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ATLAS discussion meeting
on NLO PDF's
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"User" comments on NLO PDF's

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Key issue: **what are PDF's going to be used for**, e.g.

$\star$ error on $\sigma(\mathrm{Higgs})$ from PDF choice $\star$

or

$\star$ discovery of Higgs and error on m_{H} from γ non-isolation $\star$

People tend to concentrate on the first

Basics

General-purpose event generators provide
$\hat{\sigma}(\mathrm{LO}) \otimes \mathrm{PDF}(\mathrm{LO}) \otimes$ showers.
Each component separately is positive definite.

Showers are often matched to $\hat{\sigma}(\mathrm{NLO})$ in hard-emission region,
but handles soft/collinear regions by Sudakovs $\Longrightarrow$ positivity preserved.
Exception: external NLO input, e.g. MC@NLO or other Les Houches.

In NLO only $\hat{\sigma}(\mathrm{NLO}) \otimes \mathrm{PDF}(\mathrm{NLO})$ required to be positive,
PDF(NLO) on its own not physical (e.g. $\overline{\mathrm{MS}}$ vs. DIS).
Therefore $\hat{\sigma}(\mathrm{LO}) \otimes \mathrm{PDF}(\mathrm{NLO})$ *may* give crap.

Especially problematical at small x and Q^2.
E.g. $p_\perp = 1.4$ GeV scattering at LHC:
$Q^2 \approx p_\perp^2 \approx 2\ \mathrm{GeV}^2$, $x \geq 4p_\perp^2/s = 4 \cdot 10^{-8}$.

This is the region we need to test before we let the genie out of the bottle.
($\hat{\sigma}(\mathrm{LO}) \otimes \mathrm{PDF}(\mathrm{LO})$ at least is “sensible” here, even if not “correct”.)

Some numbers

Study multiple interactions, using Tune A with slower energy dependence

$$p_{\perp 0} = (2.0\ \text{GeV}) \left(\frac{E_{\text{cm}}}{1.8\ \text{TeV}} \right)^{0.16}$$

and CTEQ5L (PYTHIA default, used in Tune A)

	Tevatron Run II	LHC
$p_{\perp 0}$ (GeV)	2.03	2.78
$\sigma_{\text{nondiffractive}}$ (mb)	39.0	54.7
$\sigma_{\text{interaction}}$ (mb)	141	377
$\langle n_{\text{int}} \rangle$	3.61	6.90
$p_{\perp\text{median}}$ (GeV)	1.80	2.80
$\langle n_{\text{int}}(p_\perp < 2\ \text{GeV}) \rangle$	2.07	1.96
CTEQ5L- = times $(x/0.01)^{0.1}$ for $x < 0.01$		
σ_{int} (mb)	105	225
CTEQ5L+ = times $(0.01/x)^{0.1}$ for $x < 0.01$		
σ_{int} (mb)	196	659
ratio CTEQ5L+/CTEQ5L-	~ 2	~ 3

The proof of the pudding . . .

Assume the best description of physics is obtained with
(a) $\hat{\sigma}(\mathrm{NLO}) \otimes \mathrm{PDF}(\mathrm{NLO})$.

Interesting comparisons would then be with the scenarios:
(b) $\hat{\sigma}(\mathrm{LO}) \otimes \mathrm{PDF}(\mathrm{LO})$.
(c) $\hat{\sigma}(\mathrm{LO}) \otimes \mathrm{PDF}(\mathrm{LO}) \otimes \mathrm{showers}$.
(d) $\hat{\sigma}(\mathrm{LO}) \otimes \mathrm{PDF}(\mathrm{NLO})$.
(e) $\hat{\sigma}(\mathrm{LO}) \otimes \mathrm{PDF}(\mathrm{NLO}) \otimes \mathrm{showers}$.
Only if (e) is a better approximation to (a) than is (c) would the use of NLO PDF's be motivated in a general-purpose generator.

Technical aside:
(a) = external NLO program.
(c), (e) = PYTHIA/HERWIG/. . . without primordial $k_\perp$, MI or hadronization.
(b), (d) = ditto, also without ISR and FSR showers.

Obvious comparison approach:
use jet clustering algorithm (with all its problems),
plot single-jet spectra $\mathrm{d}\sigma_{\mathrm{jet}}/\mathrm{d}p_\perp$ and $\mathrm{d}\sigma_{\mathrm{jet}}/\mathrm{d}y$.
But NLO = 2 + 3 jets, LO = 2 jets, LO + shower $\geq$ 2 jets,
so not easy to address jet correlations.

... lies in the eating

Therefore complement with alternative approach,
to gauge event-by-event total activity. Define:

$$(i) \qquad E_\perp = \sum_i |p_{\perp i}|$$

$$(ii) \qquad Y = \frac{1}{E_\perp} \sum_i |p_{\perp i}|\, y_i$$

$$(iii) \qquad (\Delta Y)^2 = \frac{1}{E_\perp} \sum_i |p_{\perp i}|\, (y_i - Y)^2$$

summed over all partons i in the event,
and plot the cross sections d$\sigma/$d$E_\perp$, d$\sigma/$dY and d$\sigma/$d(ΔY).
Measures are infrared and collinear safe because of $p_\perp$-weighting.

(i) probes small-Q behaviour when plotted down to $E_\perp \approx 2$ GeV.
(ii) probes small-x region by large-Y behaviour.
(iii) further probes small-x impact (e.g. $Y = 0$ mix of all x).
Can also be sliced further, e.g. in $E_\perp$ bins, for more detailed picture.