Single Spin Asymmetry at Large x_F and $k_\perp$

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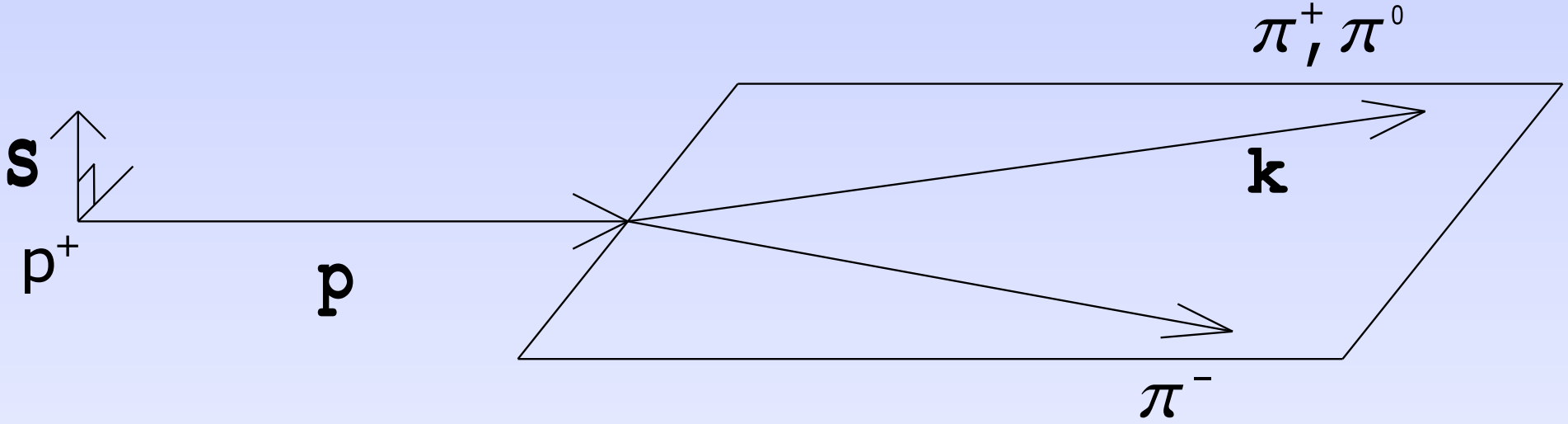
Outline

Single spin asymmetry in $p^{\uparrow}p \to \pi X$ as a coherence effect

- Long motivation
  - Experimental data
  - Previous studies of large x_F coherence effects
- $p^{\uparrow}p \to \pi X$ at large x_F: sample calculation
- Conclusion

Transverse SSA in $p^{\uparrow}p \to \pi(x_F, k_\perp) + X$



$$\boldsymbol{k} = (x_F\, p_{\rm lab}, \boldsymbol{k}_\perp)$$

We concentrate on forward pions (large x_F)

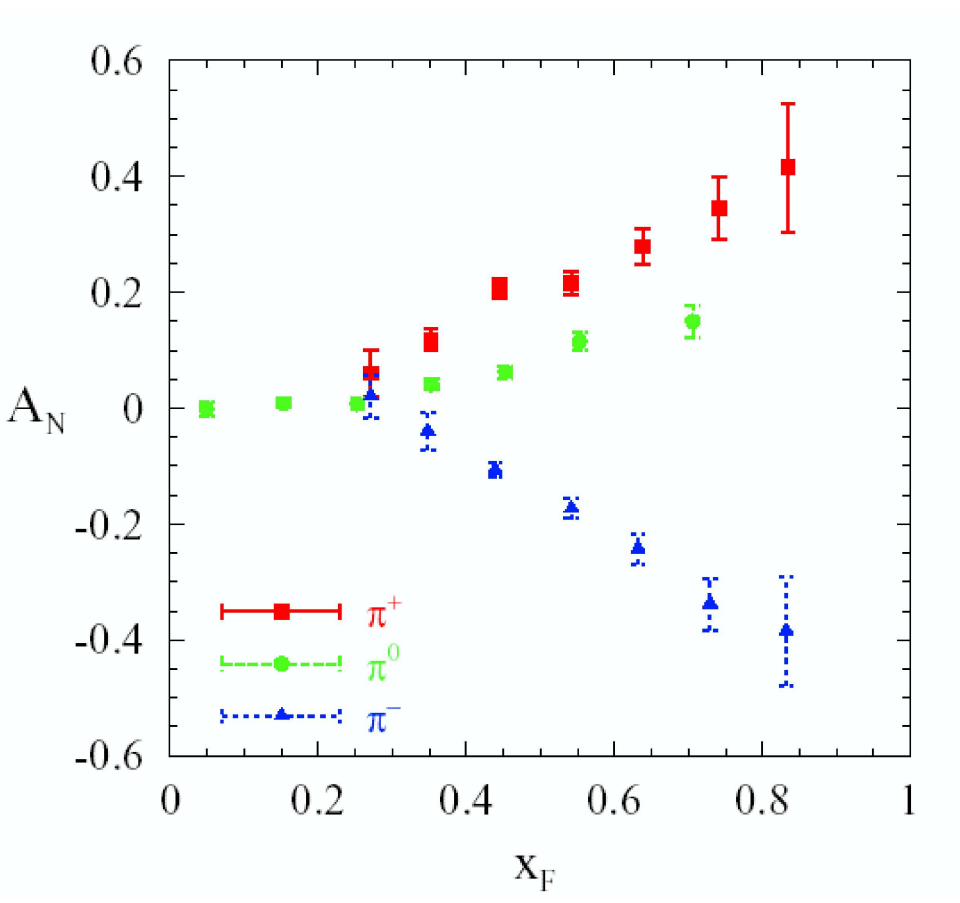
Pion transverse momentum $k_\perp$ sets the hard scale

$$A_N(x_F, k_\perp) \propto \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

Motivation: Data for $p^{\uparrow}p \to \pi(x_F, \boldsymbol{k}_\perp) + X$

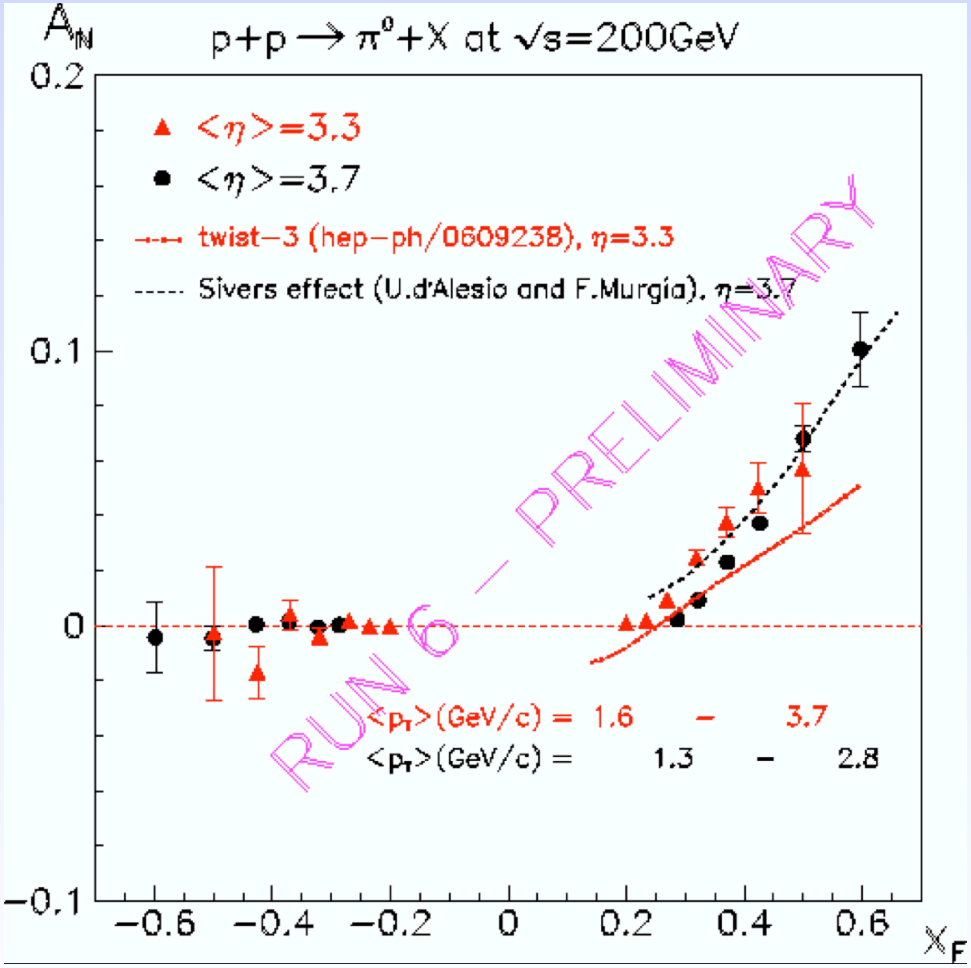
FNAL-E704 data ($\sqrt{s} = 20$GeV, $k_\perp \sim$1-2GeV):

[PLB261(1991)201, PLB264(1991)462]



STAR data: A_N for π^0 production at $\sqrt{s} = 200\text{GeV}$

[arXiv:0705.3483]

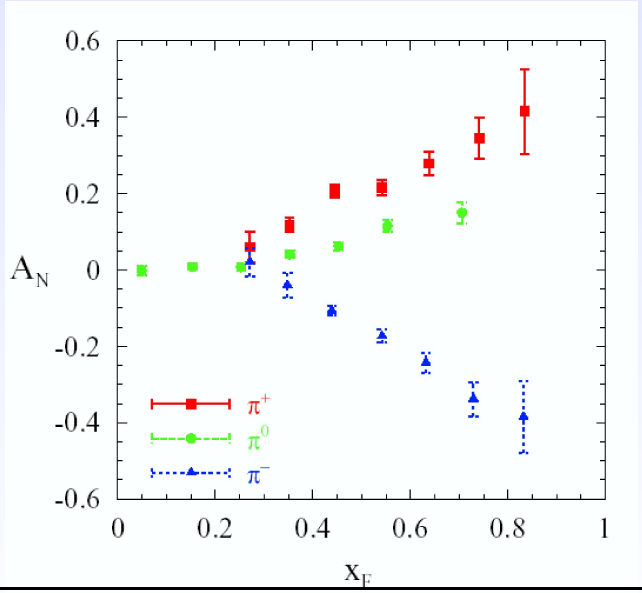


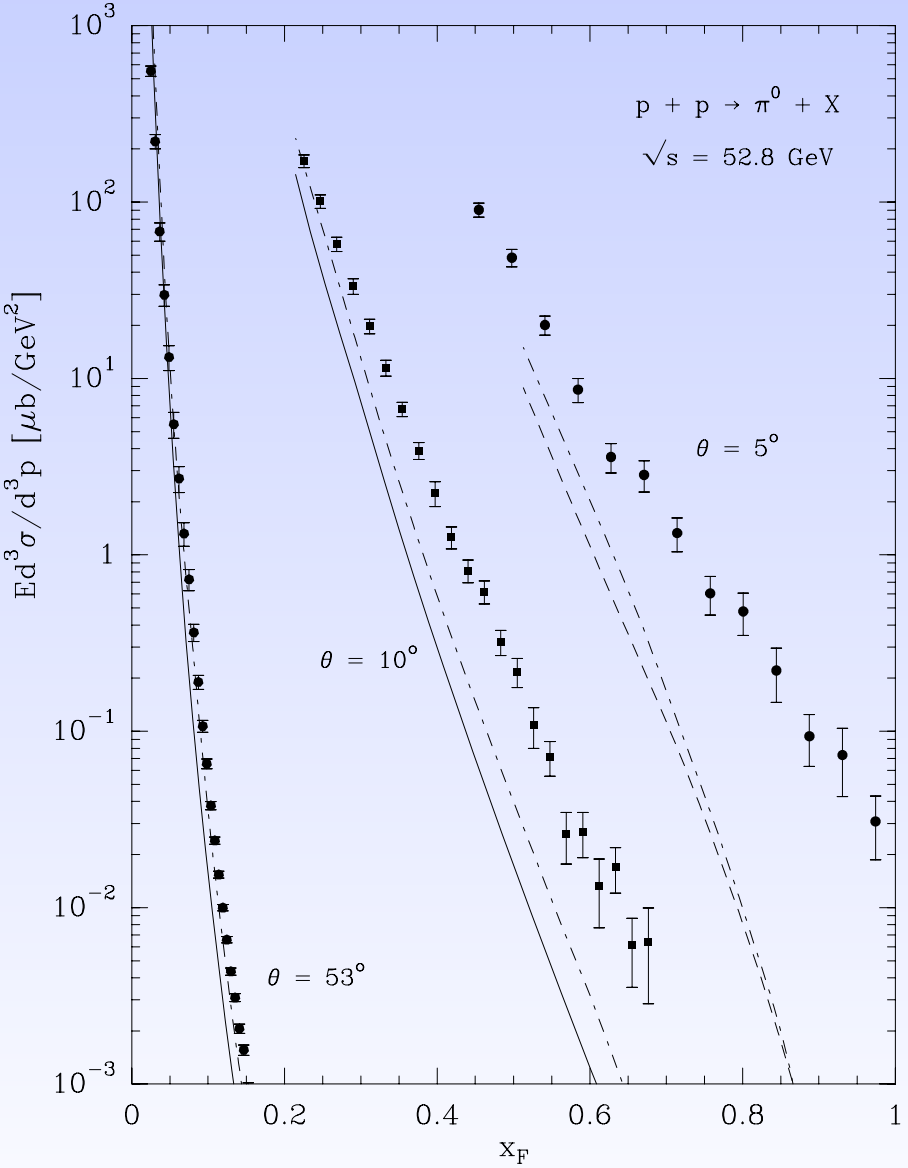
Motivation: Failure of PQCD for forward π^0

$x_F \simeq 0.8 \Rightarrow$ Distribution and fragmentation functions with $x, z \sim 0.9$

NLO PQCD fails to produce the total cross-section for forward $pp \to \pi^0 X$ for $\sqrt{s} = 52.8$ GeV

[Bourrely, Soffer EPJC36(2004)371]

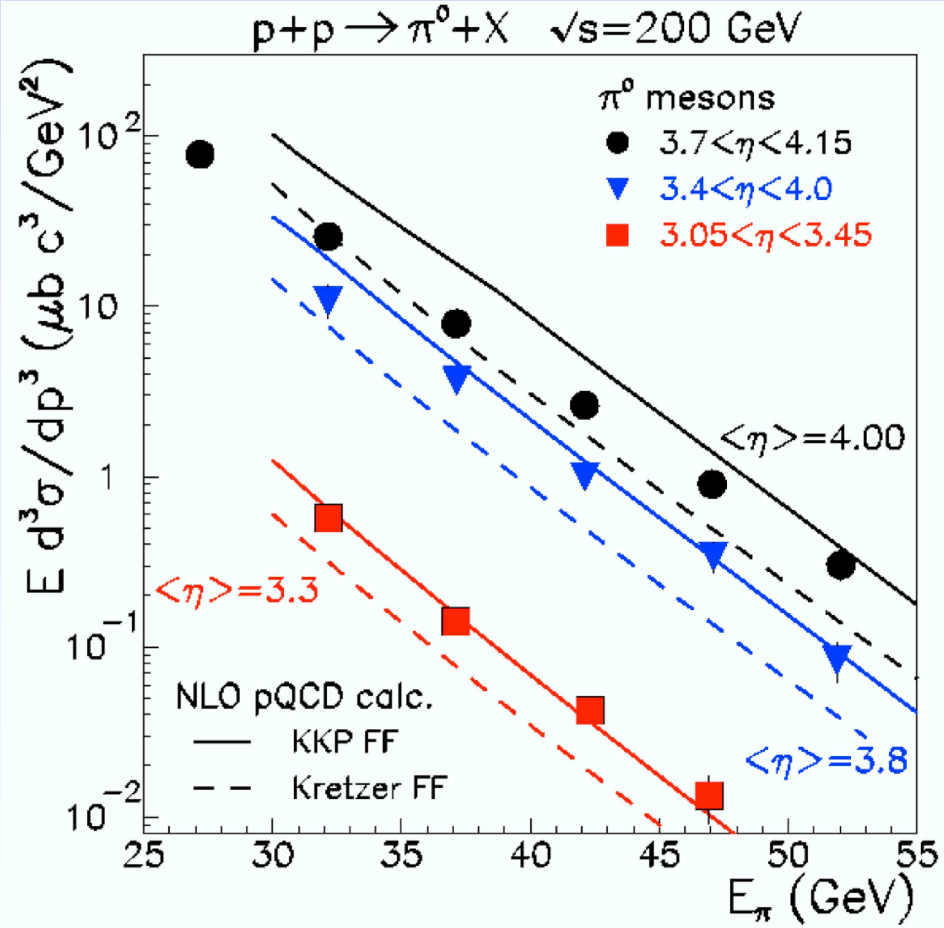


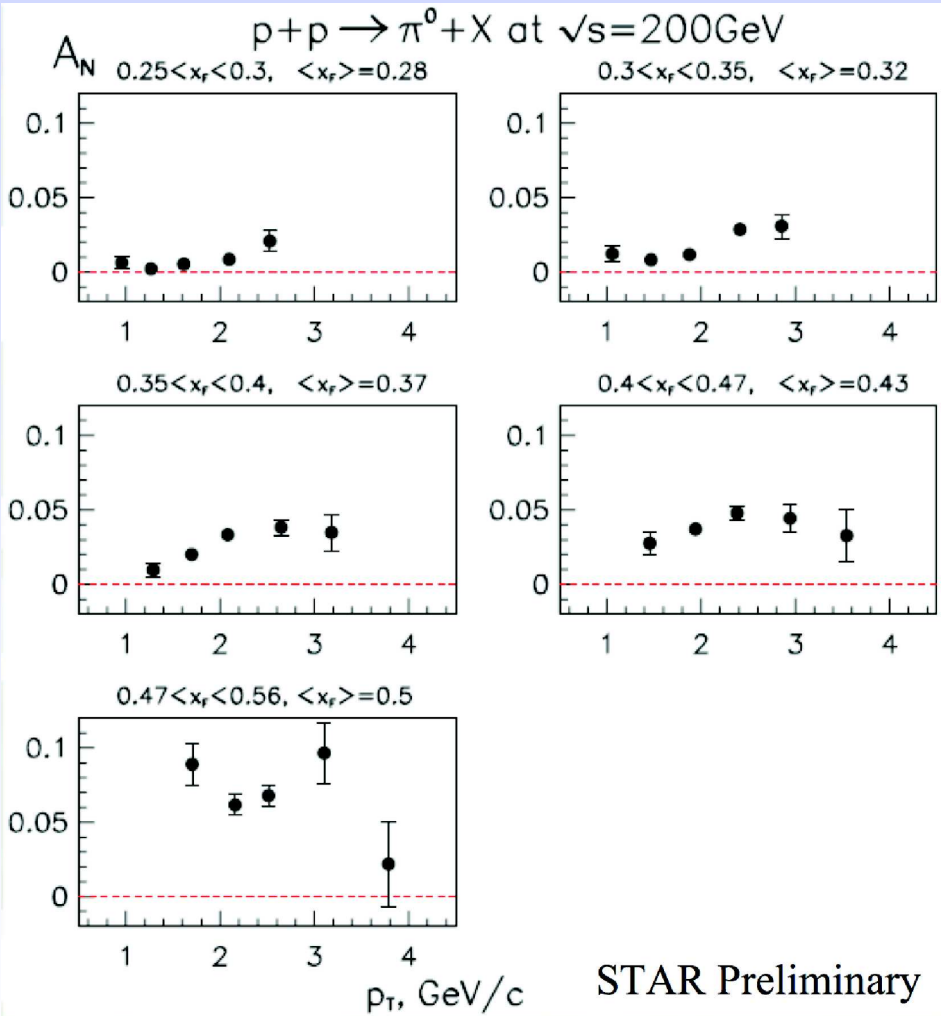


Motivation: PQCD predictions and STAR results

STAR total cross section is consistent with PQCD

However, the predicted behavior $A_N \propto \Lambda_{QCD}/k_\perp$ is not seen



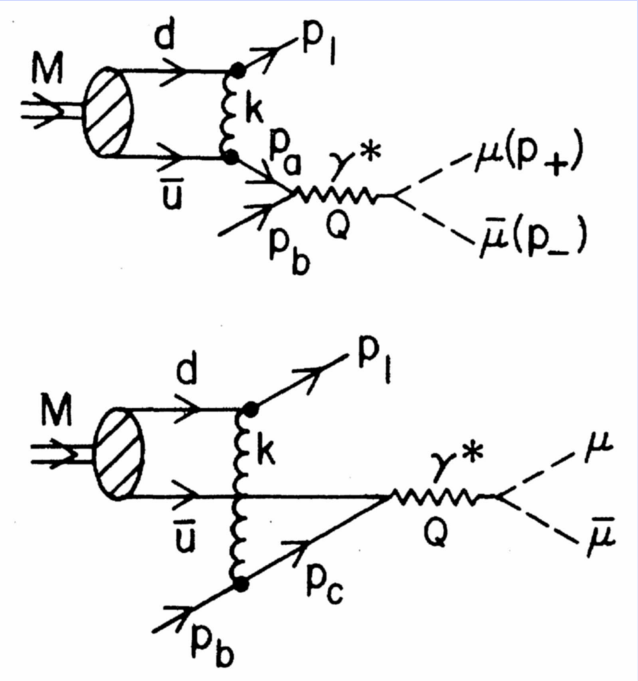


Motivation: Coherence effects at large x_F

- Large x_F coherence effects studied in (unpolarized) Drell-Yan $\pi p \to \mu^+ \mu^- X$
- Physics at large x_F involves the full (multiquark) projectile wave function: Single quark factorization fails

  [Berger & Brodsky, PRL42(1979)940]
- Expected longitudinal polarization of the γ^* at large x_F later seen in experiments

  [Conway *et al.*, PRD39(1989)92]



Large x_F dynamics

We study $p^{\uparrow}p \to \pi(x_F, \boldsymbol{k}_\perp) + X$ for $k_\perp \to \infty$ with

$k_\perp^2(1-x_F)$ fixed, $\quad k_\perp^2(1-x_F) \sim \Lambda_{QCD}^2$

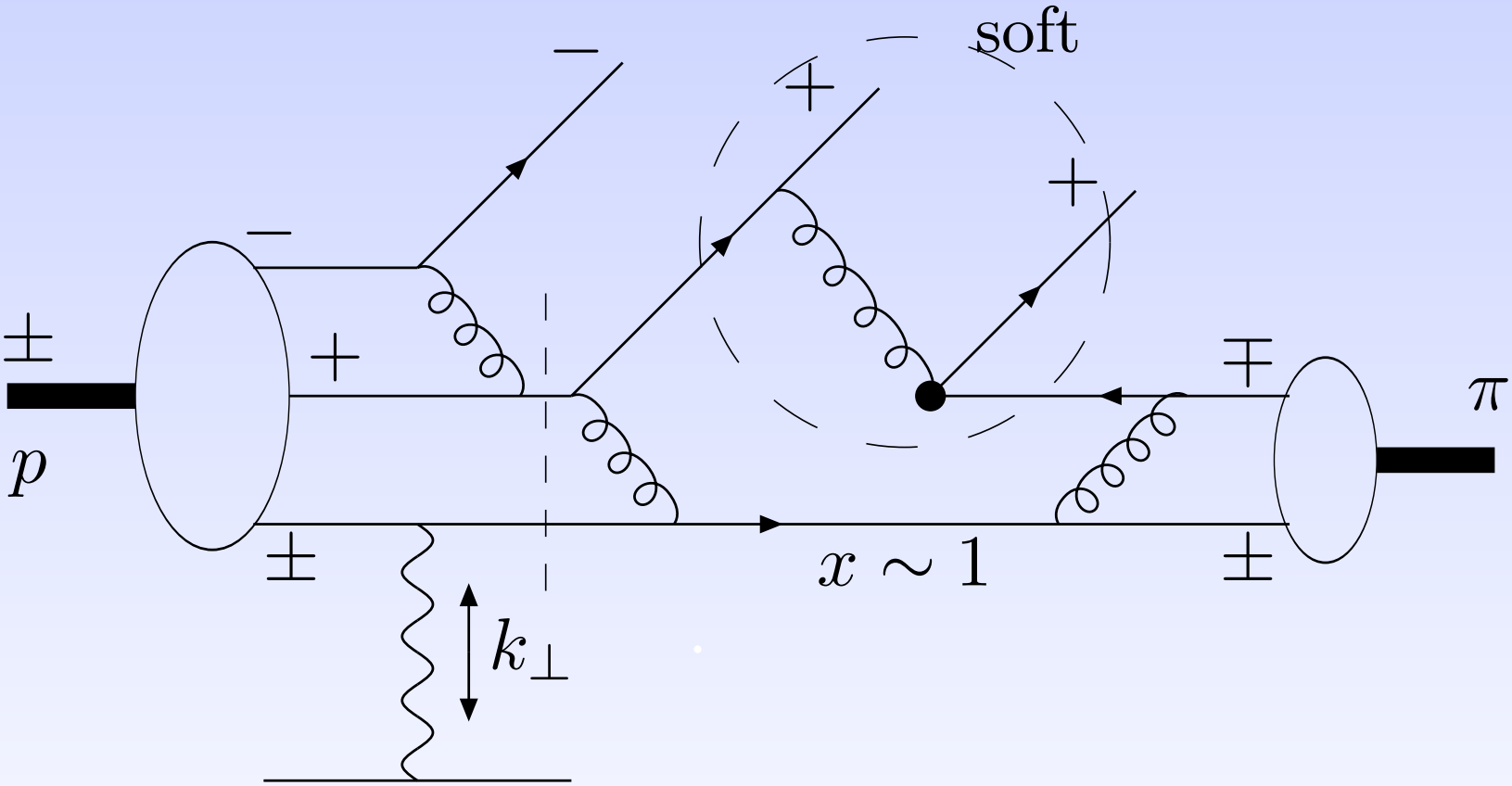
$\Rightarrow$ No single quark factorization

Soft part of the amplitude $\left(\text{scale } \Lambda_{QCD}^2/(1-x_F)\right)$ becomes coherent with the hard interactions $\left(\text{scale } k_\perp^2\right)$

$\Rightarrow$ naturally large A_N ?

A mechanism for a sizeable A_N in $p^\uparrow p \to \pi X$

- Overall coherence at fixed $k_\perp^2(1-x_F)$

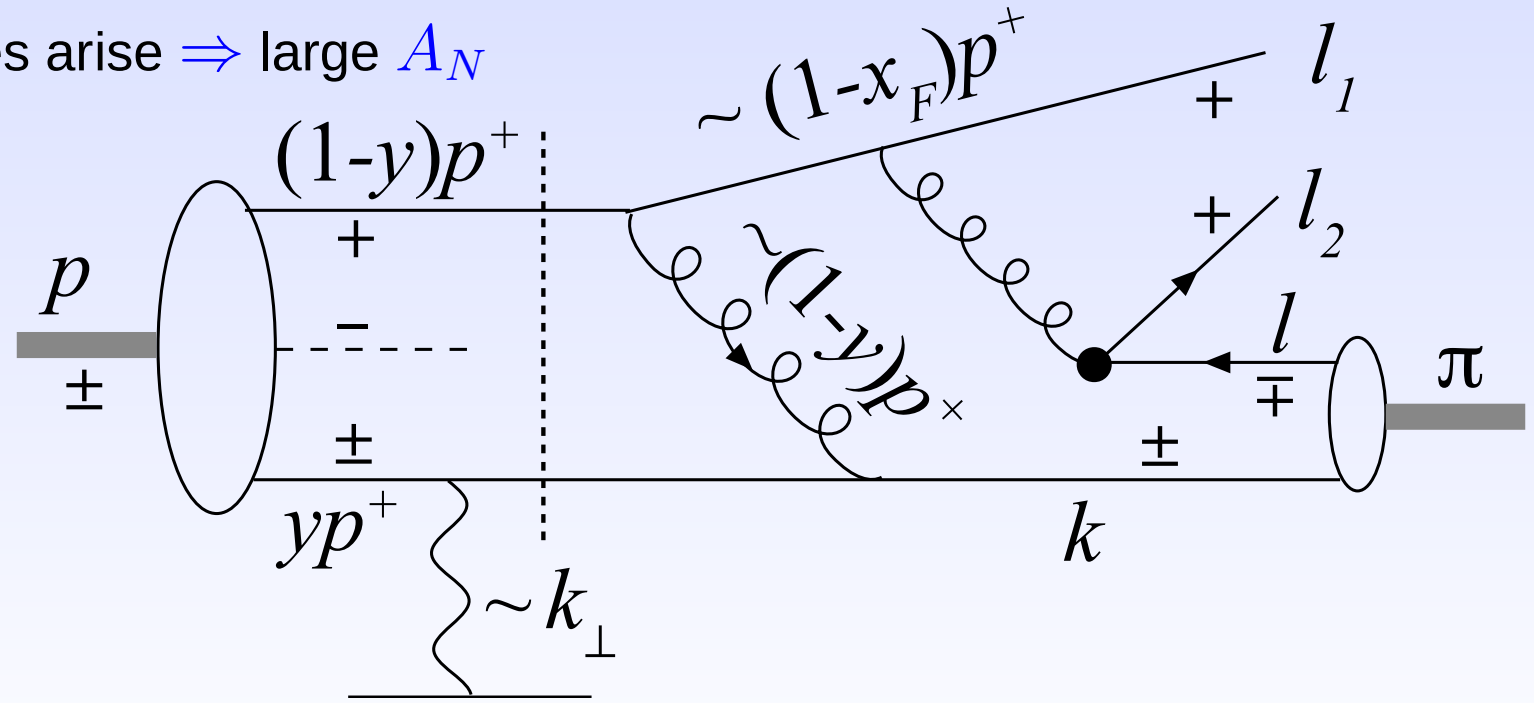


Recall: $A_N \propto \mathrm{Im}\left[\mathcal{M}_{+-}\mathcal{M}^*_{++}\right] \Rightarrow$ Helicity flip and dynamical phase needed

A sample calculation

- We drop one quark from the proton and the gluon exchange inside the pion
- Only a single diagram, Abelian gluons and $s \to \infty$
- The soft quark-antiquark pair has a (constituent) mass $M \sim \Lambda_{QCD}$ to allow the spin flip, otherwise massless quarks

$\Rightarrow$ large phases arise $\Rightarrow$ large A_N



Conclusion

- Multiquark effects arise at $k_\perp^2 (1 - x_F)$ fixed
- If soft and hard parts of the amplitudes are coherent large asymmetries may arise naturally
- Our mechanism for A_N supported by the observed $k_\perp$ dependence