Measurement of the ϕ^* distribution of $Z/\gamma^* \rightarrow l^+l^-$ events from DØ

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Small-x discussion forum
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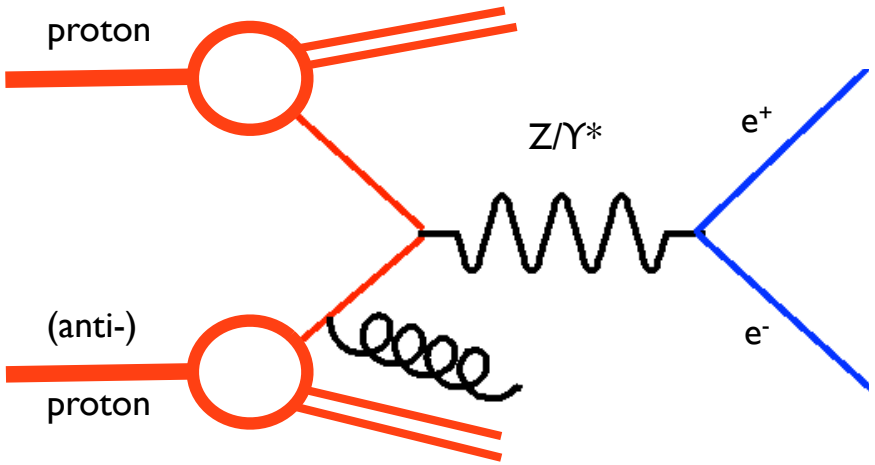
Drell-Yan process

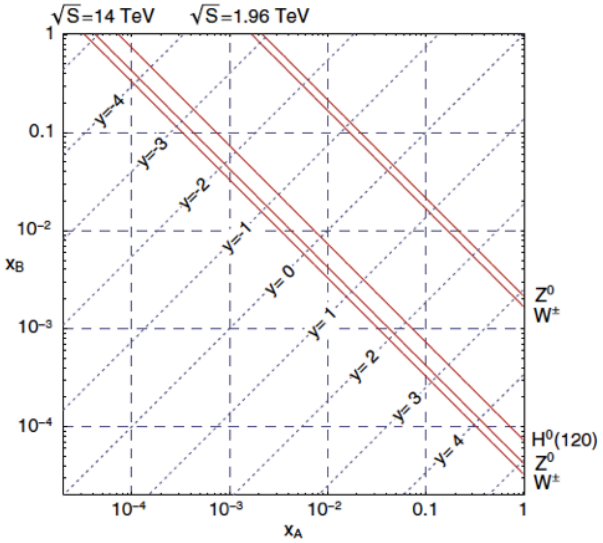
- Powerful probe of the PDFs and higher order QCD effects.
- E.g., the p_T distribution is particularly interesting.
  - Calculation requires matching of soft-gluon resummation at for $p_T << Q$, with fixed order pQCD at larger p_T[1].
  - Implemented in, e.g., ResBos MC program[2].



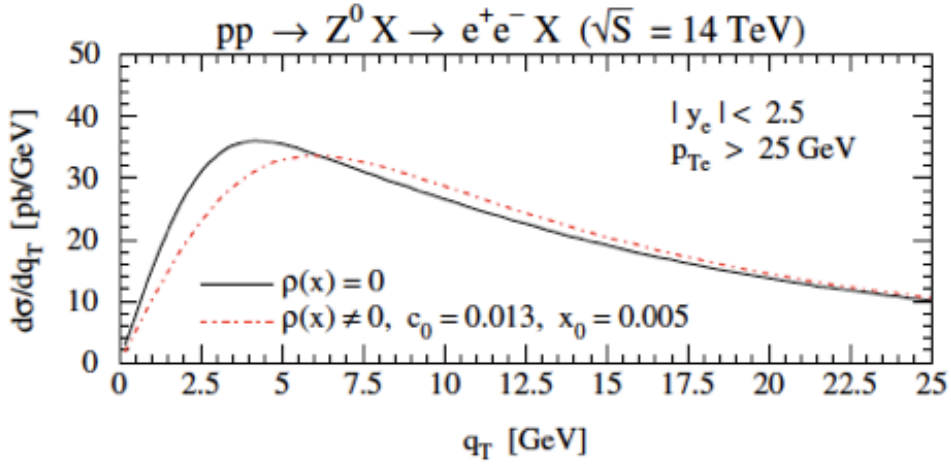
(1) J. Collins, D. Soper, G. Sterman, Nucl. Phys. B 250, 199 (1985).
(2) C. Balazs and C.-P. Yuan, Phys. Rev. D 56 5558 (1997).

NP form factor and interest in small-x

- ResBos includes a non-perturbative form factor.
  - Constrained by global fit to Z and low Q^2 DY data[1].
  - Similar analysis of SIDIS data from HERA[2].
    - broadening of the form factor at small-x (e.g, $x < 10^{-2}$)?
    - Corresponding to $|y| > 2$ for Z production at the Tevatron[3].



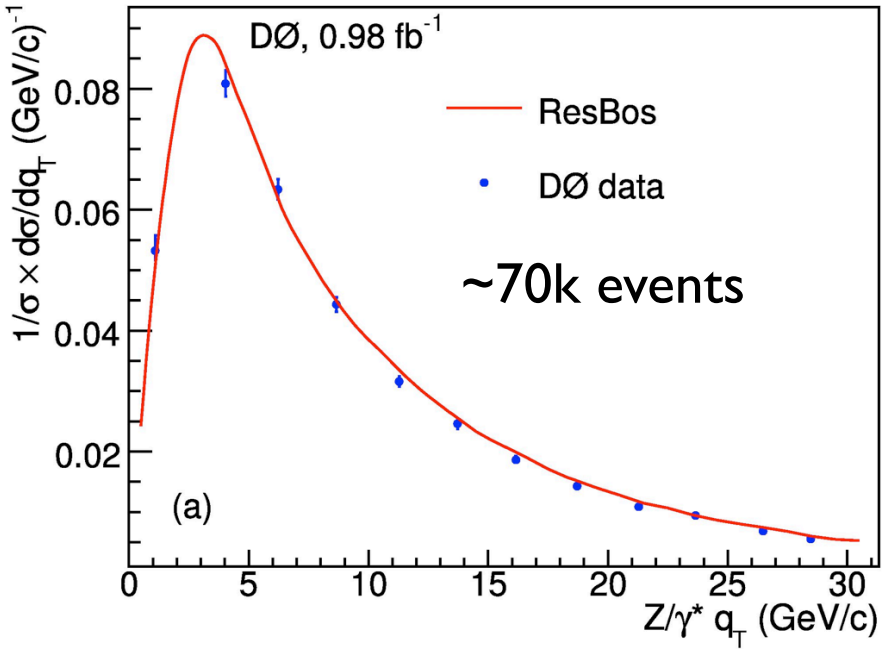
Large effect on <u>inclusive</u> Z (and W, H, etc..) at the LHC[3].

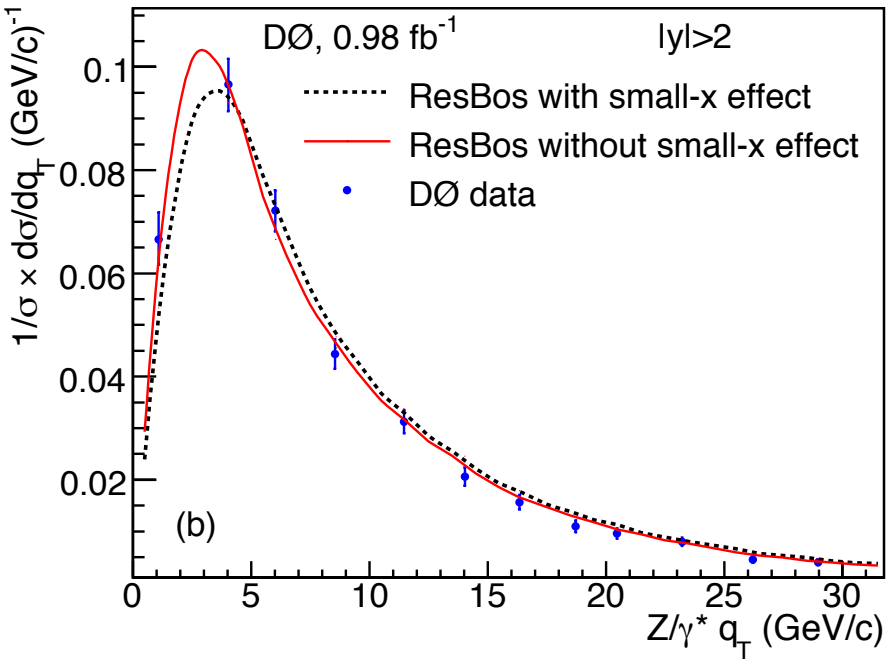


(1) F. Landry et al., Phys. Rev D 67, 073016 (2003).
(2) P. M. Nadolsky, D. R. Stump, C.-P. Yuan, Phys. Rev D 64 114011 (2001).
(3) S. Berge, P. M. Nadolsky, F. I. Olness, C.-P. Yuan, Phys. Rev D 72, 033015 (2005).

DØ p_T measurement with 1 fb^{-1}

- In general agreement with ResBos predictions.
  - Large |y| data are not yet sensitive to small-x effect.
  - Now have 10x more luminosity (x2 if include μμ channel).
  - However, already dominated by experimental systematics*.



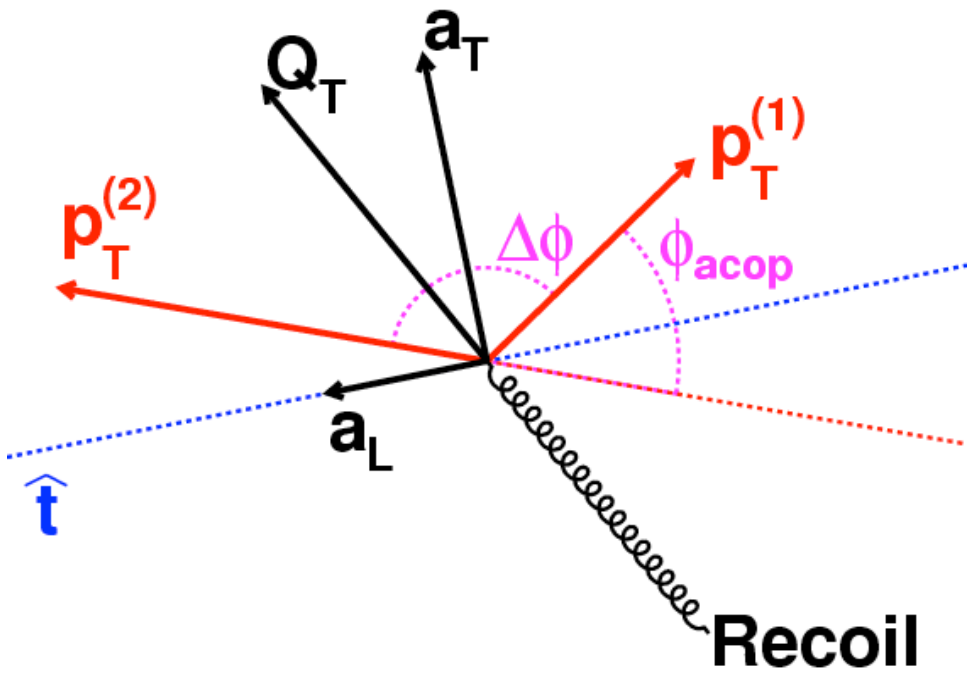


(1) V. M. Abazov et al., PRL 100 102002 (2008).

*Though still statistics limited in the large |y| region.

ϕ^* variable

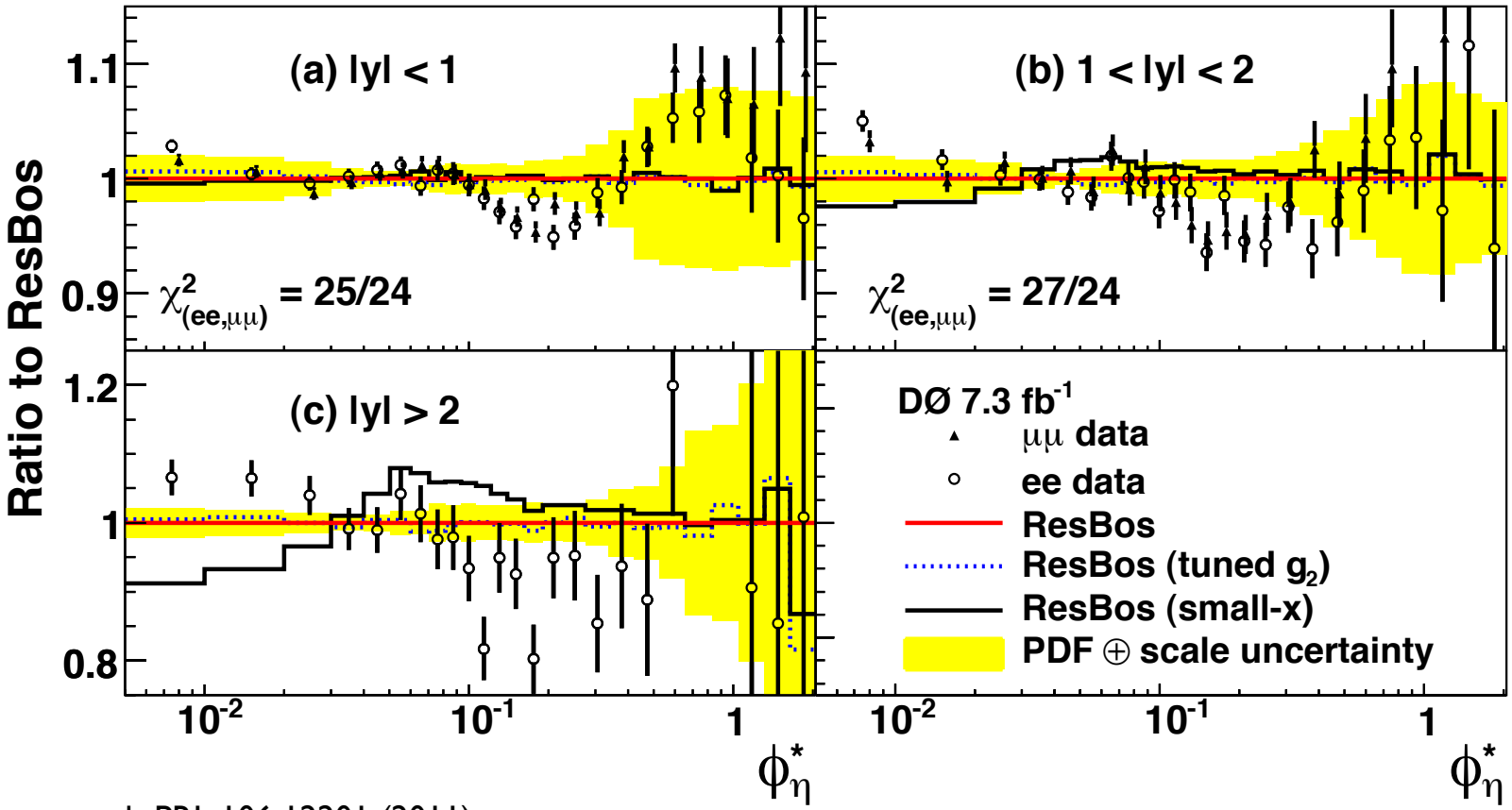
- Measure a different observable, e.g., ϕ^*, that is less sensitive to resolution and efficiency effects[1,2]
  - $\phi^* = \tan(\phi_{acop}/2)\sin\theta^*$, where $\cos\theta^* = \tanh[(\eta^{(1)} - \eta^{(2)})/2]$
    - Determined only from angles (good resolution).
    - Less correlated than the p_T with the lepton isolation.



(1) MV, T.R. Wyatt, NIM A 602, 432 (2009)
(2) A. Banfi, S. Redford, MV, P. Waller, T. R. Wyatt, EPJ C 71, 1600 (2011).

DØ ϕ^* measurement with 7.3 fb^{-1}

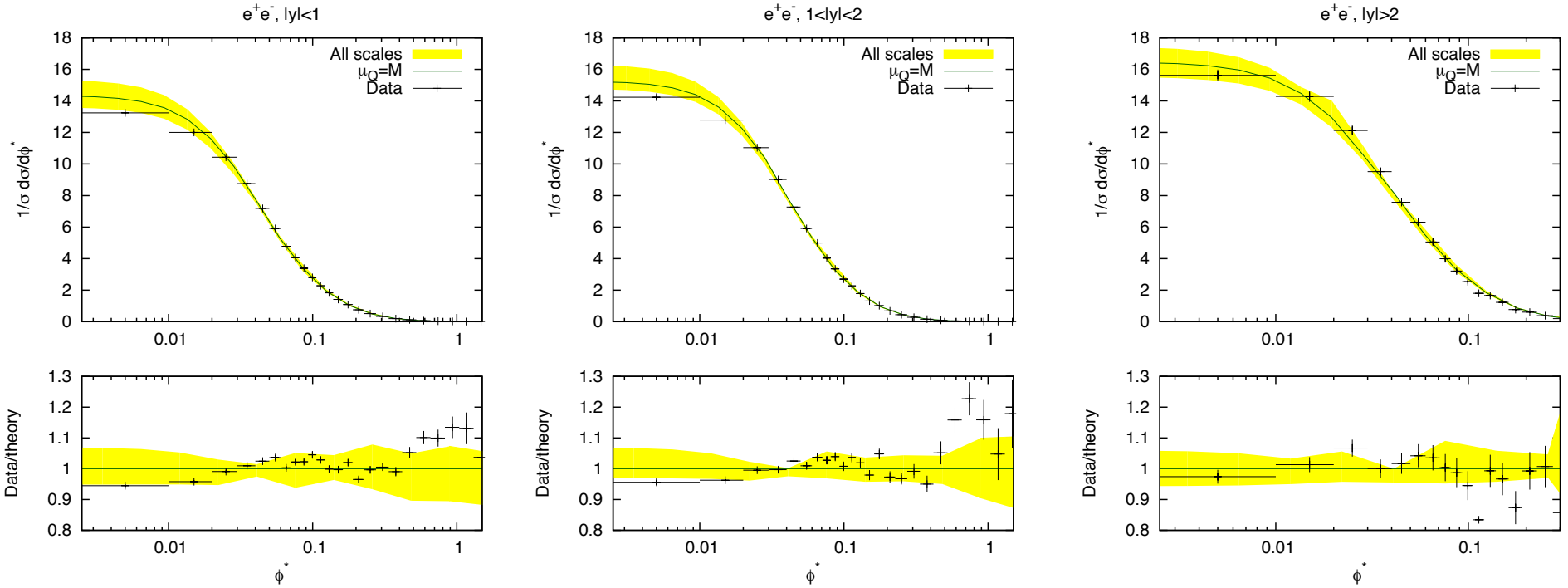
- Measure ϕ^* distribution in 3 bins of |y|
  - 970k events in ee and μμ channels.
  - ResBos is unable to describe the shape at this level of precision.
  - Small-x hypothesis is strongly disfavoured by the |y| > 2 data.



(1) V. M. Abazov et al., PRL 106 12201 (2011).

Recent phenomenological analysis[1]

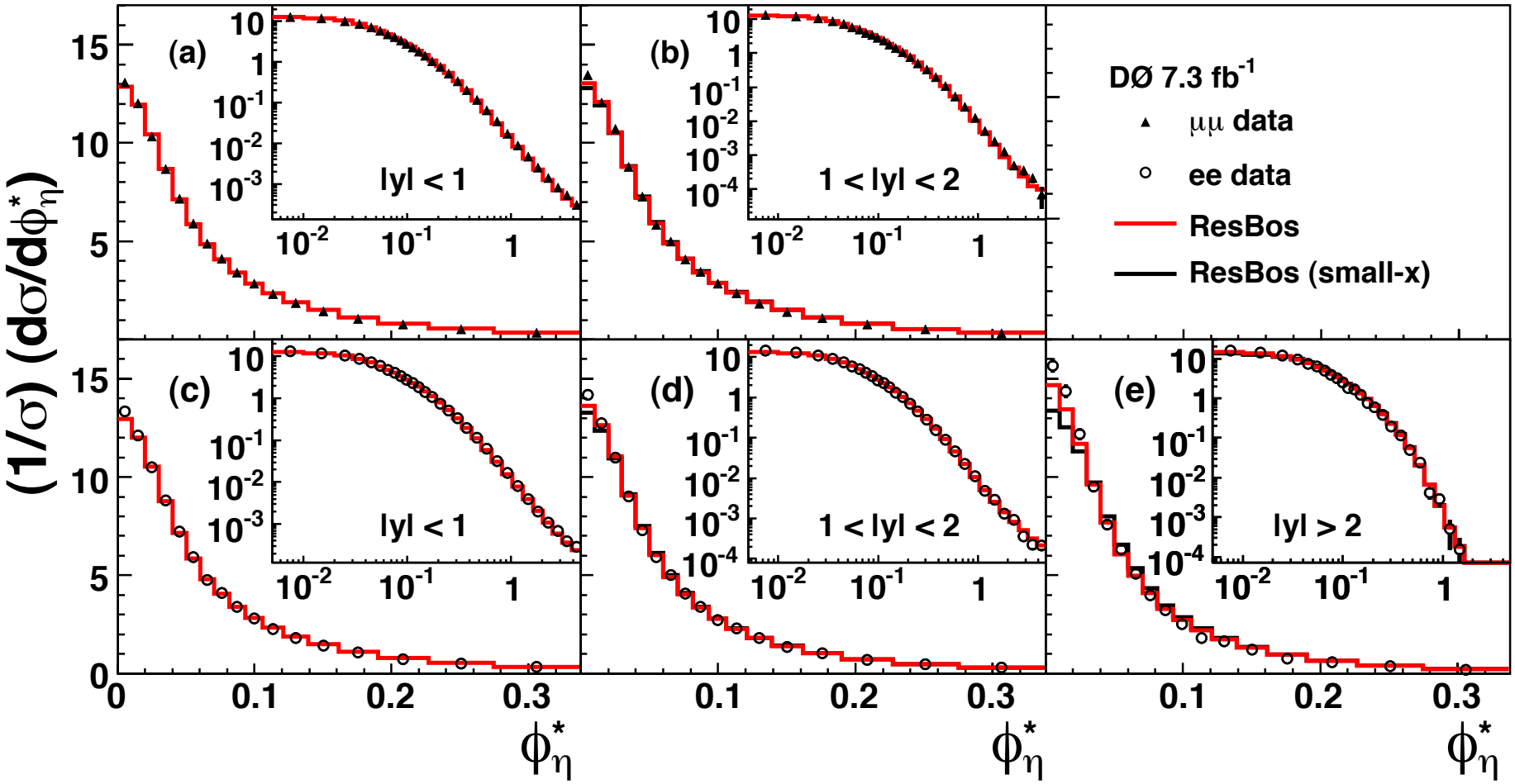
- State of the art matching of large-log resummation and fixed order.
- Careful treatment of the perturbative uncertainties.
- Within these uncertainties, is there any sensitivity to NP effects at all?



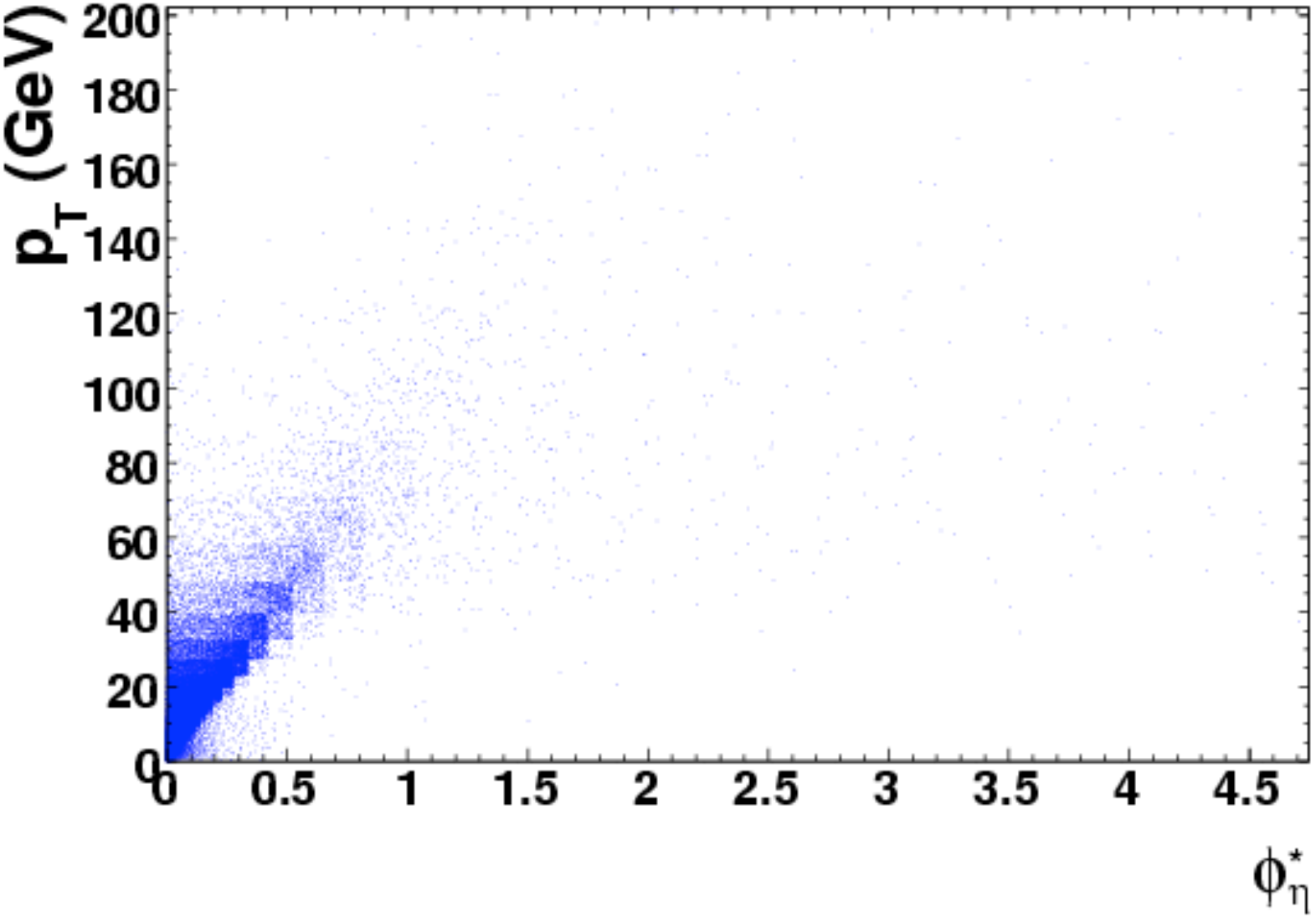
(1) A. Banfi, M. Dasgupta, S. Marzani, L. Tomlinson, arXiv:1110.4009v1[hep-ph] (2011).

Backup slides

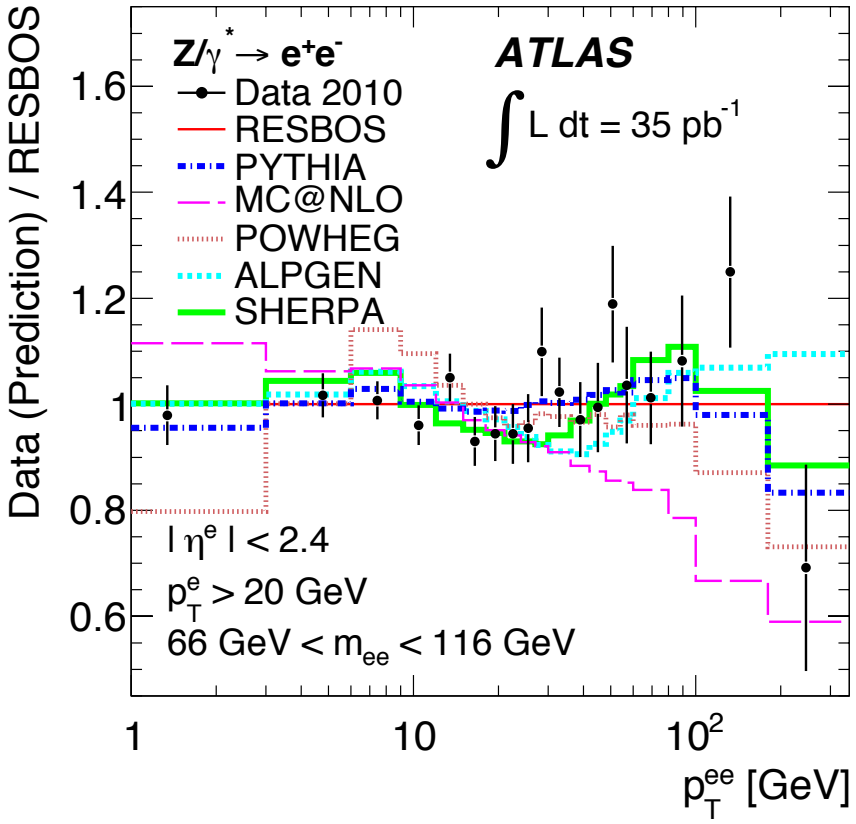
DØ ϕ* measurement

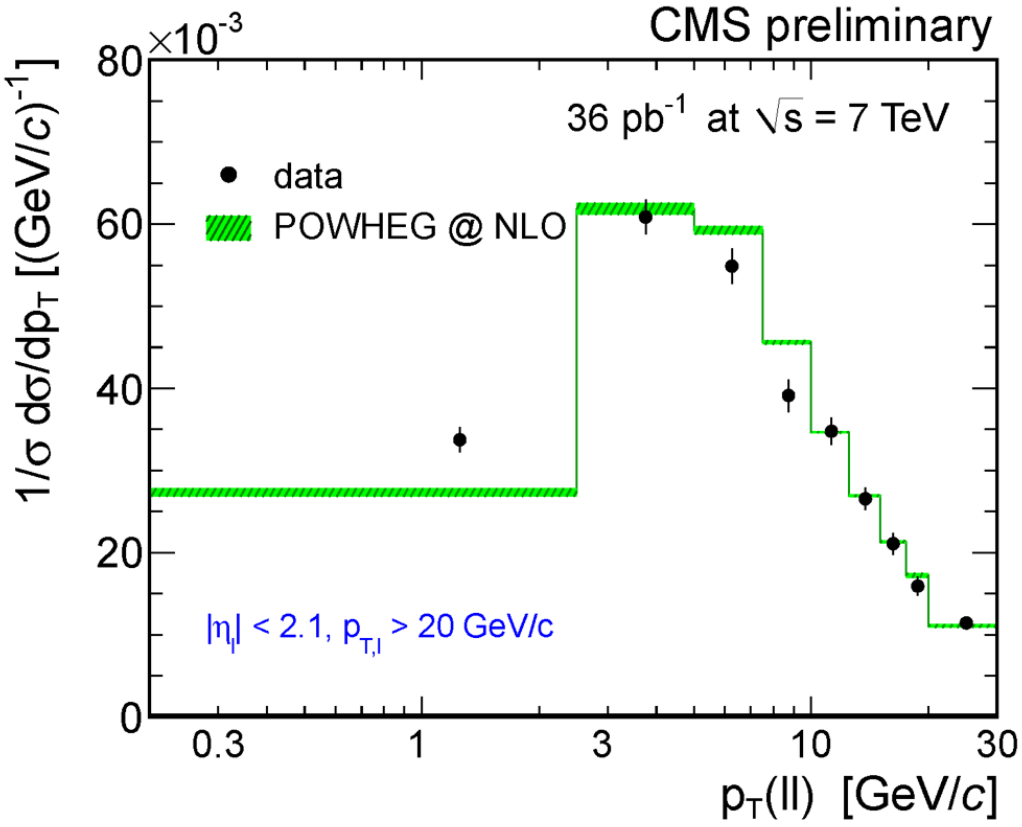


p_T vs ϕ^*


p_T (GeV)
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
ϕ^*_η

ATLAS/CMS results on the Z/γ^* p_T

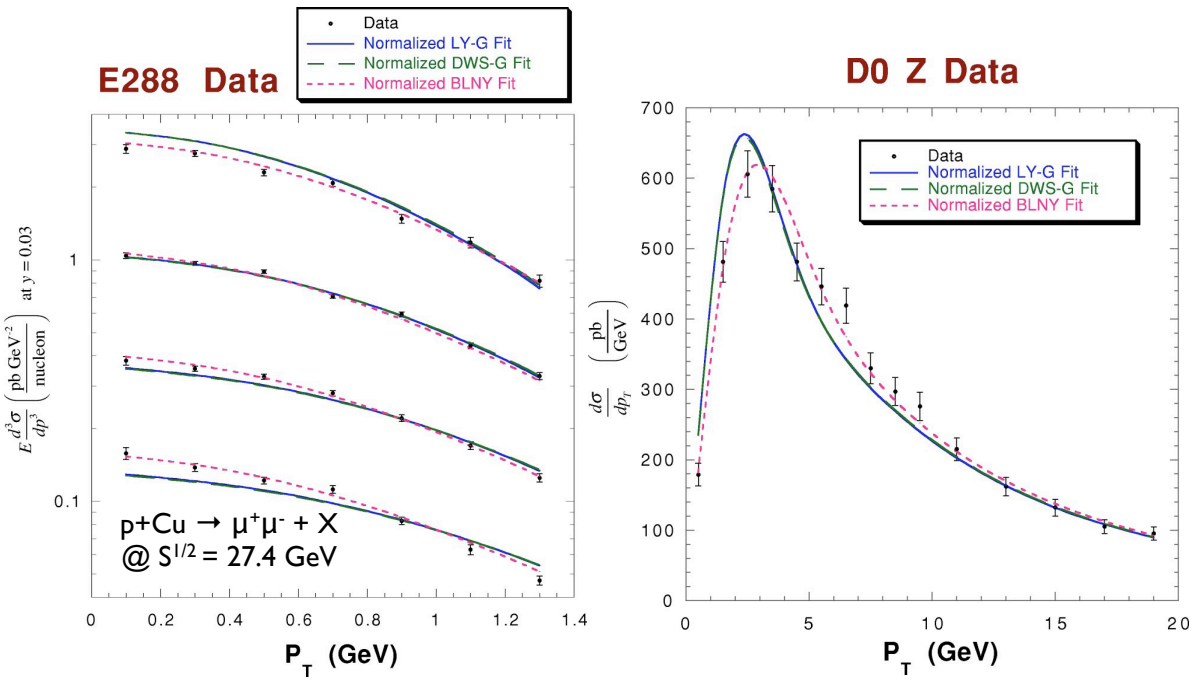


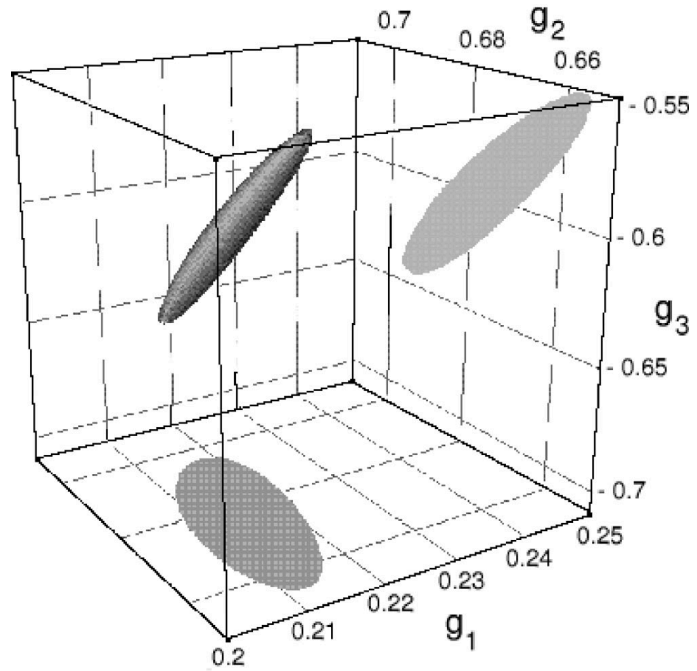


Global Drell-Yan p_T analysis

- Paper by Brock, Landry, Nadolsky and Yuan.
  - Tevatron Run I Z data, and lower Q^2 DY data.

$$\tilde{W}_{j\bar{k}}^{\mathrm{BLNY}} = \exp\left[-g_1 - g_2 \ln(\frac{Q}{2Q_0}) - g_1 g_3 \ln(100 x_1 x_2)\right] b^2$$

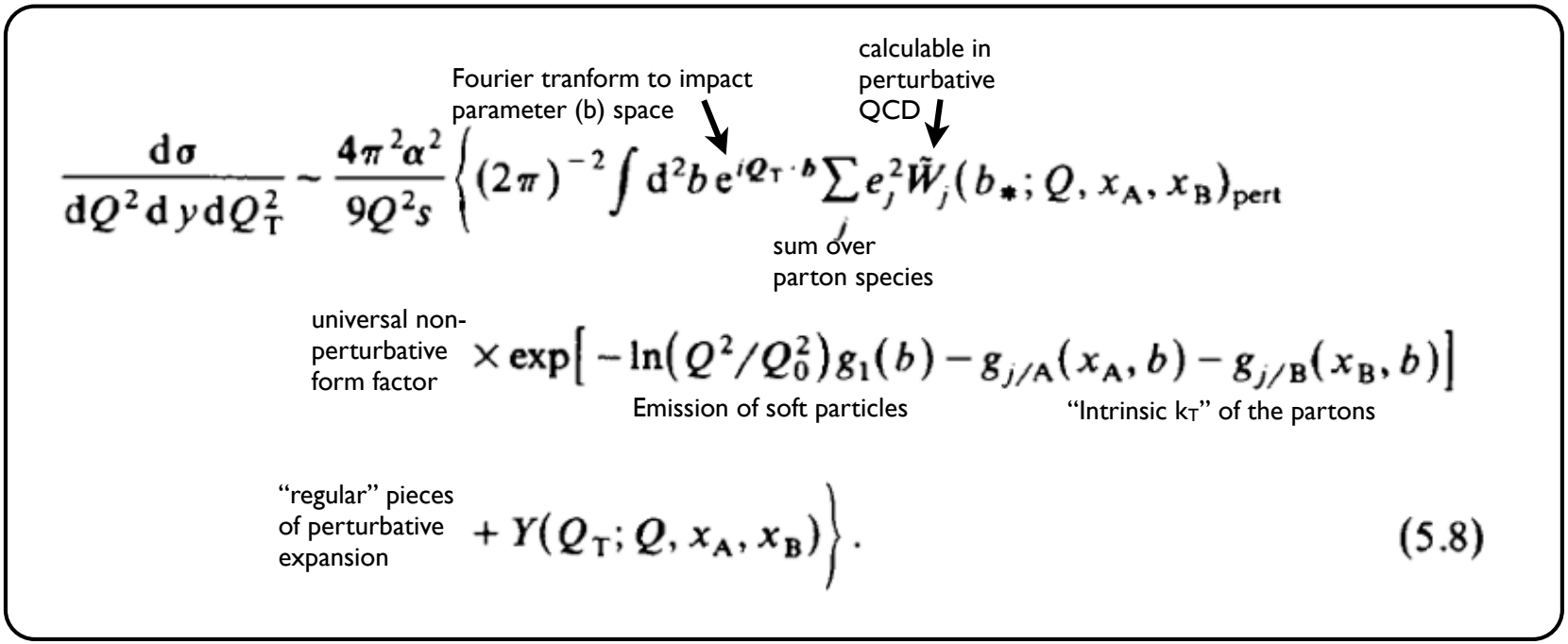




(1) F. Landry et al., Phys. Rev D 67, 073016 (2003).

Collins Soper Sterman formalism

- Soft gluon resummation



$$\frac{d\sigma}{dQ^2\,dy\,dQ_T^2} \sim \frac{4\pi^2\alpha^2}{9Q^2 s}\left\{(2\pi)^{-2}\int d^2b\, e^{iQ_T\cdot b}\sum_j e_j^2 \tilde{W}_j(b_*; Q, x_A, x_B)_{pert}\right.$$

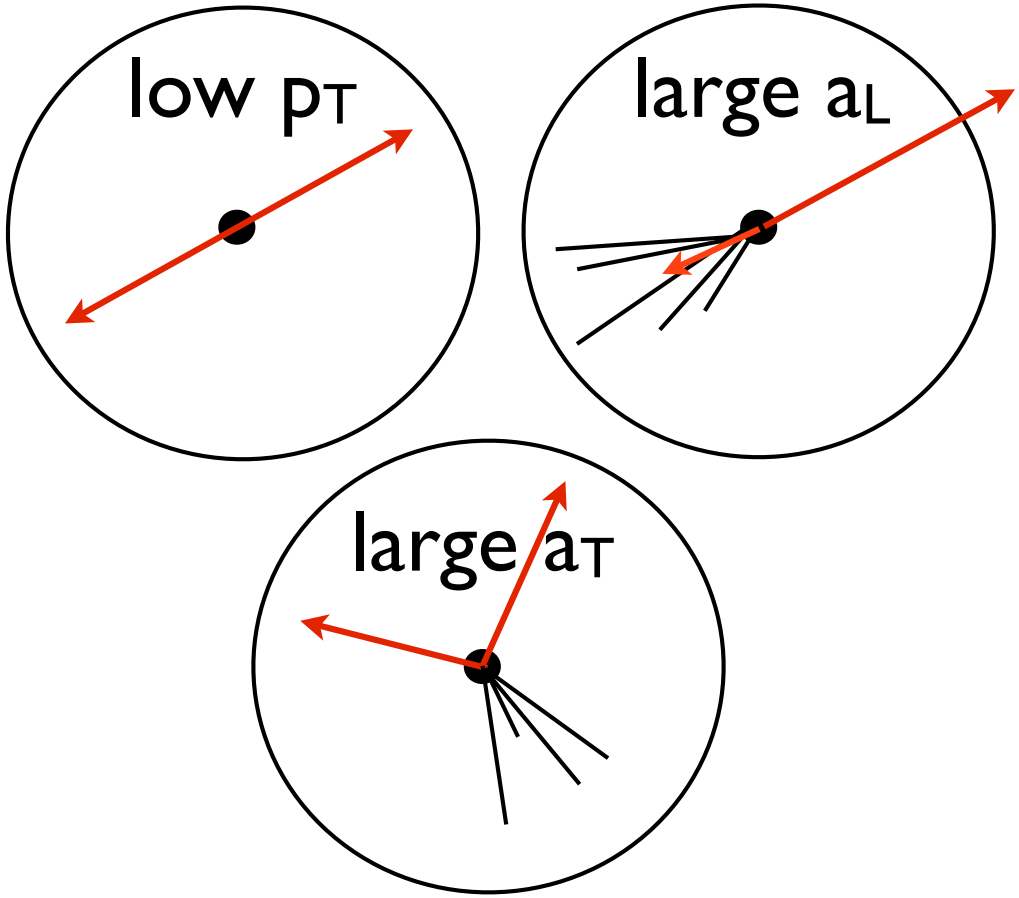
$$\times \exp\left[-\ln(Q^2/Q_0^2)g_1(b) - g_{j/A}(x_A, b) - g_{j/B}(x_B, b)\right]$$

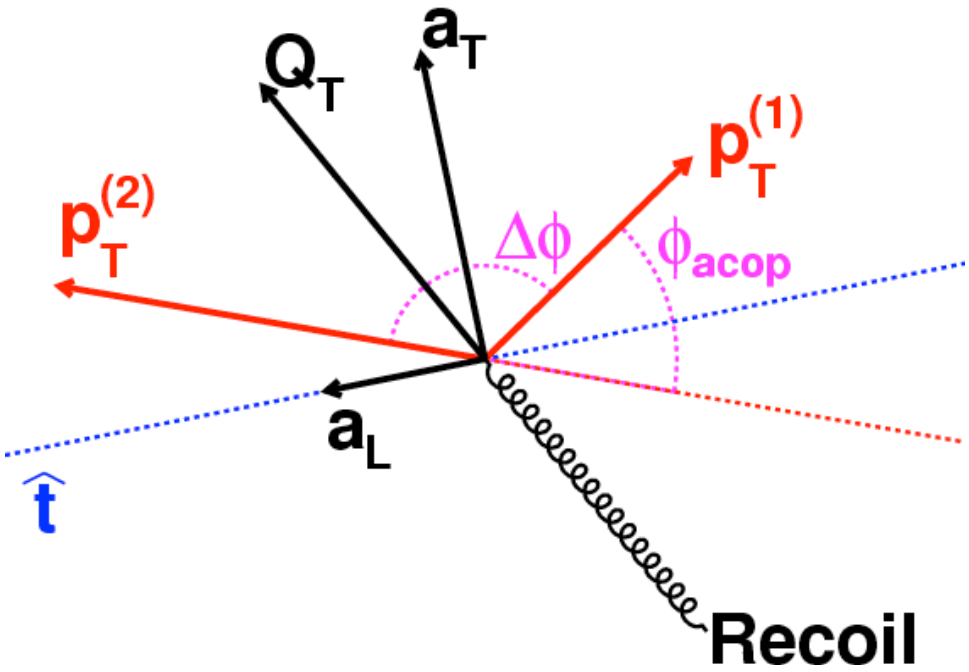
$$\left. + Y(Q_T; Q, x_A, x_B)\right\}. \qquad (5.8)$$

(1)J. Collins, D. Soper, G. Sterman, Nucl. Phys. B 250, 199 (1985).

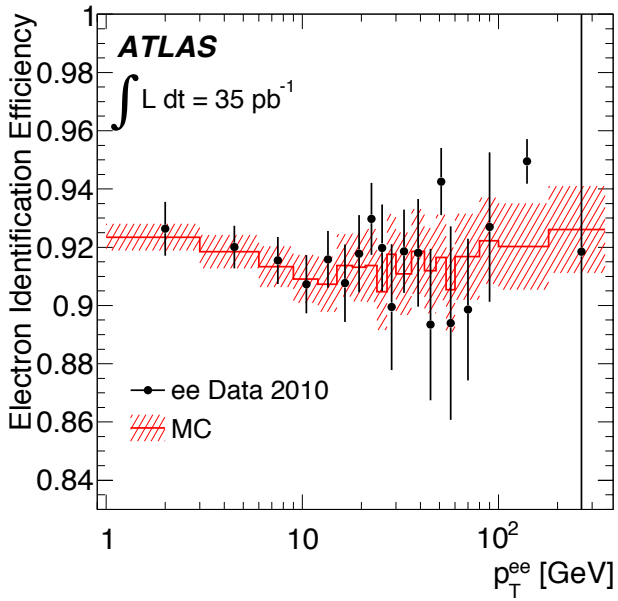
Isolation, and a_T

- The a_L component of the p_T is highly correlated with efficiencies to pass cuts on lepton isolation – not for a_T.





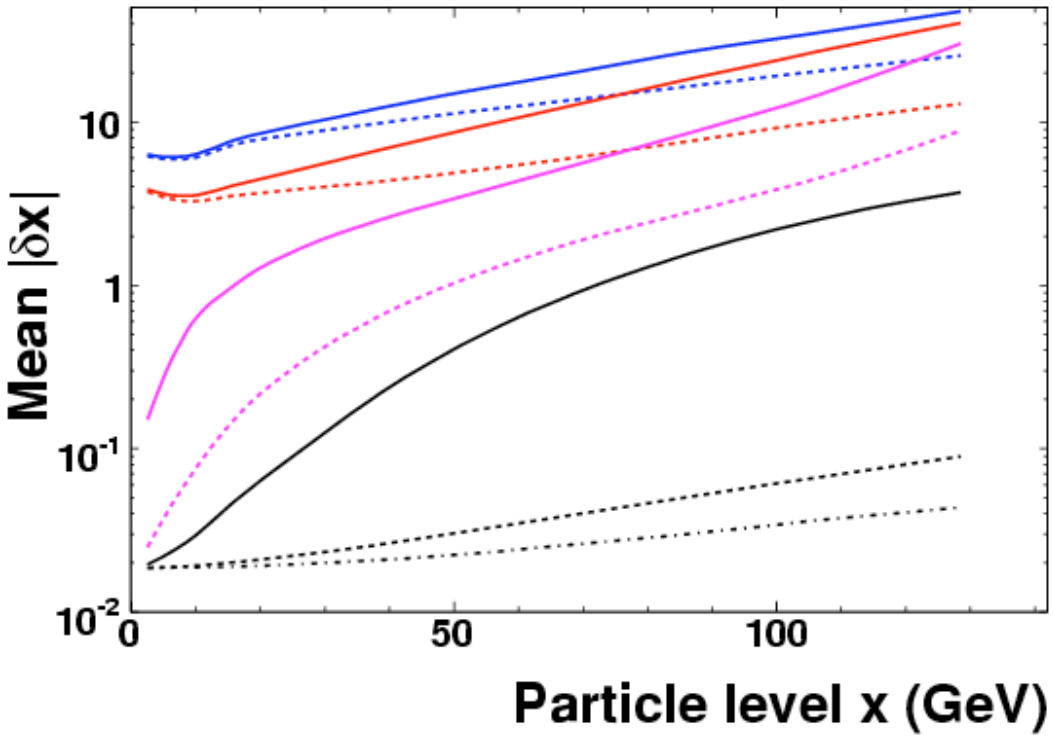
Same problem at ATLAS/CMS

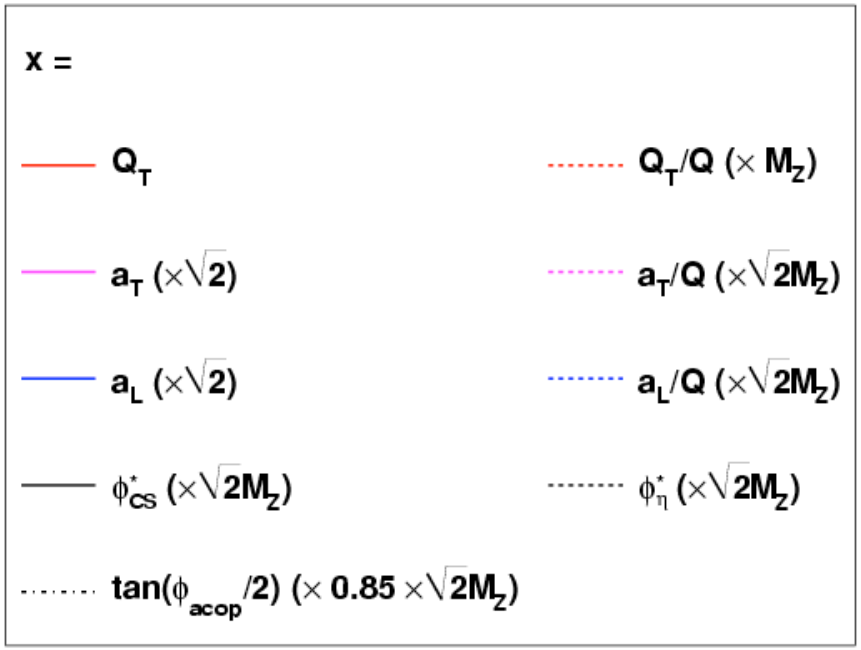


(1) MV, T. R. Wyatt, Nucl. Instr. Meth. Phys. Res. A 602, 432 (2009)

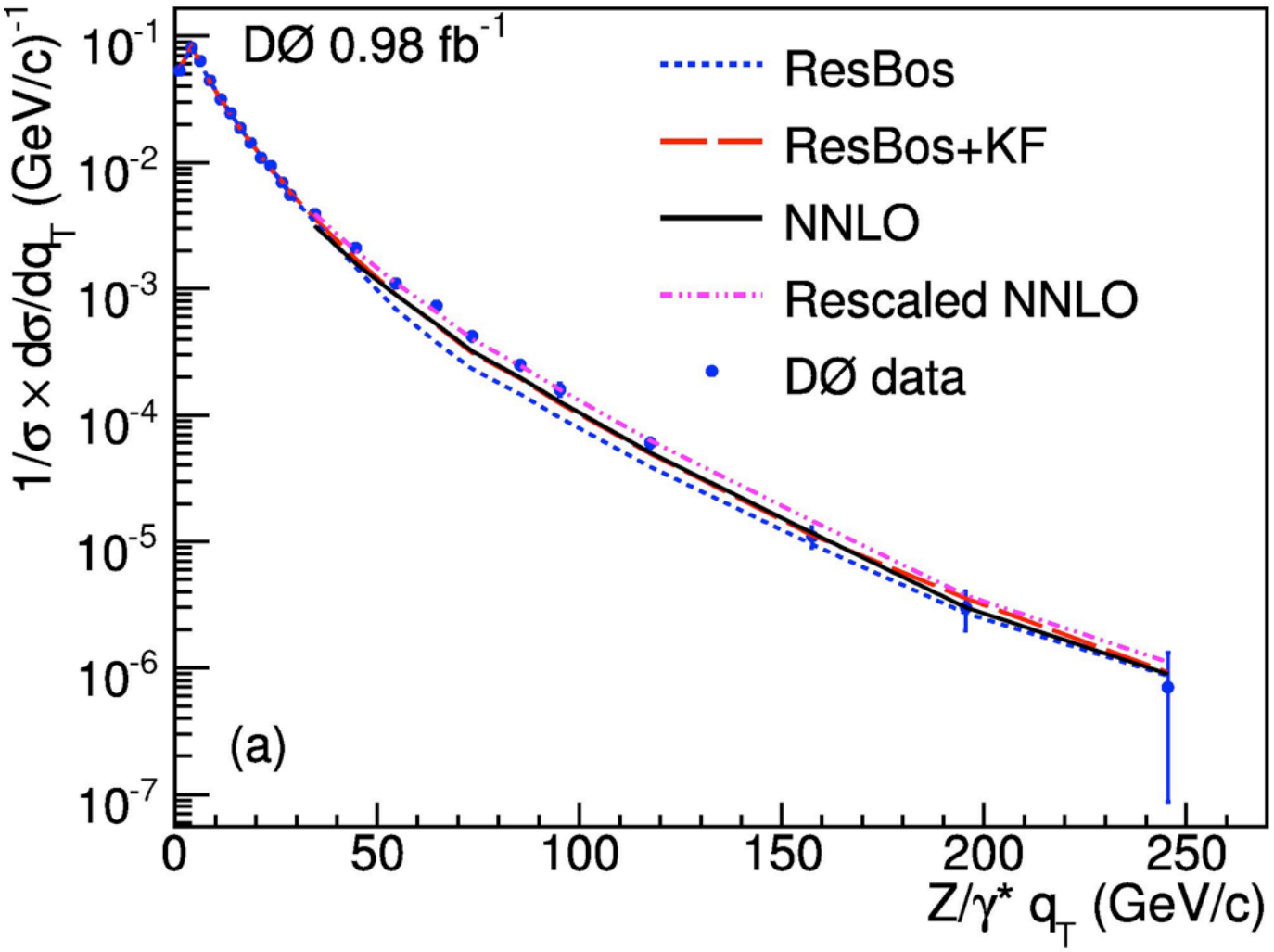
ϕ^* resolution

- The optimal variable for studying the p_T distribution at hadron colliders
  - $\phi^* = \tan(\phi_{acop}/2)\sin(\theta^*)$, where $\cos(\theta^*) = \tanh[(\eta^- - \eta^+)/2]$.





DØ Run IIa p_T(ee) measurement



DØ Run IIa $p_T(\mu\mu)$ measurement