Measuring primordial k_T @ (the) EIC

Mark D. Baker
Brookhaven National Laboratory

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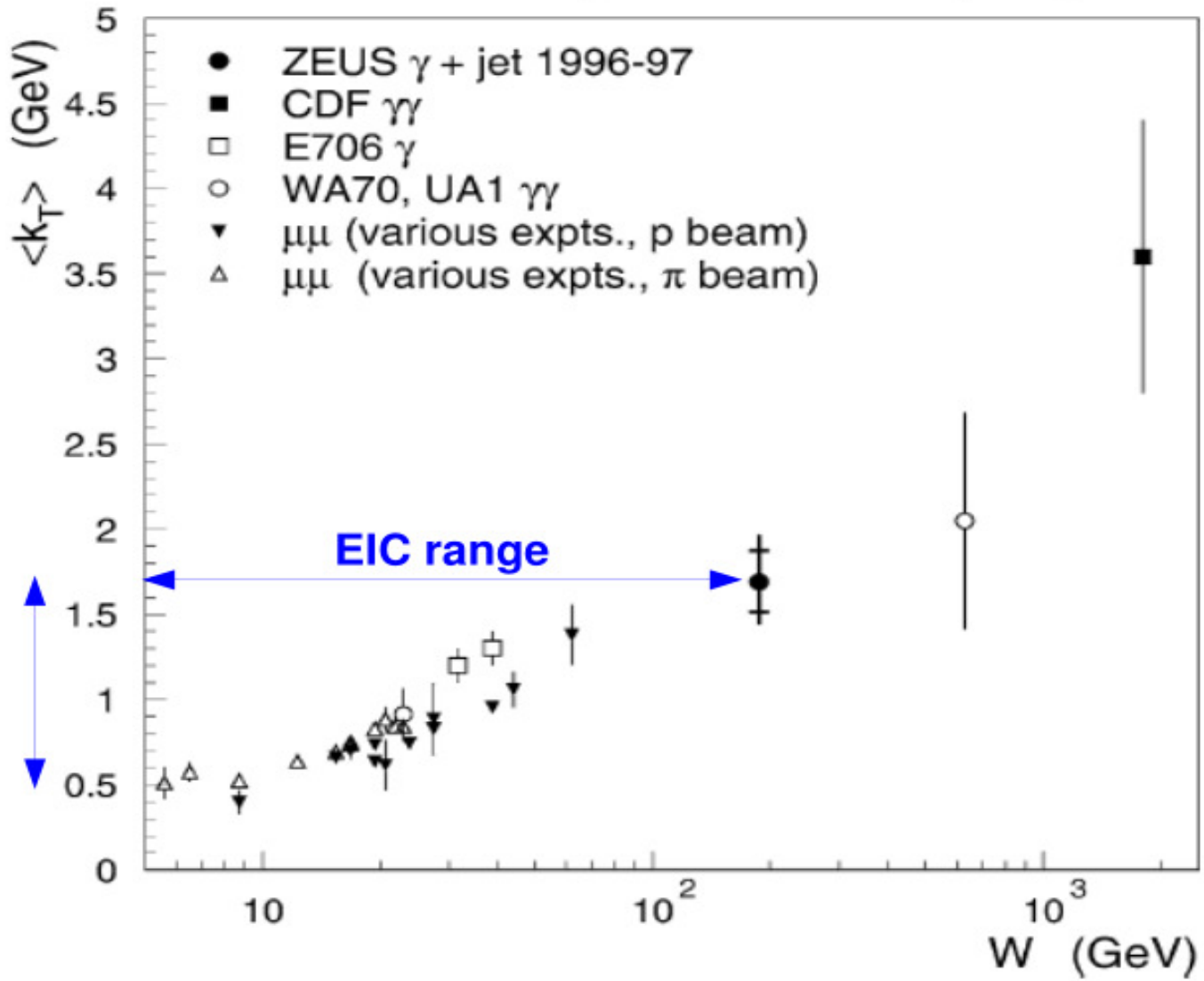
Thanks to: E. Aschenauer, T. Burton, J.H.Lee, & L. Zheng

Intrinsic k_T

- Measuring intrinsic (or primordial) k_T in ep
  - is challenging.
  - is interesting as part of nucleon structure (TMDs).
  - is essential as a baseline for studying Q_s in eA.
- Consider two observables
  - LOST LORE: Full seagull plot: $\langle p_T^2 \rangle$ vs. x_F
  - Azimuthal asymmetry ("Cahn Effect")

Running of effective k_T

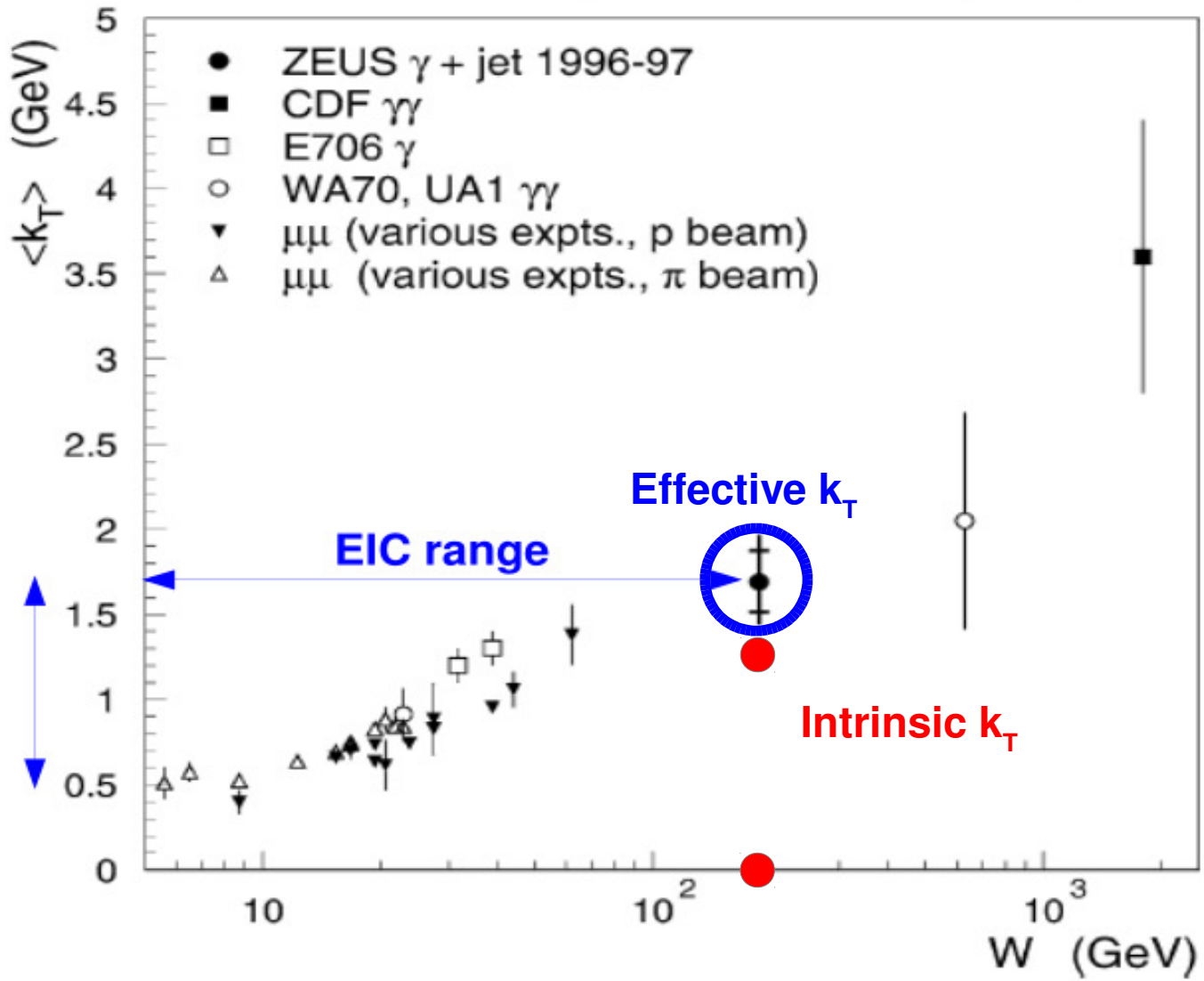
ZEUS Collaboration / Physics Letters B 511 (2001) 19–32



Note: Gaussian: $\langle k_T \rangle = \mathrm{sqrt}(\pi/4) * k_T^{rms}$

Running of effective k_T

ZEUS Collaboration / Physics Letters B 511 (2001) 19–32



ZEUS k_T total = **1.69 GeV** is 1.25 GeV (intrinsic) + parton shower using Pythia 6.1

OR 0 (intrinsic) + ~1.9 GeV parton shower using HERWIG

The Pythia 6 Manual describes the problem nicely

"It is customary to assign a primordial transverse momentum to … take into account the motion of the quarks inside the original hadron..".

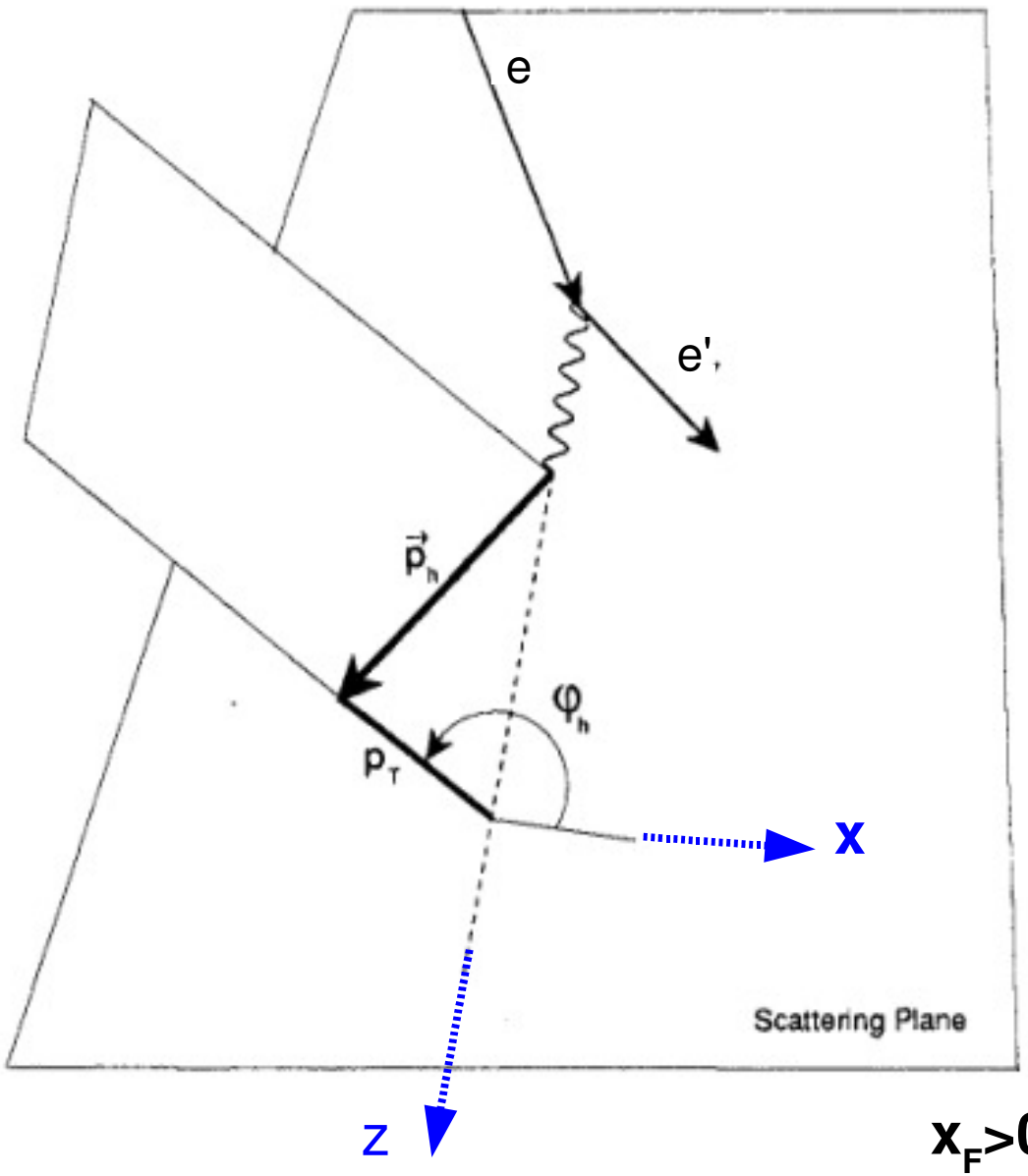
"A number of order … 300 MeV could therefore be expected. However in hadronic collisions much higher numbers than that are often required to describe the data … 1GeV [or] 2 GeV."

"Any shortfall in [parton] shower activity … has to be compensated by the Primordial k_T source, which thereby largely loses its original meaning."

Pythia 6.4 manual hep-ph/0603175

If we don't make measurements that distiguish k_T from PS:
Then it will be difficult to relate k_T to fundamentals like Q_s.

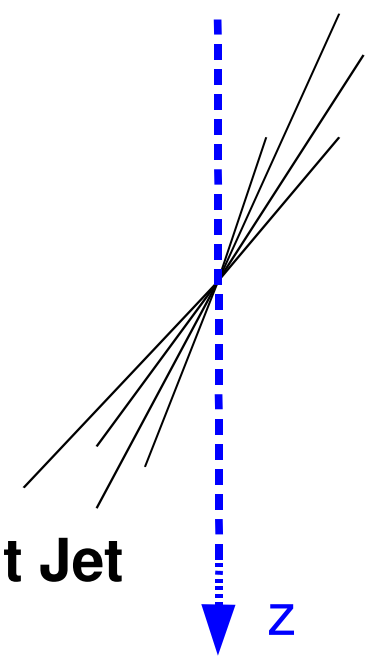
Kinematics in γ*p cm frame



W is the γ*p cm energy

Feynman x: $x_F=2p_z/W$

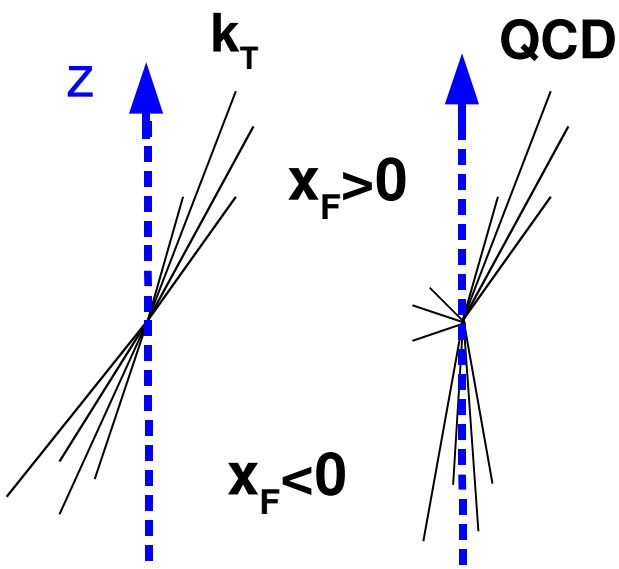
LO DIS:



What does k_T look like?

Basic physics points:

1. Target remnant k_T = - struck parton k_T
2. It is the struck parton that is accelerated and radiates gluons.



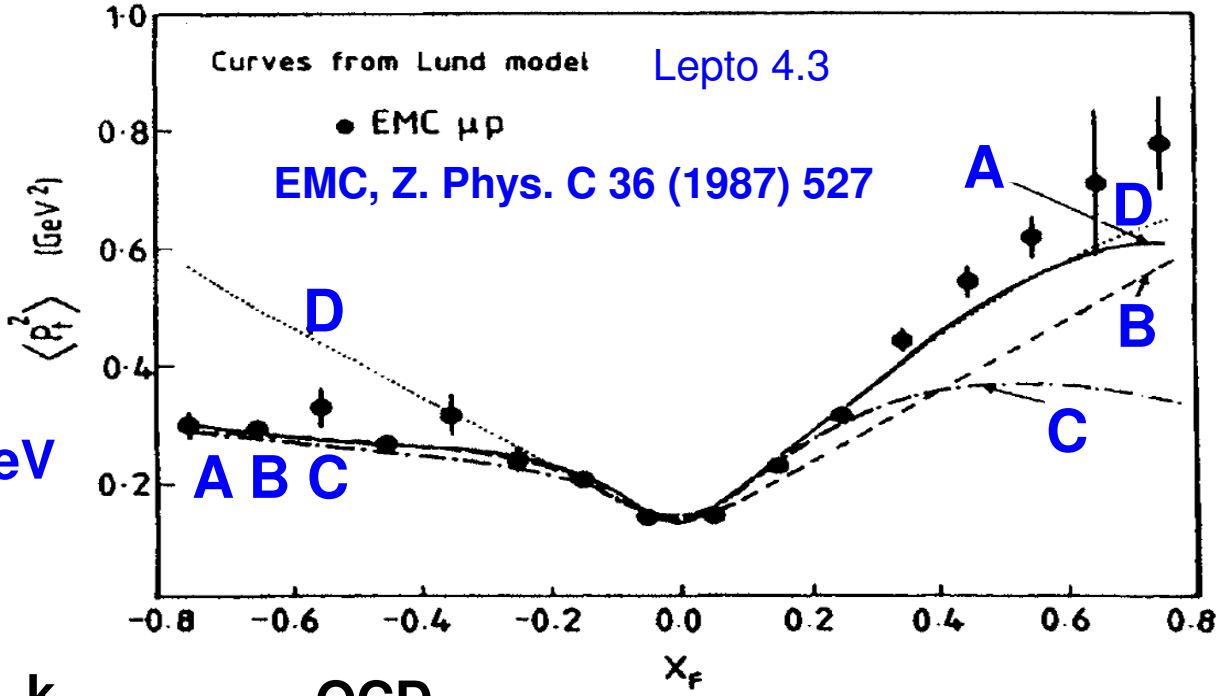
- Primordial parton k_T shows up in both hemispheres.
- QCD radiation only shows up at $x_F \geq 0$

What does k_T look like?

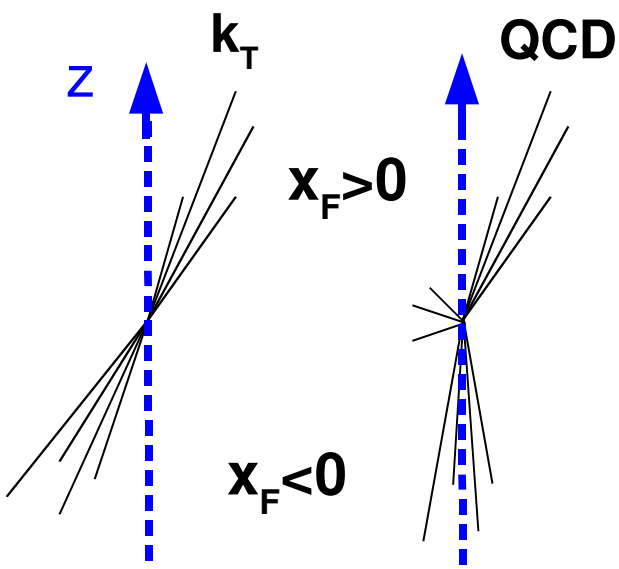
k_T (rms)

D: 0.88 GeV

A-C: 0.44 GeV



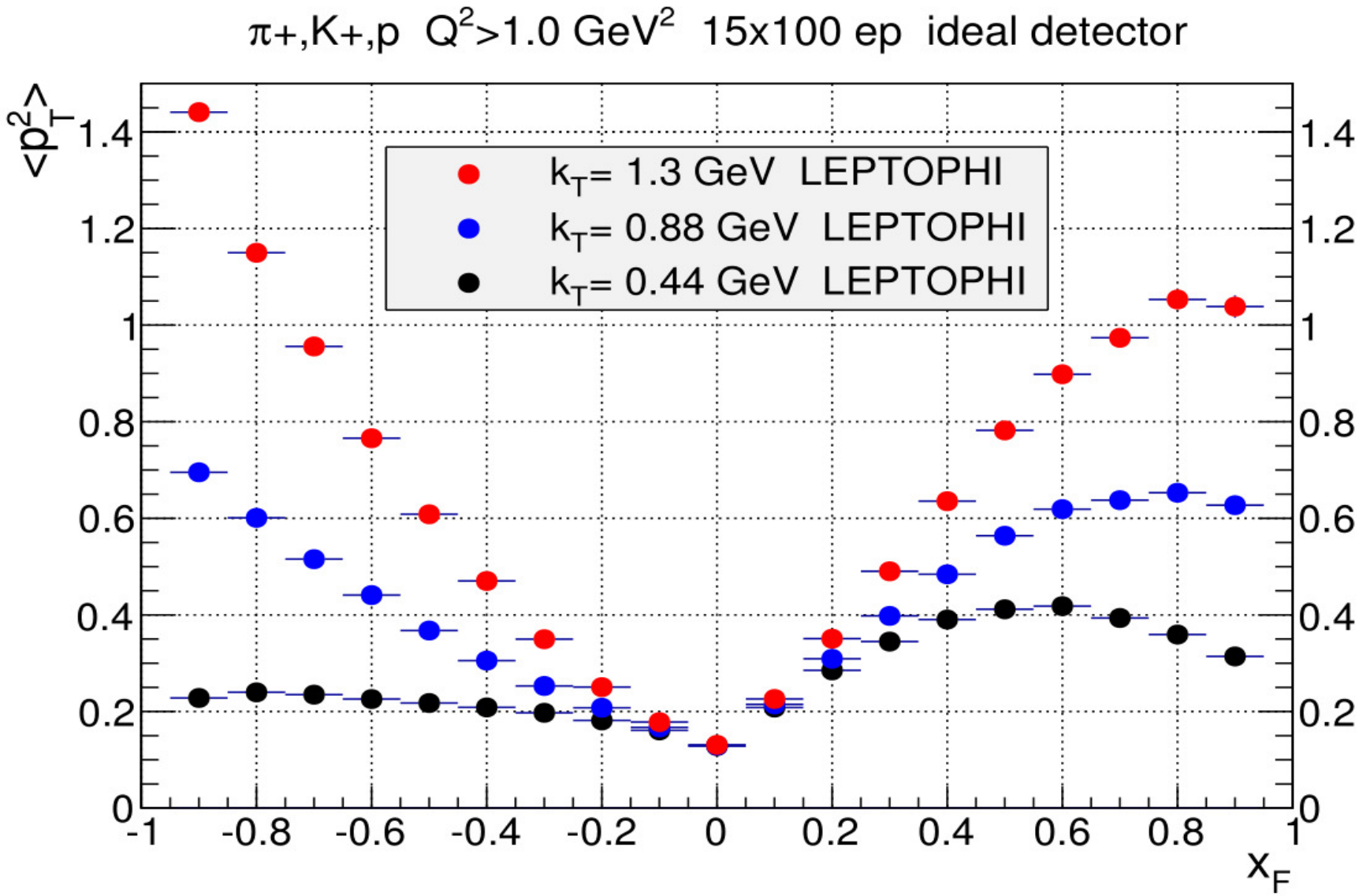
k_T (rms)	Hard QCD	Soft QCD
D 0.88	Y	N
A 0.44	Y	Y
B 0.44	N	Y
C 0.44	Y	N



- Primordial parton k_T shows up in both hemispheres.
- QCD radiation only shows up at $x_F \geq 0$

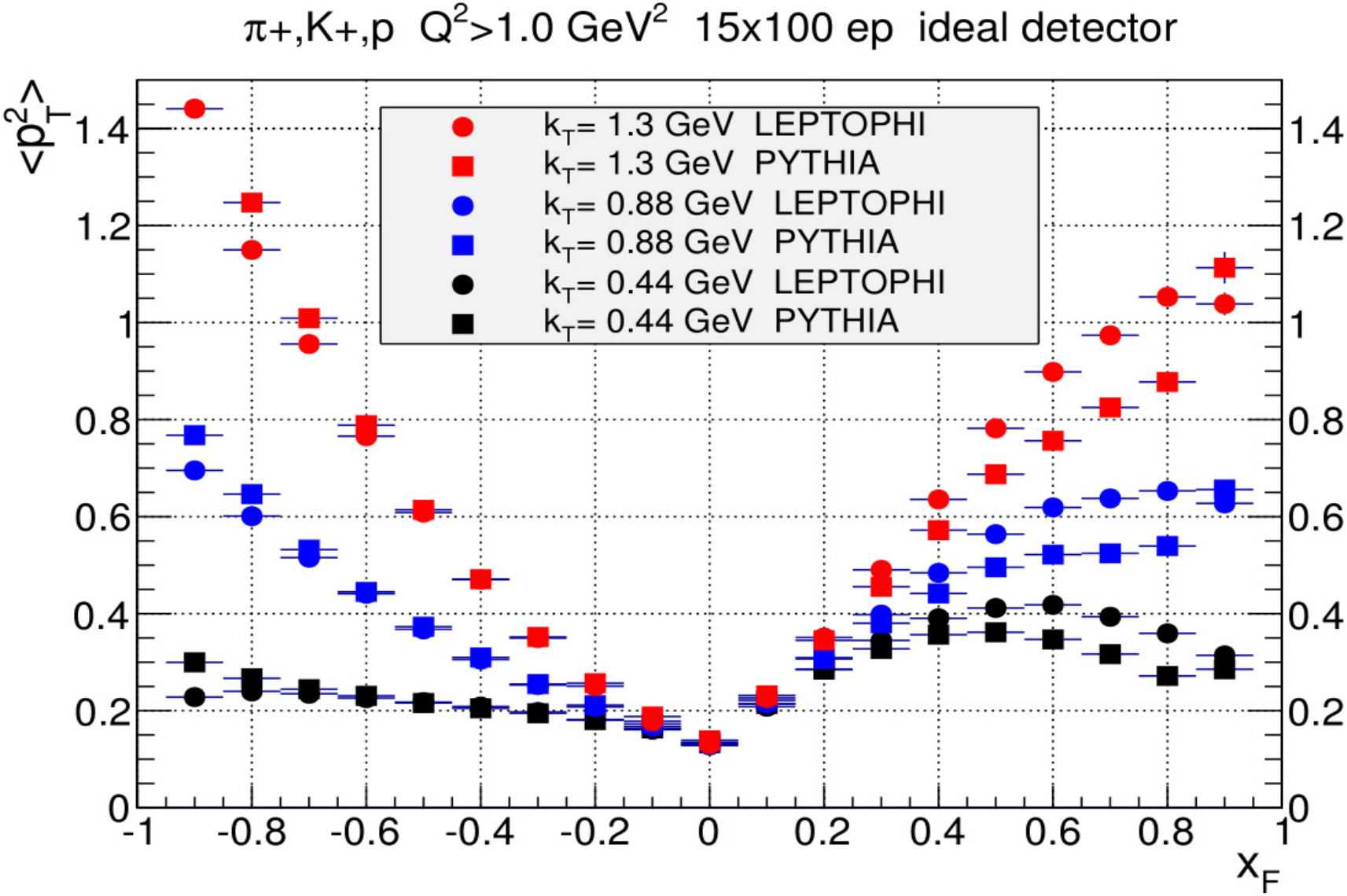
Measurement of k_T cleanest for $x_F < -0.3$

Primordial k_T shows up at high $|x_F|$



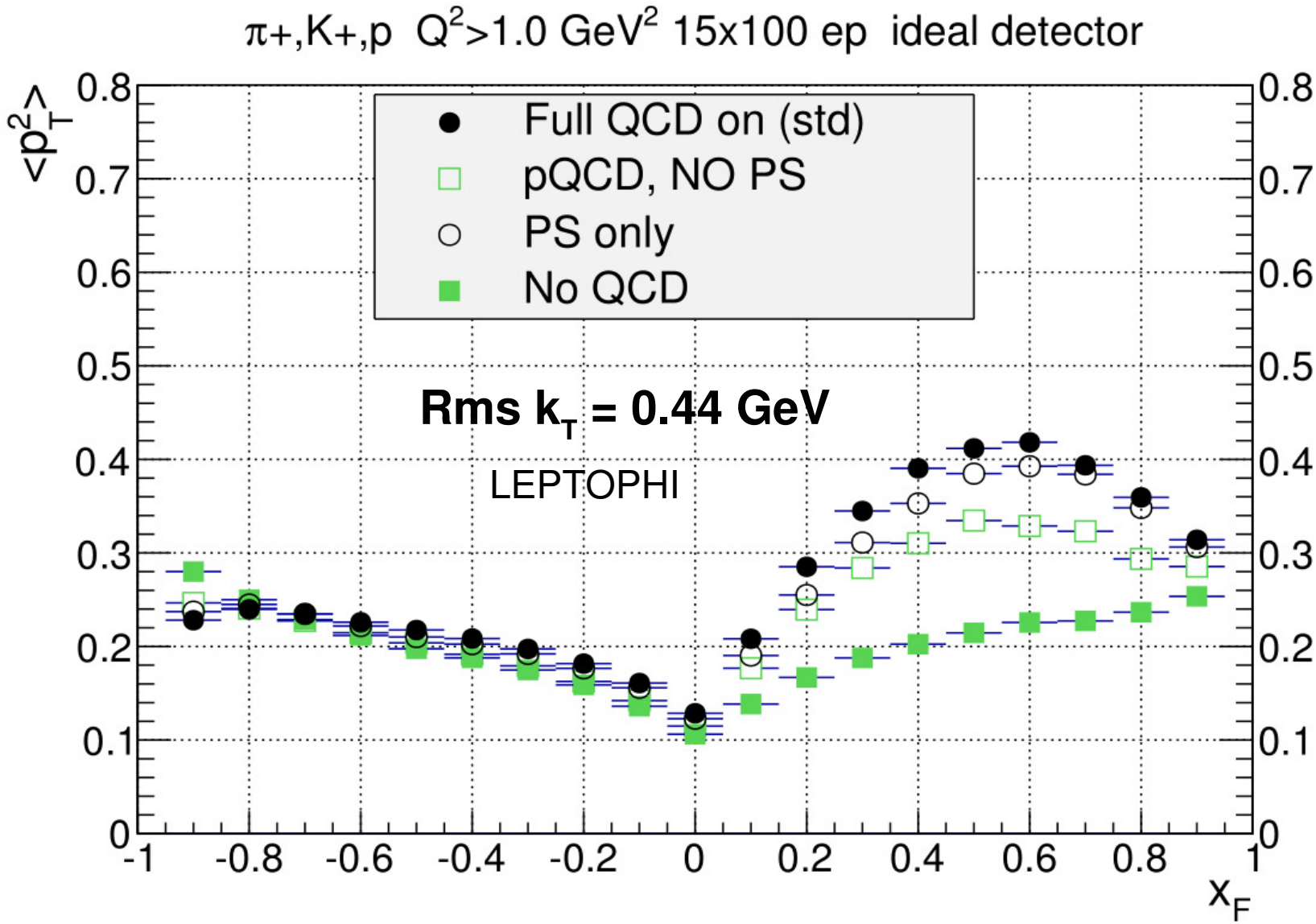
Effects of k_T show up for $|x_F|>0.3$

Less model dependent for $x_F<0$



NOTE: Pythia refers to EIC-modified Pythia @ BNL: Add HERMES tweaks (Elke)
Fix a “feature” in the target remnant (Mark)

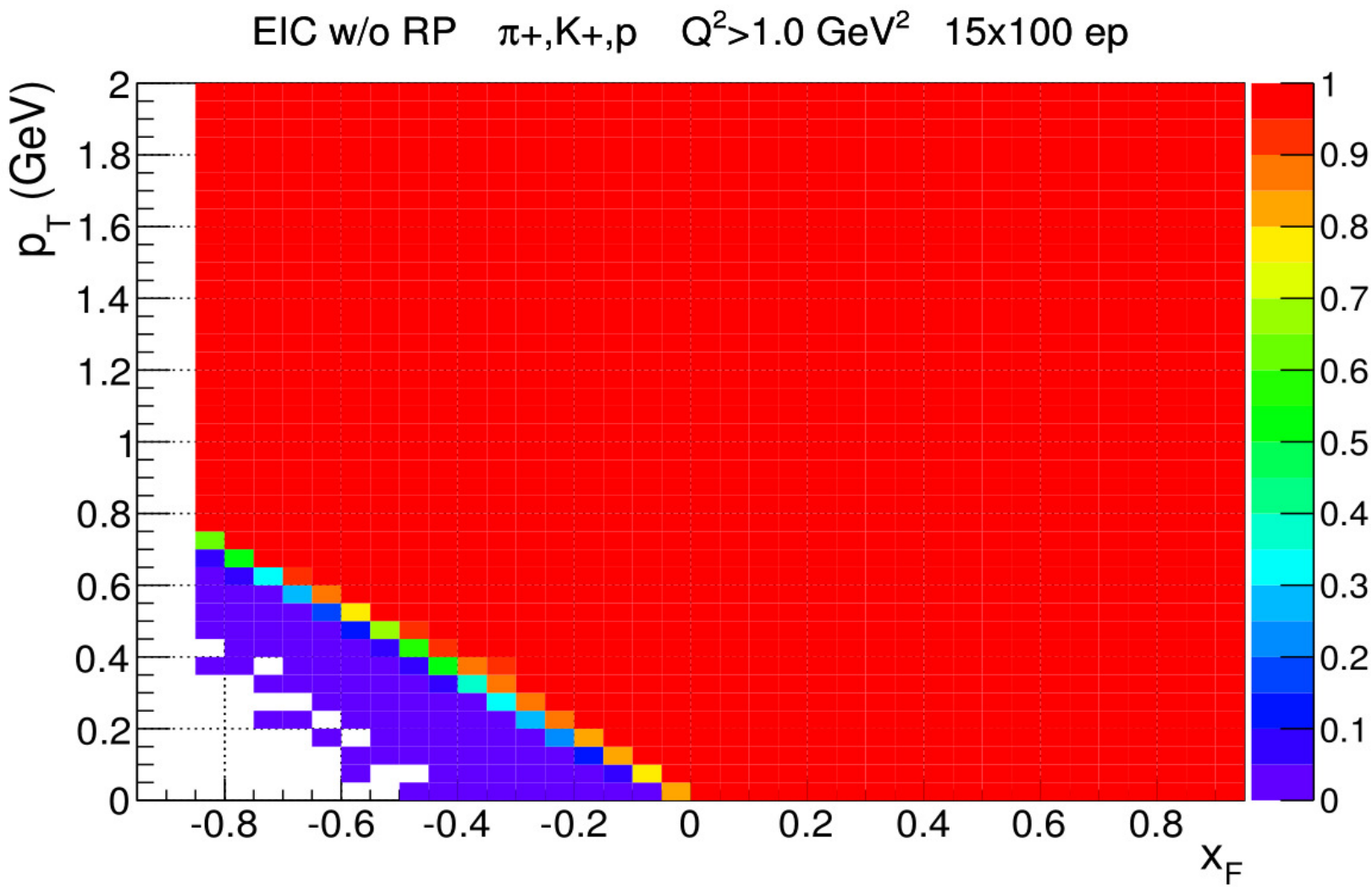
QCD shows up at positive x_F



Measurement of k_T cleanest for x_F<-0.3

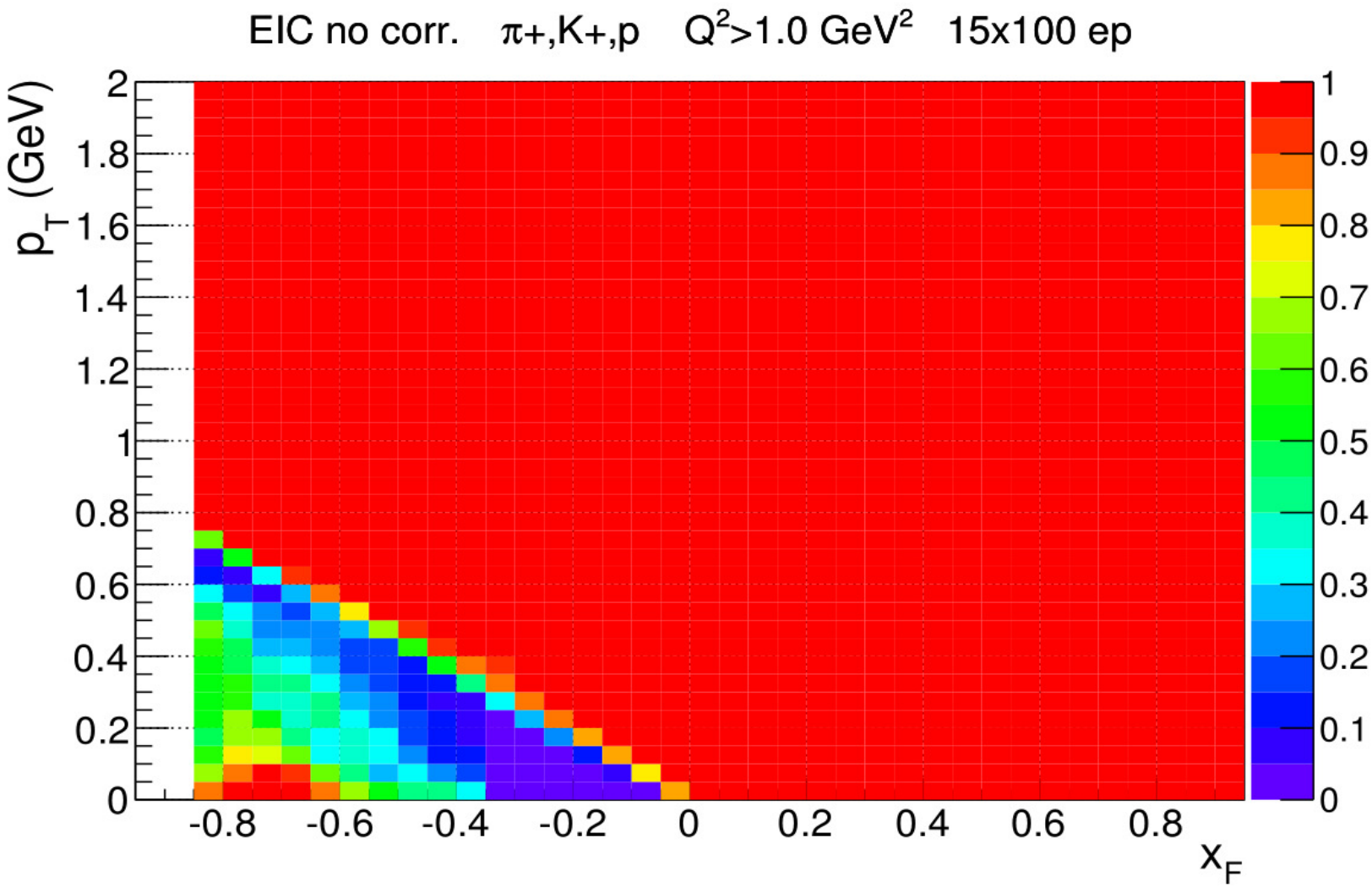
EIC-dedicated detector @eRHIC

Full acceptance in -5.4<η<5.4 but w/o Roman Pots



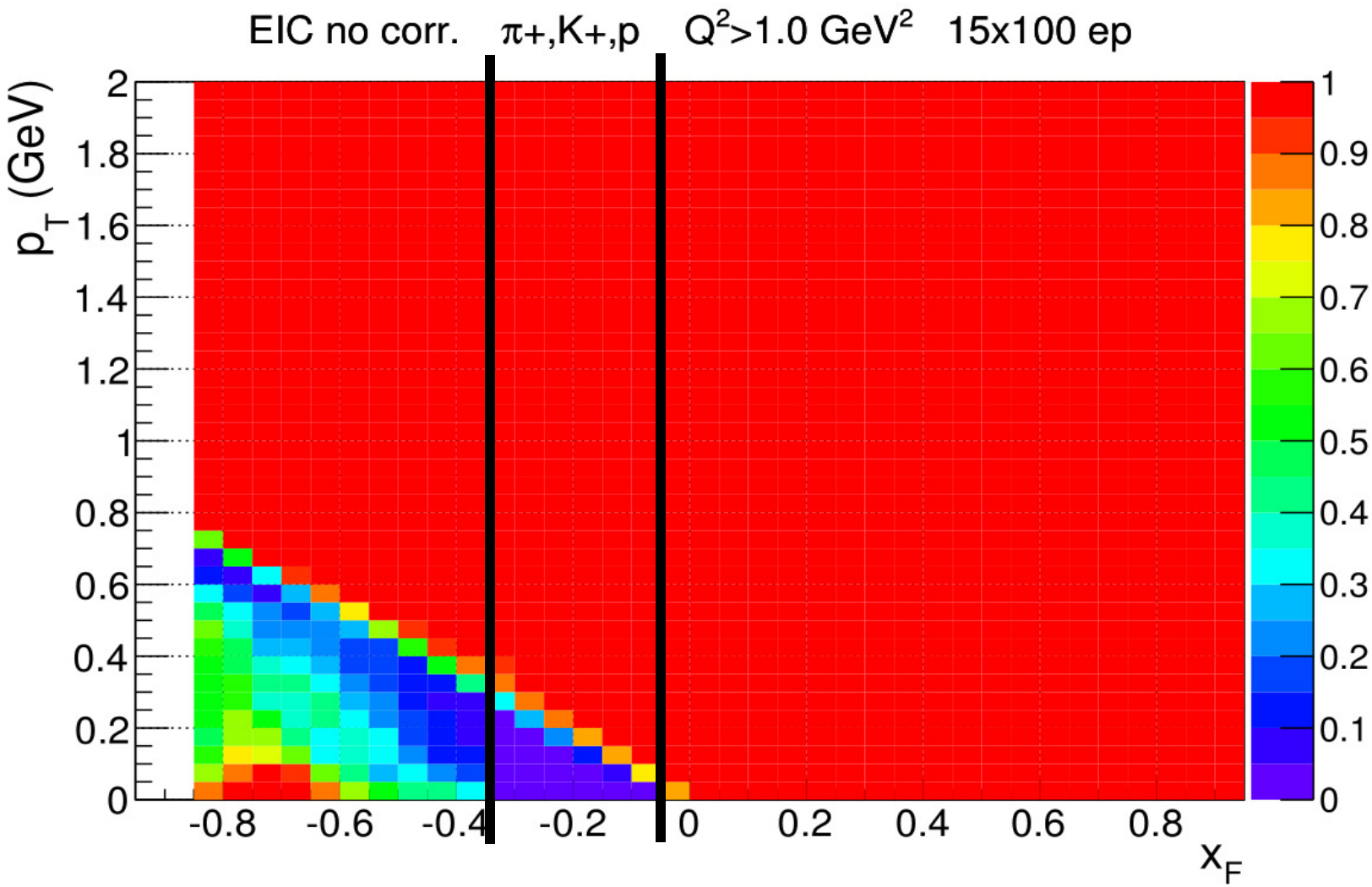
EIC-dedicated detector @eRHIC

Full acceptance in -5.4<η<5.4 WITH Roman Pots



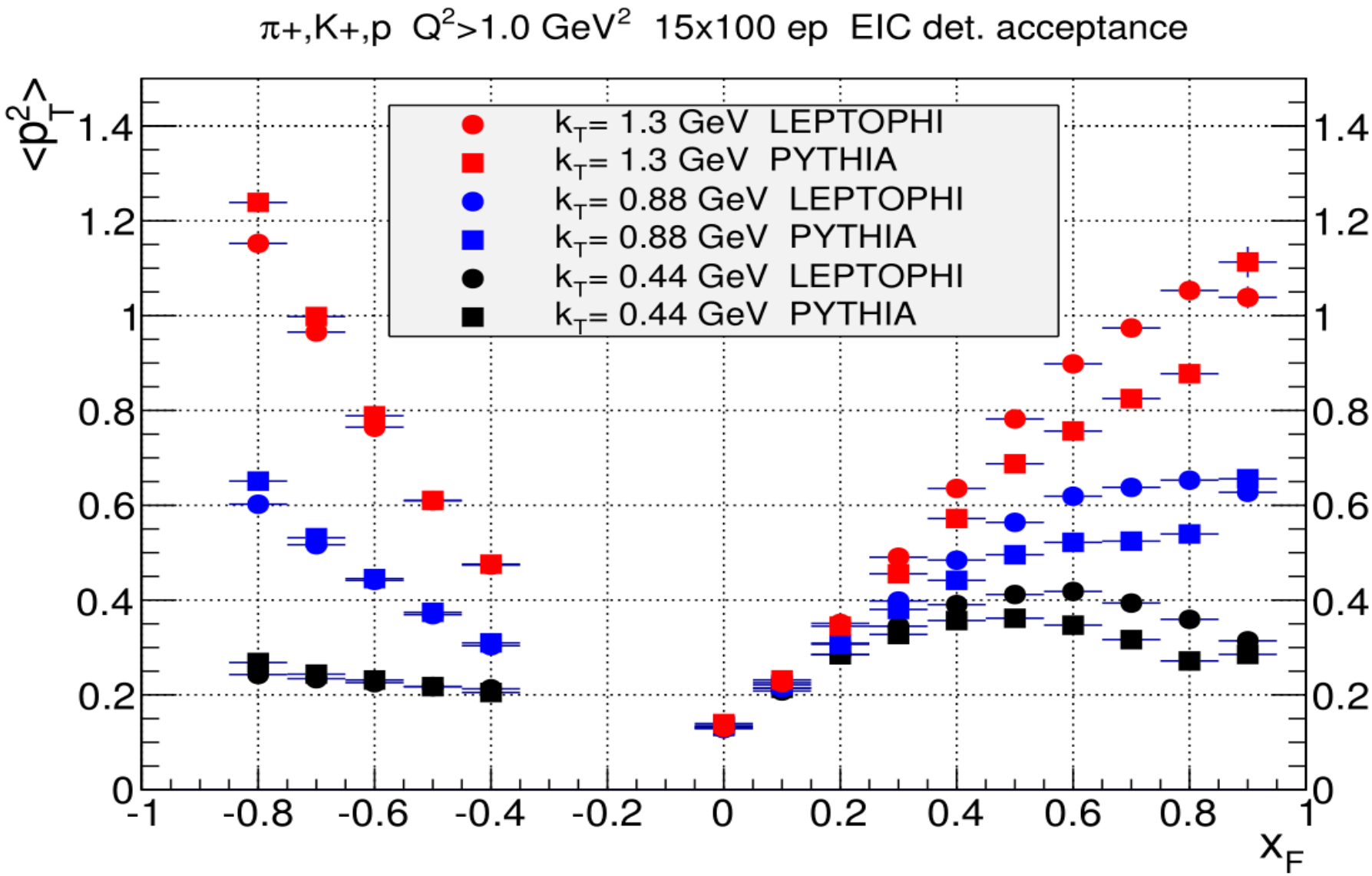
EIC-dedicated detector @eRHIC

Full acceptance in -5.4<η<5.4 WITH Roman Pots



Fiducial cut: remove $-0.35<x_F<-0.05$

Seagull: EIC det. accept. @ eRHIC

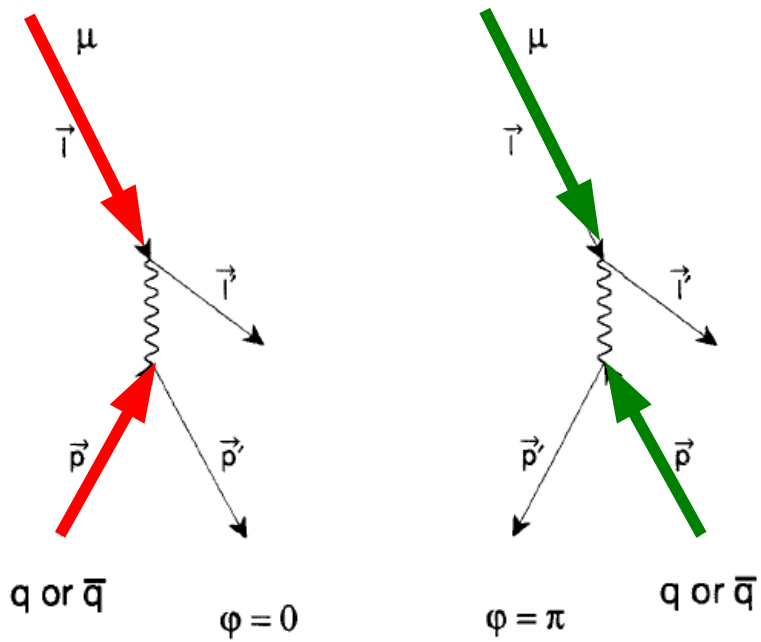


1M events or 1.7pb^{-1} of data (<1 day)

The “Cahn effect” in LO DIS

$\sigma \sim s^2 + u^2$

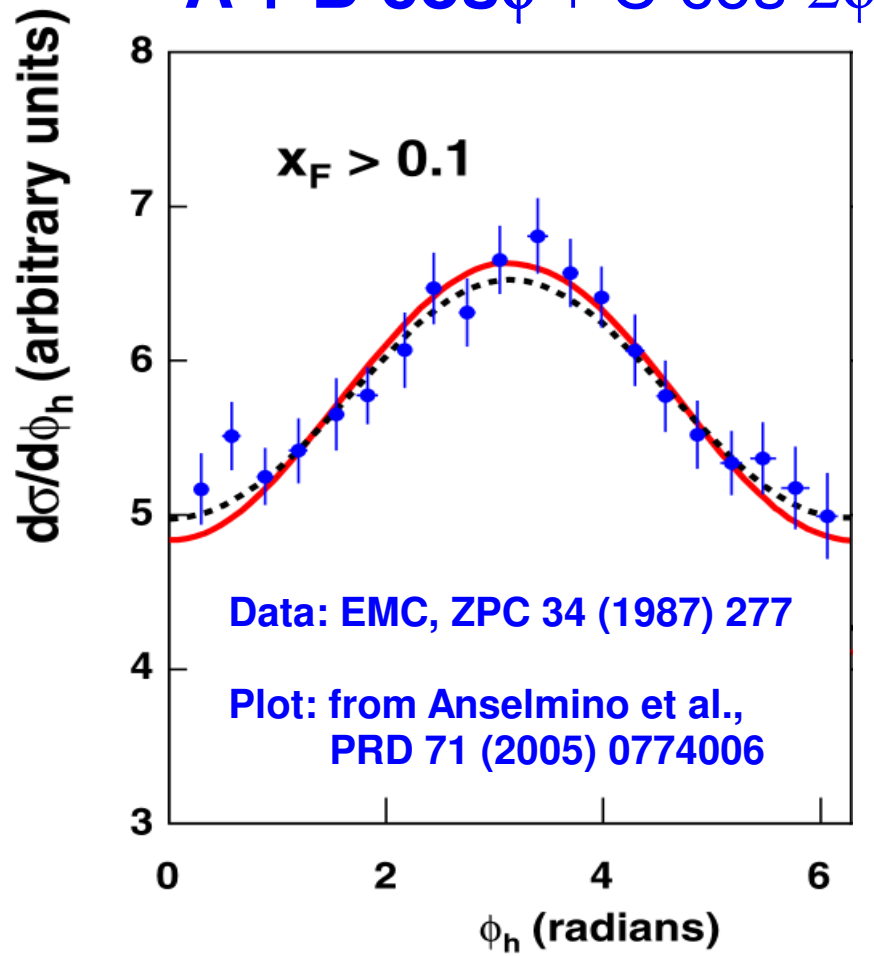
$\varphi=\pi$ is more collinear: higher s,u



ϕ=0 UNFAVORED **$\phi=\pi$ FAVORED**

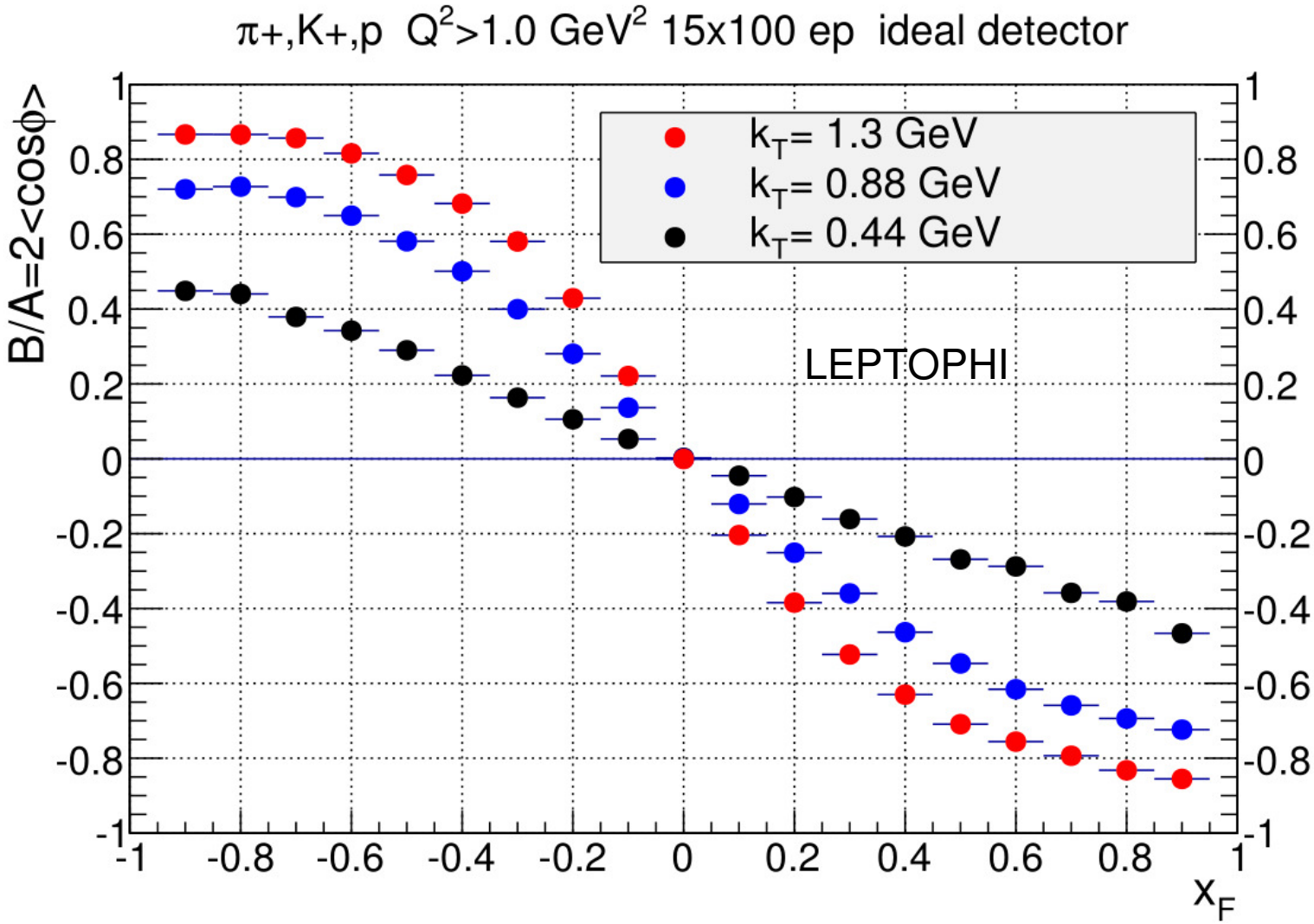
for $x_F>0$

A + B cosϕ + C cos 2ϕ



B/A<0 for $x_F>0$

LEPTOPHI – Cahn to $O(\alpha_s)$

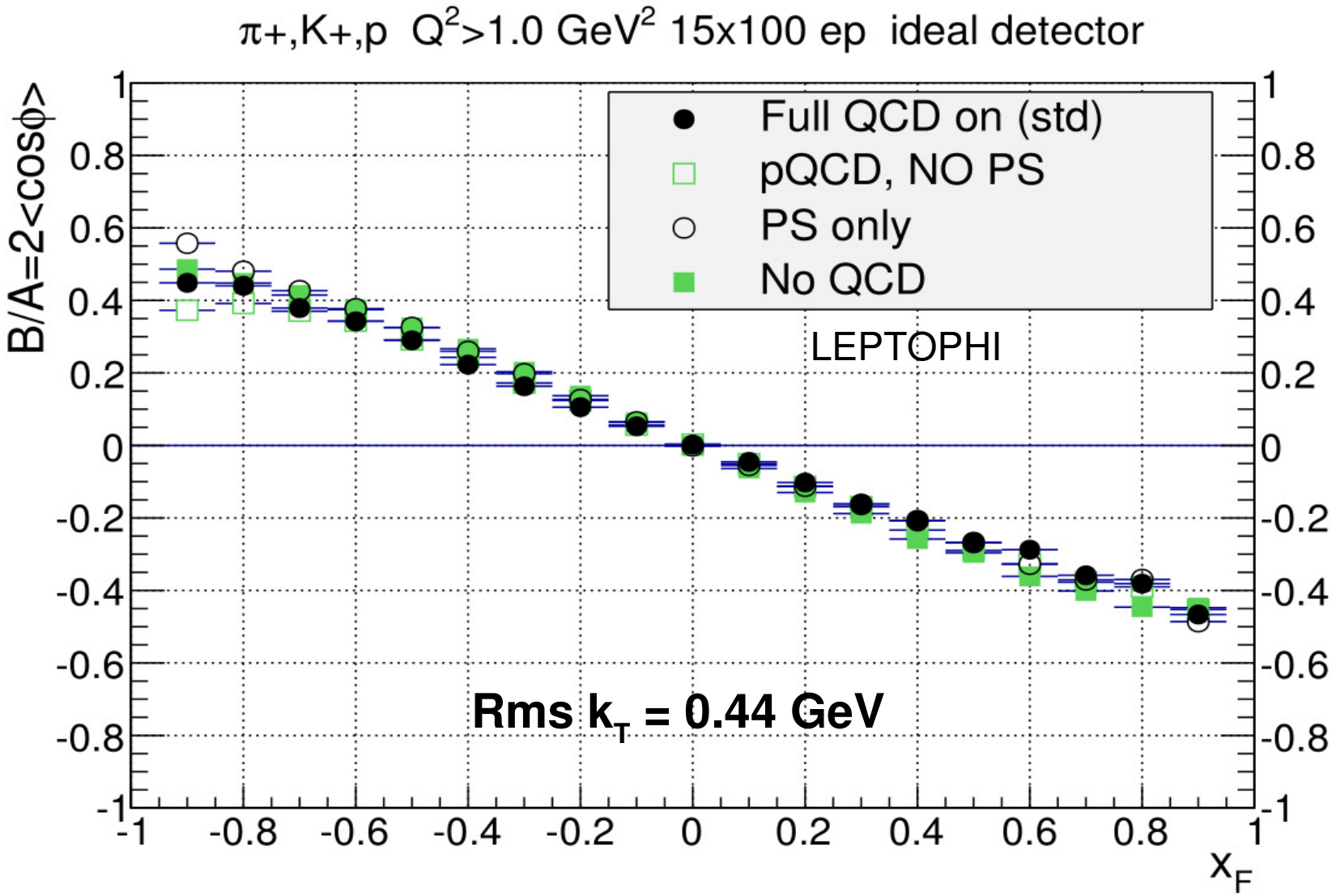


LEPTO 6.5.1 + Azimuthal Asymmetry to $O(\alpha_s)$

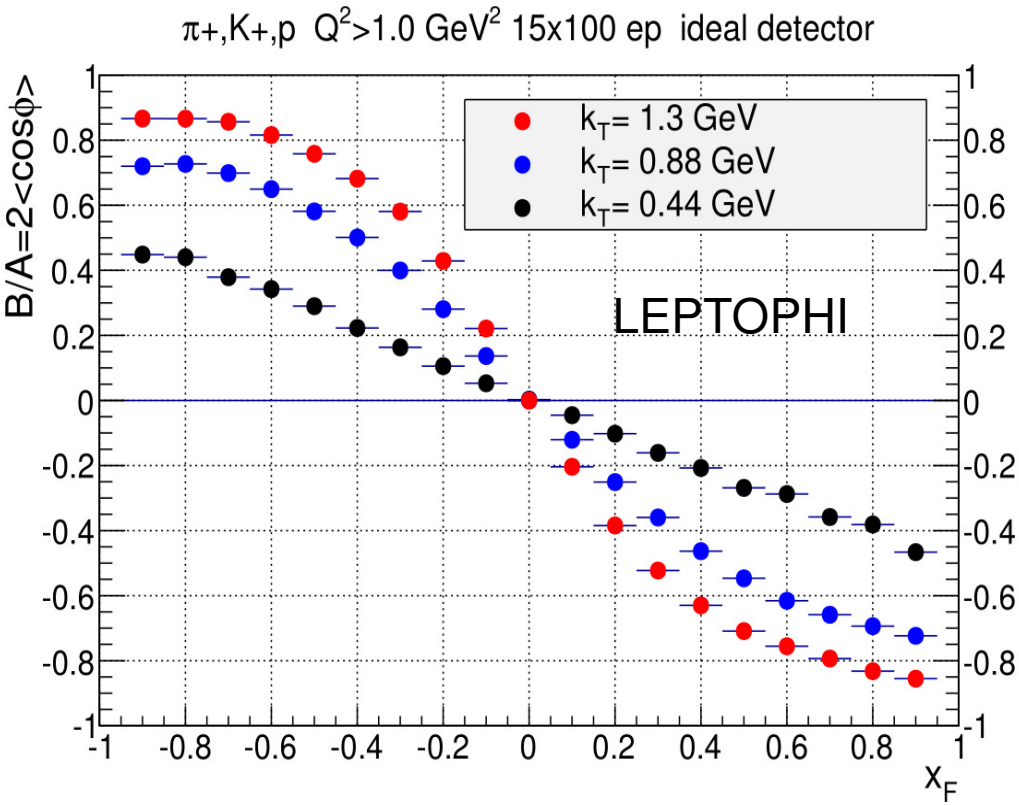
See: MDB PhD Thesis (MIT, 1993) for details

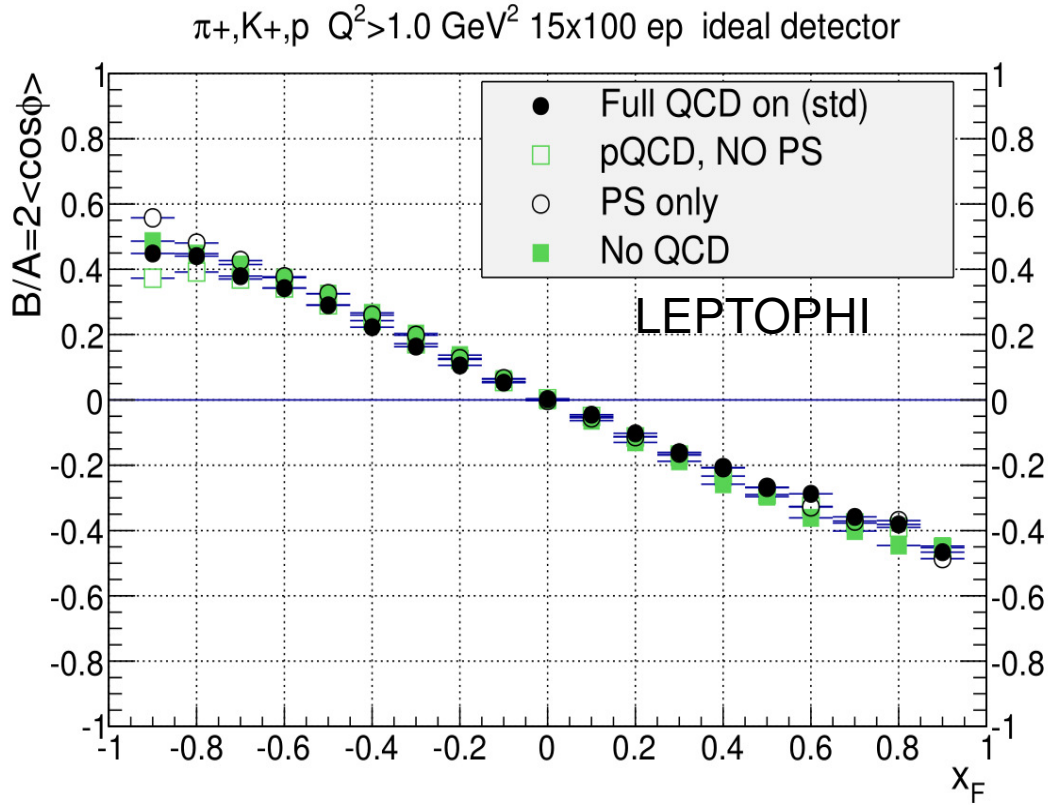
http://lss.fnal.gov/archive/thesis/1900/fermilab-thesis-1993-57.pdf

Cahn not too sensitive to QCD



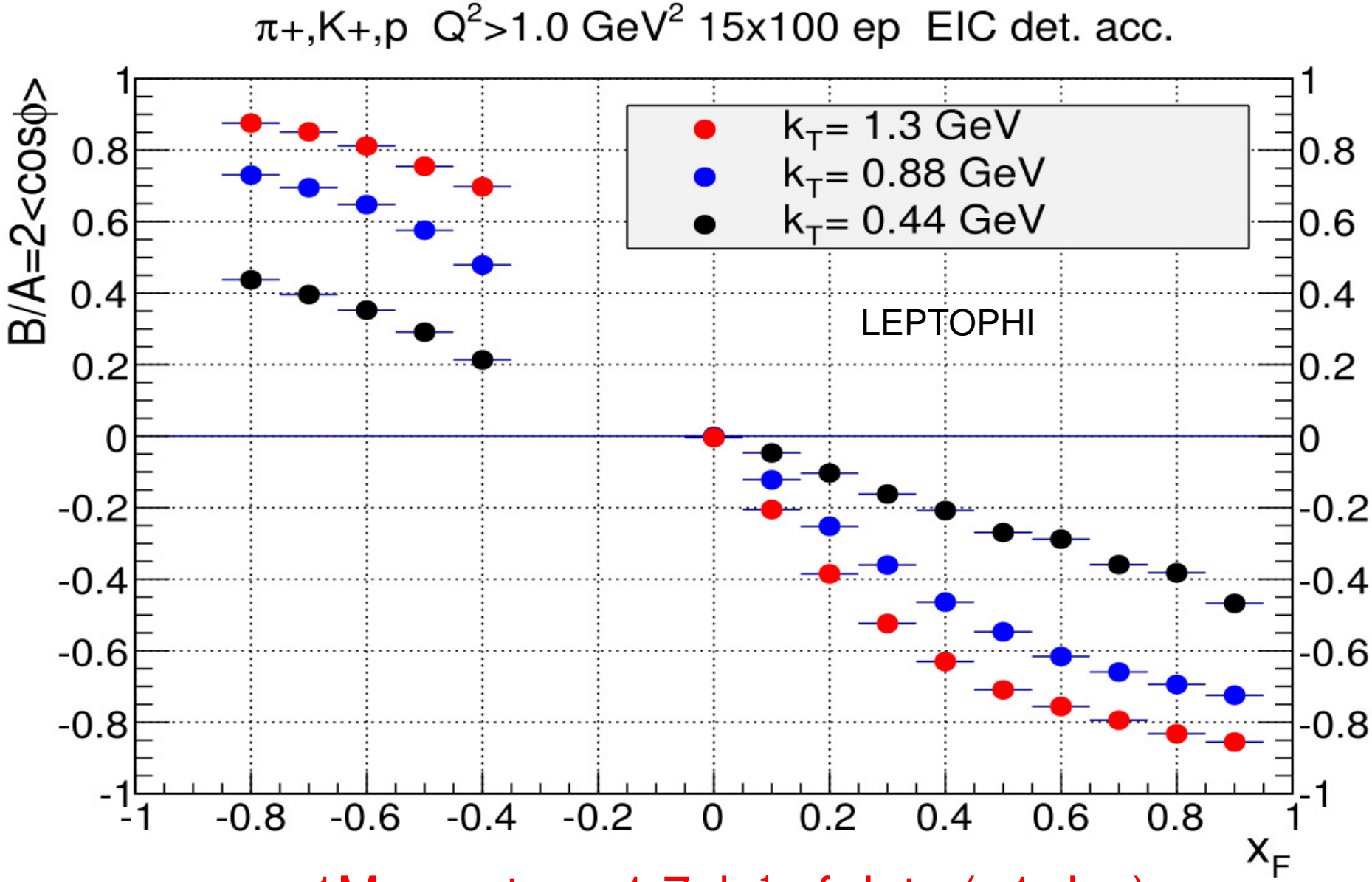
Good variable





- Cahn effect very sensitive to k_T
- Only weakly dependent on soft or hard QCD

Cahn: EIC det. accept. @ eRHIC



1M events or 1.7pb^{-1} of data (<1 day)

Conclusion

We can separate intrinsic k_T from QCD effects

Intrinsic k_T of the struck parton:

- reflected in recoil of target jet as well as in the current jet
- shows up in both hadron p_T and $\langle\cos\phi\rangle$ at high $|x_F|$

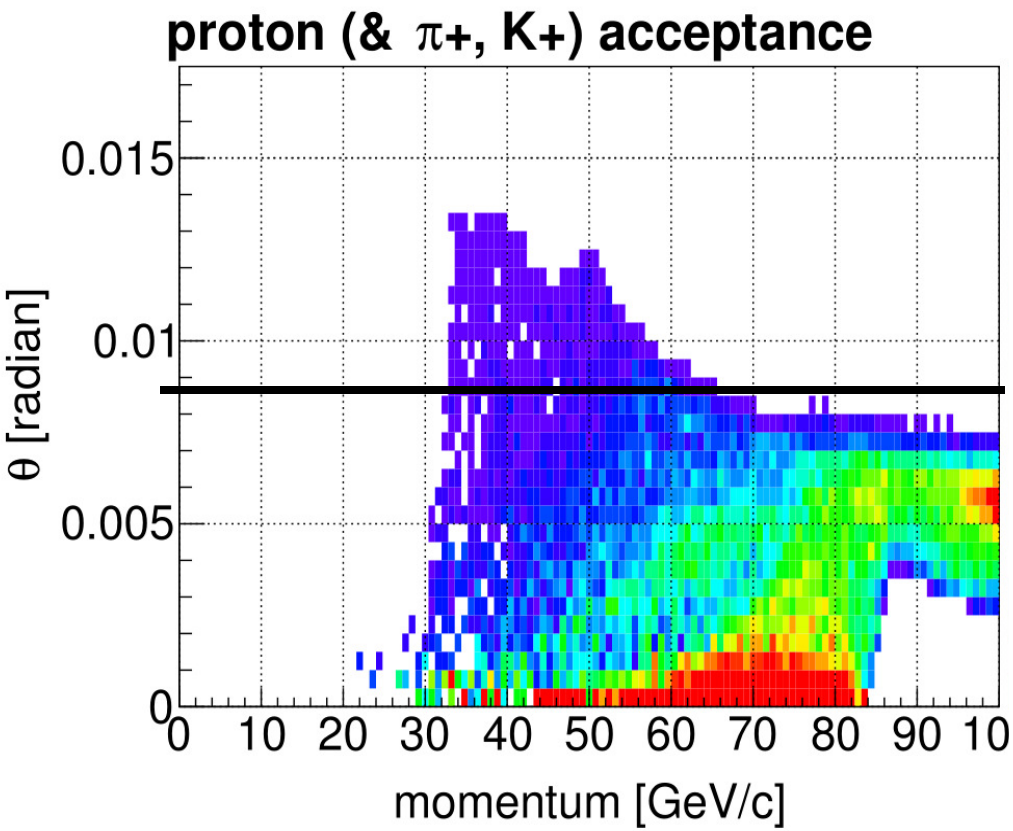
Soft (parton showering) and hard QCD effects

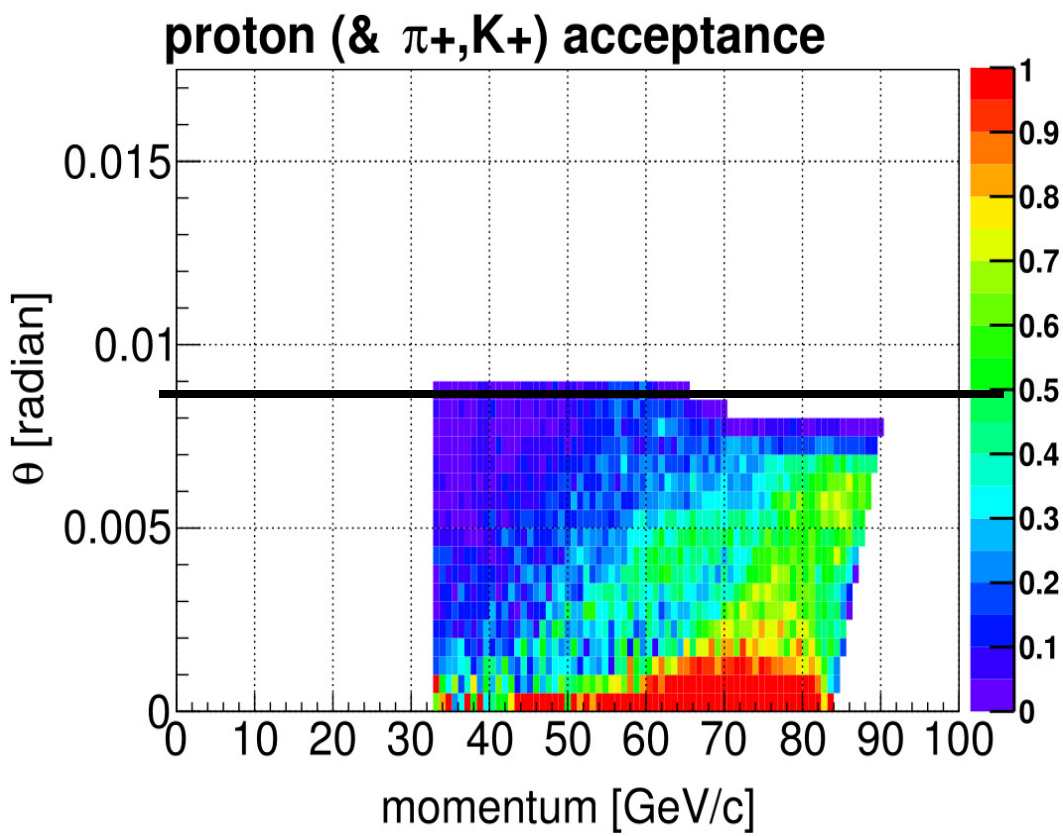
- show up at $x_F>0$

Therefore intrinsic k_T cleanest at $x_F<-0.3$

Roman Pot Acceptance!

Acceptance is really fractional coverage in lab ϕ angle





From J.-H. Lee

Fiducial cut