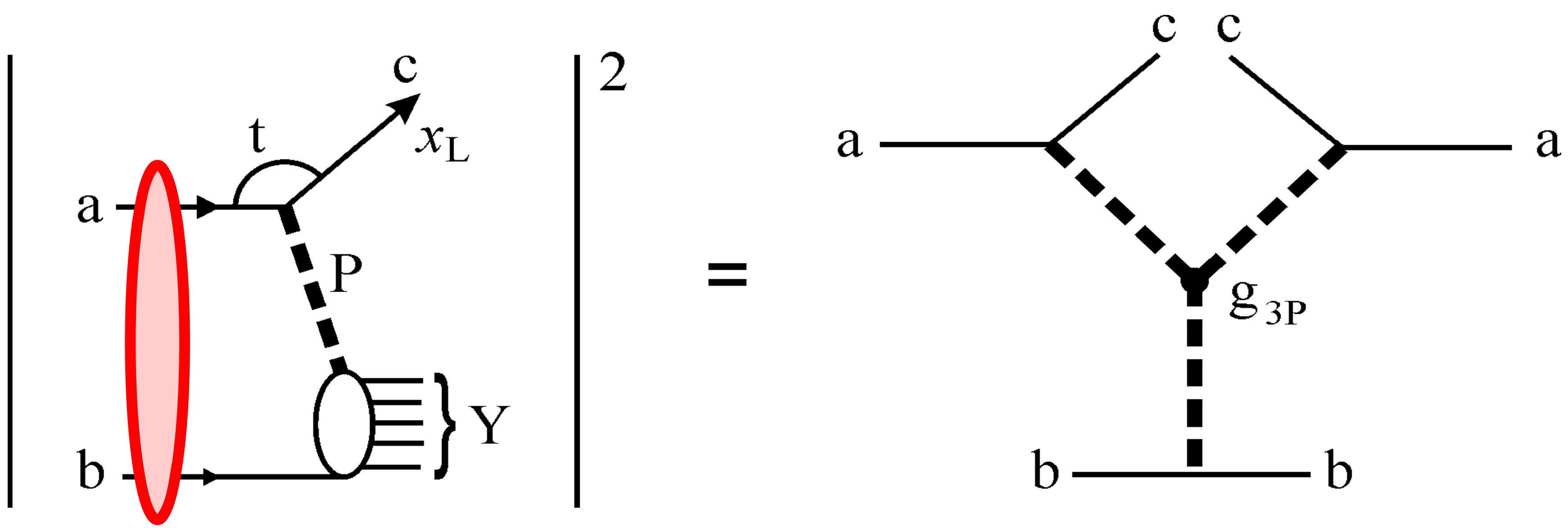
(multi-ch eikonal)

Also have non-eikonal high-mass SD, DD :



need triple-Pomeron coupling g_{3P}

Determination of triple-Pomeron coupling g_{3P}

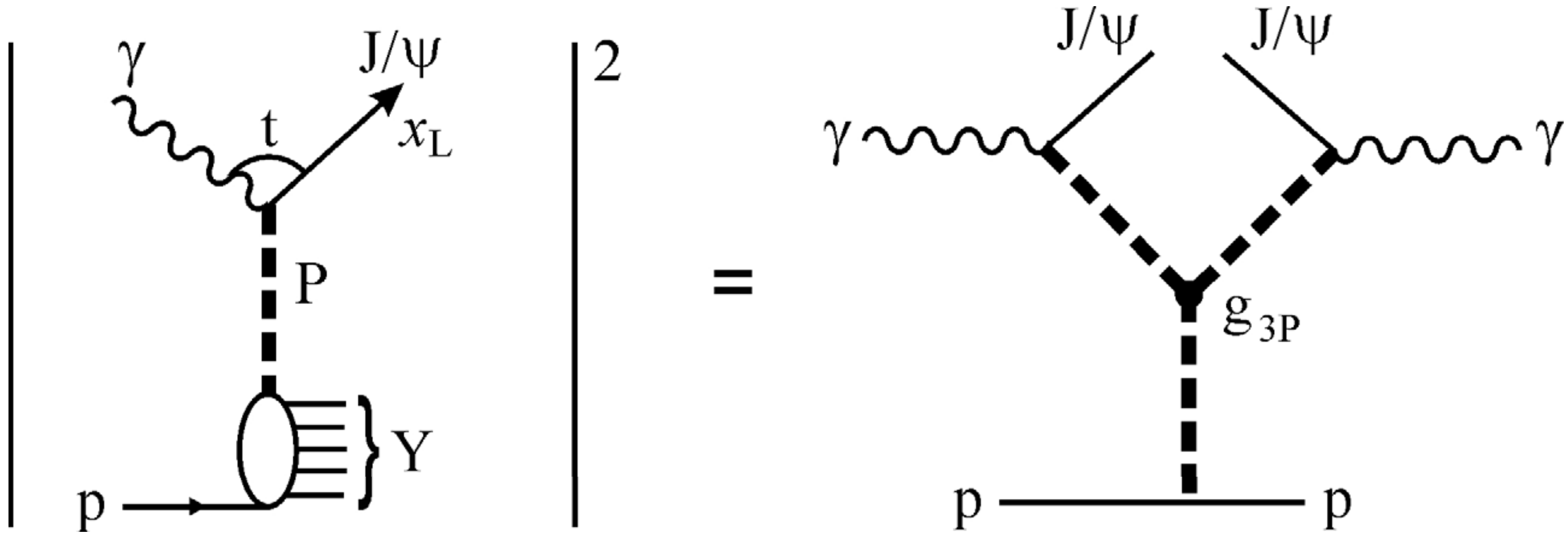


e.g. pp→pY, πp→πY….   at large M_Y and s/M_Y^2

Soft rescatt: leading hadron → secondaries → smaller x_L
→ populate/destroy rapidity gap

old hadron data → effective g_{3P} (which embodies S^2)

Estimate of bare triple-Pomeron coupling g_{3P}



$c\bar{c}$ system v. compact → rescatt. suppressed

so need $\gamma p \to J/\psi$ Y data as a func. of large M_Y

some info.exists as bkgd to $\gamma p \to J/\psi$ p ZEUS,H1

ZEUS,H1

		$\sigma_i \sim W^{\delta_i}$	$\sigma \sim e^{bt}$
elastic	$\gamma p \to J/\psi\, p$	$\delta_{el} \sim 0.7 \pm 0.05$	$b_{el} \sim 4.5$
incl. Y	$\gamma p \to J/\psi\, Y$	$\delta_Y \sim 0.7 \pm 0.2$	$b_Y \sim 0.7$

$$\sigma_Y \sim (M_Y^2)^{0.08}$$ ← expected for PPP

(expected for PPP → δ_Y)

PPP more compact than proton (→ b_Y)

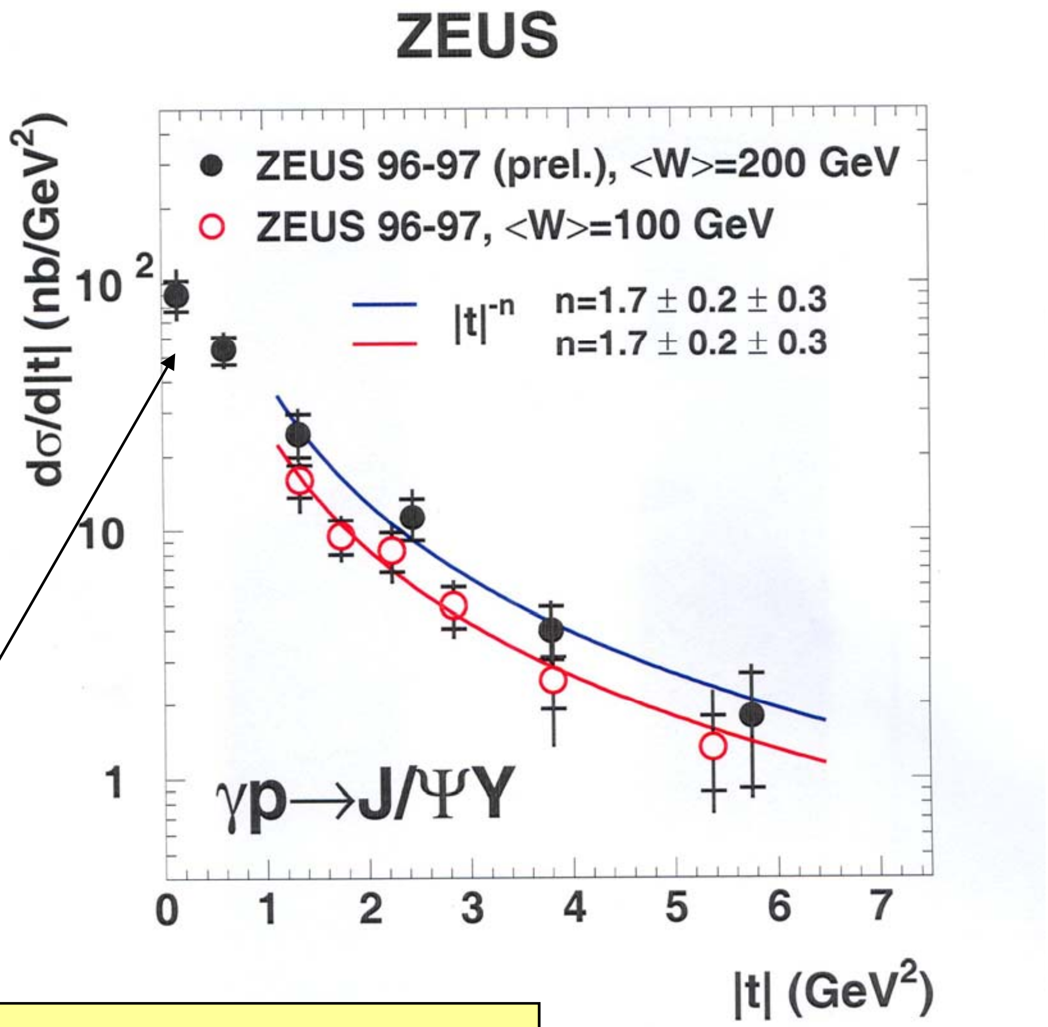
$\gamma p \to J/\psi$: $\frac{\sigma_Y}{\sigma_{el}} \simeq 1 \pm 0.3$

$\gamma p \to \rho$: $\frac{\sigma_Y}{\sigma_{el}} \simeq 0.6 \pm 0.2$

} stronger abs. for ρ

$$\frac{\int \frac{d\sigma_Y}{dt\, dM_Y^2}\, dM_Y^2}{\frac{d\sigma_{el}}{dt}} \Rightarrow \frac{g_{3P}^{bare}}{g_N} \sim \frac{1}{3} \quad \left(\frac{g_{3P}^{eff}}{g_N} \sim \frac{1}{10}\right)$$

(new) (old)



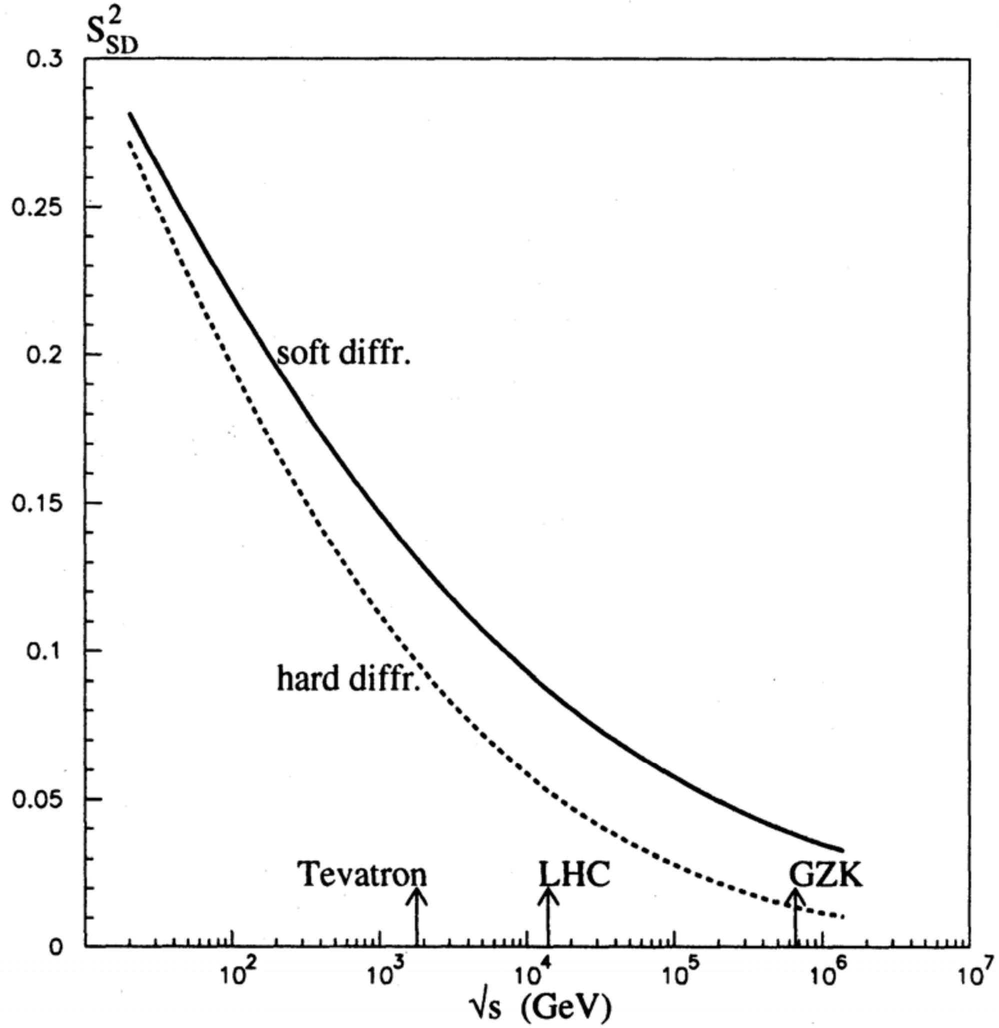
first evidence that $g_{3P}(t)$ does not vanish as $t \rightarrow 0$.

first exptal. evidence of "strong coupling" of Pomeron

$$\frac{1}{\sigma_{tot}} \frac{d\sigma^{SD}}{dt\,dx_L} \sim \frac{g_N^2(t)\, g_{3\mathbb{P}}(t)}{g_N(0)} (1-x_L)^{\alpha_{\mathbb{P}}(0)-2\alpha_{\mathbb{P}}(t)} \, S^2_{SD}(s,t)$$

factors ~0.5 ~0.5
from data in going
W = 20→1800 GeV

consistent with
decrease of $S^2(s)$.



Unlike limiting $frag^{n.}$ hypothesis, normalised σ depends on energy due to S^2

Conclusions

Leading neutrons/forward physics: S^2 is important
but no effect from enhanced diagrams

Forward physics at LHC needs prediction of SD
to quantify “pile-up” backgrounds
see following talks

From inclusive $\gamma p \rightarrow J/\psi\ Y$ photoprod. we estimate
the bare g_{3P} coupling to be about 3 times larger
than old hadron estimate of the effective g_{3P}.
(already anticipated---but is a direct estimate)

Conclusions continued…

Is “soft” physics a speciality at the LHC, since
first interest is in high p_t leptons, photons and jets ??

No --- perhaps it is generally important !
At LHC need good knowledge of underlying event.

e.g. consider $H \rightarrow \gamma\gamma$ with small signal on huge bkgd.
Accurate $\gamma\gamma$ mass is crucial – but what about π^0’s
from underlying/pile-up events !! Correlations.

(Moreover some believe there is deep theoretical
link between “soft” and “hard” physics.)