Motivation

The NLO calculations for inclusive charged hadron production appear to clearly overshoot the large-$p_T$, LHC data.

Goal: Work out the systematics of the observed inconsistency and chart the different sources of uncertainties.

Fragmentation functions

The inclusive charged hadron production in $p+p$ collisions is calculated by

$$d^3\sigma_{h+/h-}/d^3p = \sum_{i,j,k} f_i(x_i, \mu_{i0}) \otimes f_j(x_j, \mu_{j0}) \otimes d^3\hat{p}_X \otimes D_k(z, \mu_{k0})$$

where $f_i(x_i, \mu_{i0})$ = parton distribution function (PDF) of a proton

$D_k(z, \mu_{k0})$ = parton-to-hadron fragmentation function (FF)

$\hat{p}_X$ = the partonic coefficient functions

The PDFs and FFs are obtained from data through QCD analyses

Available charged hadron FFs [see [1] for the Refs.]

<table>
<thead>
<tr>
<th>FF set</th>
<th>Species</th>
<th>Fitted data</th>
<th>uncert. bins</th>
<th>$Q^2$ [GeV$^2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kretzer</td>
<td>$p^+, K^+, h^+, h^0$</td>
<td>yes</td>
<td>10$^{-3}$, 10$^{-2}$</td>
<td>[5]</td>
</tr>
<tr>
<td>KKP</td>
<td>$\pi^+, K^+, K^0, K^0_S, \eta, \eta'$</td>
<td>no</td>
<td>0.1</td>
<td>[1]</td>
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<tr>
<td>BFGW</td>
<td>$h^+$</td>
<td>yes</td>
<td>10$^{-2}$, 10$^{-1}$</td>
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<tr>
<td>AKKO5</td>
<td>$\pi, K, p, \bar{p}$</td>
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</tr>
<tr>
<td>HKNS</td>
<td>$\pi^+, K^+, K^0, K^0_S, \eta, \eta'$</td>
<td>yes</td>
<td>10$^{-1}$</td>
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<tr>
<td>AKKO6</td>
<td>$\pi^+, K^+, K^0, K^0_S, \eta, \eta'$</td>
<td>yes</td>
<td>10$^{-1}$</td>
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<tr>
<td>DSS</td>
<td>$K^+, K^0, K^0_S, \eta, \eta'$</td>
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<td>10$^{-1}$</td>
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</tr>
</tbody>
</table>

FFs constrained mostly by $e^+e^-$ data

DSS and AKKO6 use also $p+p(\pi)$ data from RHIC, Tevatron and SPS

Only HKNS provides error sets

Comparison between data and NLO

NLO computations performed with improved 1BICNLO-code using

$\mu_{NLO}$ = $\mu_0 = 20 GeV$

$\Delta$ scale choice $\mu_{sc} = \mu_{CT10}$, $\mu_{NN}$ = $p_T$, and 16 combinations to estimate the stability of the NLO approximation:

$$\frac{\Delta \sigma_{h+/h-}/d^3p}{\mu_{CT10}, \mu_{NN}, \mu_{sl}}$$

Data used for the comparison:

- CMS: $p+p$ at $\sqrt{s} = 900, 2760 GeV, |\eta| < 1.0$ [2,8]
- ALICE: $p+p$ at $\sqrt{s} = 900, 2760 GeV, |\eta| < 0.8$ [2,16]
- CDF: $p+p$ at $\sqrt{s} = 1960 GeV, |\eta| < 1.0$ [5]
- UA1: $p+p$ at $\sqrt{s} = 900 GeV, |\eta| < 2.5$ [5]

Qualitative differences in proton-to-pion and kaon-to-pion ratios:

- The data from different experiments consistent with each other
- PDF uncertainties small, huge scale uncertainties at $p_T \lesssim 10$ GeV/c
- Large deviations between different FFs, data best described by the Kretzer FFs

The shape of proton-to-pion ratio not described by NLO calculations at small $p_T$:

- non-perturbative effects of 10% at $p_T < 10$ GeV/c in total $h^+ + h^-$ yield

Conclusions

- NLO calculations and TeV-data for large-$p_T$, charged hadron production not consistent within the theoretical and experimental uncertainties
- Appears to follow from presently too hard gluon-to-hadron FFs
- Calls for a complete re-analysis of FFs using the data at $p_T > 10$ GeV/c where the theoretical uncertainties are tolerable and the independent parton-to-hadron fragmentation appears applicable

References