Influence of k_T on High-p_T Particle Production

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High p_T Physics at RHIC II: Jets, j_T, k_T
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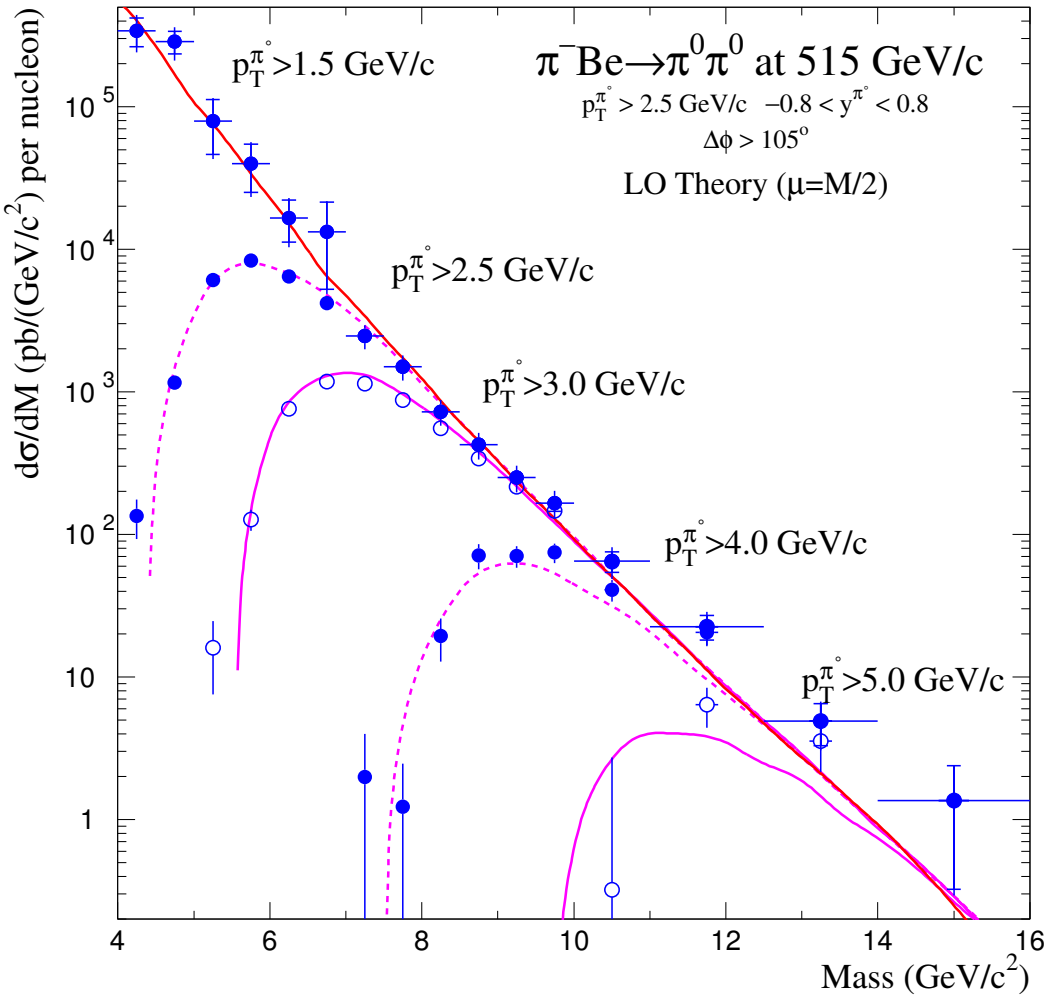
E706 Dipion Mass Distributions

The mass of the two leading particles is a natural observable for testing pQCD.

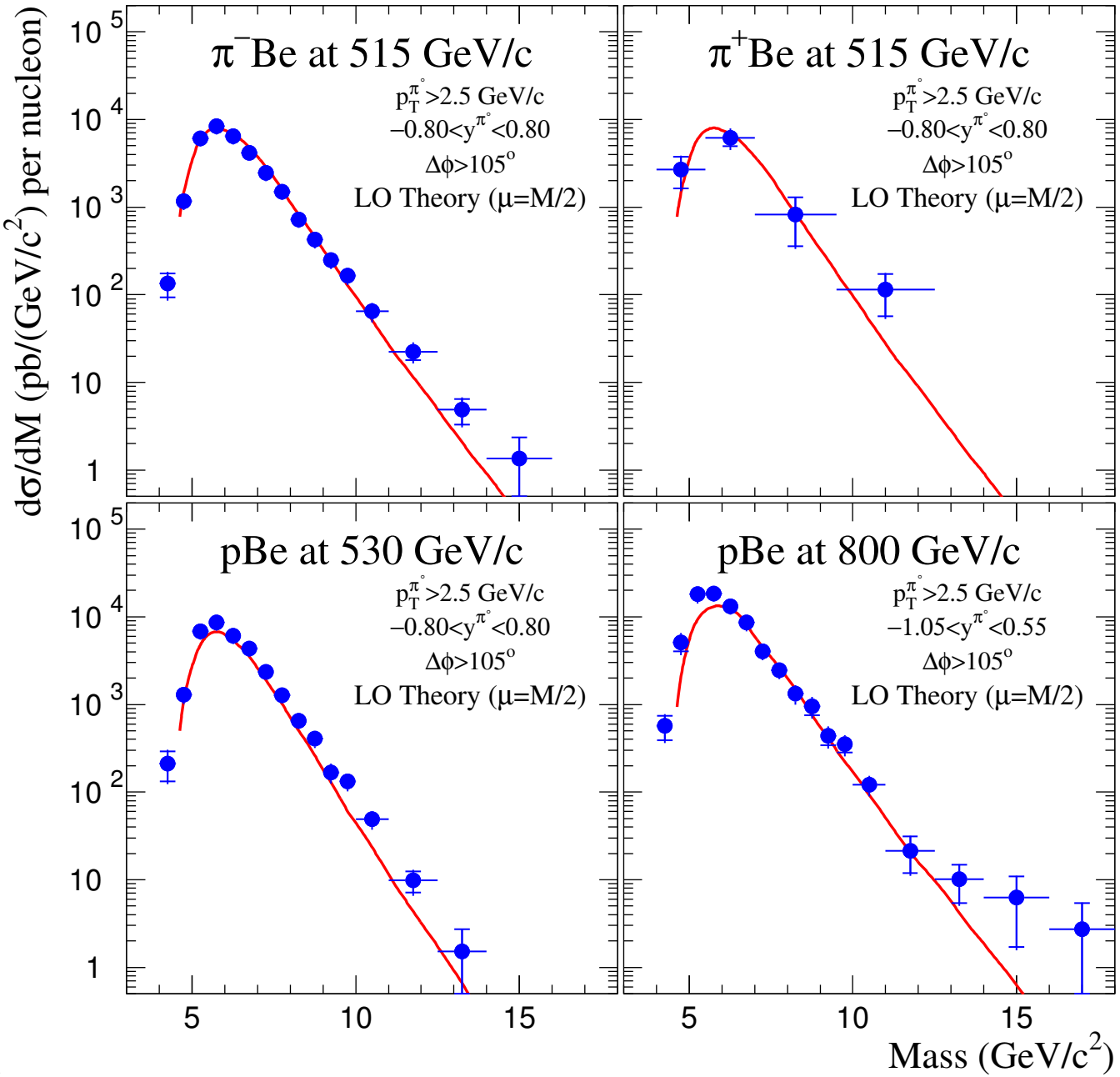
Additionally, mass is invariant under boosts and is therefore insensitive to the effects of initial-state radiation.

Typically, for k_T-insensitive quantities, LO pQCD compares well with data.

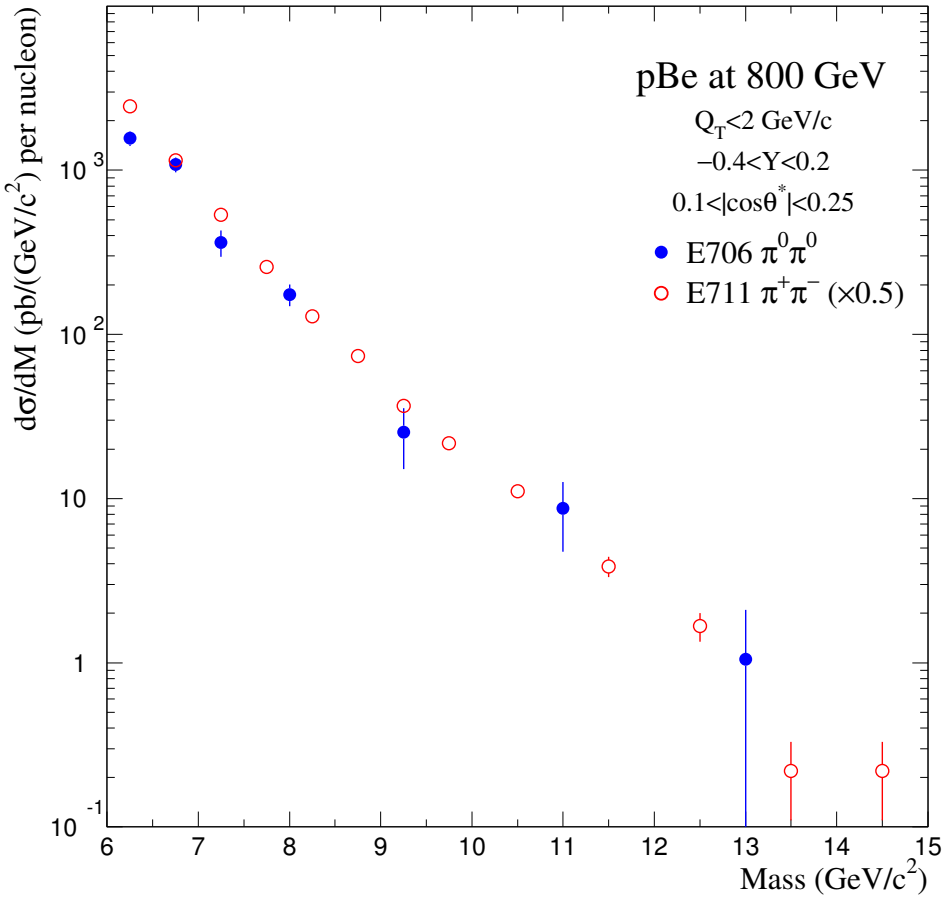


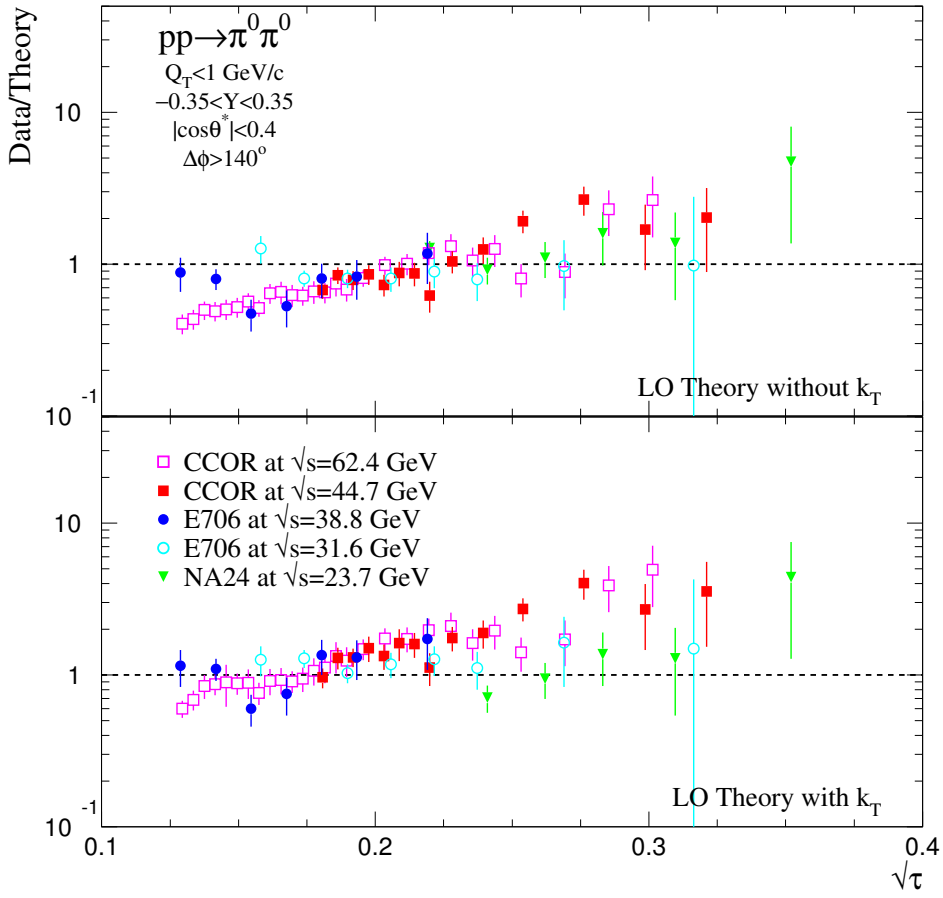
E706 Dipion Mass Distributions

$\sqrt{s} \approx 30 - 40$ GeV



Dipions at NA24/E706/E711/CCOR



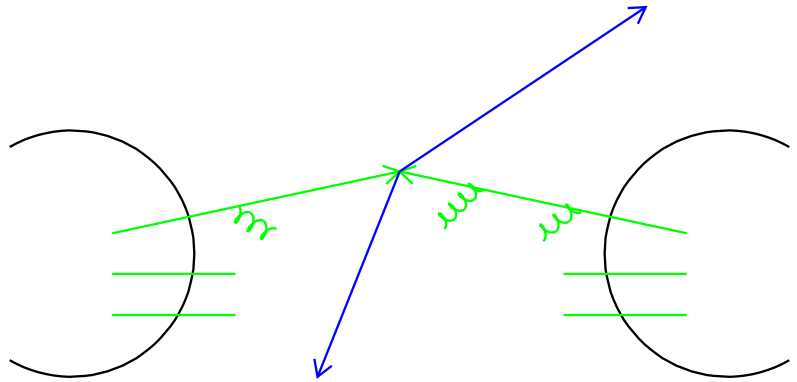


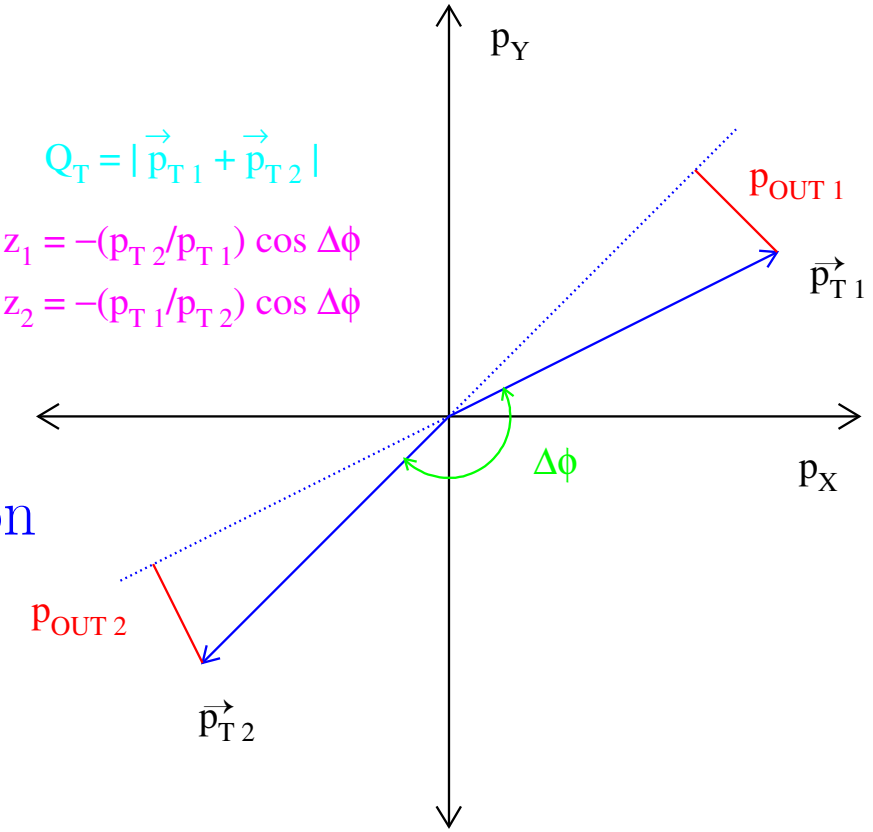
The $\pi\pi$ data in these plots have equivalent cuts.
Most of the data agree within uncertainties.

Correlations in Pair Production

Correlations between high-p_T particles probe aspects of the hard-scatter not easily accessible via studies of inclusive particle production.

In particular, studies of high-mass pairs of particles such as direct-photons and pions may be used to extract information about the transverse momenta of partons prior to the hard-scatter (k_T).

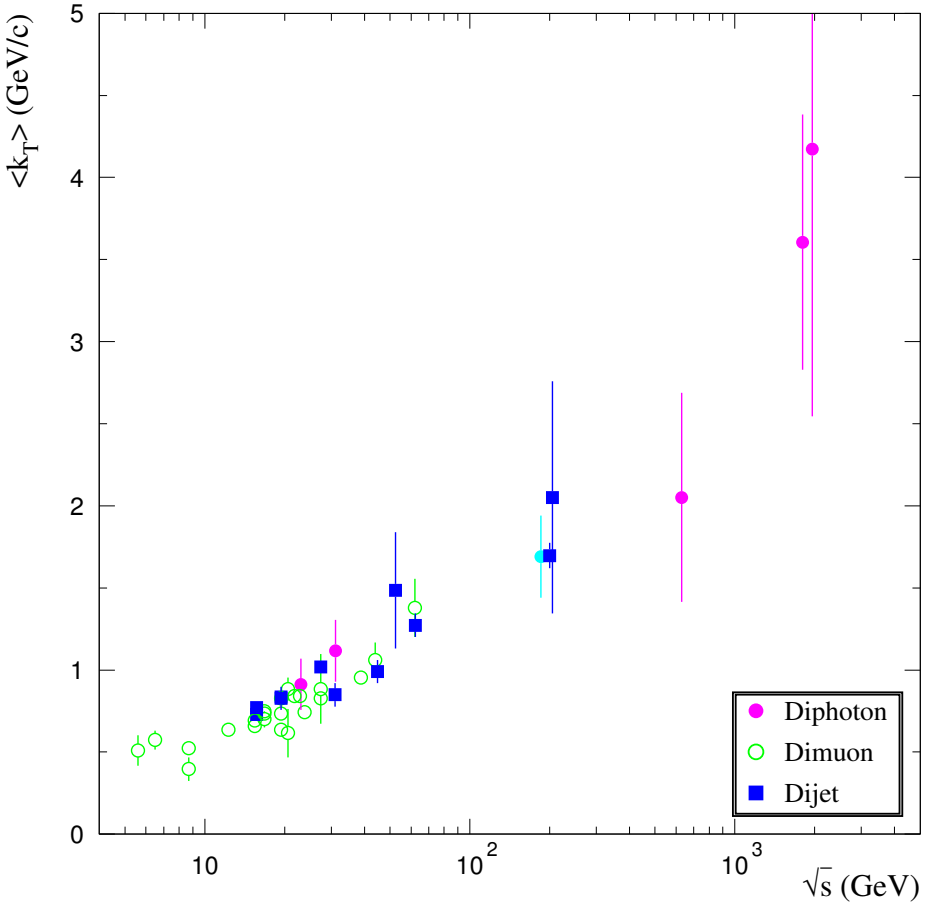




About k_T Effects

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 Drell-Yan and diphoton production, and have been interpreted as resulting from multiple soft gluon emissions.



k_T is expected to modify

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

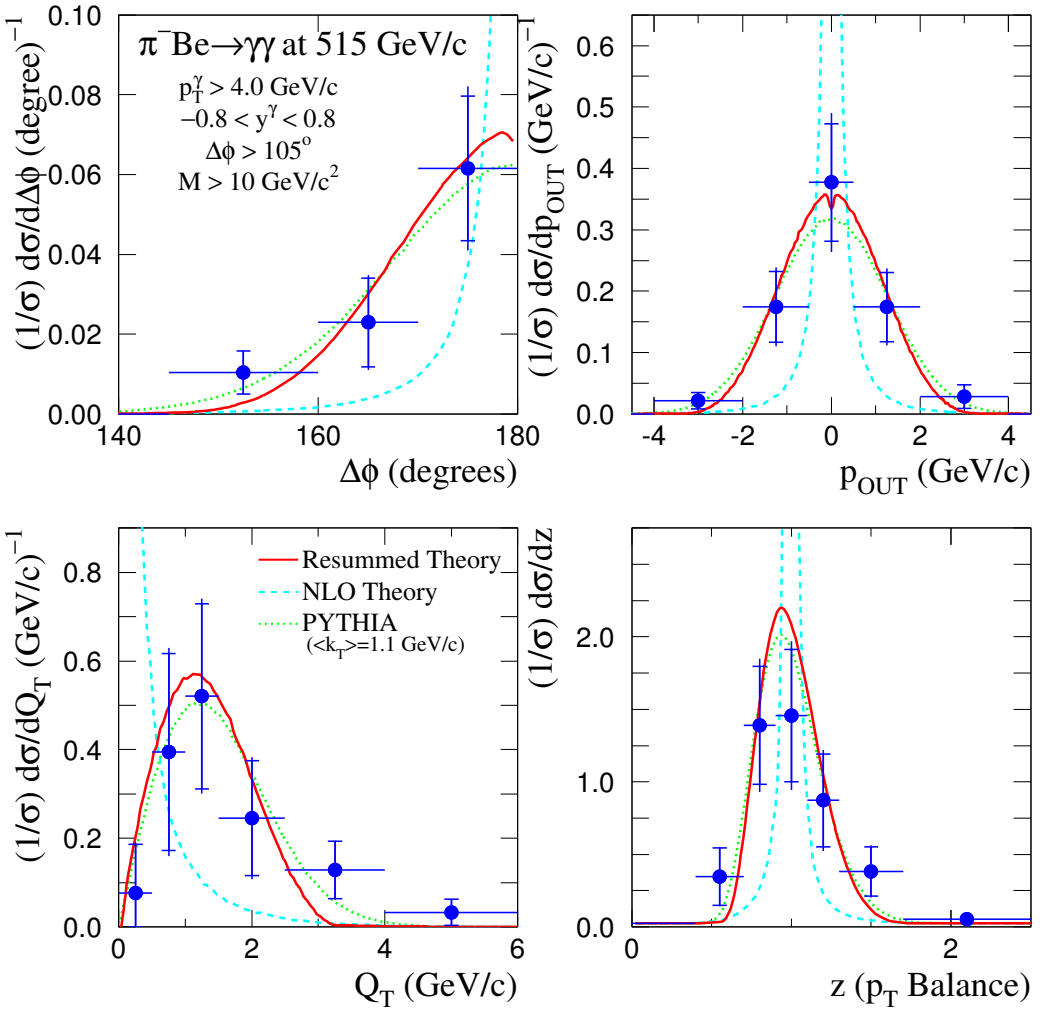
E706 Diphoton Correlations

$\sqrt{s} = 31.1$ GeV

Fixed order pQCD calculations do not sufficiently describe kinematic correlations between pairs of direct photons.

Resummed pQCD calculations agree well with the data distributions.

PYTHIA with k_T smearing also describes the data.

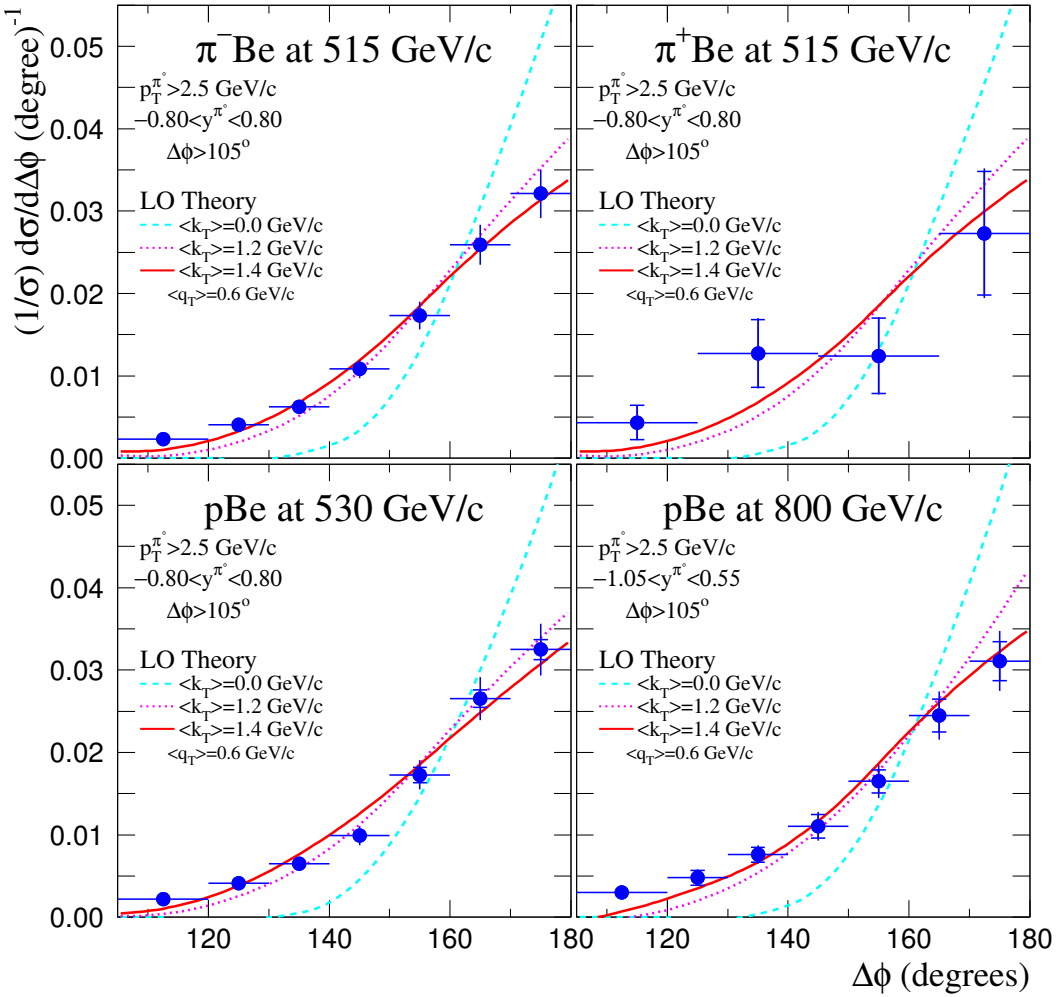


E706 Dipion Correlations

$\sqrt{s} \approx 30 - 40$ GeV

A LO pQCD calculation that models k_T via Gaussian smearing is compared against the data.

We assume $\langle j_T \rangle = 0.6$ GeV/c based on CCOR and R702 measurements.
(labelled as $\langle q_T \rangle$ in the plots).



E706 Dipion Correlations

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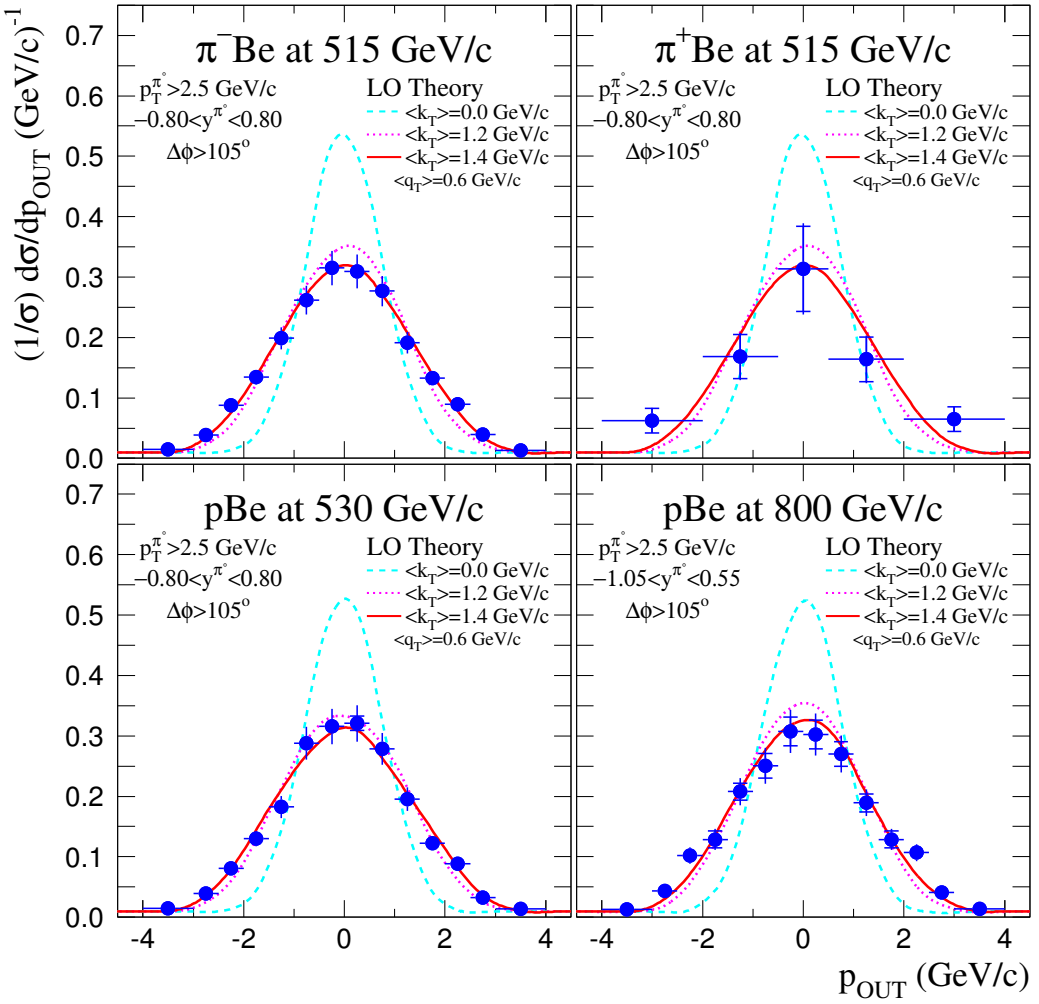
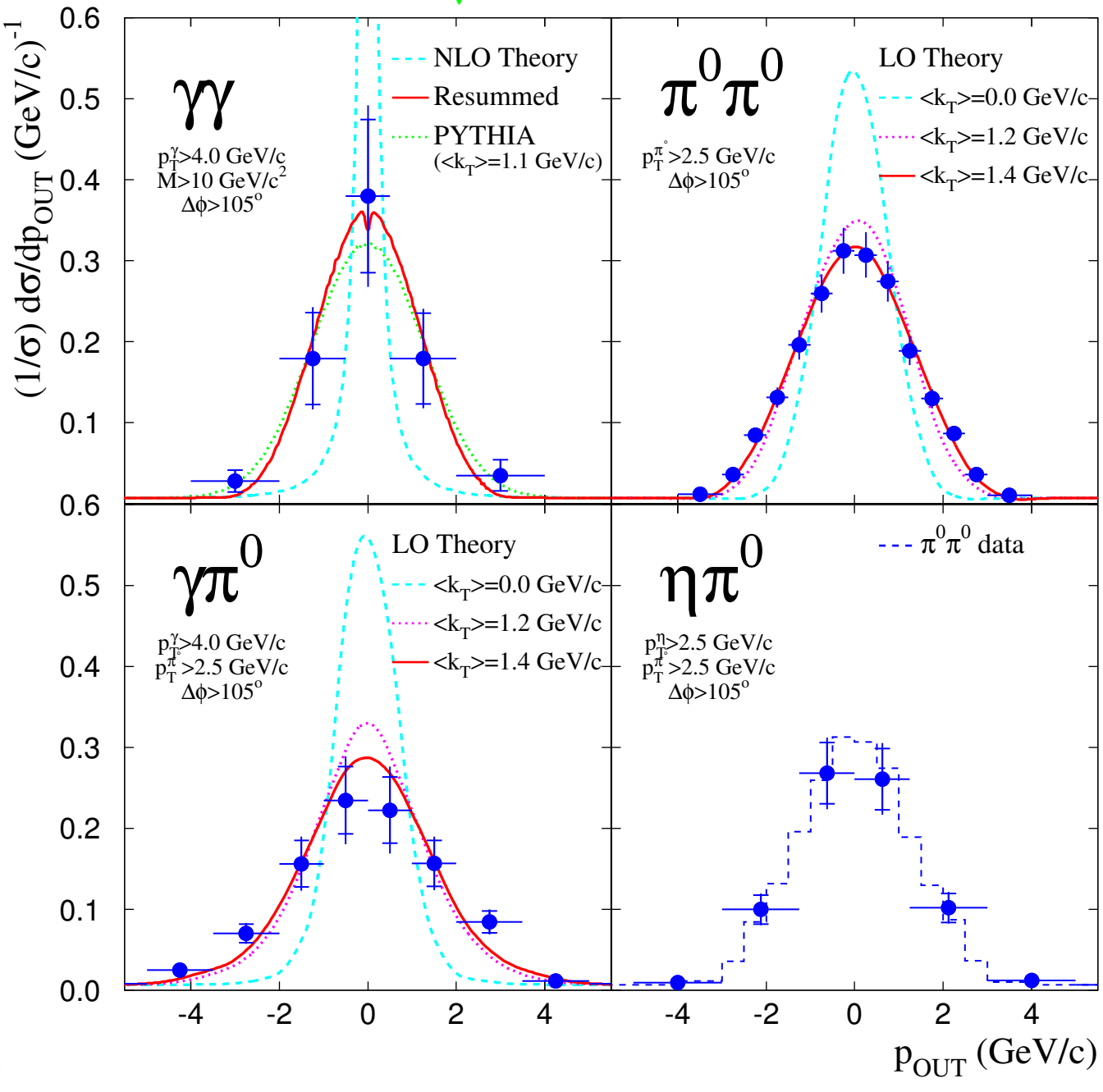
(labelled as $\langle q_T \rangle$ in the plots).

Each pair enters twice.



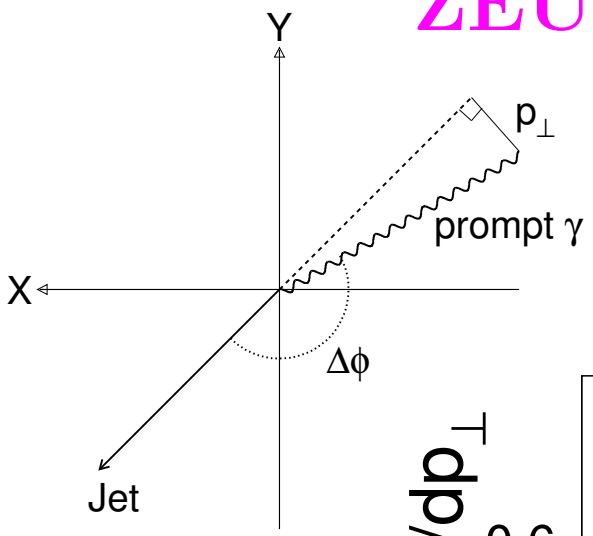
E706 Correlations Summary

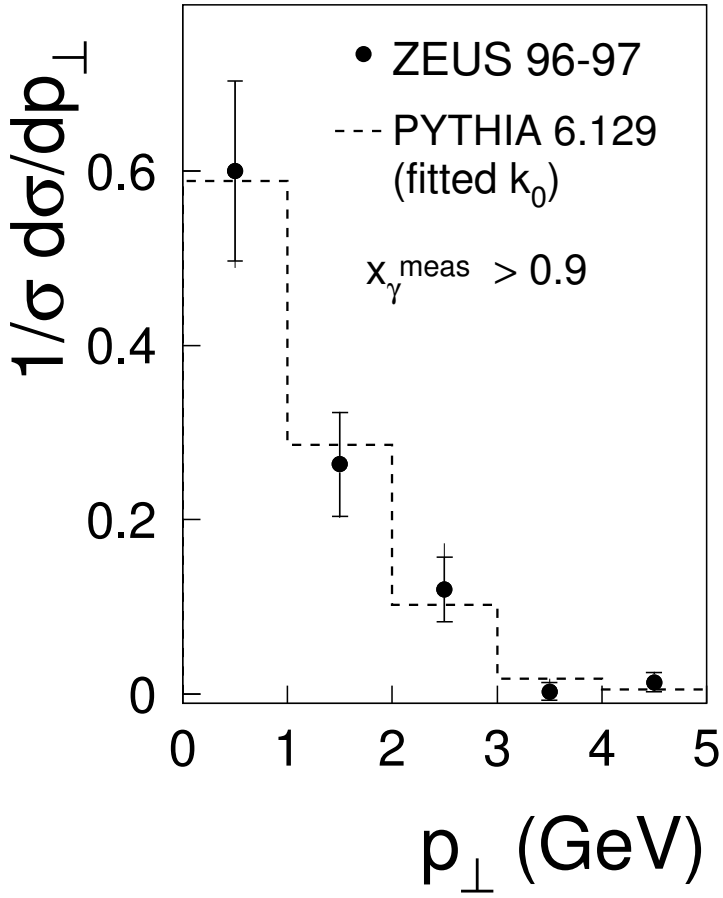
$\sqrt{s} = 31.1$ GeV

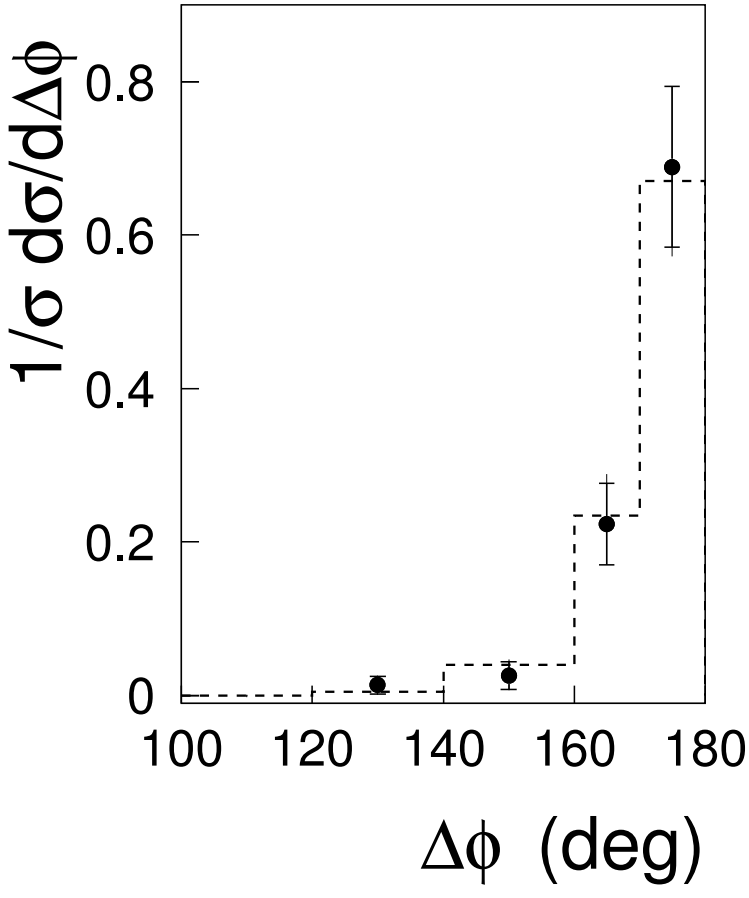


ZEUS Photon Correlations

$\sqrt{s} \approx 200\,\mathrm{GeV}$



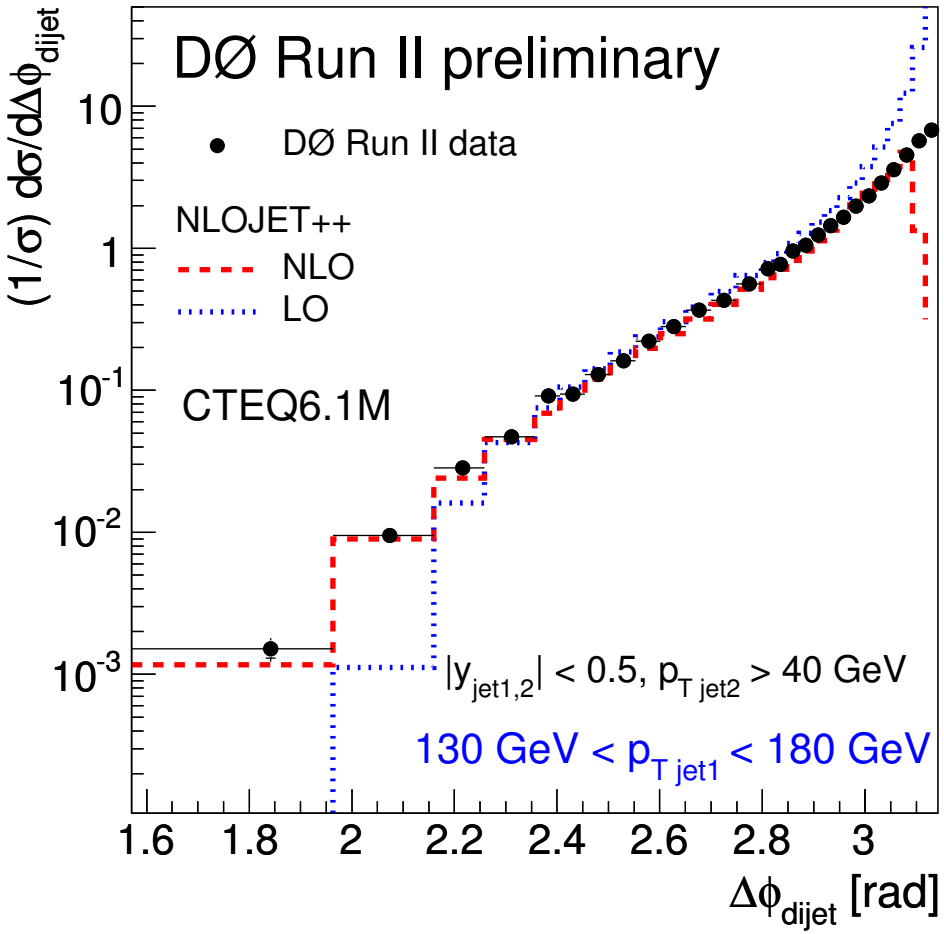


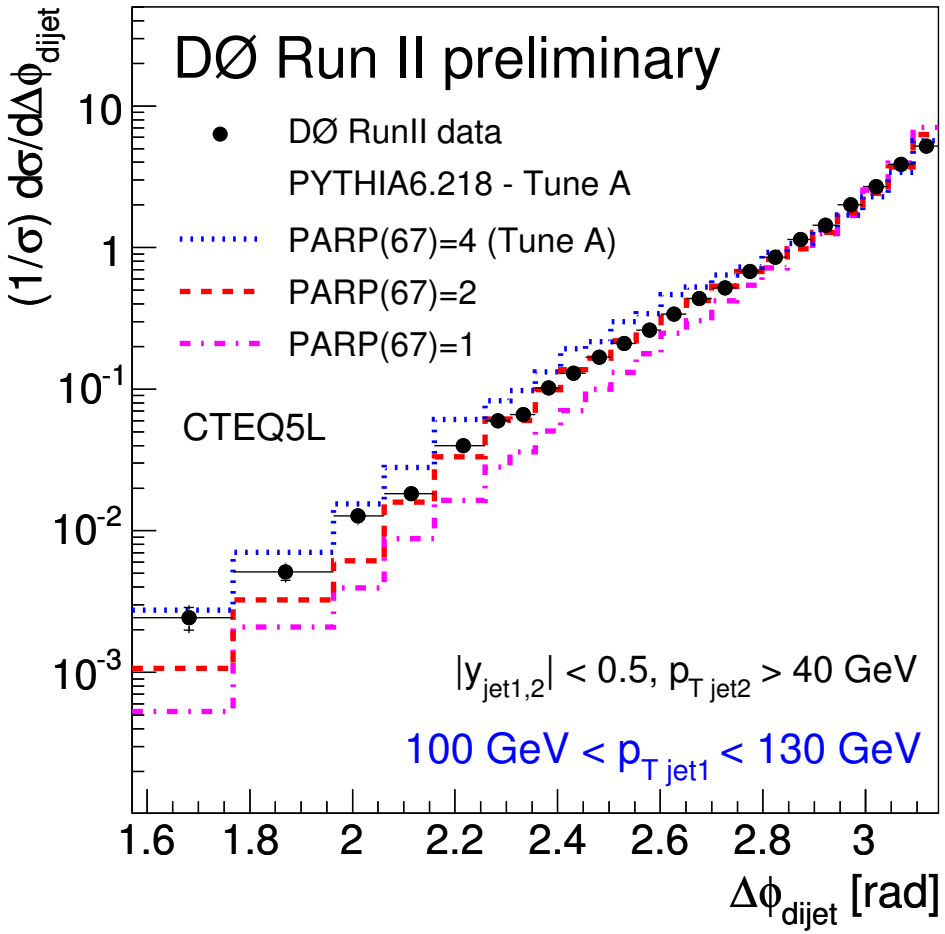


$\langle k_T \rangle = 1.69 \pm 0.18^{+0.18}_{-0.20}\,\mathrm{GeV/c}$

DØ Dijet Production

$\sqrt{s} = 1960$ GeV

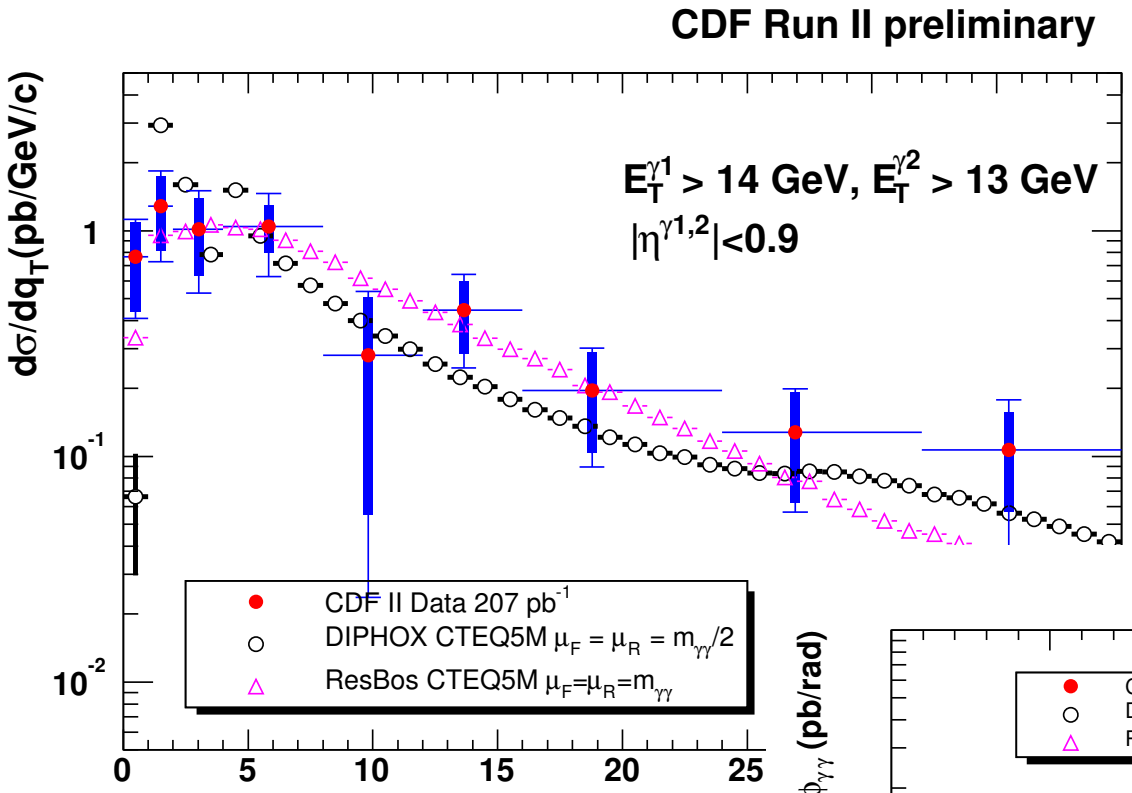


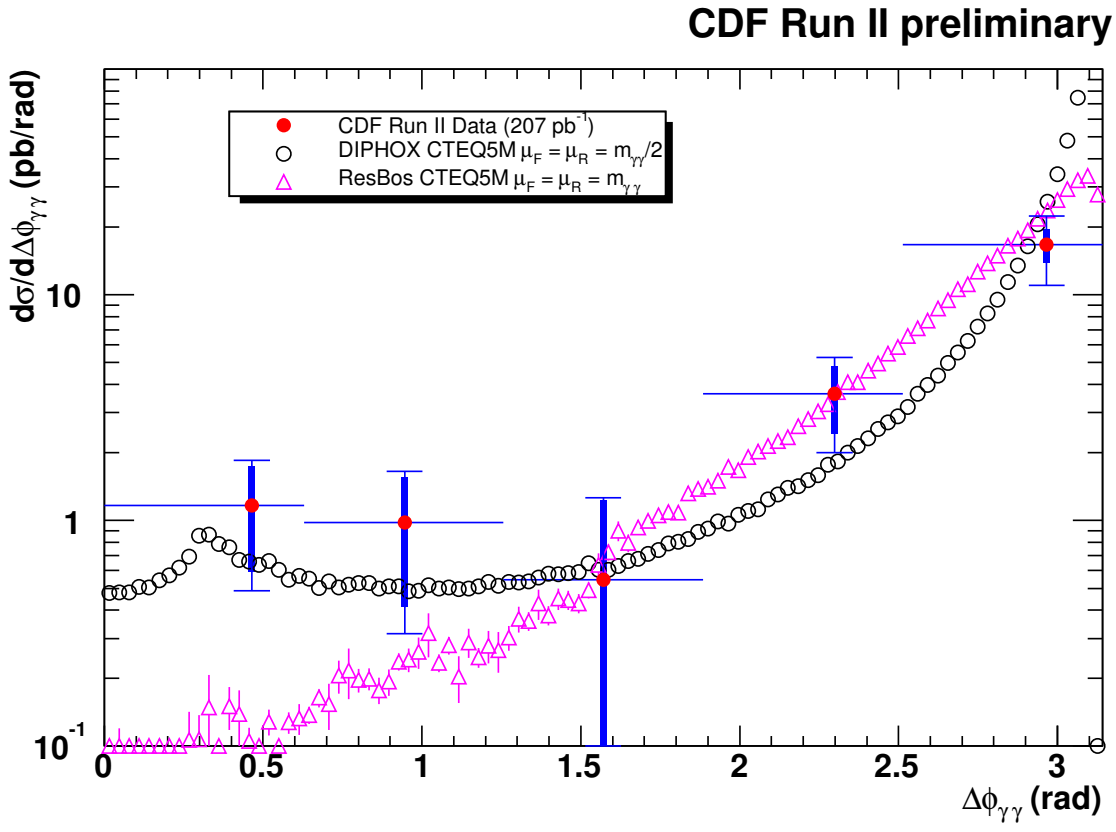


Higher-order pQCD calculations have additional radiation. One that includes LO 4-parton emission (NLO in 3-parton) agrees better with data than one limited to 3-parton emission (LO). Both calculations diverge at $\Delta\phi \sim \pi$. Tuned PYTHIA with $\langle k_T \rangle \approx 2 - 3$ GeV/c also matches the dijet $\Delta\phi$ distribution.

CDF Diphoton Correlations

$\sqrt{s} = 1960$ GeV



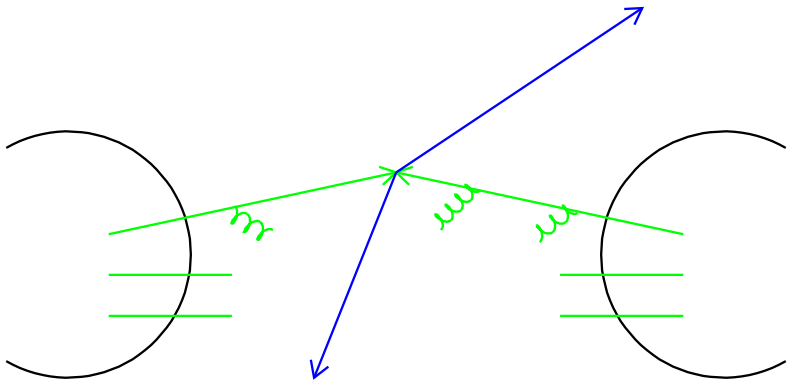


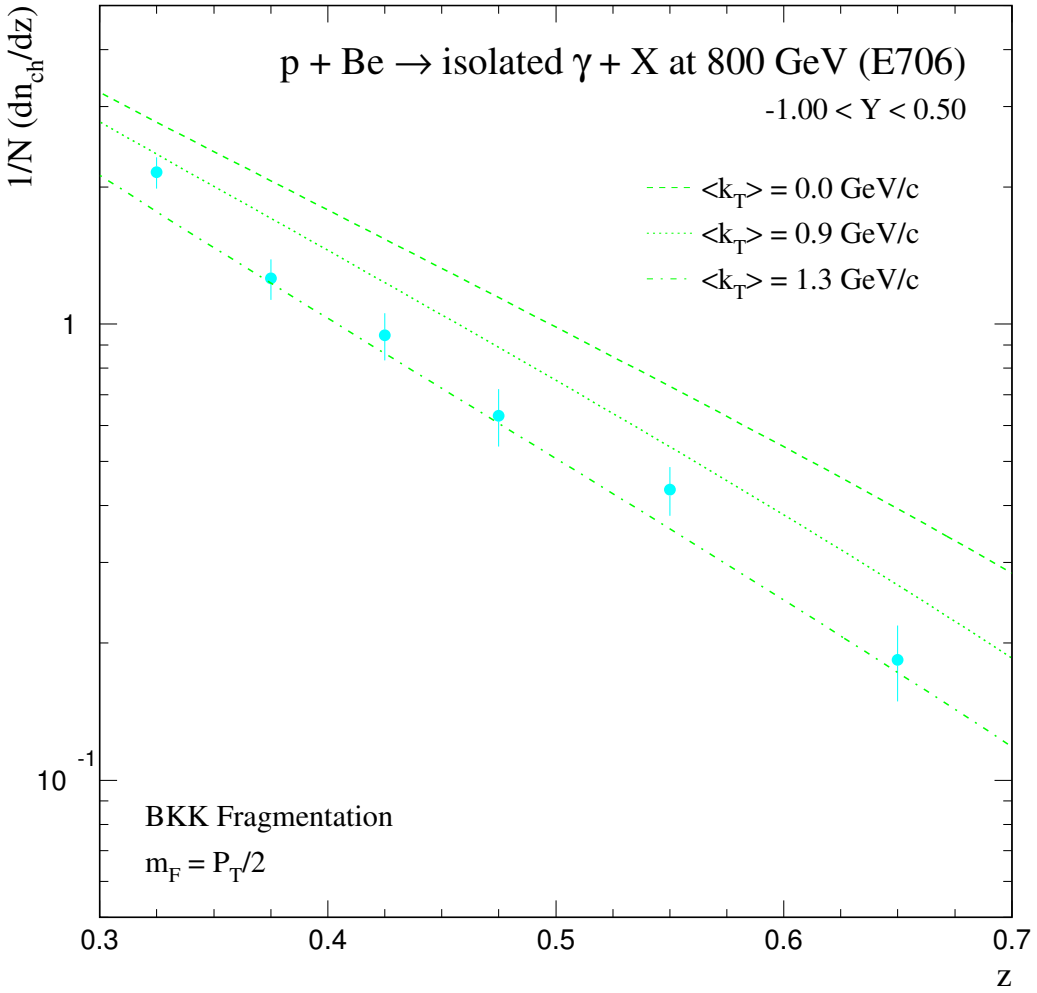
E706 Away-side Particles

$\sqrt{s} = 38.8$ GeV

k_T affects fragmentation distributions in jets recoiling against high-p_T triggers.

Particles produced opposite a high-p_T trigger have softer distributions — this effect is similar to *trigger bias*.





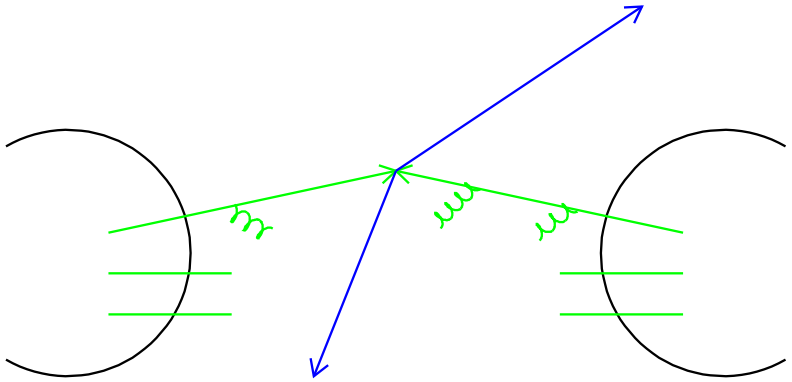
Single Particle Inclusive Production

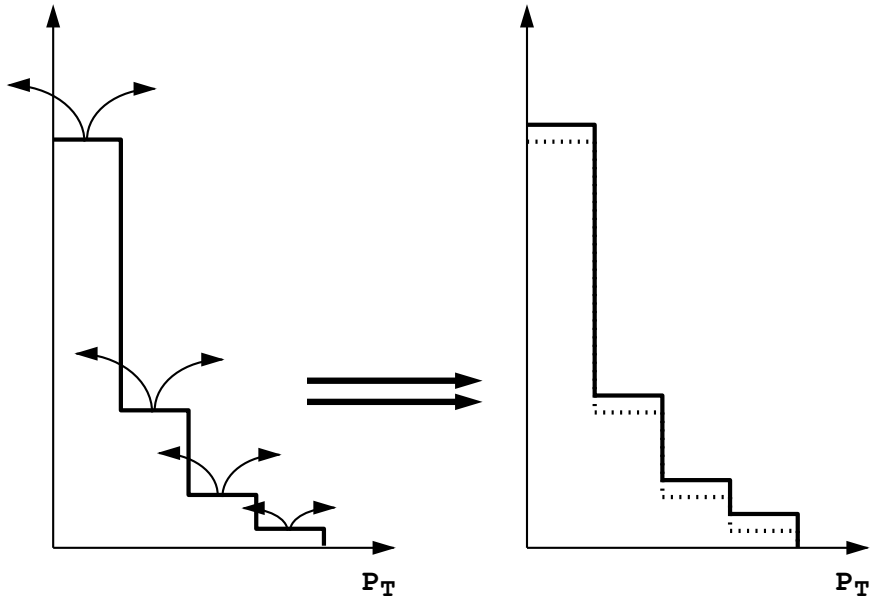
k_T has an impact on the magnitude and shape of high-p_T inclusive cross sections.

In many respects, k_T affects p_T distributions like resolution smearing. Distributions may show an effect for $p_T >> \langle k_T \rangle$.

Resummed pQCD calculations should properly include k_T effects.

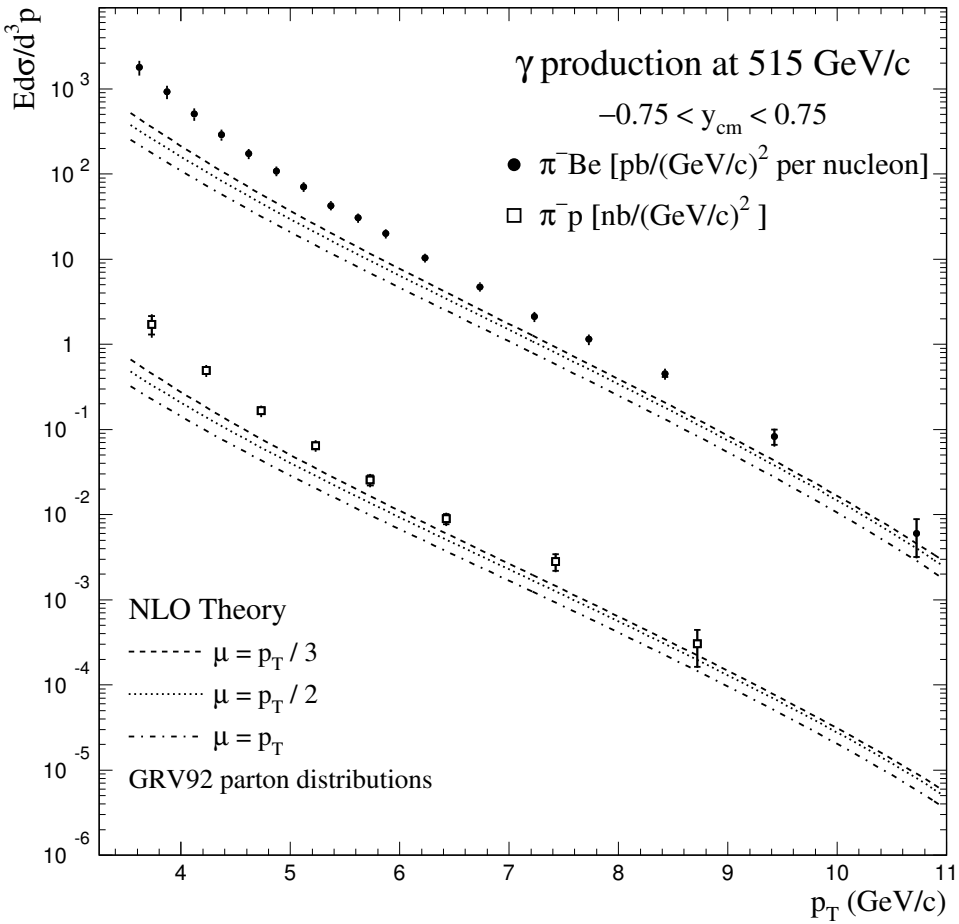
High-order pQCD calculations should also partially compensate for this effect by including additional radiation.

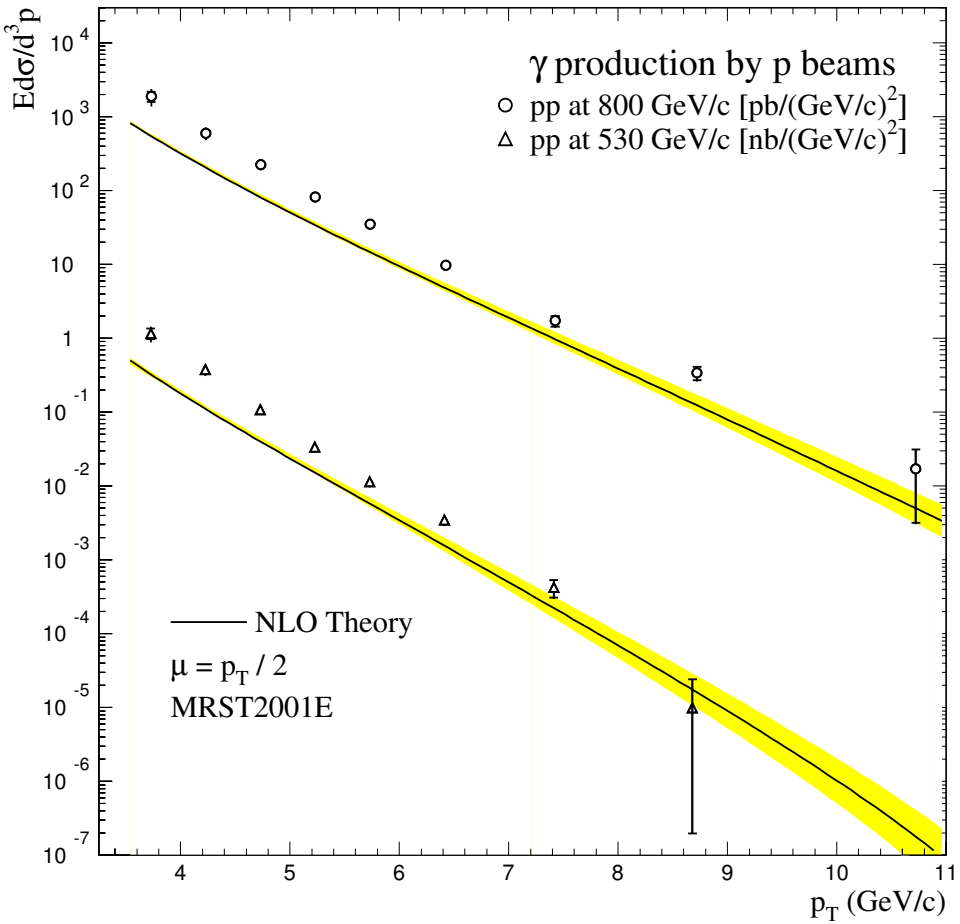




E706 Inclusive Production

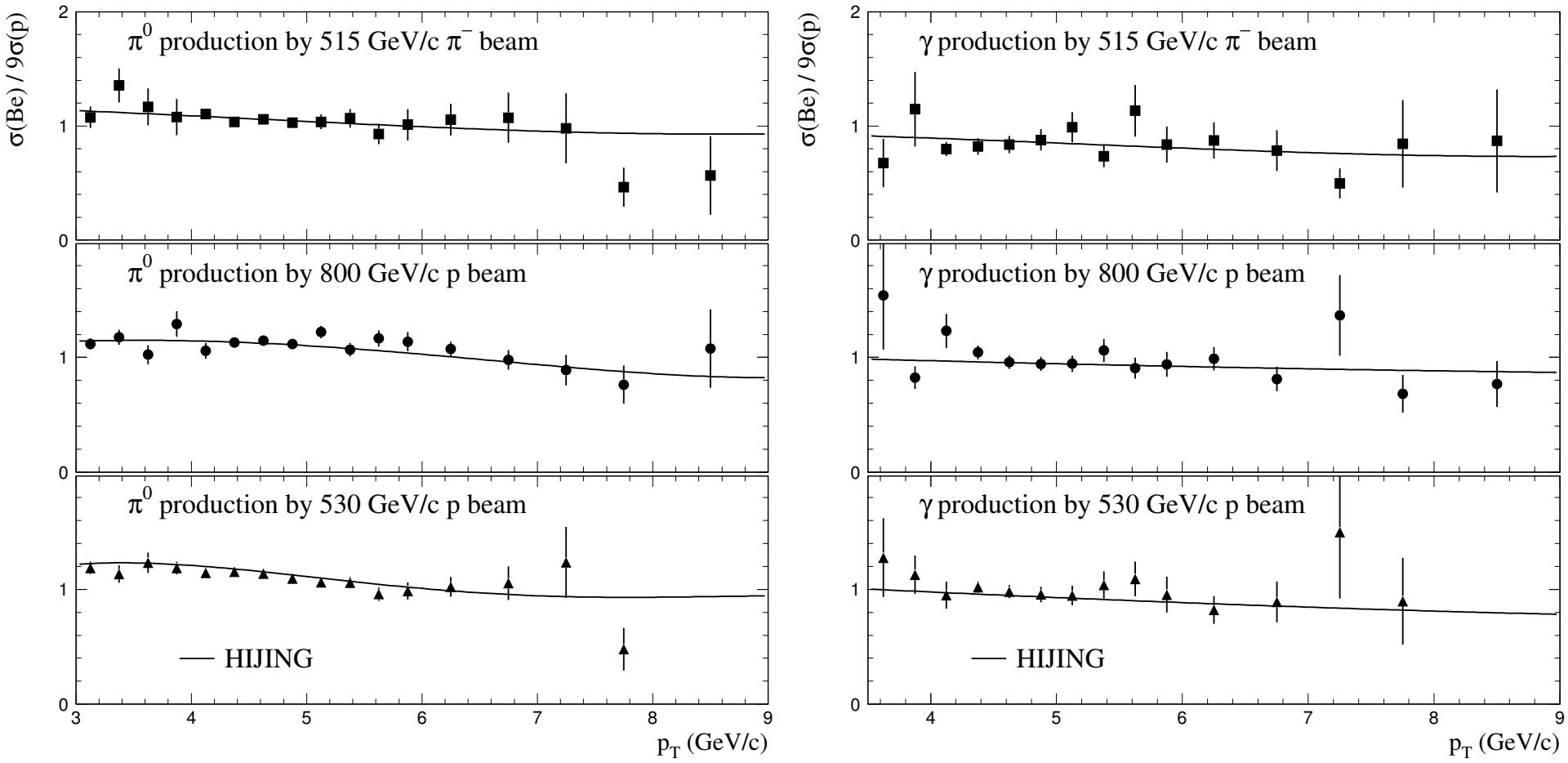
$\sqrt{s} \approx 30 - 40$ GeV





NLO pQCD calculations do not agree with measurements of direct photon production and exibit large scale dependence. PDF uncertainties, while large, do not have sufficient flexibility to make up the difference.

Nuclear Dependence — Be/H



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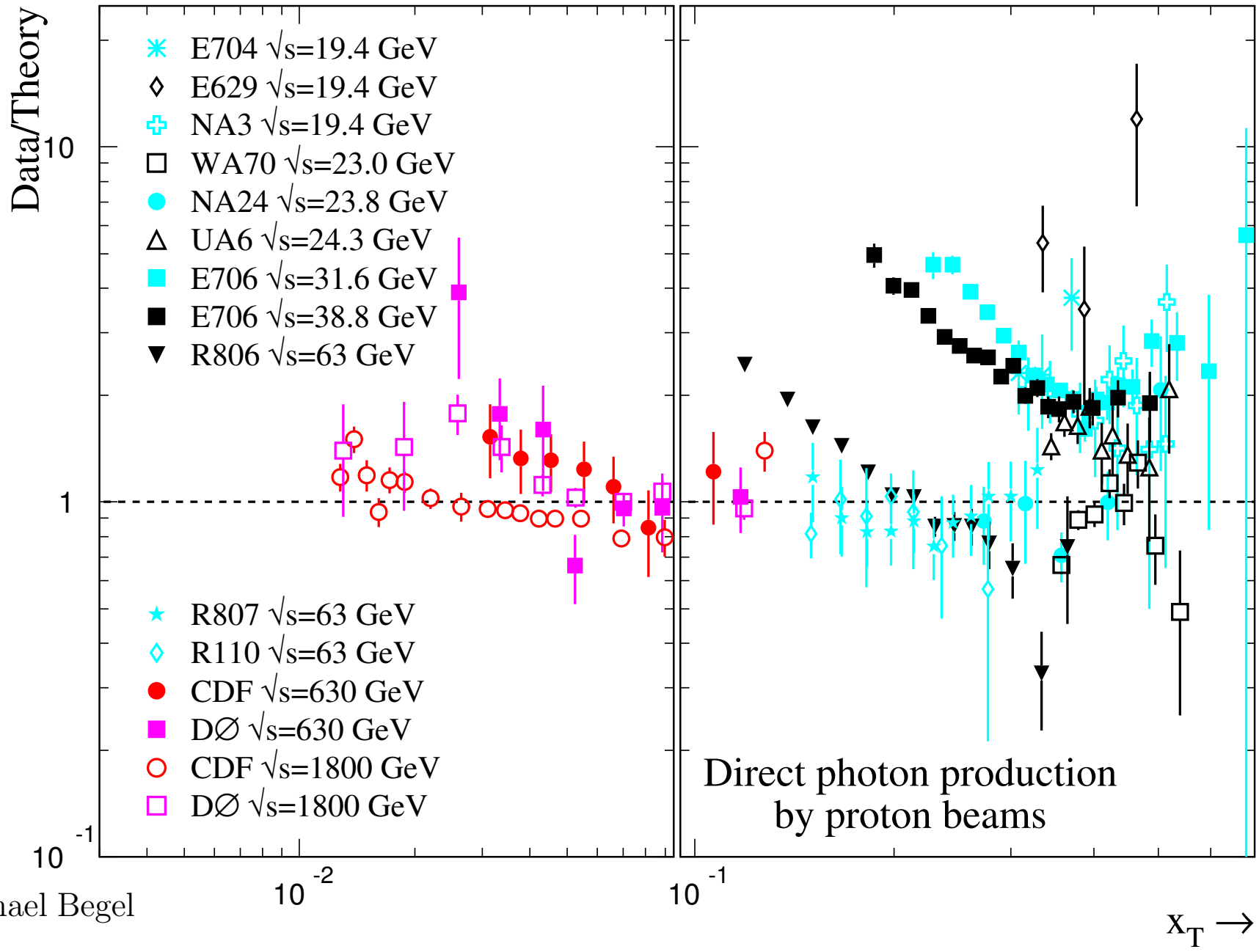
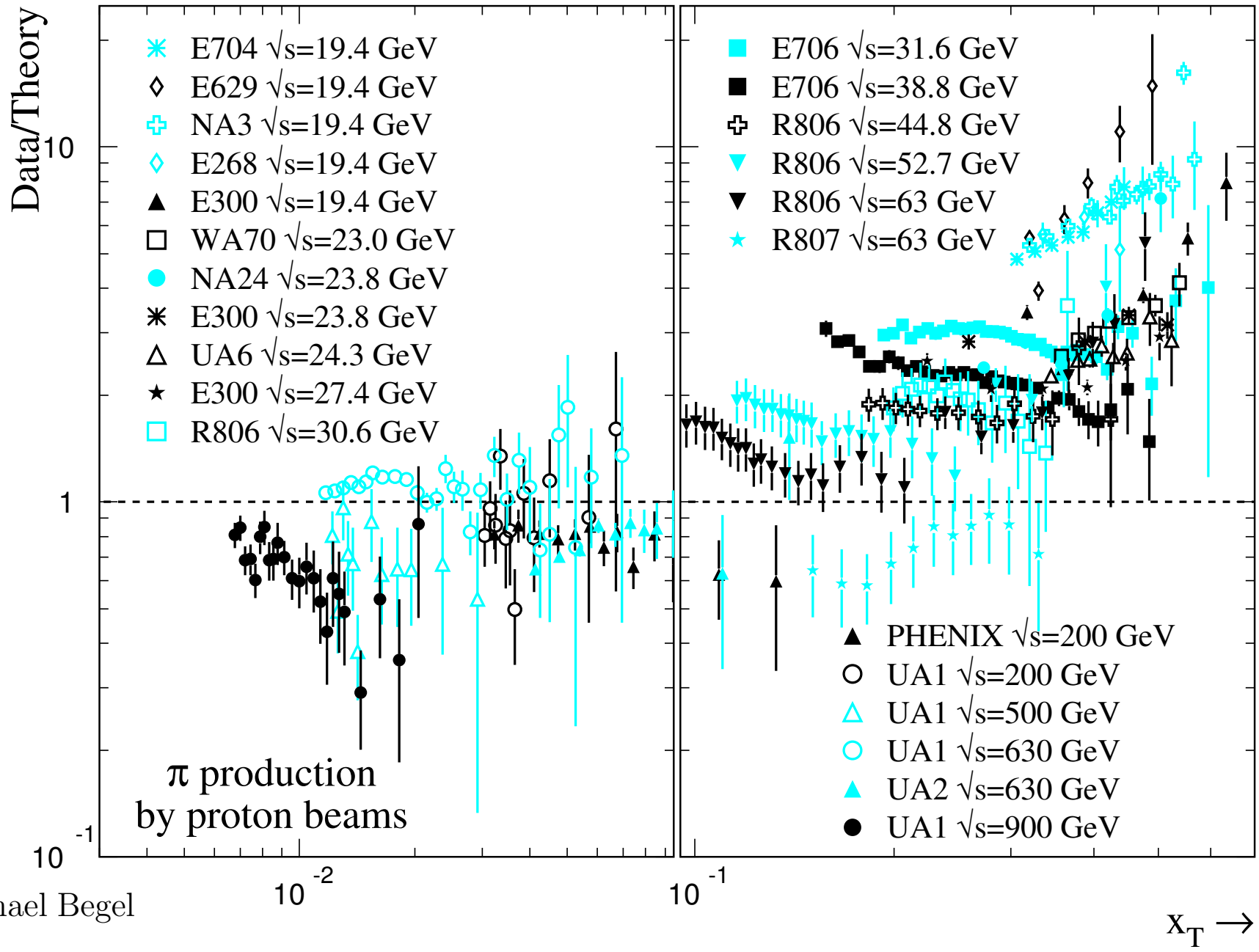
Photon Production at Hadron–Hadron Experiments



Pion Production at Hadron–Hadron Experiments



Modeling k_T Effects

LO pQCD calculations model incident-parton k_T using Gaussian smearing. This smearing is not available in current NLO pQCD calculations.

Approximate treatment:

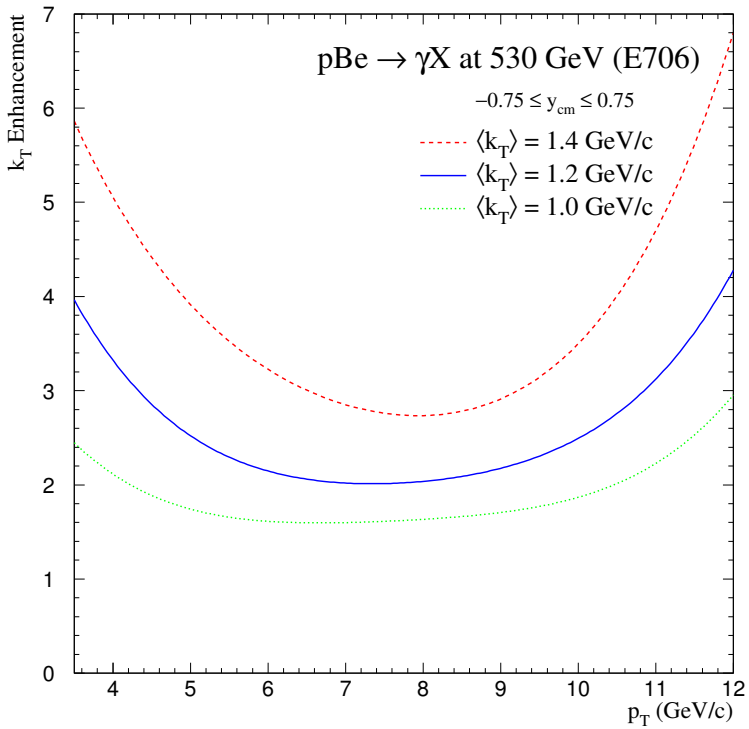
$$\sigma^{\mathrm{NLO}} \times \mathrm{K}^{\mathrm{LO}}(p_T),$$

where,

$$\mathrm{K}^{\mathrm{LO}}(p_T) = \frac{\sigma^{\mathrm{LO}}\left(\langle k_T \rangle\right)}{\sigma^{\mathrm{LO}}\left(\langle k_T \rangle = 0\right)}.$$

Double-counting of contributions is expected to be small:

- $\langle p_T \rangle_{\gamma\gamma}^{\mathrm{NLO}} \sim$ a few hundred MeV/c
- $\langle p_T \rangle_{\gamma\gamma}^{\mathrm{RESUMMED}} \approx 1.5$ GeV/c at $\sqrt{s} = 31.1$ GeV



$\langle k_T \rangle$ for calculations of $\mathrm{K}^{\mathrm{LO}}(p_T)$ taken from data

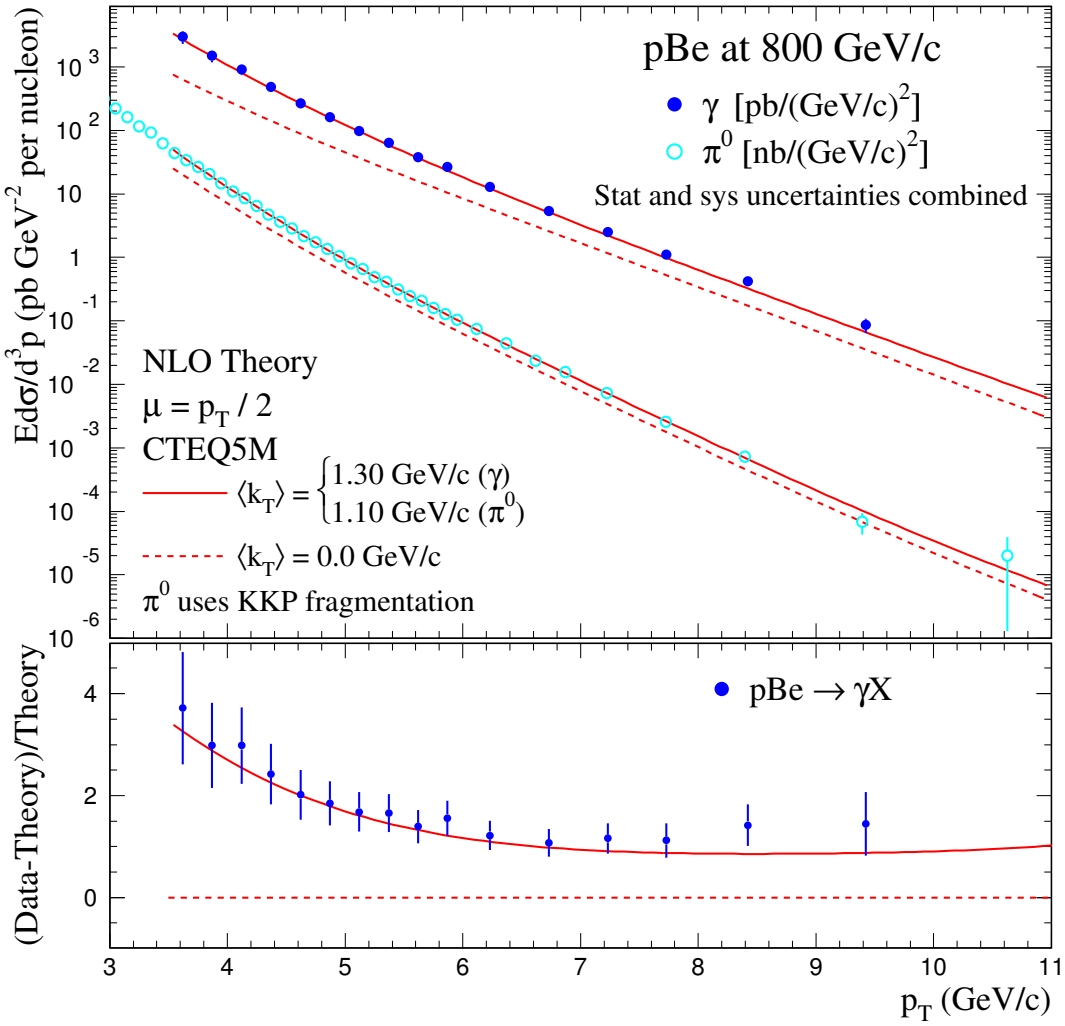
(match distributions of high-mass pairs to LO calculations)

E706 Inclusive Production with k_T

$\sqrt{s} = 38.8$ GeV

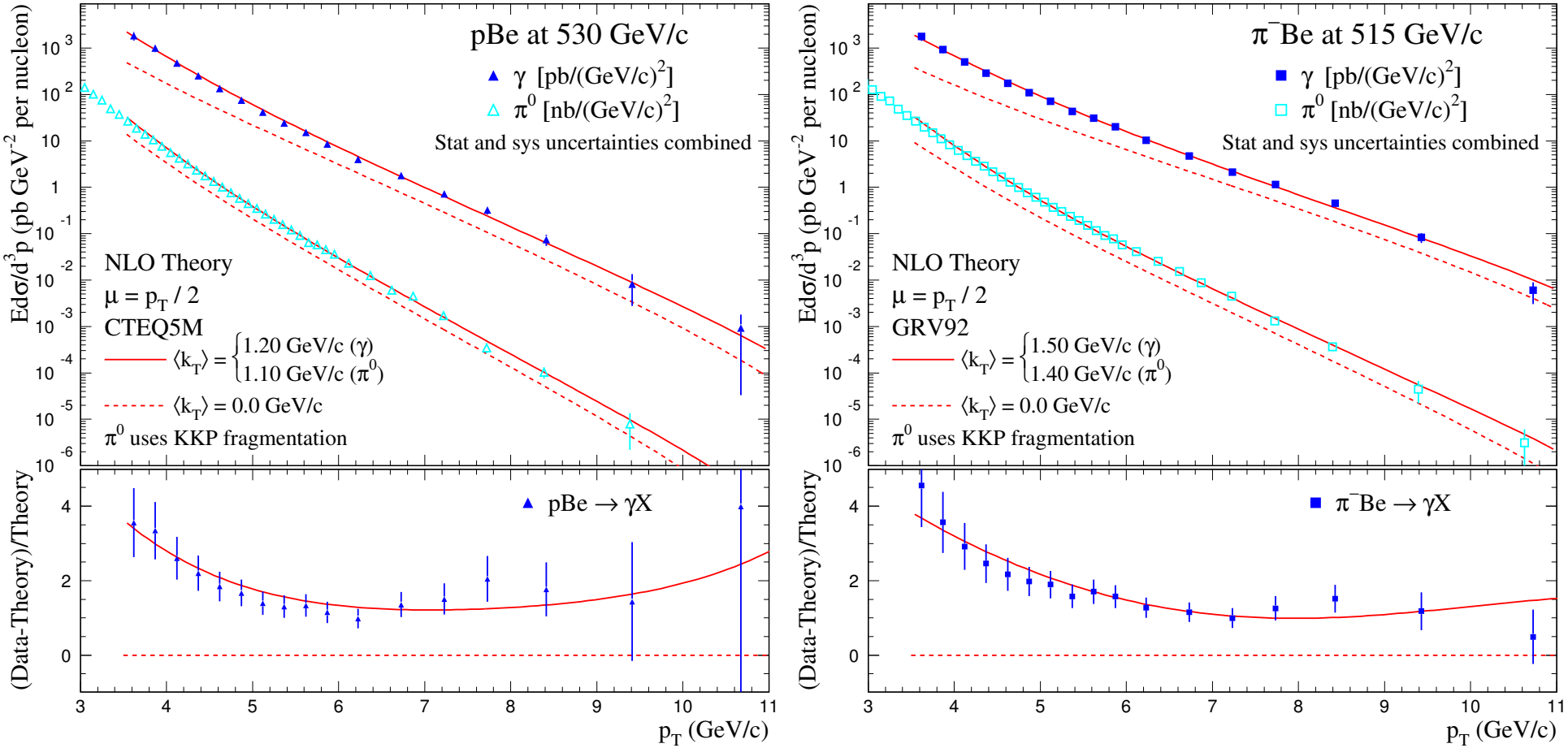
k_T-enhanced NLO pQCD compares well with both direct-γ and π^0 data.

Chosen k_T values were influenced by studies of two particle correlations but are model dependent. This is not a measurement of k_T.



E706 Inclusive Production with k_T

$\sqrt{s} \approx 31$ GeV

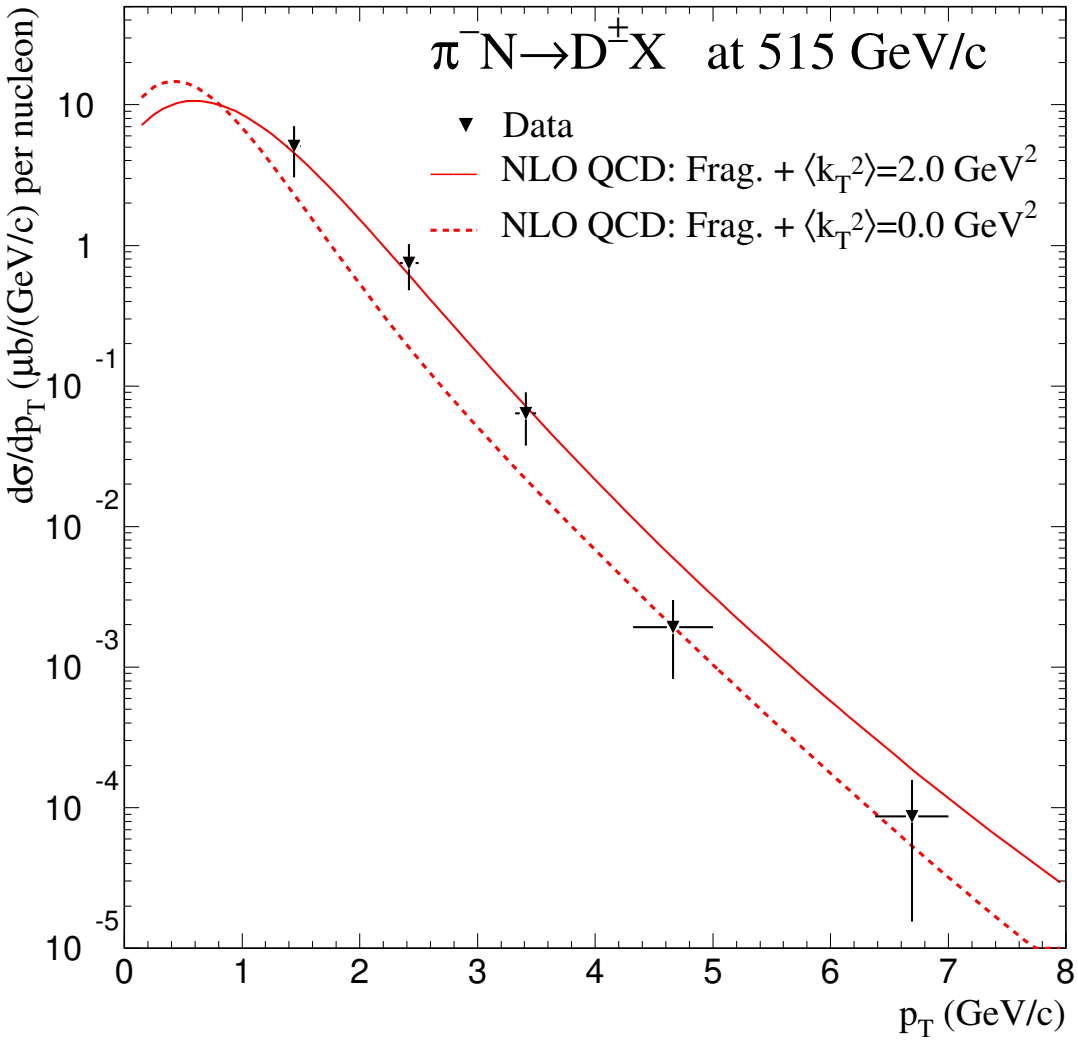


E706 Charm Production

$\sqrt{s} = 31.1$ GeV

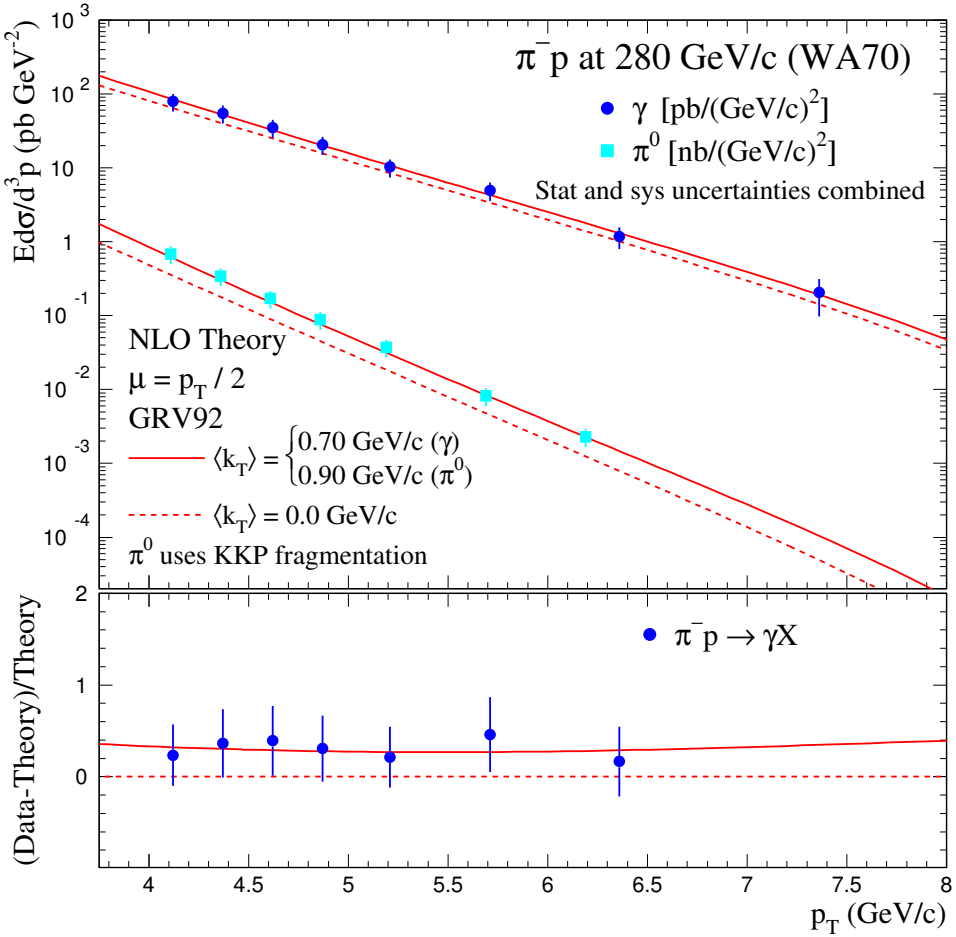
Heavy flavor production is also affected by k_T effects.

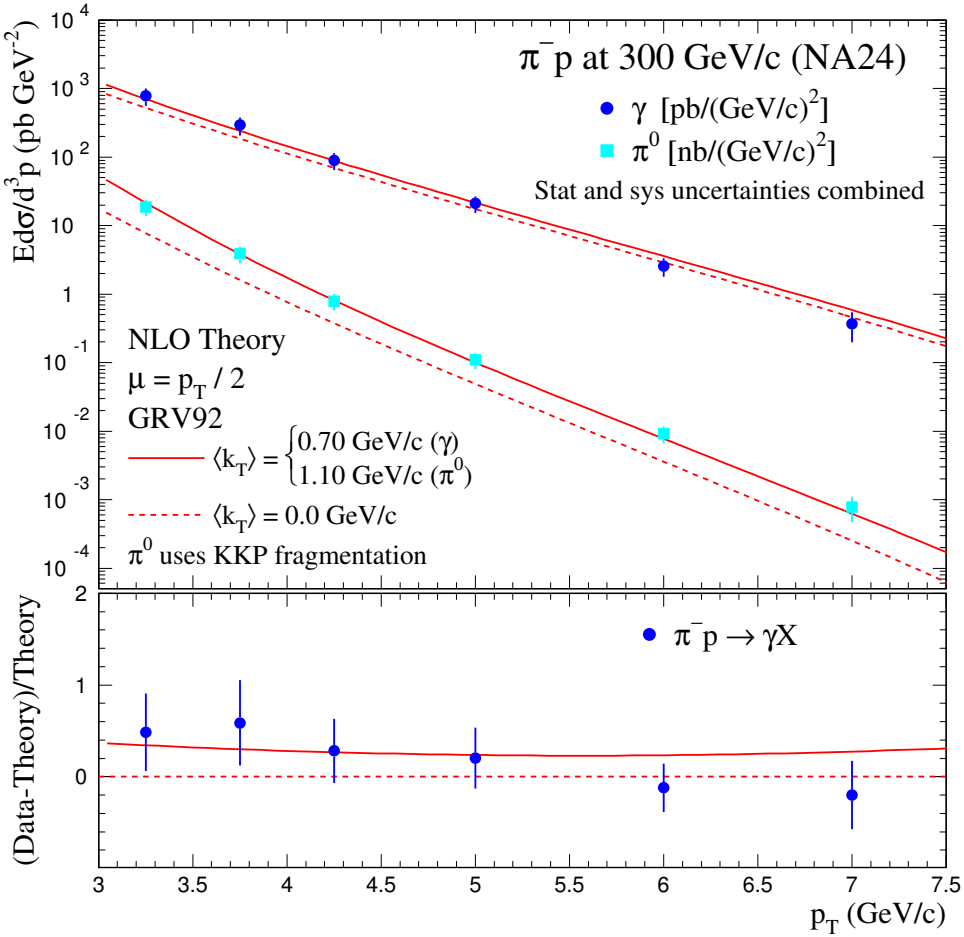
A NLO pQCD calculation that includes k_T smearing compares well with high-p_T production of $D^{\pm}$.



WA70 & NA24 Direct Photons

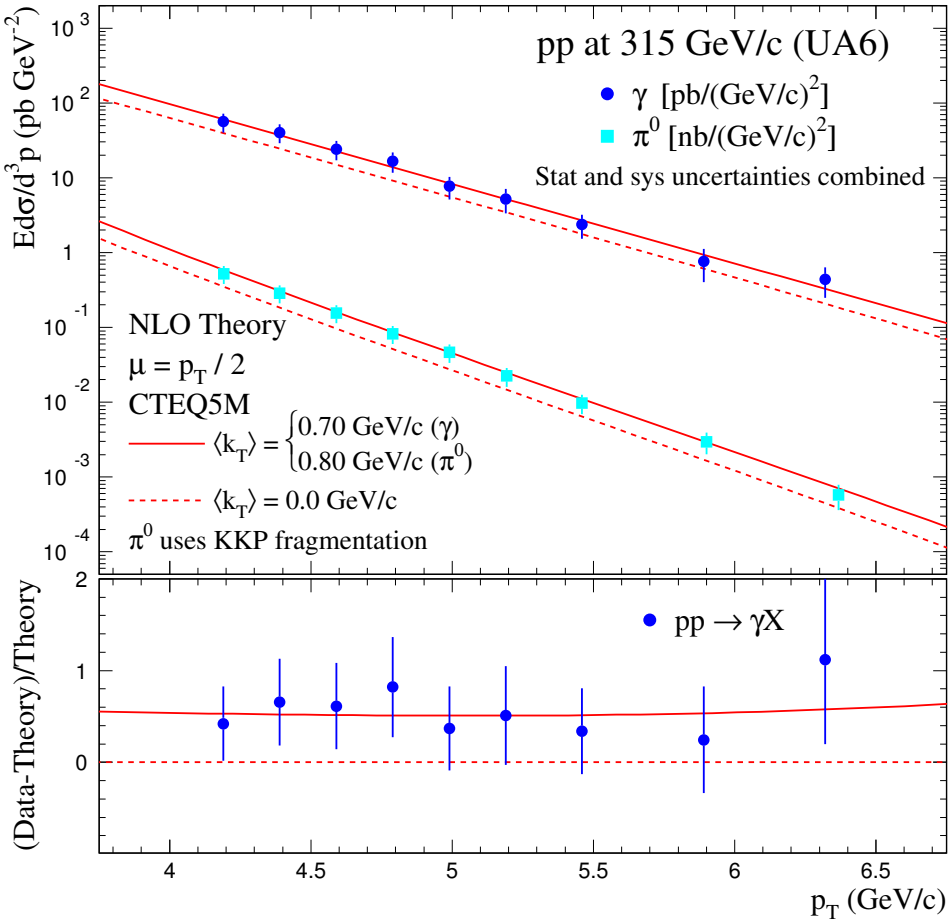
$\sqrt{s} \approx 23$ GeV

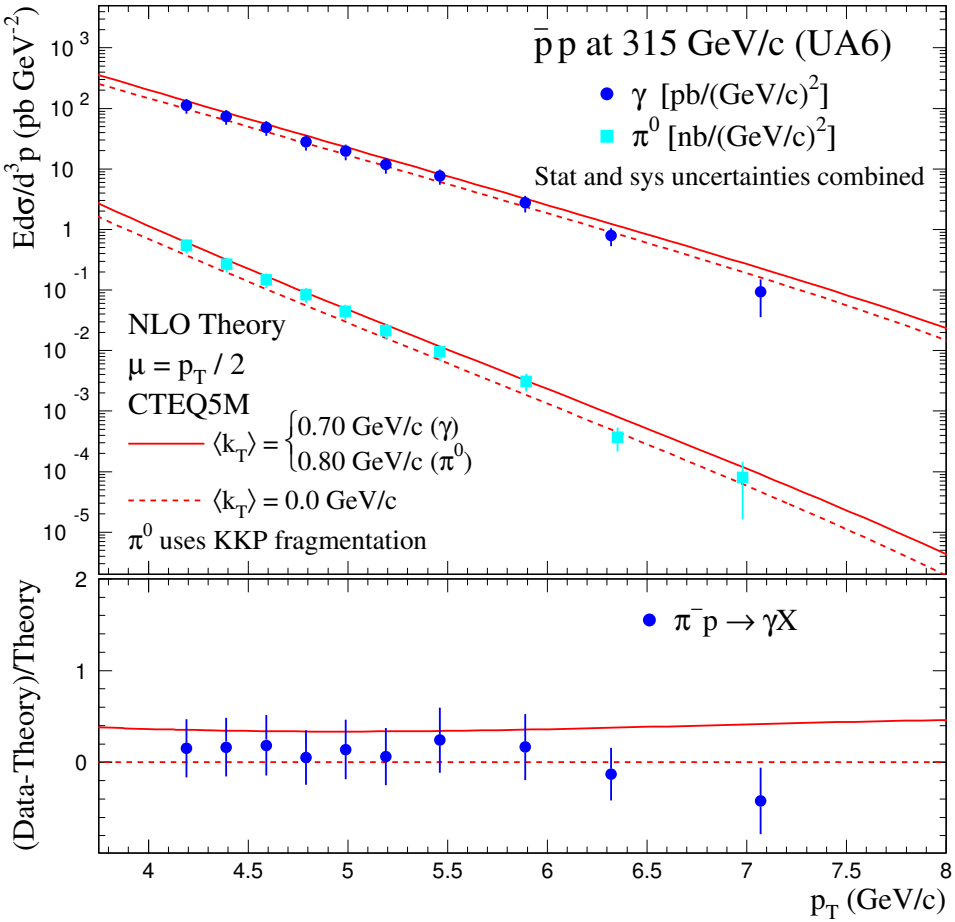




UA6 Direct Photons

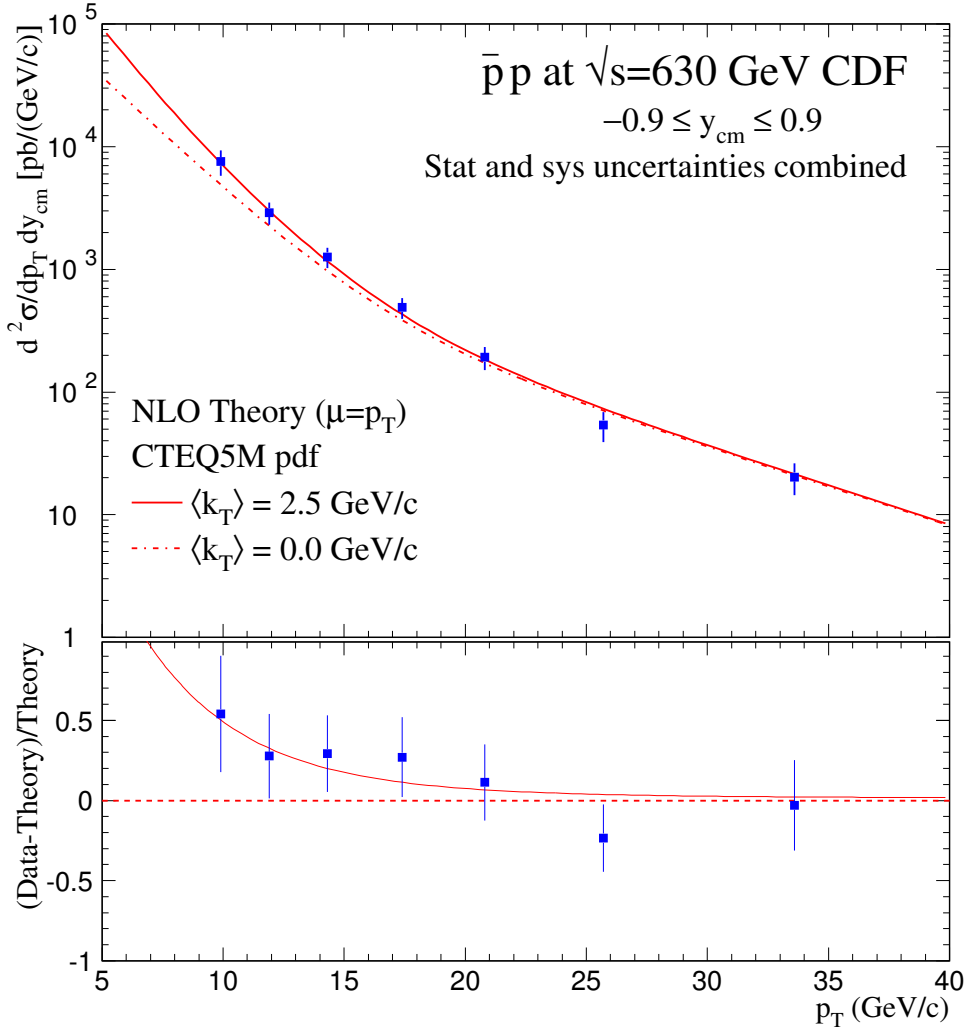
$\sqrt{s} = 24.3\,\mathrm{GeV}$

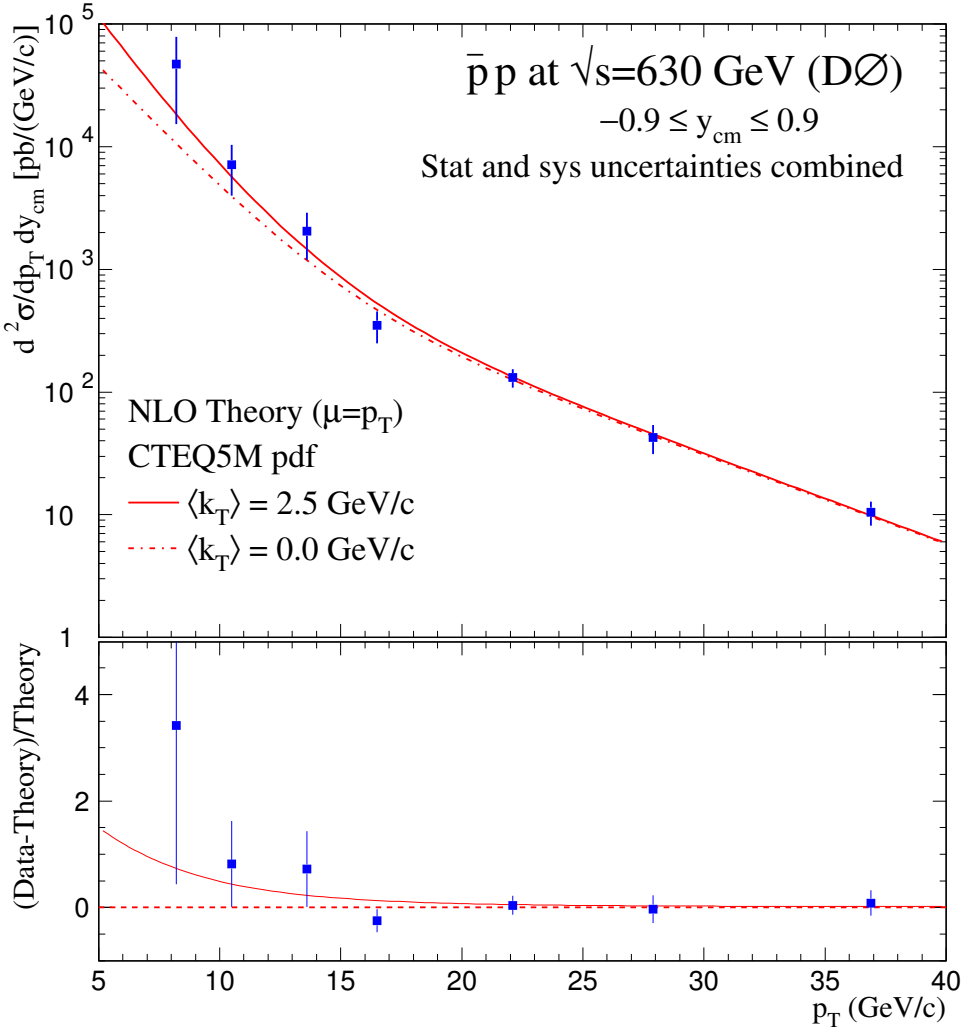




CDF & DØ Isolated Photons

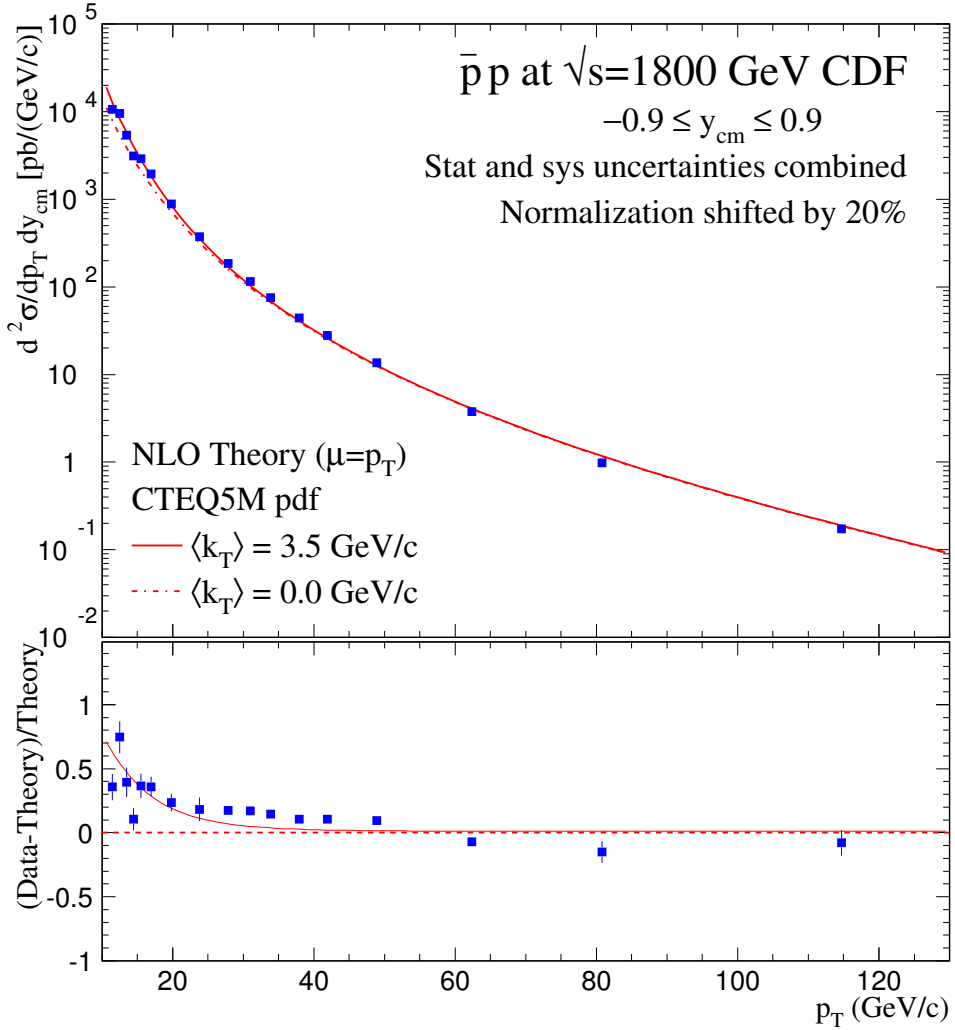
$\sqrt{s} = 630$ GeV

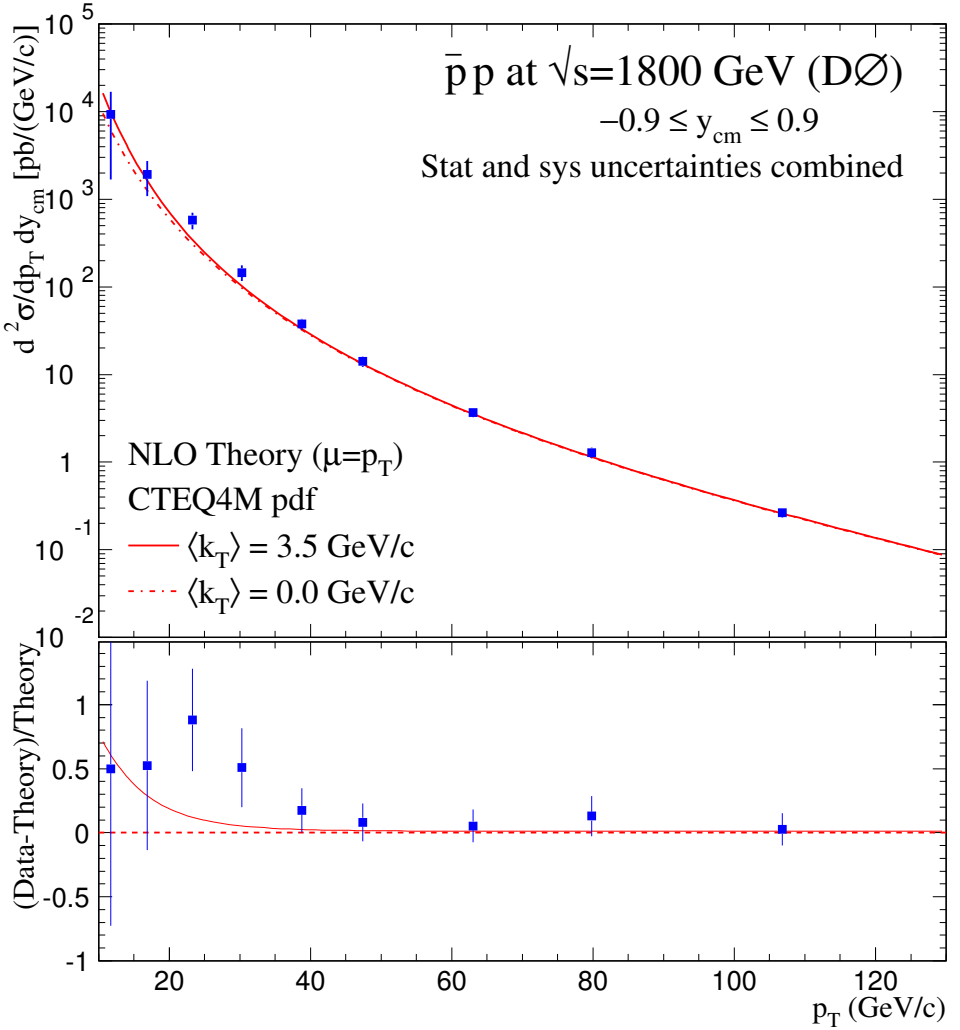




CDF & DØ Isolated Photons

$\sqrt{s} = 1800$ GeV





Conclusions

- Correlations between high-p_T particles provide useful information about the transverse momenta of partons prior to the hard scatter.
- k_T has an effect on high-mass pairs, away-side particle distributions, and single particle inclusive production as measured by many experiments from $\sqrt{s} = 5$ to 1960 GeV.
- Resummed pQCD calculations (which include soft-gluon emission) and PYTHIA (which simulates initial-state radiation via Gaussian smearing) represent the shapes of data distributions adequately.
- Simple implementations of parton k_T smearing for NLO pQCD calculations, using k_T values consistent with observations, provide reasonable descriptions of most recent direct-γ and π^0 cross sections over a wide range of $\sqrt{s}$.