- E706 L. Apanasevich et al $\pi^- Be \to \omega^0 + \ldots$

  $\omega/\pi^0 \approx 1$ ok with Pythia (not Herwig)

  $\sigma_\omega \approx 4 \times$ Pythia (& Herwig)

- π^0/γ yields worldwide

  Apanasevich, Bromberg, Huston, Kuhlmann
  Begel, Farbel, Gintner, Slattery & Zielinski

T. Farbel

PA-03e

Proceedings of

PHYSICS IN COLLISION 8

TEN YEARS OF DIRECT-PHOTON PHYSICS

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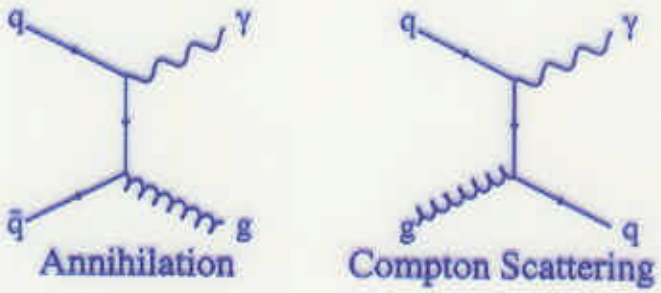
ABSTRACT: I review the latest experimental results on direct-photon production in hadronic collisions, and their phenomenologic interpretation. Without question, the confrontation between data and theory has provided one of the most impressive triumphs for perturbative QCD.

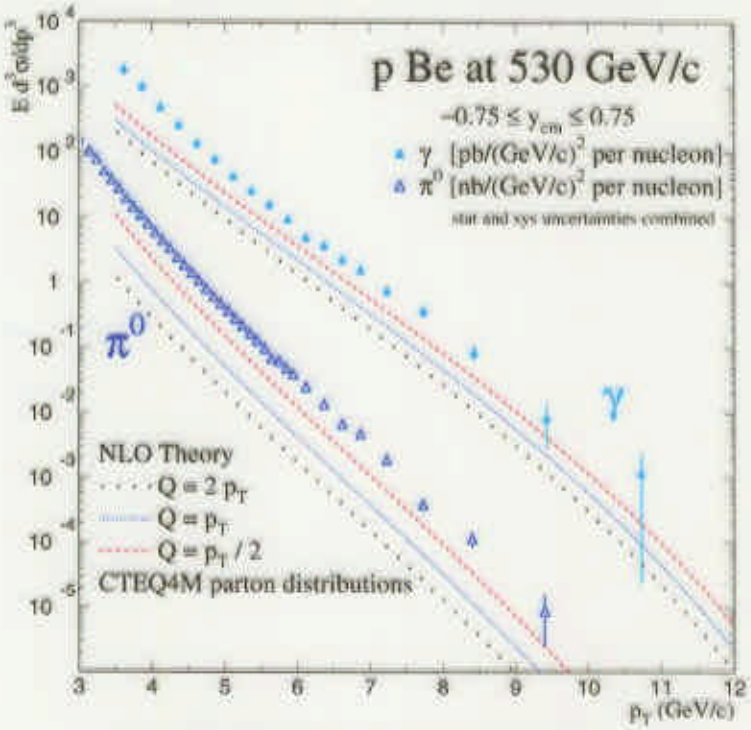
2

pQCD and Inclusive Direct Photon Production

- In LO two processes yield direct photons:



- By the time E706 started collecting data, NLO calculations of direct-γ production were available, but ...

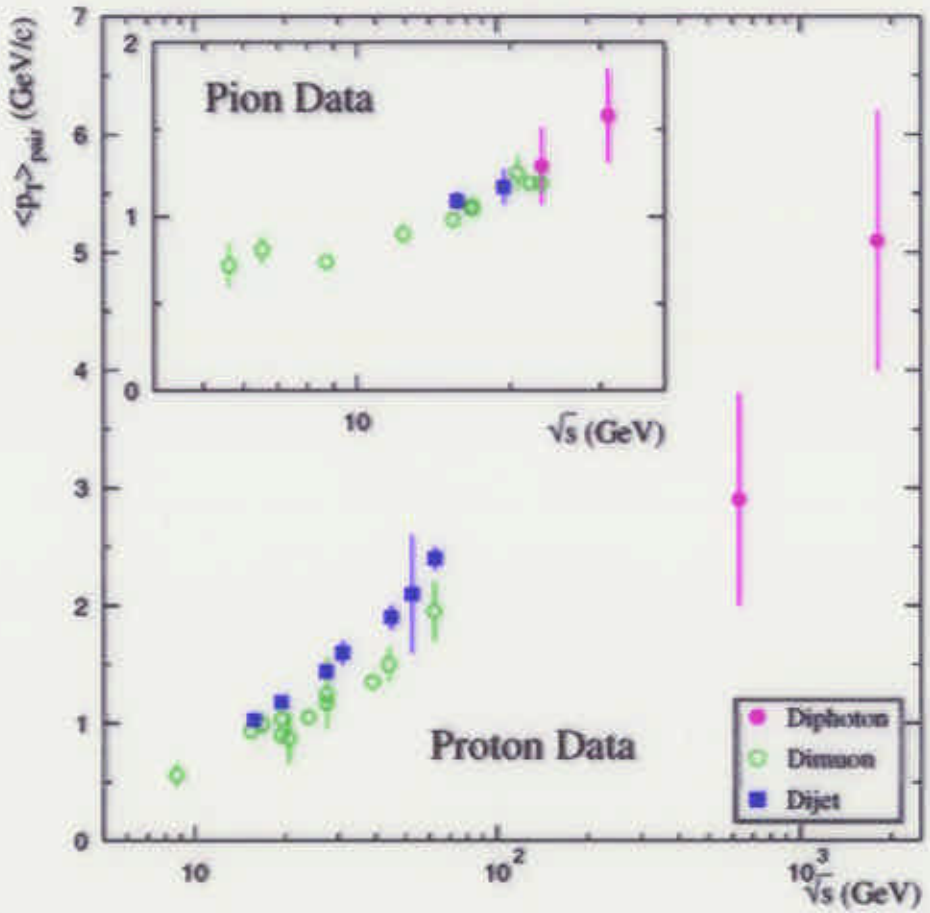


Scale Dependence of NLO pQCD

k_T Smearing

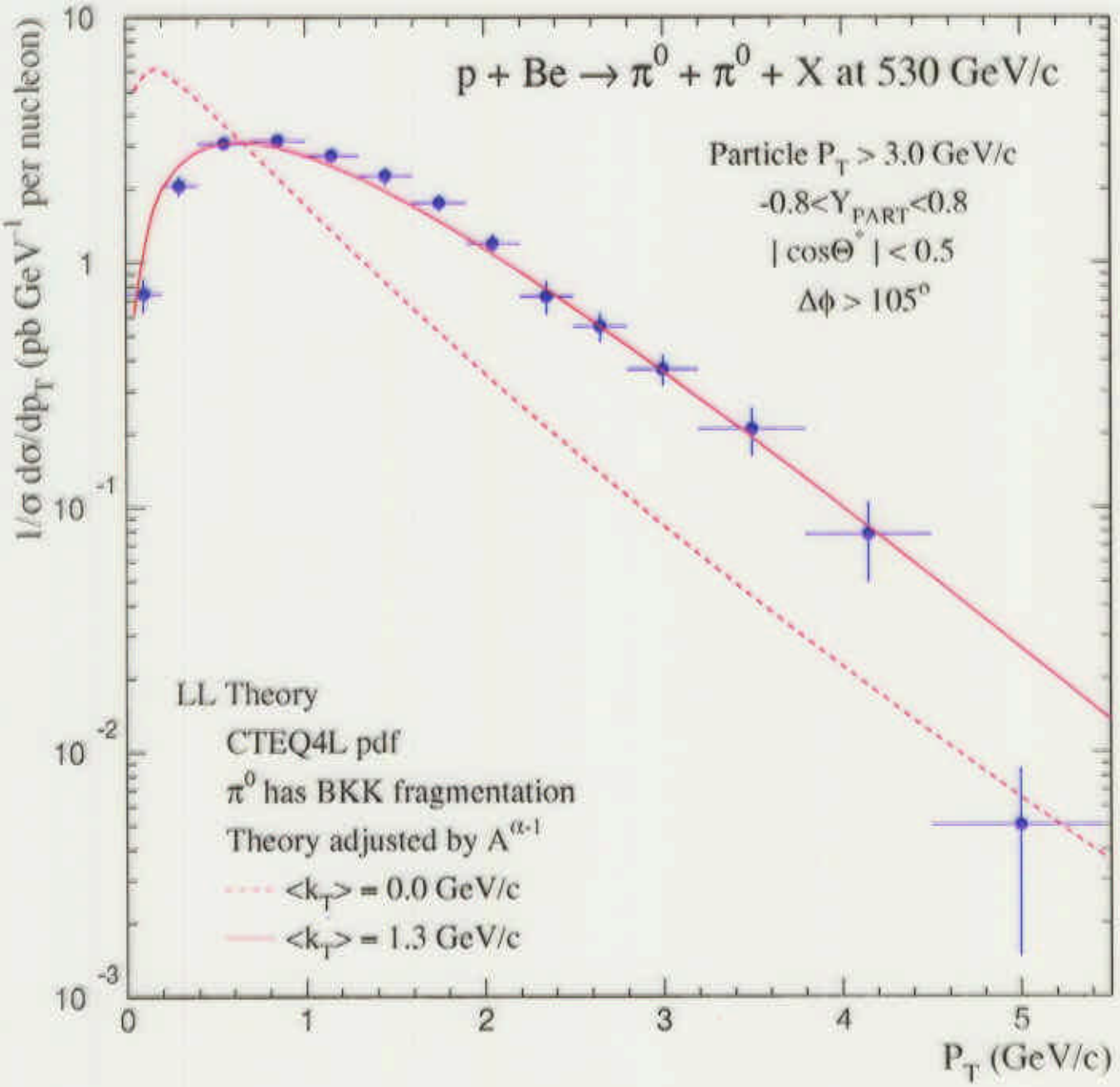
k_T refers to the magnitude of the effective transverse momentum vector of each of the two colliding partons

Average k_T values significantly larger than expected from non-perturbative hardon-size effects have been observed in dimuon, dijet and diphoton production, and have been interpreted as resulting from multiple soft gluon emissions.



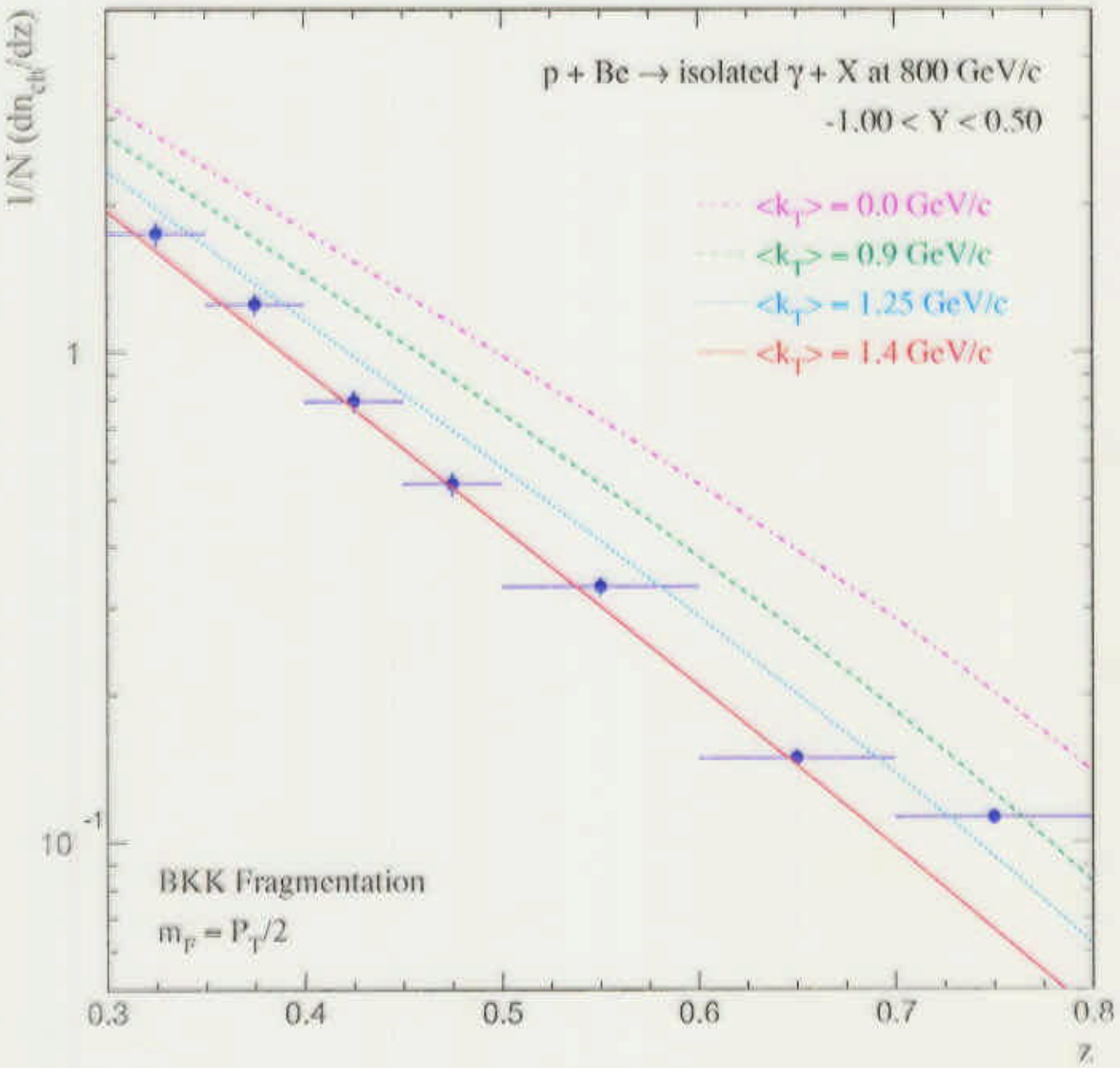
k_T smearing modifies

- back-to-back alignment of final state objects
- magnitude and shape of high-p_T inclusive cross sections
- fragmentation distributions in jets recoiling against high-p_T triggers

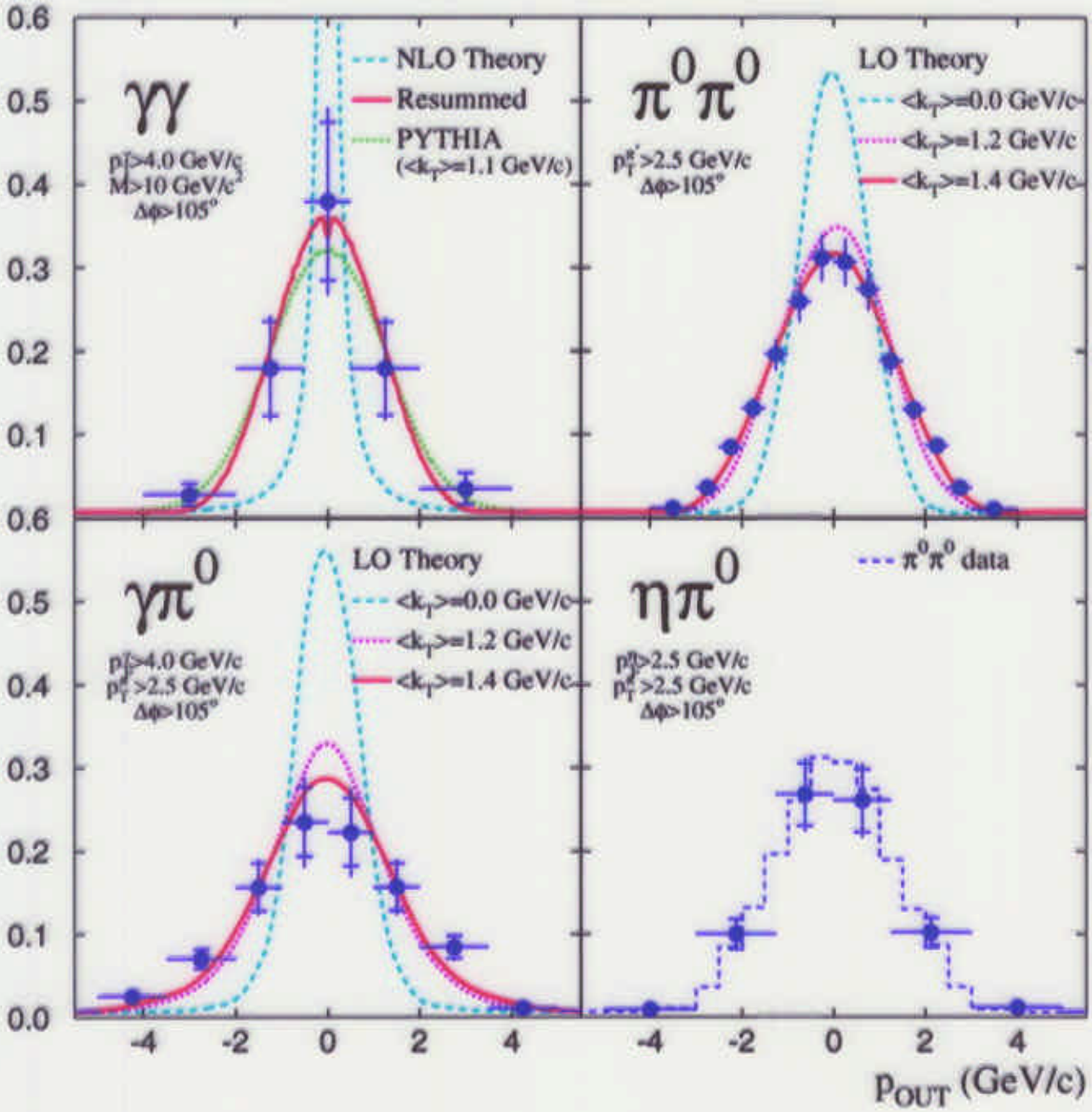

p + Be → π⁰ + π⁰ + X at 530 GeV/c
Particle P_T > 3.0 GeV/c
-0.8<Y_PART<0.8
| cosΘ* | < 0.5
Δφ > 105°
LL Theory
CTEQ4L pdf
π⁰ has BKK fragmentation
Theory adjusted by A^(α-1)
<k_T> = 0.0 GeV/c
<k_T> = 1.3 GeV/c
1/σ dσ/dp_T (pb GeV^-1 per nucleon)
P_T (GeV/c)
10
1
10^-1
10^-2
10^-3
0
1
2
3
4
5

E706 Prelim

Away Side Fragmentation



π^-Be at 515 GeV/c

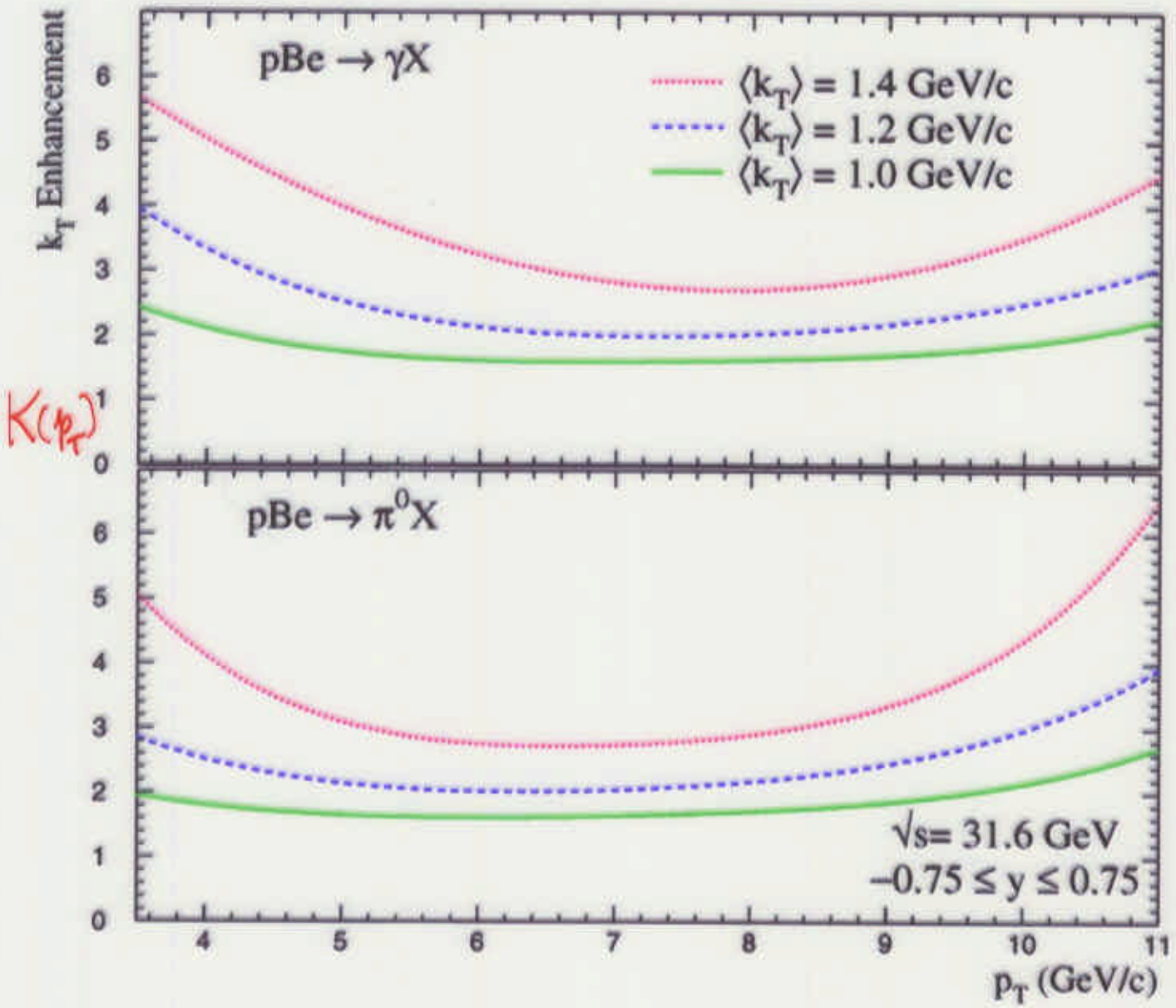


Modeling k_T Effects

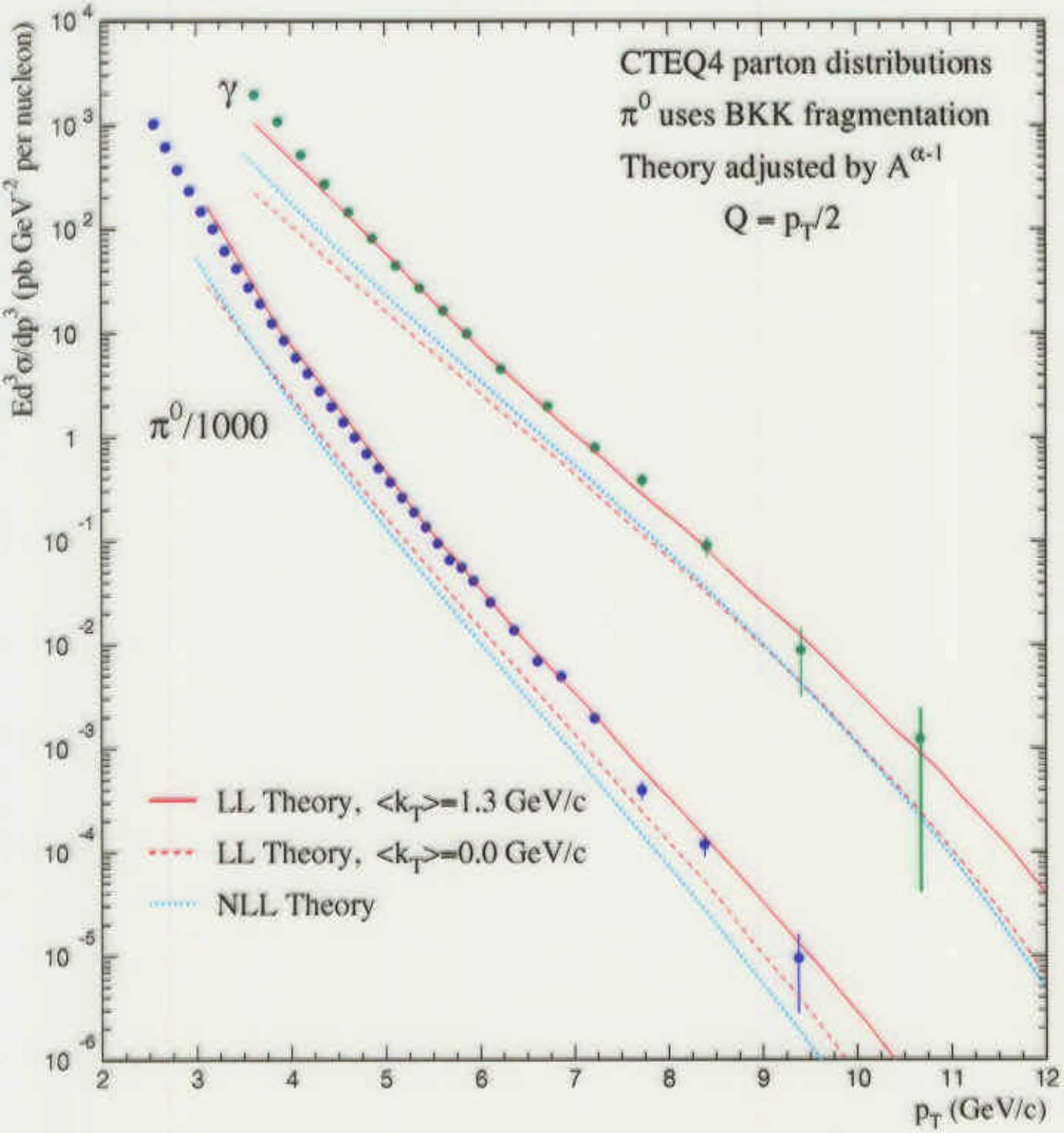
Because NLO Monte Carlos not available, use LO pQCD MCs for generating Gaussian k_T smearing, and approximate cross section by:

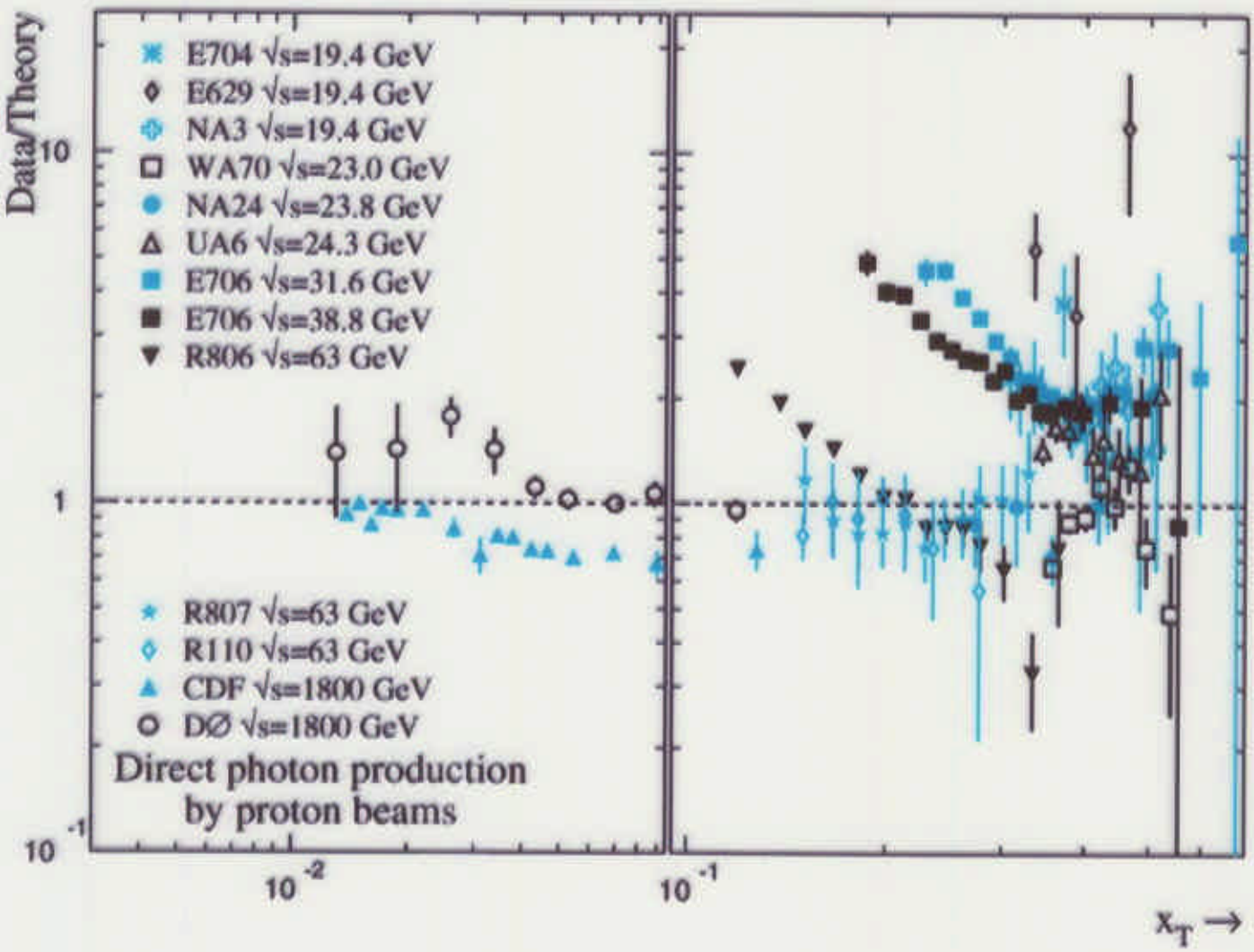
$$\sigma^{NLO} \times K(p_T)$$

with $K(p_T) = \sigma^{LO}(\langle k_T \rangle) / \sigma^{LO}(\langle k_T \rangle = 0)$

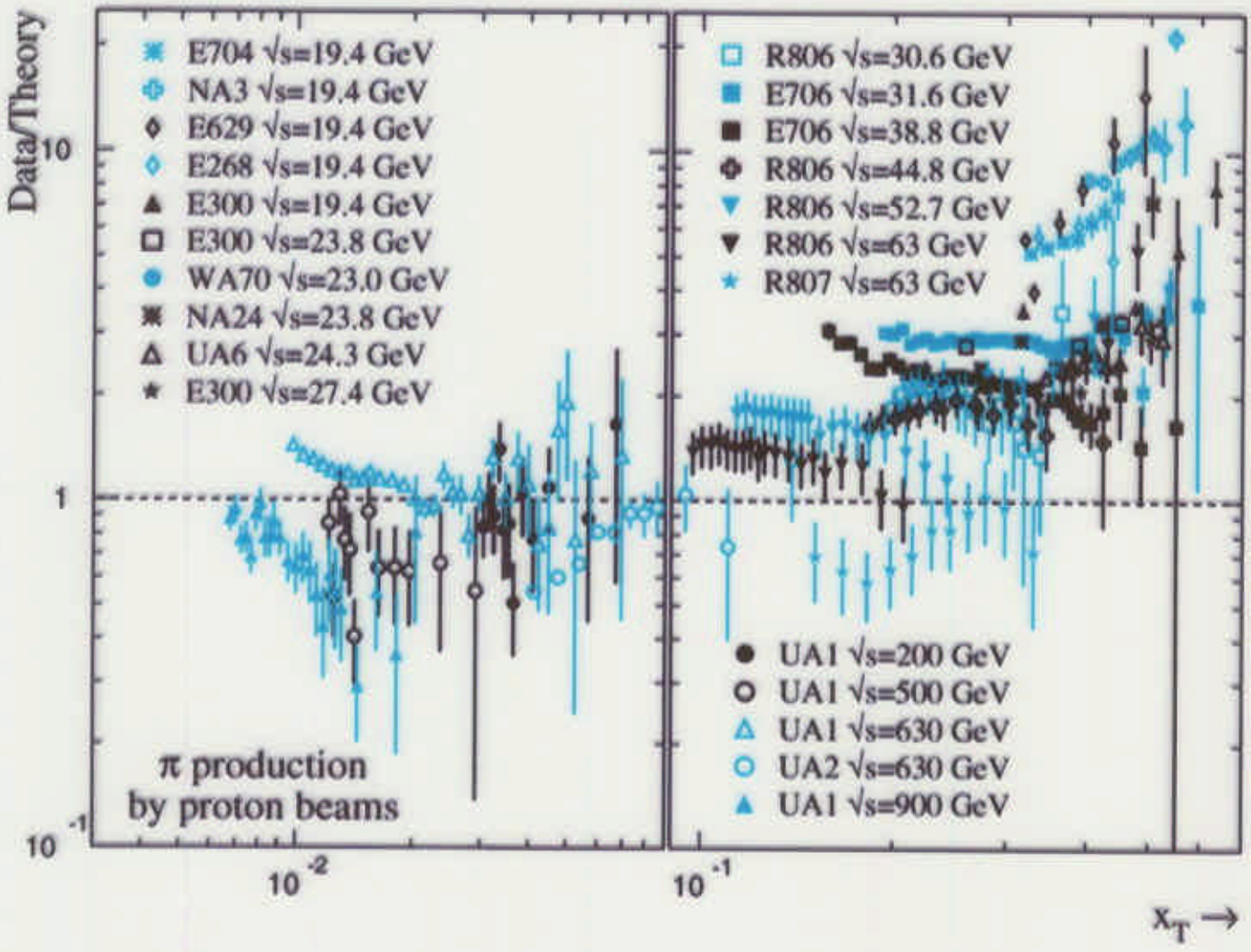


E706 pBe at 530 GeV





Comparison to NLO, with
$Q = p_T/2$, and CTEQ4M



BKK Fragmentation

What's going on? What has changed?

Studies in 1980s based on direct photons:

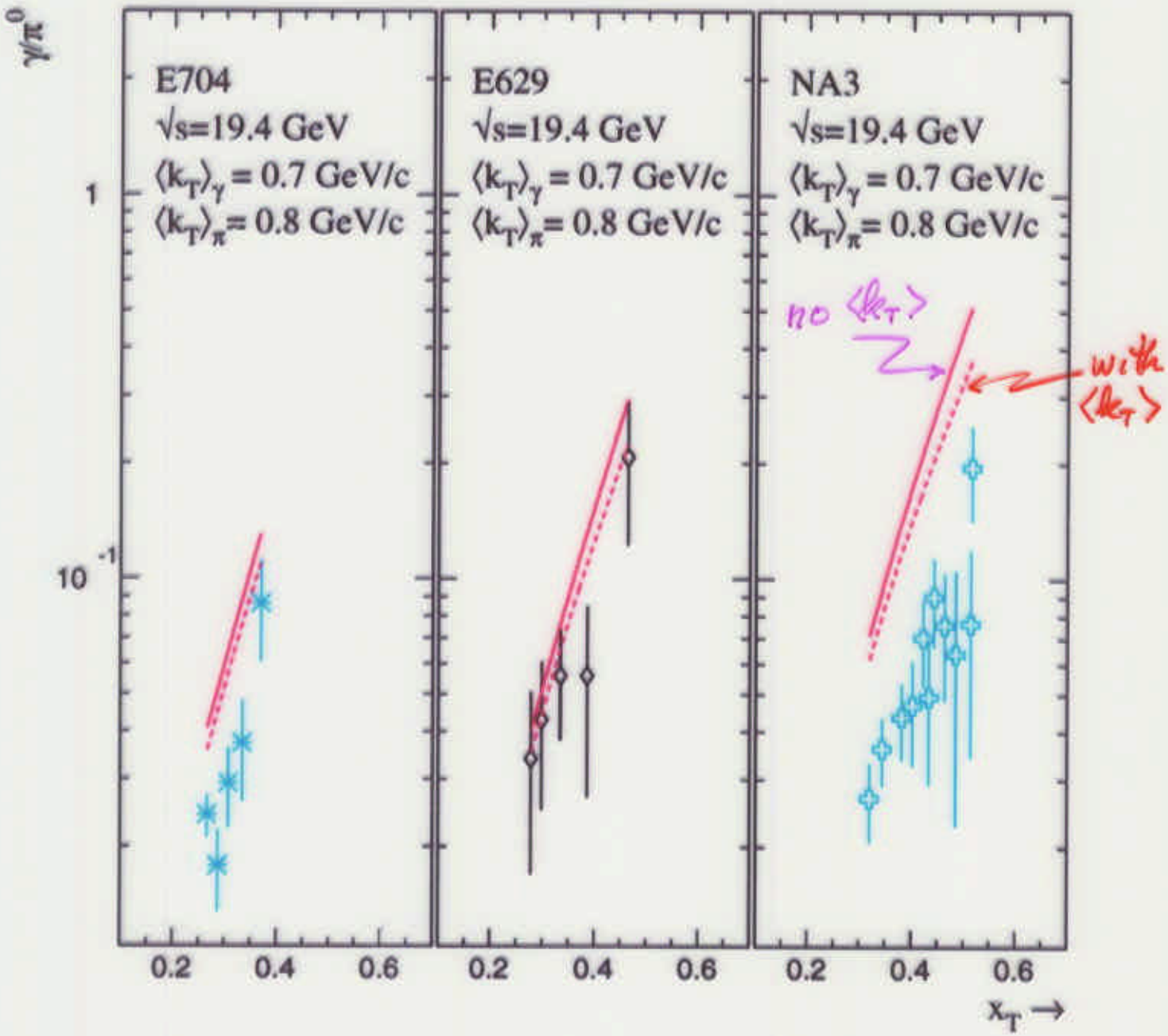
- Less data & smaller ranges of x per experiment
- Data over smaller range of $\sqrt{s}$
- NLO + Principle of Minimal Sensitivity for scale

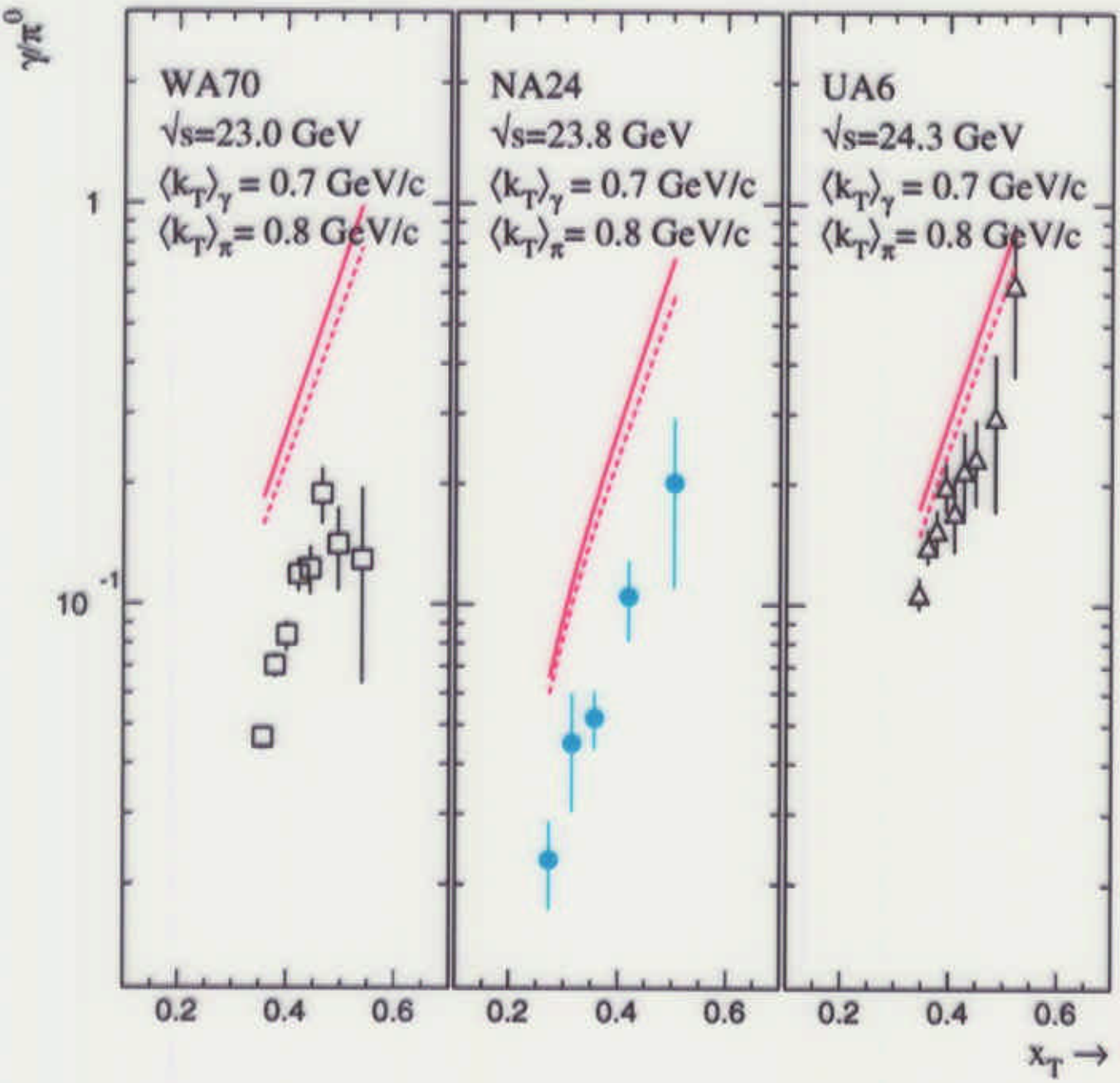
Some known problems (even for direct photons):

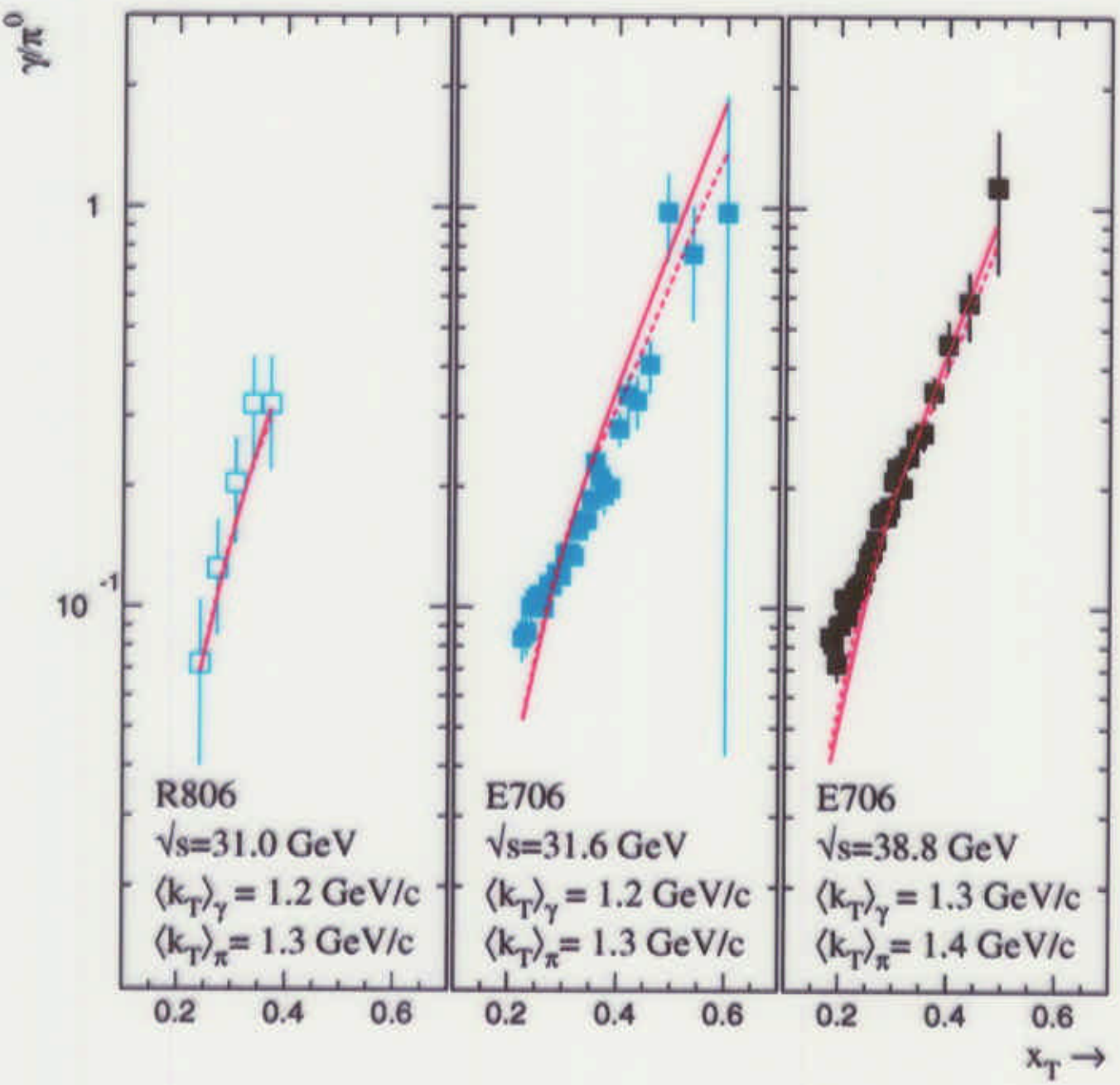
- Significant dependence of NLO on scale ($\times 2$)
- Inconsistency between data ($\times 2$)
- Until recently, soft-gluon emission usually not taken into explicit account

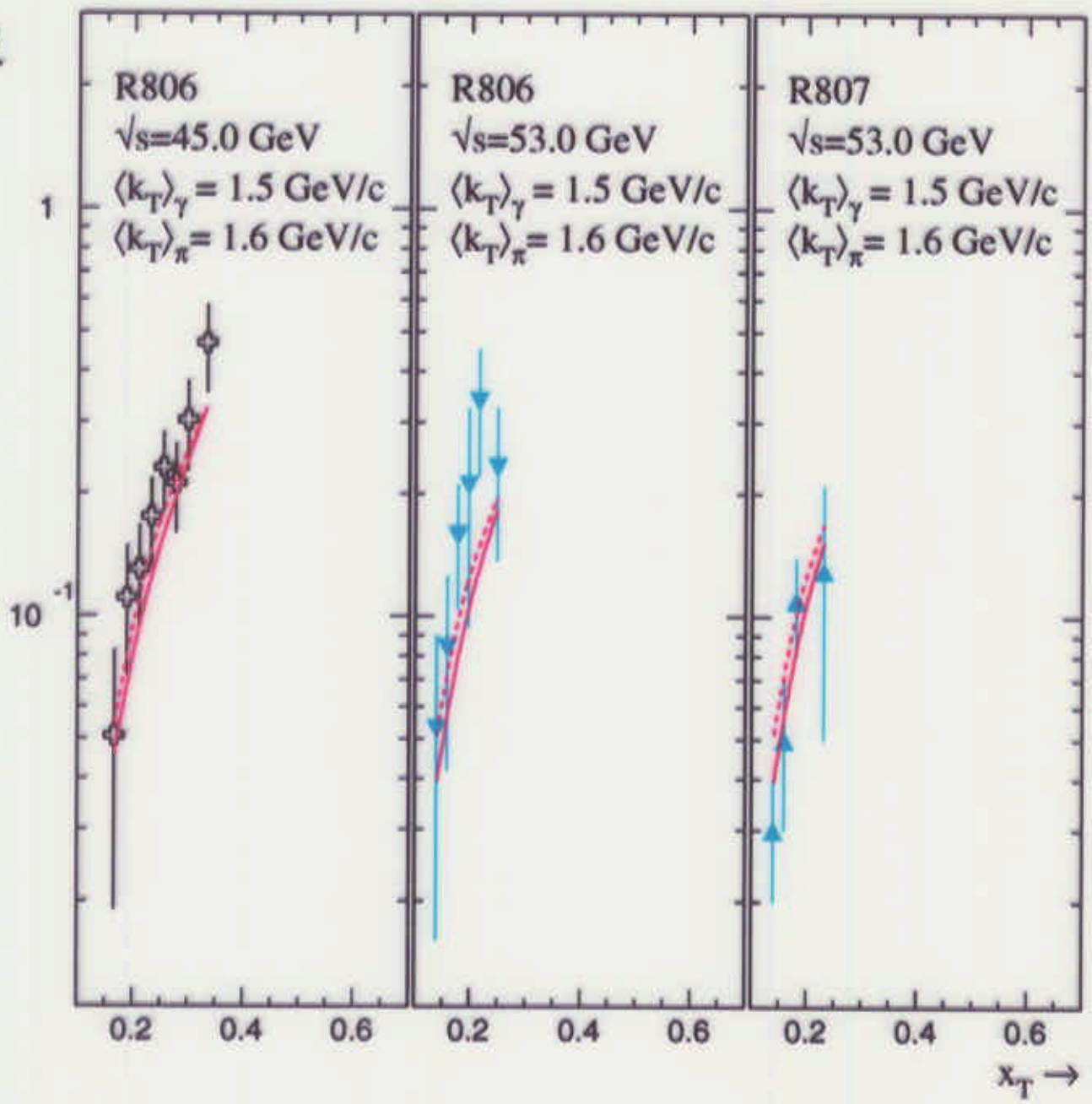
Examine γ/π^0 production ratio for more info

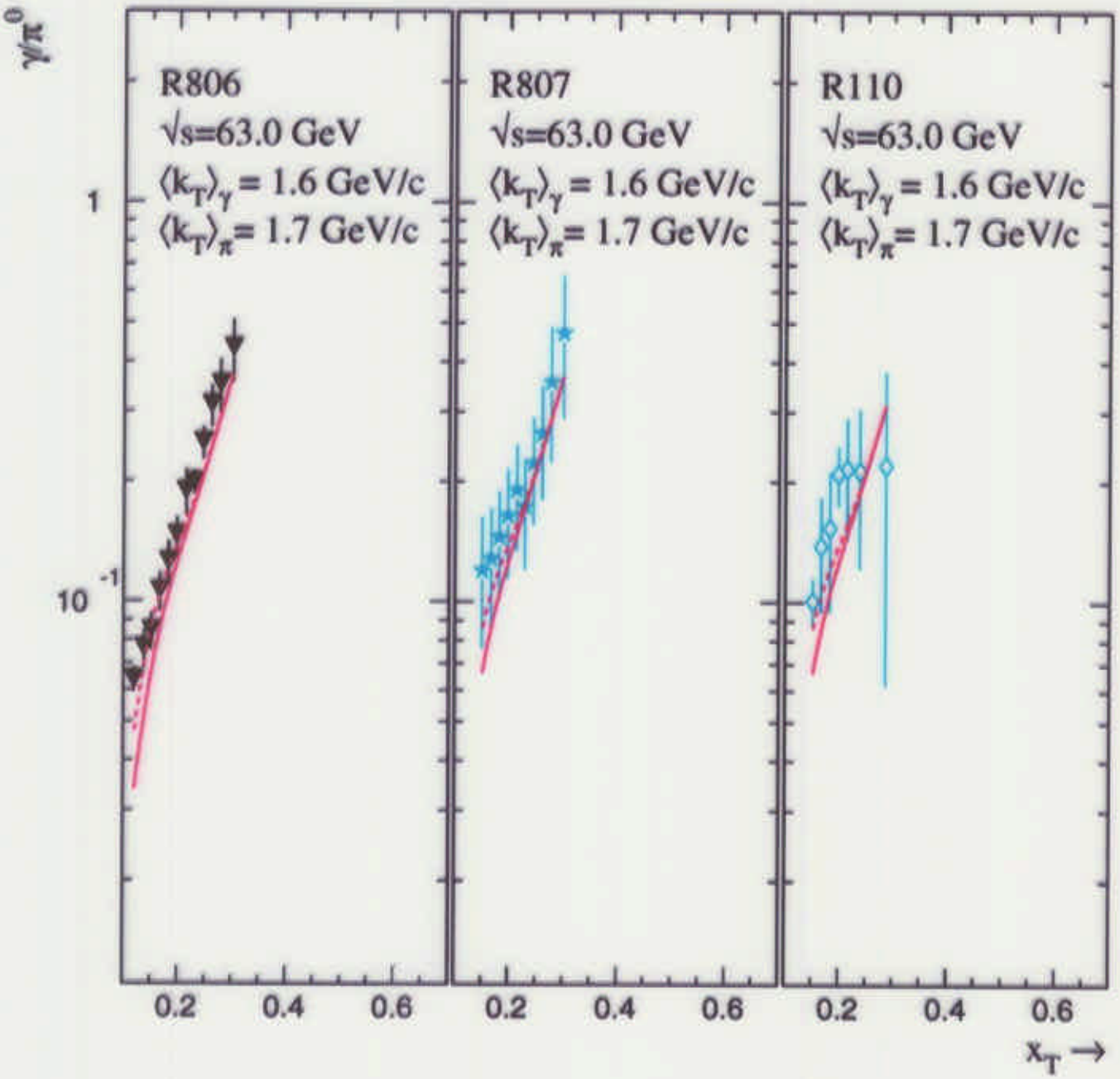
- Less sensitive to absolute normalization
- Less sensitive to extra gluon emission
- Less sensitive to scale

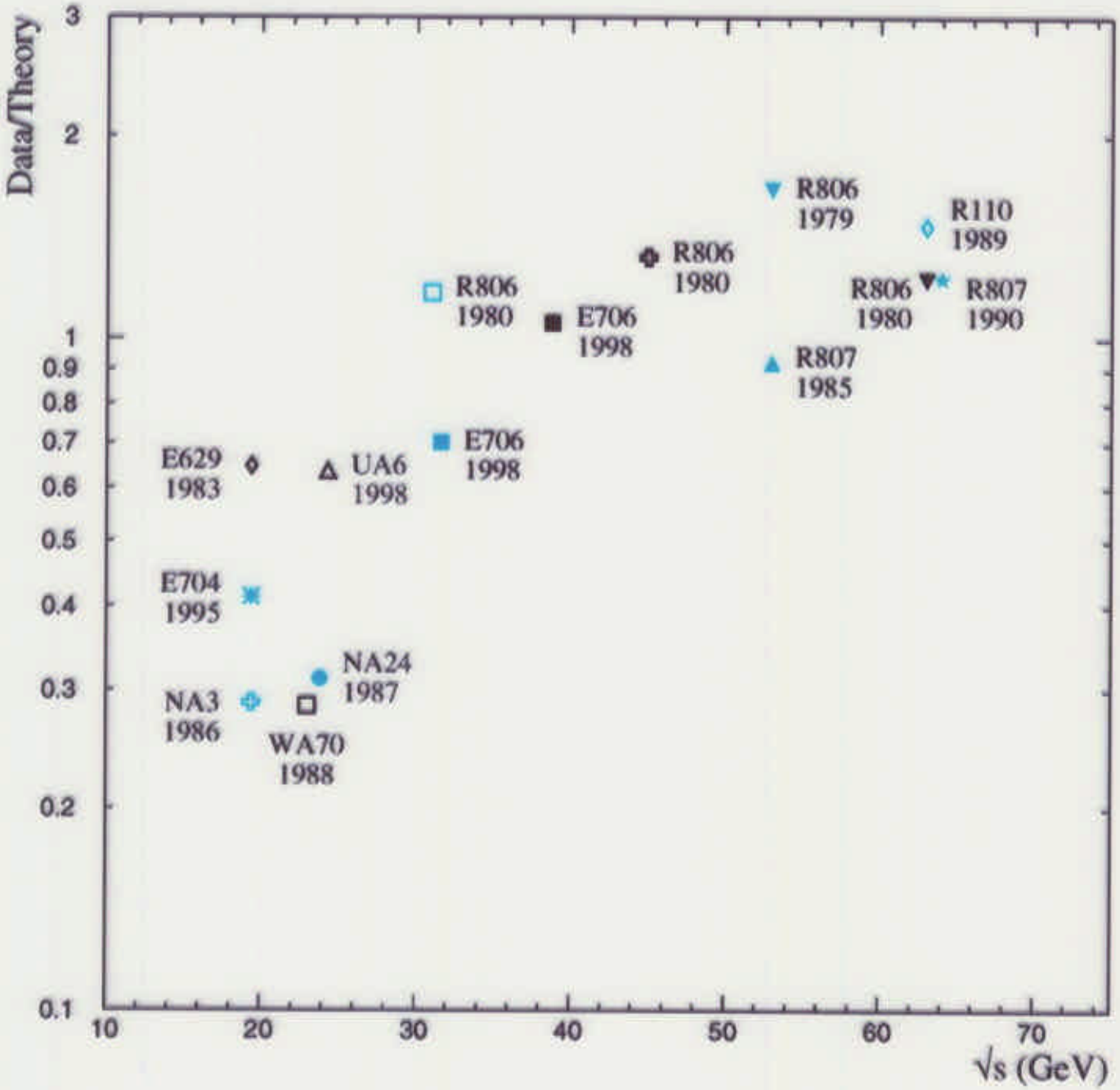

γ/π0
E704
√s=19.4 GeV
⟨kT⟩γ = 0.7 GeV/c
⟨kT⟩π = 0.8 GeV/c
E629
√s=19.4 GeV
⟨kT⟩γ = 0.7 GeV/c
⟨kT⟩π = 0.8 GeV/c
NA3
√s=19.4 GeV
⟨kT⟩γ = 0.7 GeV/c
⟨kT⟩π = 0.8 GeV/c
no ⟨kT⟩
with ⟨kT⟩
1
10 -1
0.2
0.4
0.6
xT →


γ/π⁰
WA70
√s=23.0 GeV
⟨k_T⟩_γ = 0.7 GeV/c
⟨k_T⟩_π = 0.8 GeV/c
NA24
√s=23.8 GeV
⟨k_T⟩_γ = 0.7 GeV/c
⟨k_T⟩_π = 0.8 GeV/c
UA6
√s=24.3 GeV
⟨k_T⟩_γ = 0.7 GeV/c
⟨k_T⟩_π = 0.8 GeV/c
1
10^-1
0.2
0.4
0.6
x_T →


γ/π⁰
1
10⁻¹
R806
√s=31.0 GeV
⟨k_T⟩_γ = 1.2 GeV/c
⟨k_T⟩_π = 1.3 GeV/c
E706
√s=31.6 GeV
⟨k_T⟩_γ = 1.2 GeV/c
⟨k_T⟩_π = 1.3 GeV/c
E706
√s=38.8 GeV
⟨k_T⟩_γ = 1.3 GeV/c
⟨k_T⟩_π = 1.4 GeV/c
0.2
0.4
0.6
x_T →


γ/π⁰
R806
√s=45.0 GeV
⟨k_T⟩_γ = 1.5 GeV/c
⟨k_T⟩_π = 1.6 GeV/c
R806
√s=53.0 GeV
⟨k_T⟩_γ = 1.5 GeV/c
⟨k_T⟩_π = 1.6 GeV/c
R807
√s=53.0 GeV
⟨k_T⟩_γ = 1.5 GeV/c
⟨k_T⟩_π = 1.6 GeV/c
1
10⁻¹
0.2
0.4
0.6
x_T →


γ/π⁰
R806
√s=63.0 GeV
⟨k_T⟩_γ = 1.6 GeV/c
⟨k_T⟩_π = 1.7 GeV/c
R807
√s=63.0 GeV
⟨k_T⟩_γ = 1.6 GeV/c
⟨k_T⟩_π = 1.7 GeV/c
R110
√s=63.0 GeV
⟨k_T⟩_γ = 1.6 GeV/c
⟨k_T⟩_π = 1.7 GeV/c
1
10^-1
0.2
0.4
0.6
x_T →


Data/Theory
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
10
20
30
40
50
60
70
√s (GeV)
R806
1979
R110
1989
R806
1980
R806
1980
R806
1980
E706
1998
R807
1990
R807
1985
E706
1998
E629
1983
UA6
1998
E704
1995
NA24
1987
NA3
1986
WA70
1988

Ratio of data/theory for γ/π production suggests presence of other problems beyond $\langle k_T \rangle$

Can π^0 resummation be sufficiently different from γ to offer hope for resolution of the observed discrepancy?

Ignoring π^0 production, is it safe now to extract $G(x)$ from direct-photon production? (Without controversy?)