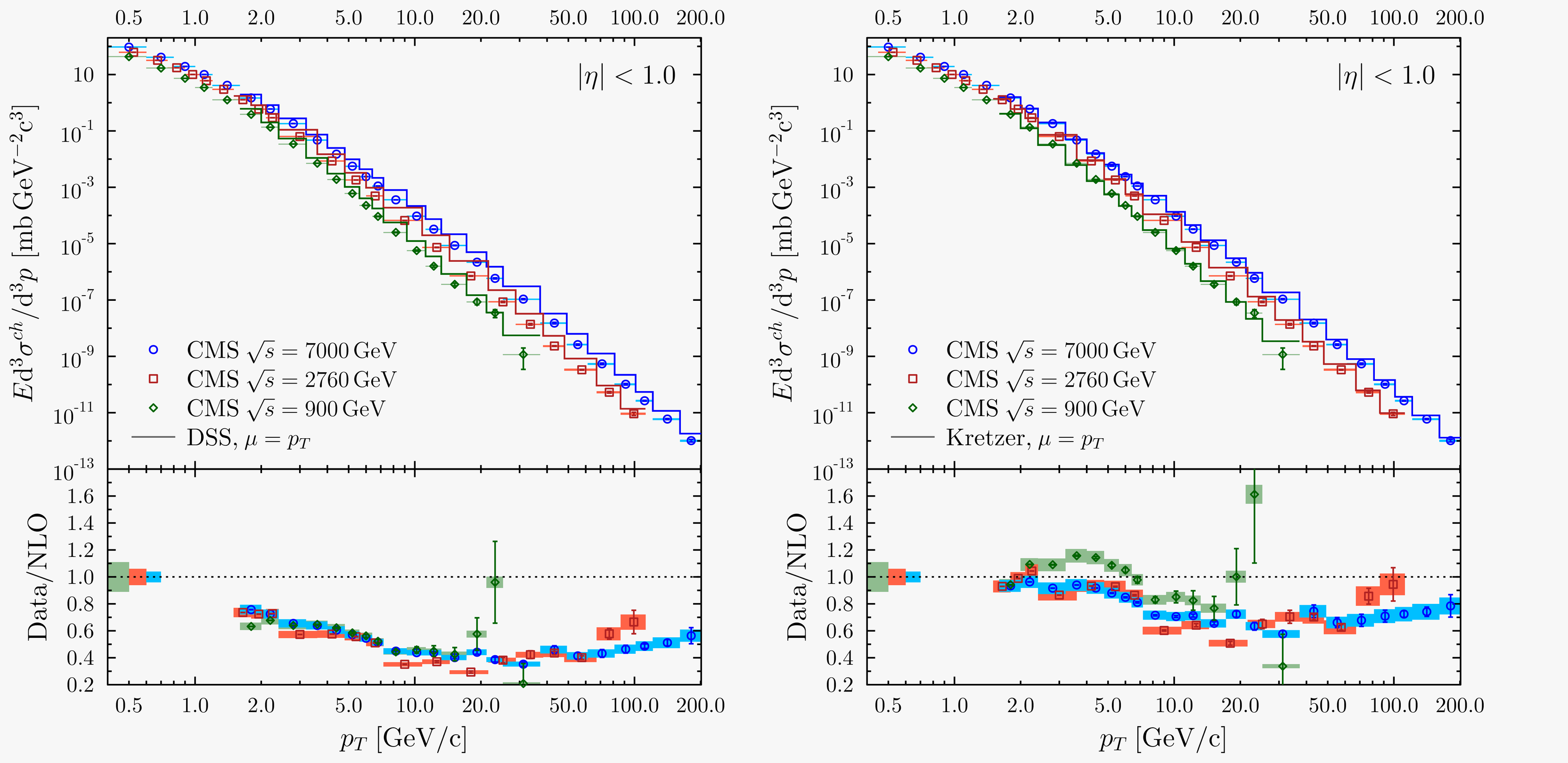
Confronting current NLO charged-hadron fragmentation functions with LHC data

Ilkka Helenius[a,b], Hannu Paukkunen[a,b], David d'Enterria[c] and Kari J. Eskola[a,b]

[a] Department of Physics, University of Jyväskylä, P.O. Box 35, FI-40014 University of Jyväskylä, Finland
[b] Helsinki Institute of Physics, P.O. Box 64, FI-00014 University of Helsinki, Finland
[c] CERN, PH Department, CH-1211 Geneva 23, Switzerland

Motivation

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



Goal[1]: 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

$$d\sigma^{p+p\to h+X} = \sum_{i,j,k,X'} f_i(x_1,\mu^2_{\rm fact}) \otimes f_j(x_2,\mu^2_{\rm fact}) \otimes d\hat\sigma^{ij\to k+X'} \otimes D^h_k(z,\mu^2_{\rm frag})$$

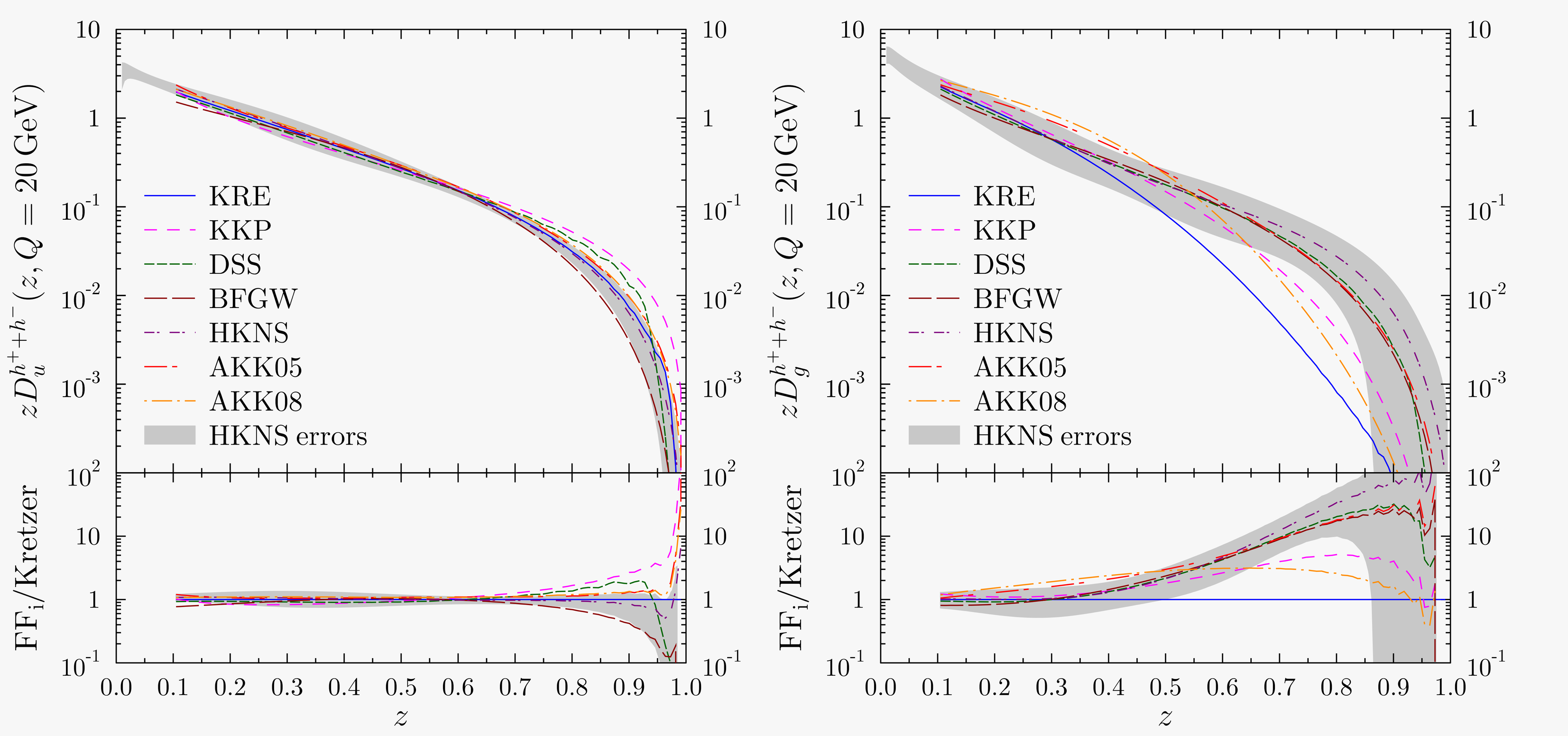
where

$f_i(x,\mu^2_{\rm fact})$ = parton distribution function (PDF) of a proton
$D^h_k(z,\mu^2_{\rm frag})$ = parton-to-hadron fragmentation function (FF)
$d\hat\sigma^{ij\to k+X'}$ = the partonic coefficient functions

- The PDFs and FFs are obtained from data through QCD analyses
- Available charged hadron FFs:[see [1] for the Refs.]

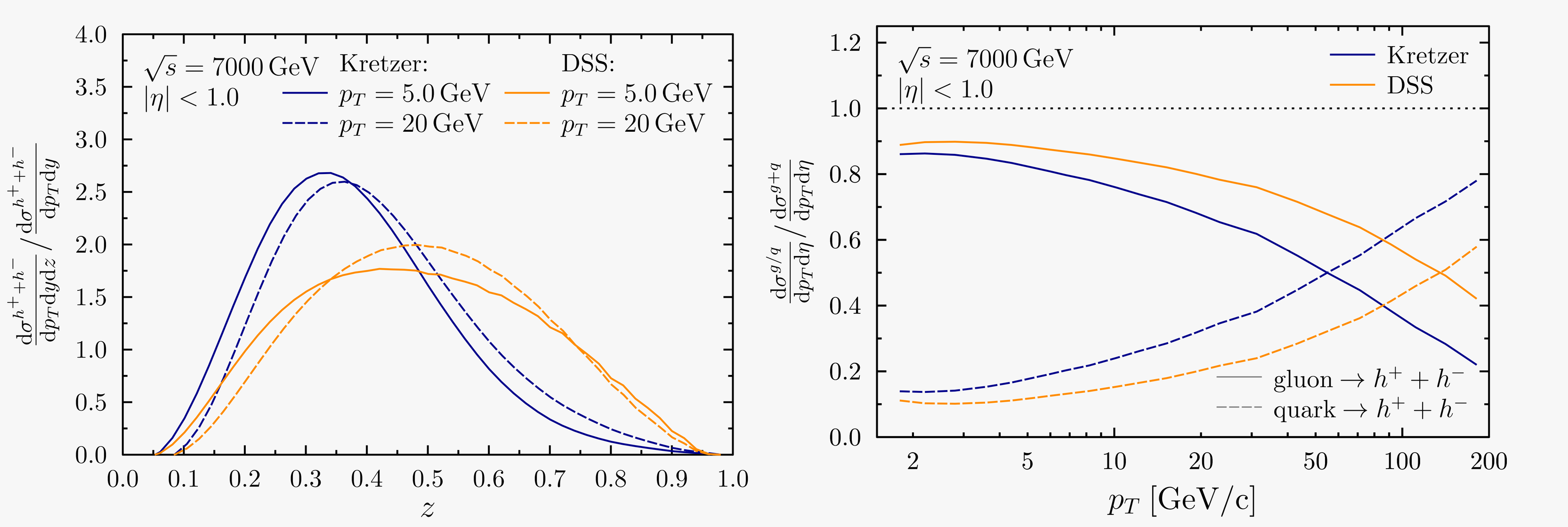
FF set	Species	Fitted data	uncert.	$z_{\min}$	Q^2 [GeV^2]
Kretzer (KRE)	$\pi^\pm, K^\pm, h^+{+}h^-$	$e^+ + e^-$	no	0.01	0.8–10^6
KKP	$\pi^+{+}\pi^-, K^+{+}K^-$ $p+\bar p, h^+{+}h^-$	$e^+ + e^-$	no	0.1	1–10^4
BFGW	$h^\pm$	$e^+ + e^-$	yes	10^{-3}	2–$1.2\cdot10^4$
AKK05	$\pi^\pm, K^\pm, p, \bar p$	$e^+ + e^-$	no	0.1	2–$4\cdot10^4$
HKNS	$\pi^\pm, K^\pm, p+\bar p$	$e^+ + e^-$	yes	0.01	1–10^8
AKK08	$\pi^\pm, K^\pm, p, \bar p$	$e^+ + e^-$, p+p	no	0.05	2–$4\cdot10^4$
DSS	$\pi^\pm, K^\pm, p, \bar p, h^\pm$	$e^+ + e^-$, p+p, e+p	yes	0.05	1–10^5

- FFs constrained mostly by $e^+ + e^-$ data
- DSS and AKK08 use also p+p($\bar{\rm p}$) data from RHIC, Tevatron and SPS
- Only HKNS provides error sets



⇒ Quark-to-hadron FFs (left) rather well constrained
⇒ Enormous deviations in gluon-to-hadron FFs (right)

- Sensitivity to different values of z and to gluon FFs at the LHC:



⇒ Cross sections get contributions from a wide z range (left)
⇒ Gluons dominate the cross sections up to highest p_T (right)

Comparison between data and NLO

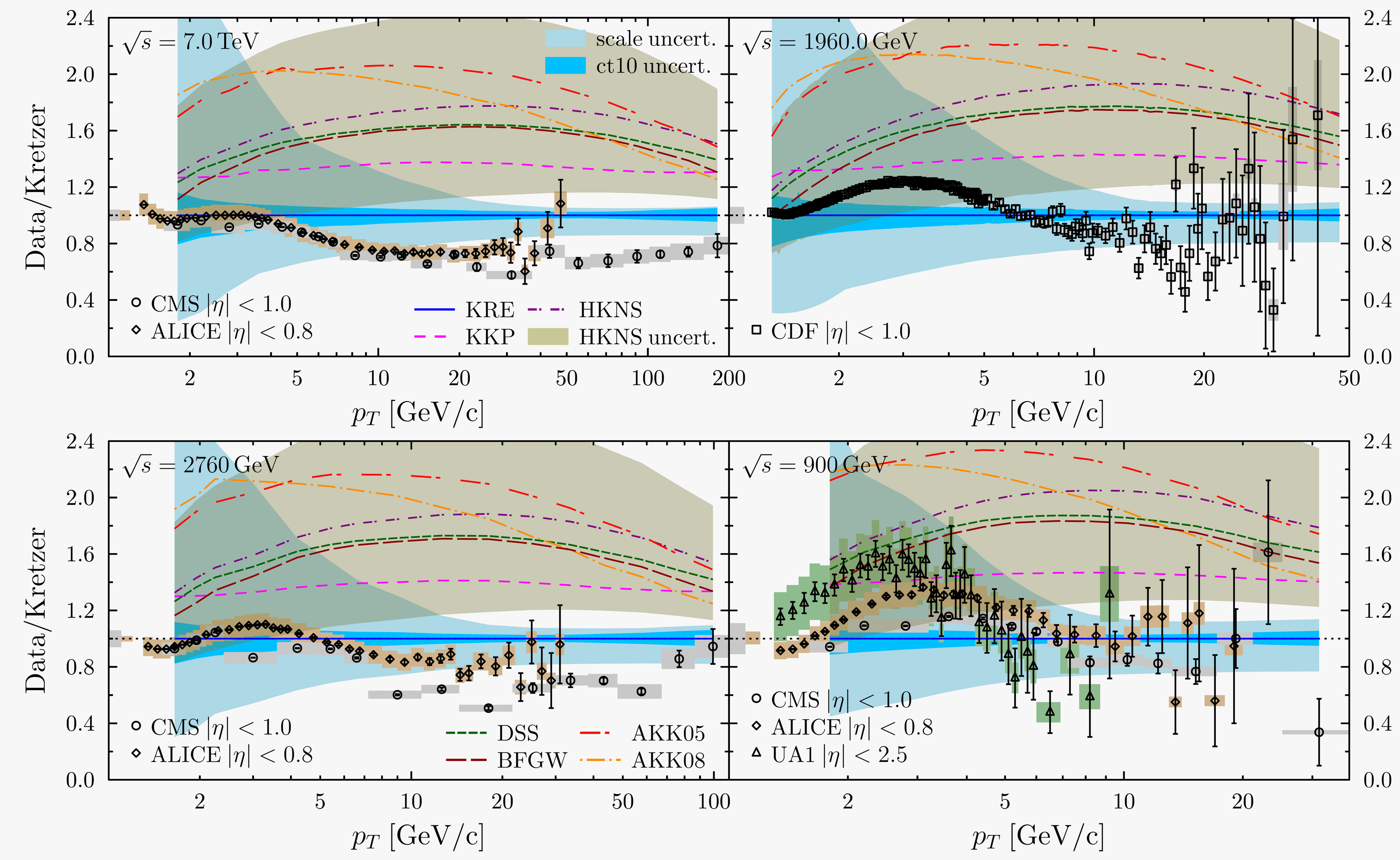
NLO computations performed with improved INCNLO-code using

- CT10NLO proton PDFs
- Scale choice $\mu_{\rm fact} = \mu_{\rm frag} = \mu_{\rm ren} = p_T$, and 16 combinations to estimate the stability of the NLO approximation:

$$\left(\frac{\mu_{\rm fact}}{p_T},\frac{\mu_{\rm ren}}{p_T},\frac{\mu_{\rm frag}}{p_T}\right) = \begin{matrix} (\tfrac12,\tfrac12,\tfrac12), & (\tfrac12,\tfrac12,1), & (\tfrac12,1,\tfrac12), & (\tfrac12,1,1), \\ (\tfrac12,1,2), & (1,\tfrac12,\tfrac12), & (1,\tfrac12,1), & (1,1,\tfrac12), \\ (1,1,2), & (1,2,1), & (1,2,2), & (2,1,\tfrac12), \\ (2,1,1), & (2,1,2), & (2,2,1), & (2,2,2) \end{matrix}$$

Data used for the comparison:

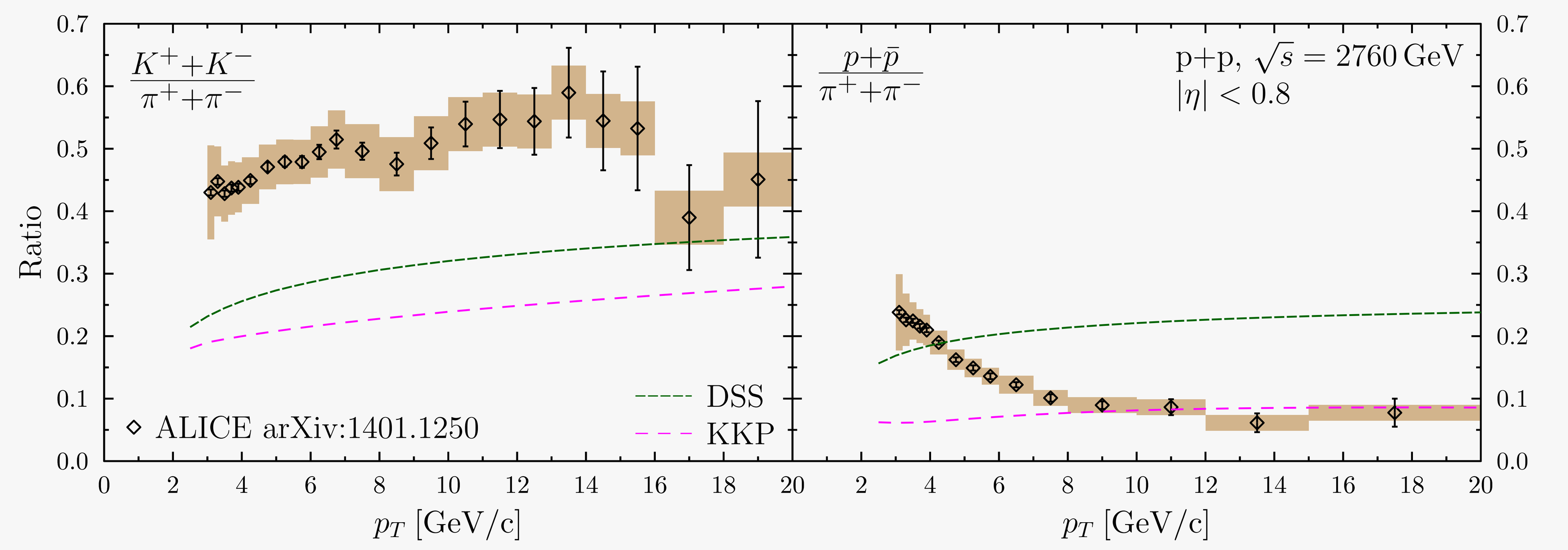
- CMS: p+p at $\sqrt{s} = 900, 2760$ and 7000 GeV, $|\eta| < 1.0$ [2,3]
- ALICE: p+p at $\sqrt{s} = 900, 2760$ and 7000 GeV, $|\eta| < 0.8$ [4]
- CDF: p+$\bar{\rm p}$ at $\sqrt{s} = 1960$ GeV, $|\eta| < 1.0$ [5]
- UA1: p+$\bar{\rm p}$ at $\sqrt{s} = 900$ GeV, $|\eta| < 2.5$ [6]



- 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 LHC and Tevatron data prefer "soft" gluon FFs

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



- 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

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 ilkka.helenius@jyu.fi