NON-EXTENSIVE MOTIVATED FRAGMENTATION FOR HADRON PRODUCTS IN HIGH-ENERGY COLLISIONS

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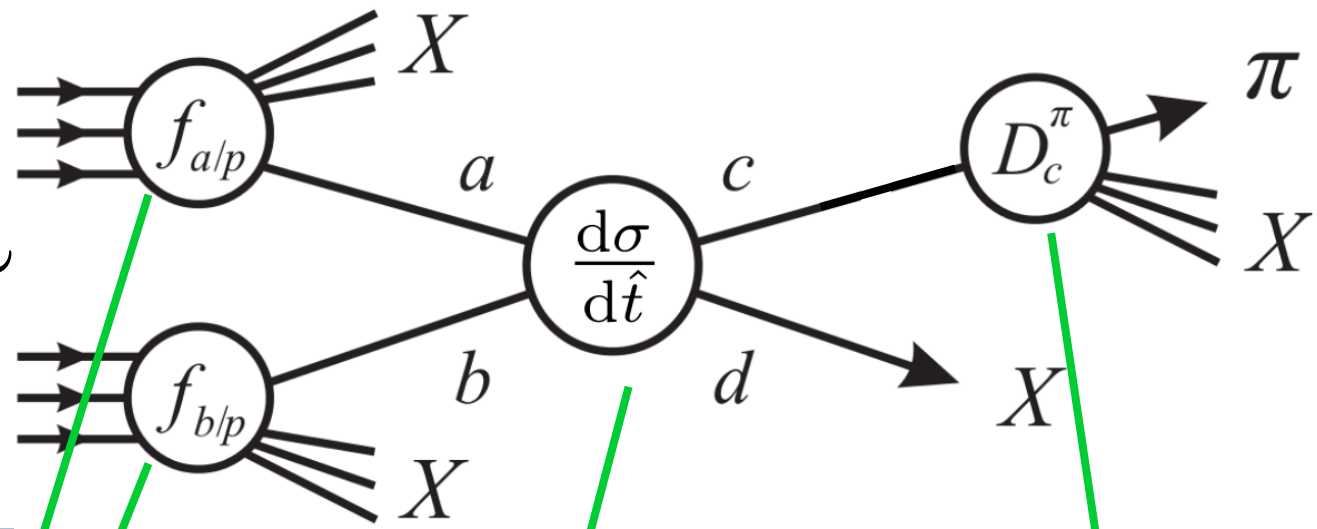
Motivation

pQCD based Parton Model

pp → *h* inclusive cross section:

$$E_h \frac{\mathrm{d}^3\sigma_h^{pp}}{\mathrm{d}^3 p_h} \sim$$



Parton Distribution (PDF) phenomenological

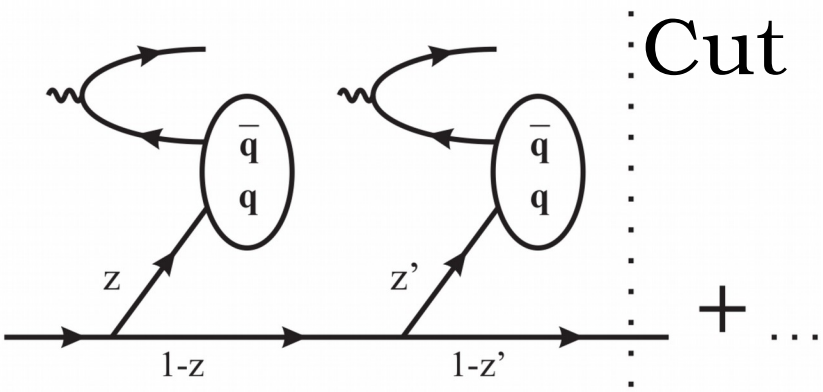
2-2 QCD Cross section

Fragmentation Function phenomenological

Fragmentation a Model for Hadroniztion

Feynman Independent Fragmentation

(de Florian, Sassot, Stratmann, Albino, Kniehl, Kramer, Kretzer, Hirai, Kumano, Nagai, Sudoh)



$$D_i^h(z, Q^2) = N_i^h z^{\alpha_i^h} (1-z)^{\beta_i^h}$$

pQCD based Parton Model

Given PDF and FF → hadronproduction is calculable [0]

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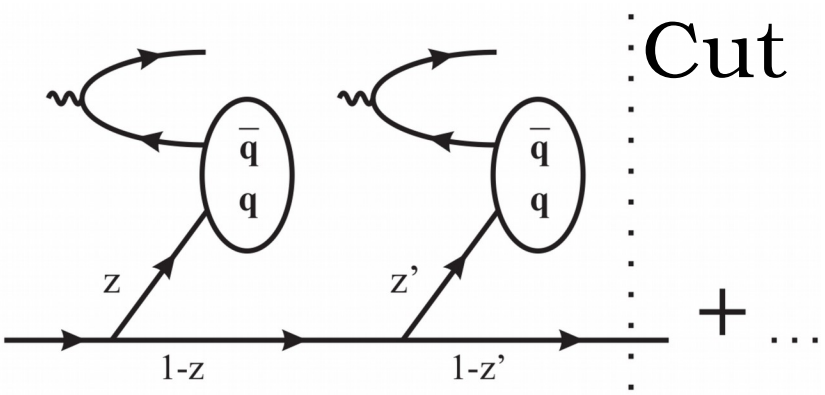

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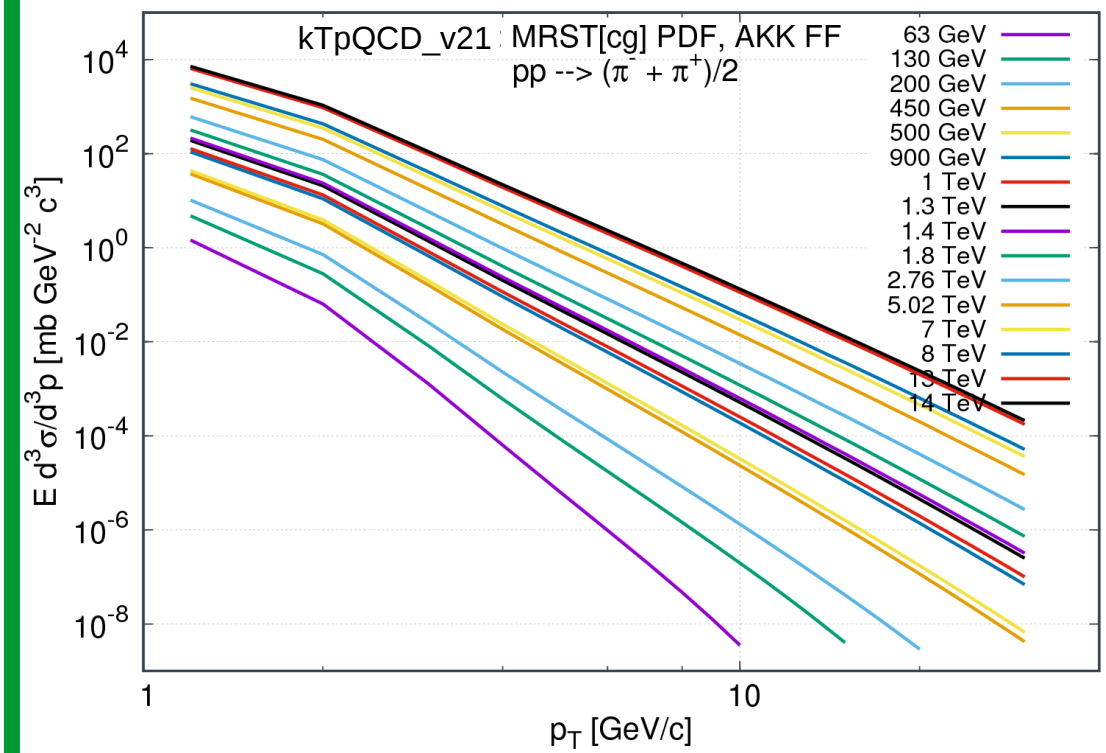

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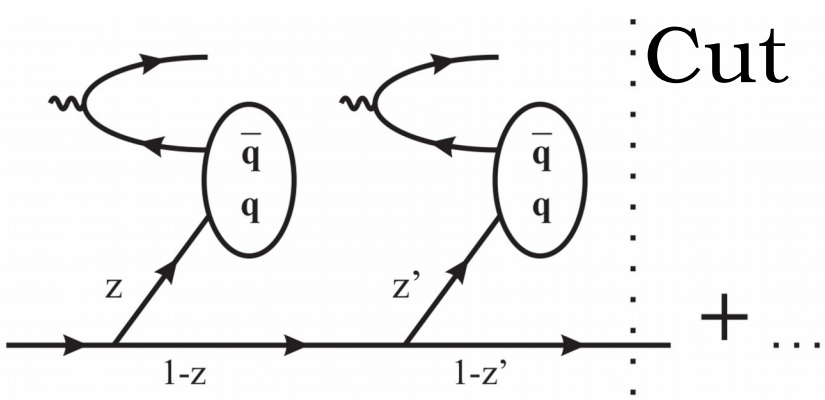
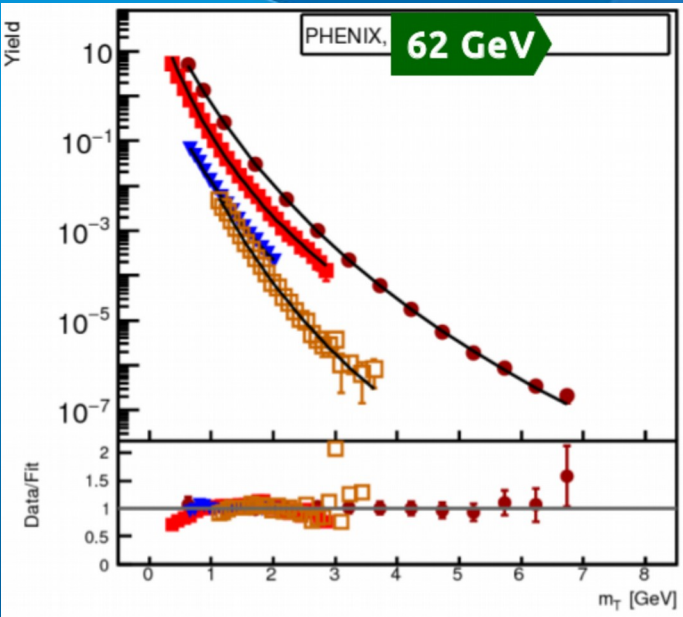


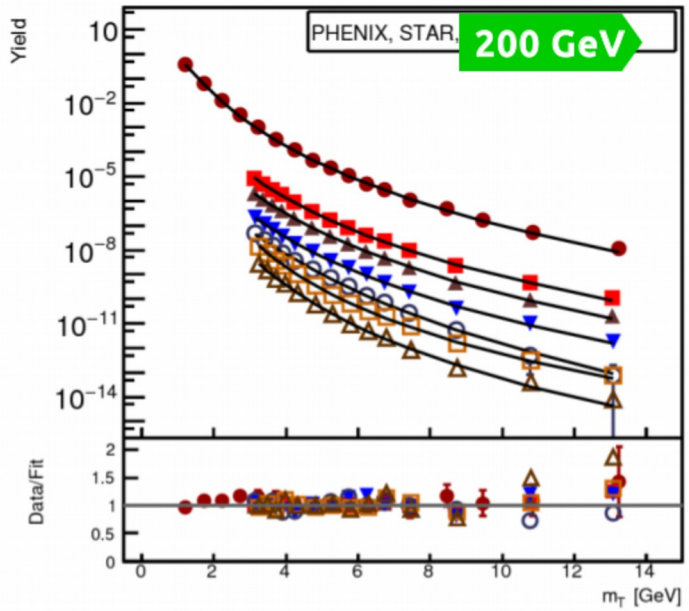
$$D_i^h(z, Q^2) = N_i^h z^{\alpha_i^h} (1-z)^{\beta_i^h}$$

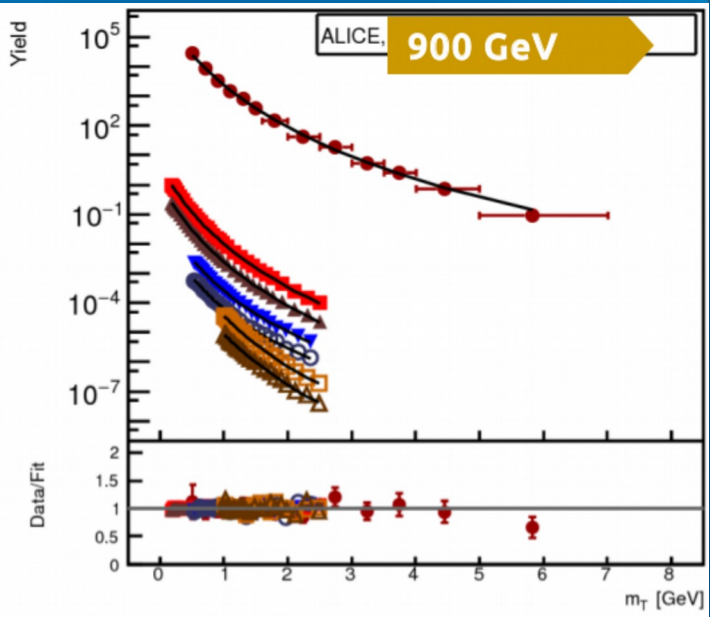
- Many FF parametrization!
  (AKK, KKP, HKNS)
- What are the meaning of α and β ?
- From fits: $\alpha = -1.1 - 8.1$
  $\beta = 0.7 - 9.8$

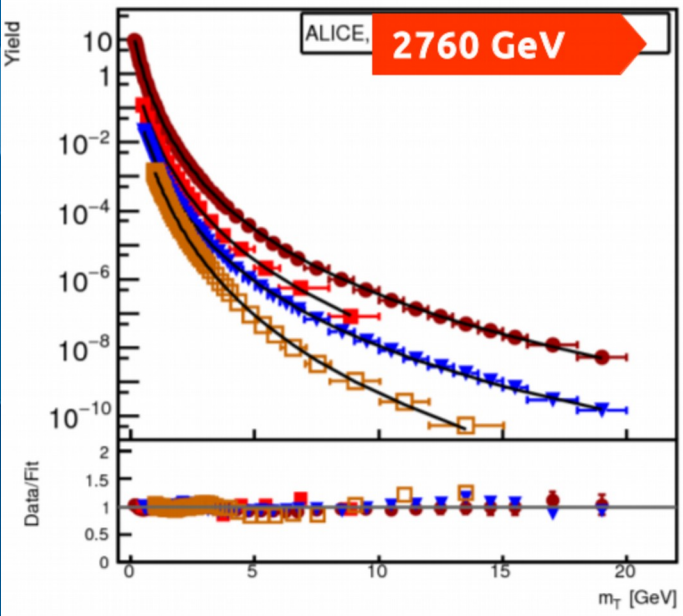
Hadron Spectra and Non-extensivity [1]

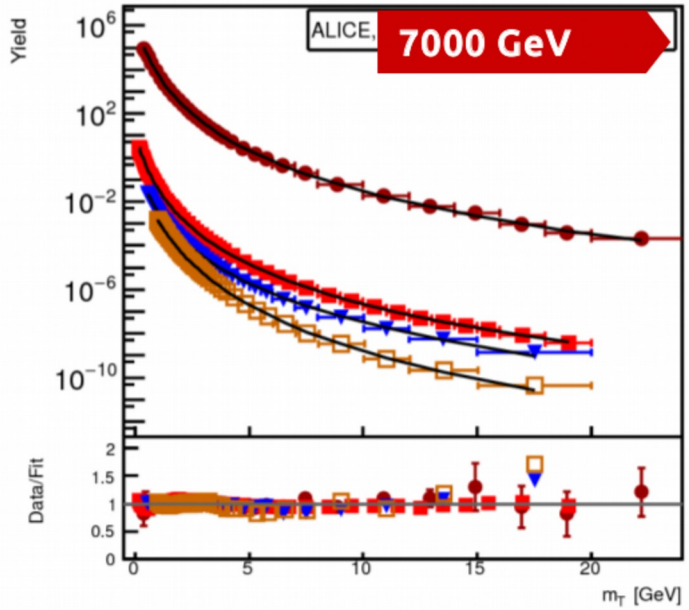
pp → PID spectra







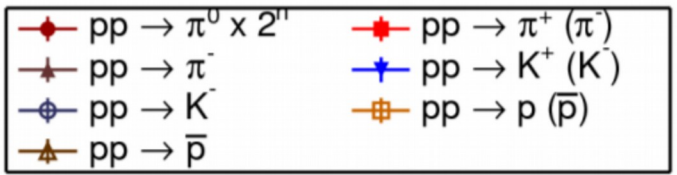




Tsallis—Pareto distribution

(q-exponential)

$$f(m_T) = N\left[1 + \frac{q-1}{T}\varepsilon\right]^{-\frac{1}{q-1}}$$



Non-Extensive Statistical Mechanics

Additive

$$S_{12} = S_1 + S_2$$

Boltzmann-Gibbs distr.

$$f(\varepsilon) \sim e^{-\beta\varepsilon}$$

Non-Additive [2]

$$S_{12} = S_1 + S_2 + (q-1)S_1 S_2$$

Tsallis-Pareto distr.

$$f(\varepsilon) \sim \left[1 + \frac{q-1}{T}\varepsilon\right]^{-\frac{1}{q-1}}$$

$$q = 1$$

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Non-extensive thermodynamics:

Physical meaning for q and T! [3-8]

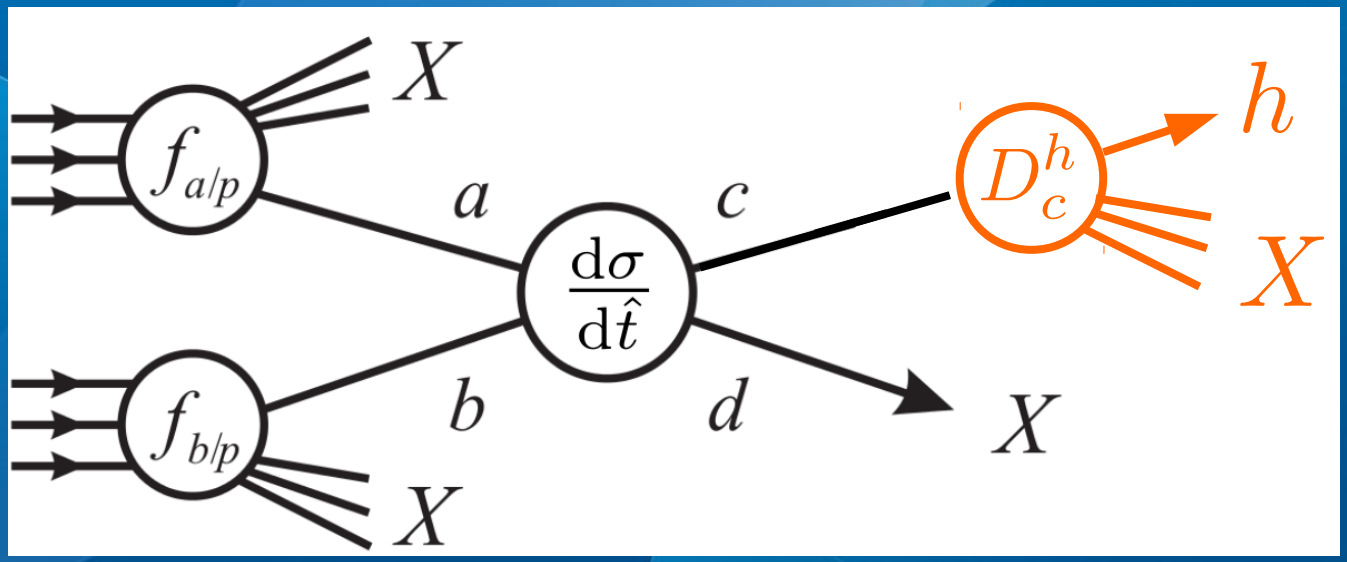
$$T = \frac{E}{\bar{n}} = \frac{1}{\langle\beta\rangle}$$

$$q = 1 - \frac{1}{\bar{n}} + \frac{(\Delta n)^2}{\bar{n}^2} = 1 - \frac{1}{C} + \frac{(\Delta\beta)^2}{\langle\beta\rangle^2}$$

Main Question:

How Non-Extensivity connected with QCD?

Non-Extensive Motivated Fragmentation

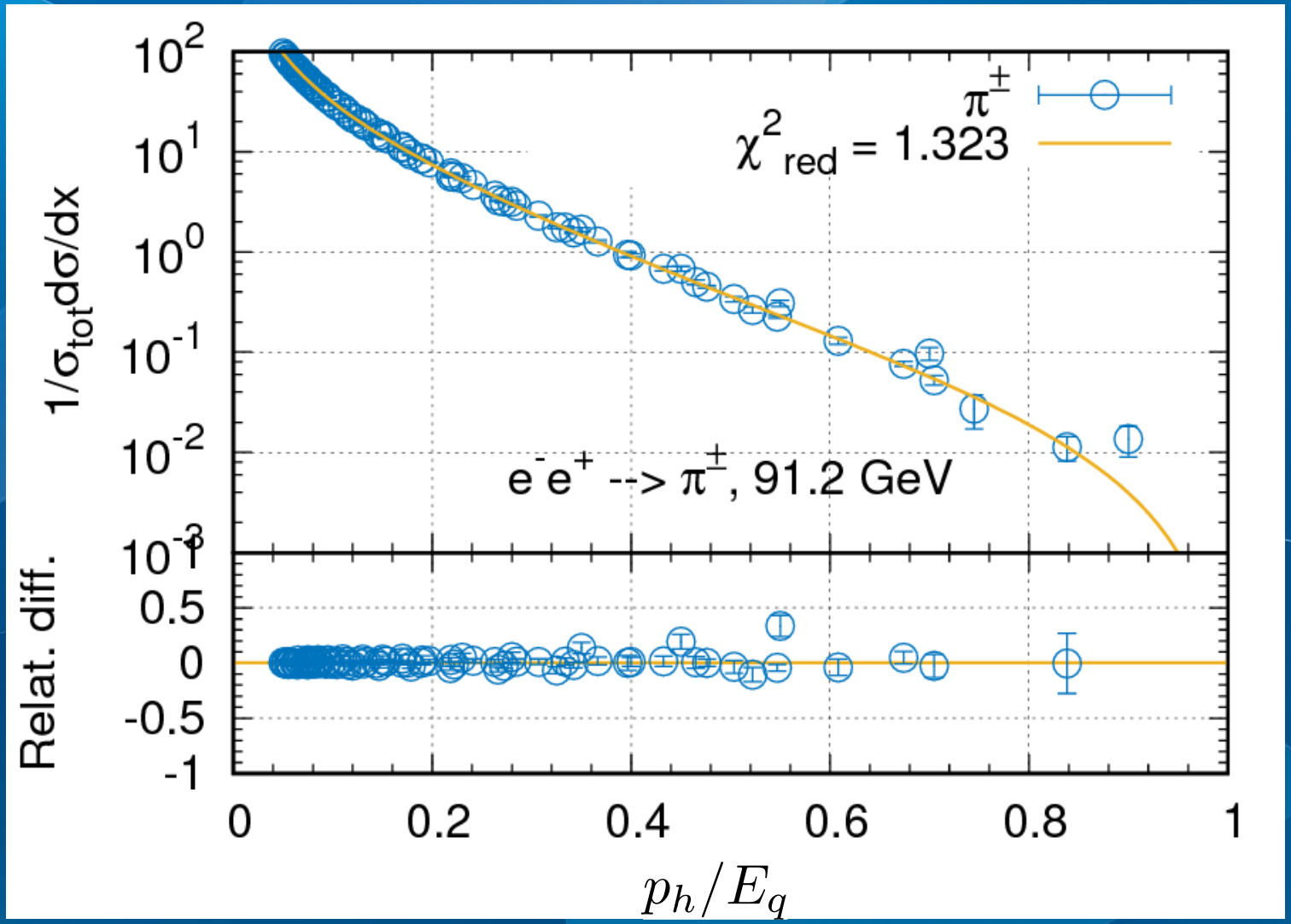


Microcanonical form of Tsallis-Pareto distribution in 1D jet fragmentation [4]

$$D_i^h(z,Q^2) = A_i^h(1-z)\left[1-\frac{q_i^h-1}{T_i^h}\frac{\sqrt{s}}{2}\log(1-z)\right]^{-\frac{1}{q_i^h-1}}$$

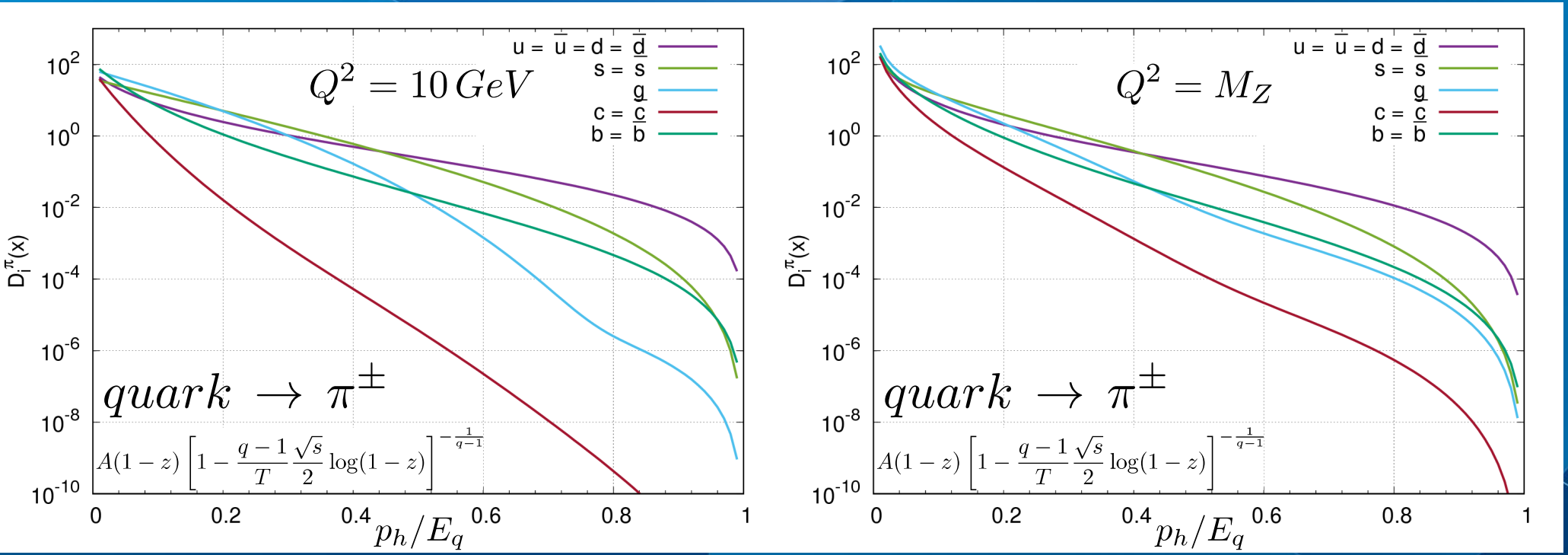
Independent parameters: A, q, T

Parametrization of the Non-Ext FF

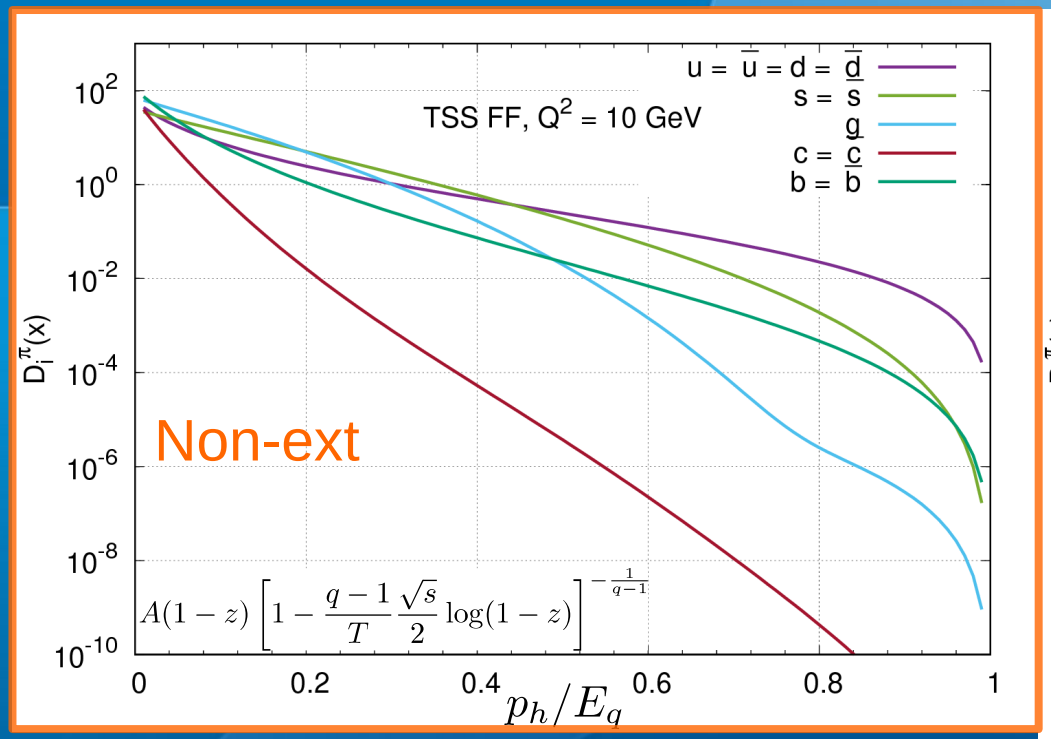


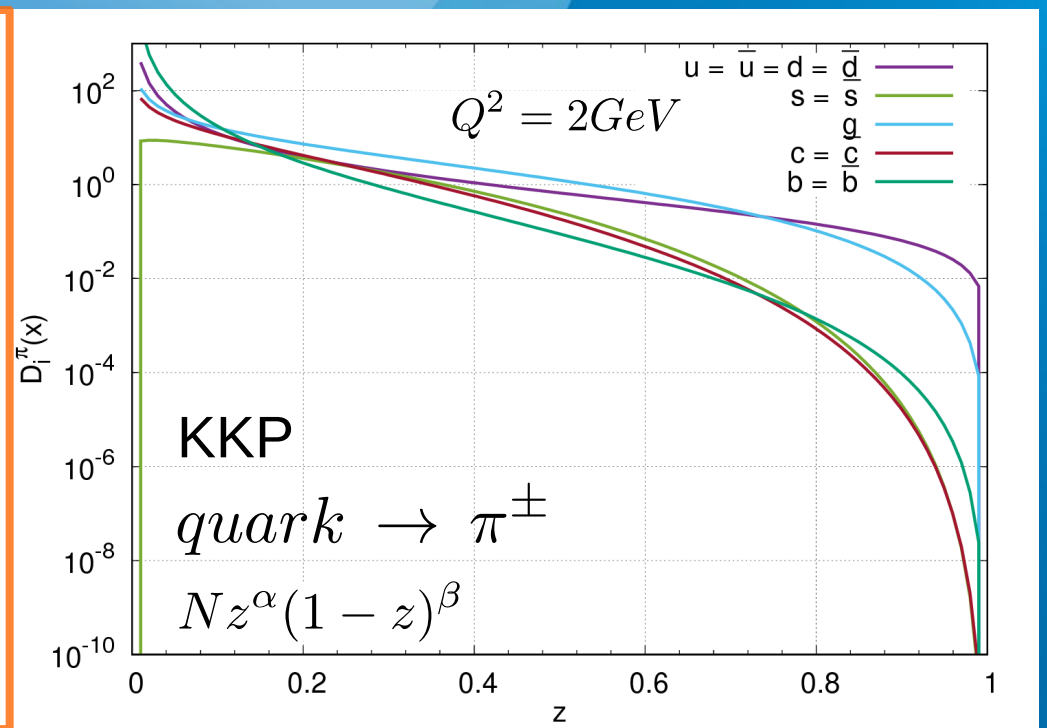
Data: SLD, ALEPH, OPAL, DELPHI collaboration

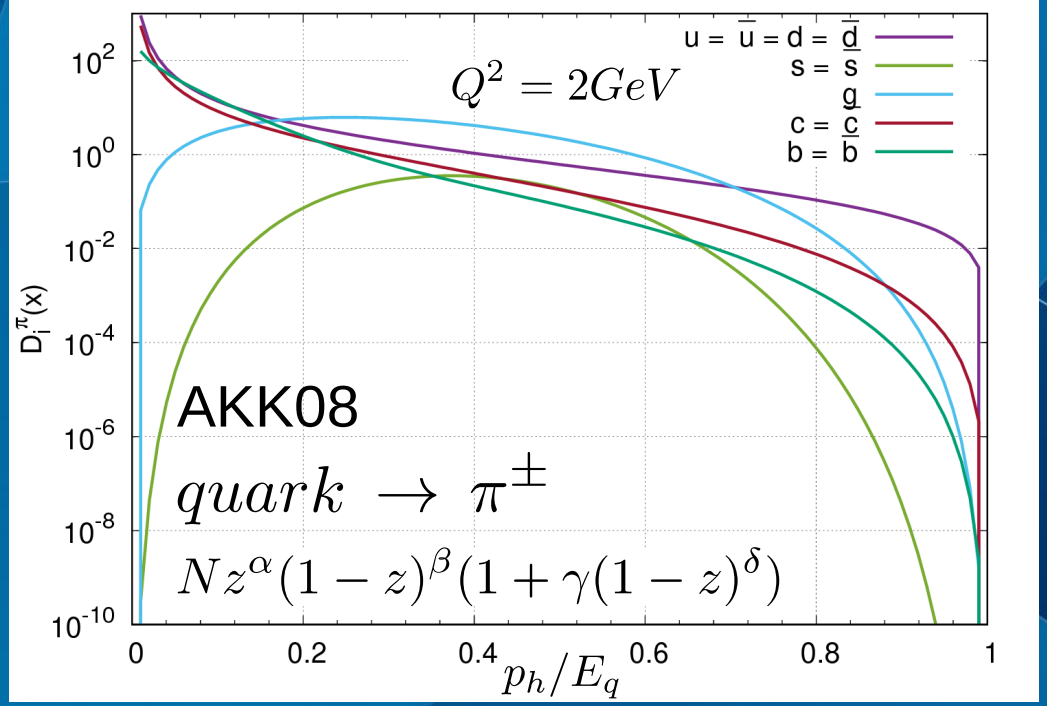
Parametrized Fragmentation Function



Scale evolution with the help of DGLAP equations







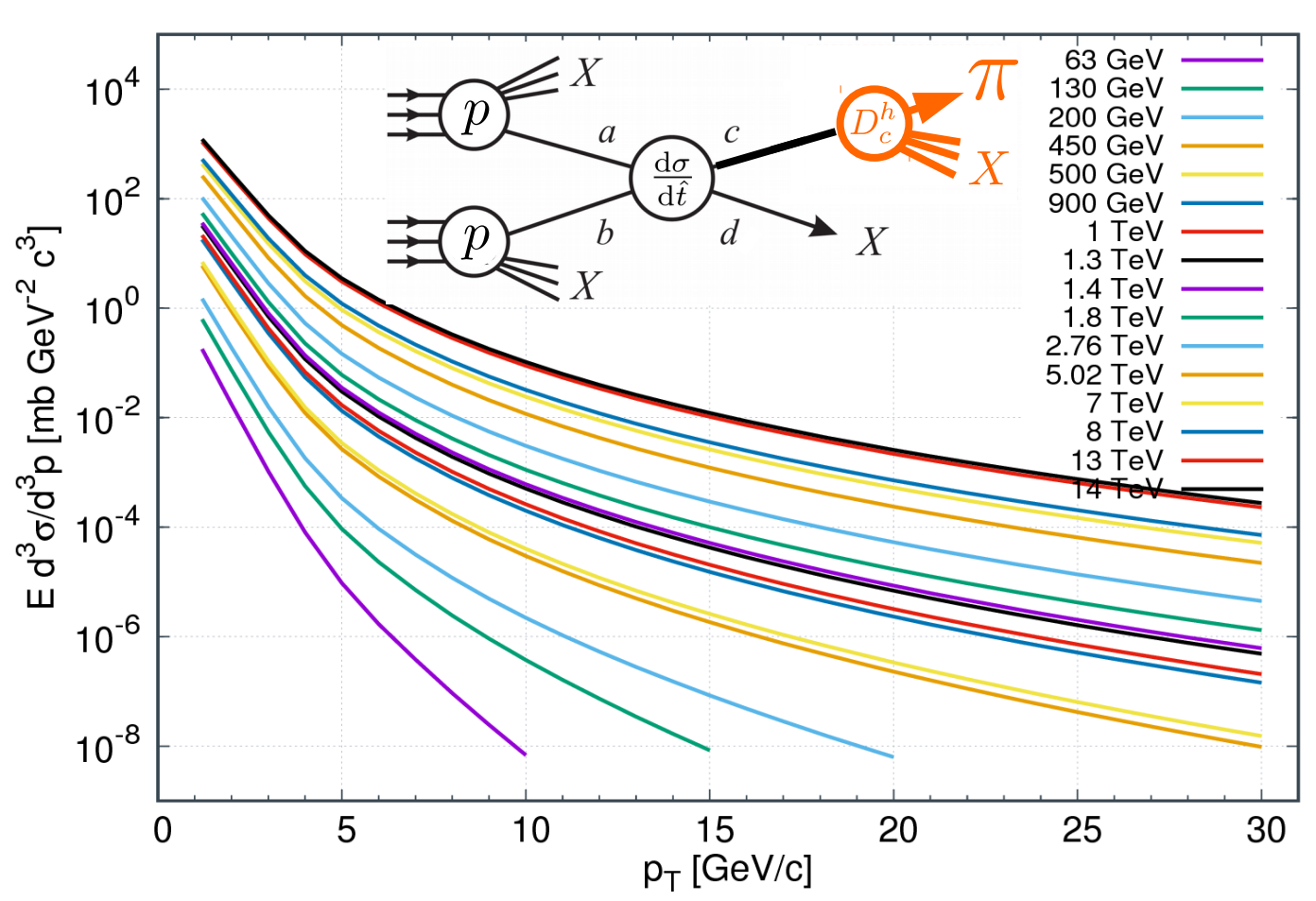
Comparsion with standard FFs

$$quark \rightarrow \pi^{\pm}$$

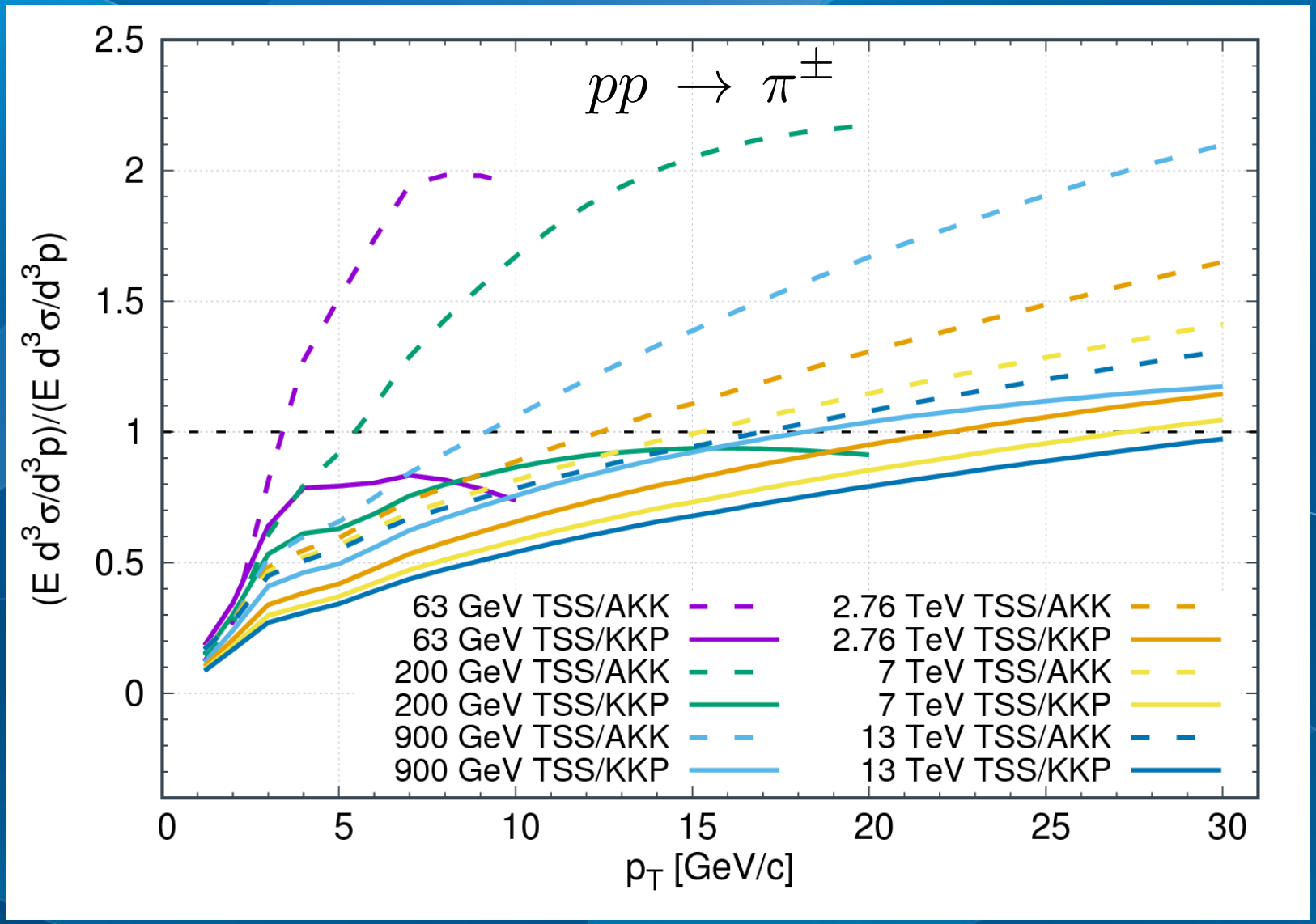
$$Q^2 \approx 2\,GeV$$

Test of the New FF in pp collision

New Non-Ext FF → Parton Model → pp→π collisions



Comparsion of hadron spectra with different FFs



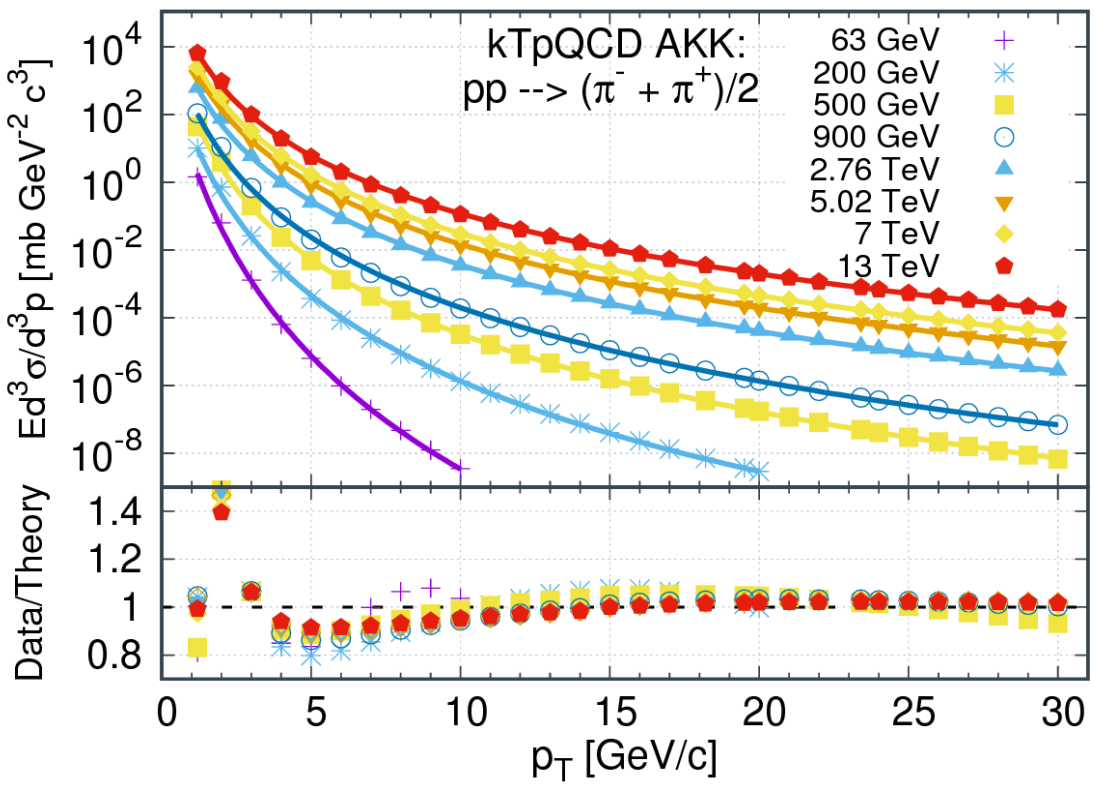
Non-Extensive Analysis

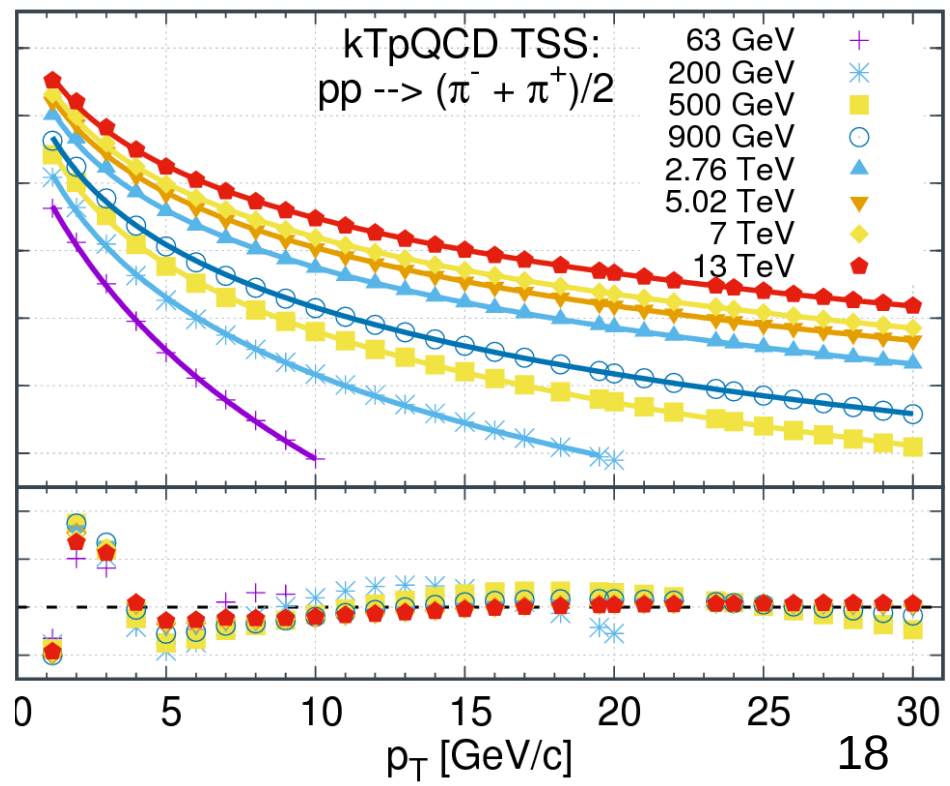
Tsallis-Pareto type fitting function

$$f(p_T) = A\left[1 + \frac{q-1}{T}\left(\sqrt{p_T^2 + m^2} - m\right)\right]^{-\frac{1}{q-1}}$$

Feyman-type fragmentation

Tsallis-type Fragmentation





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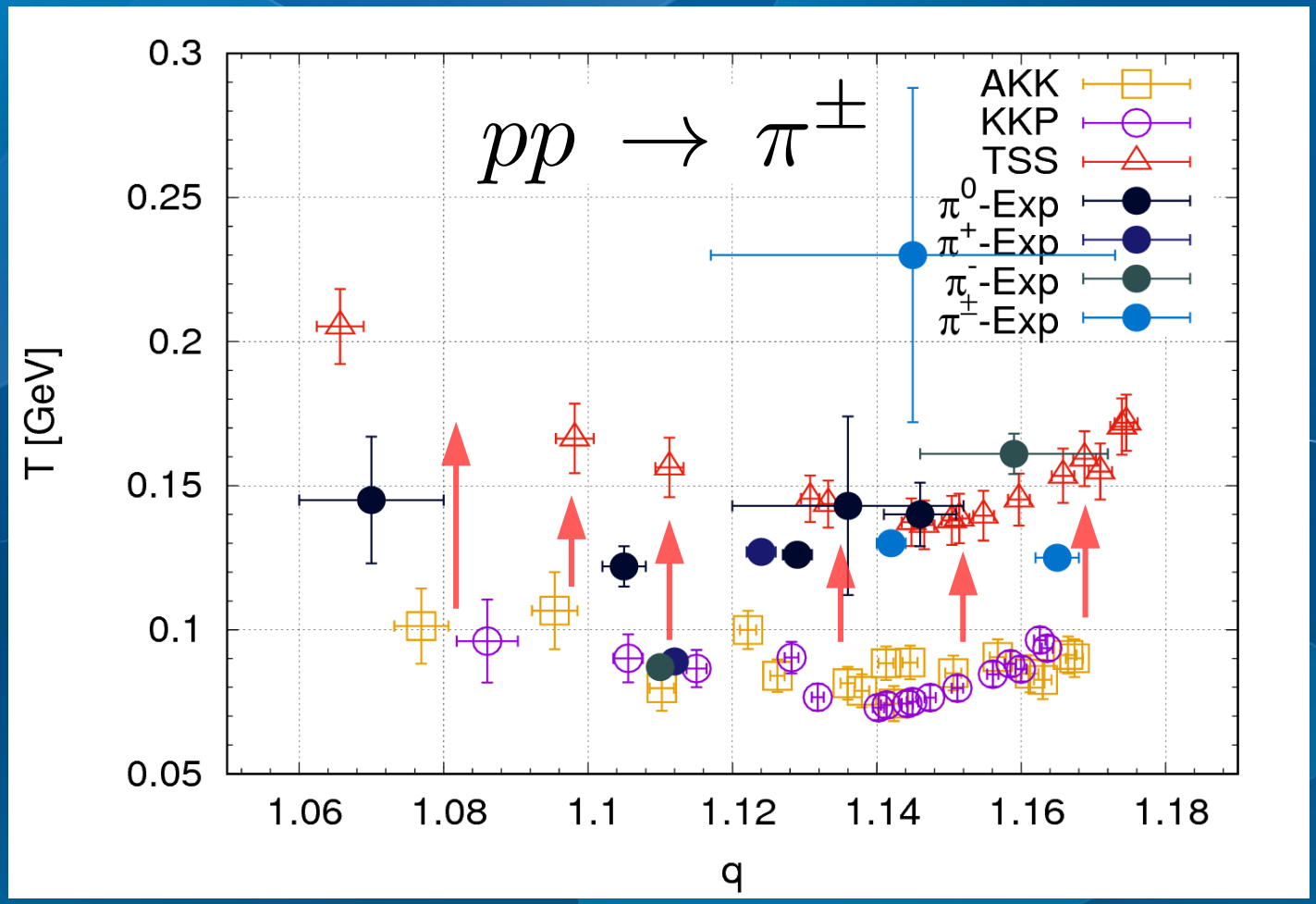

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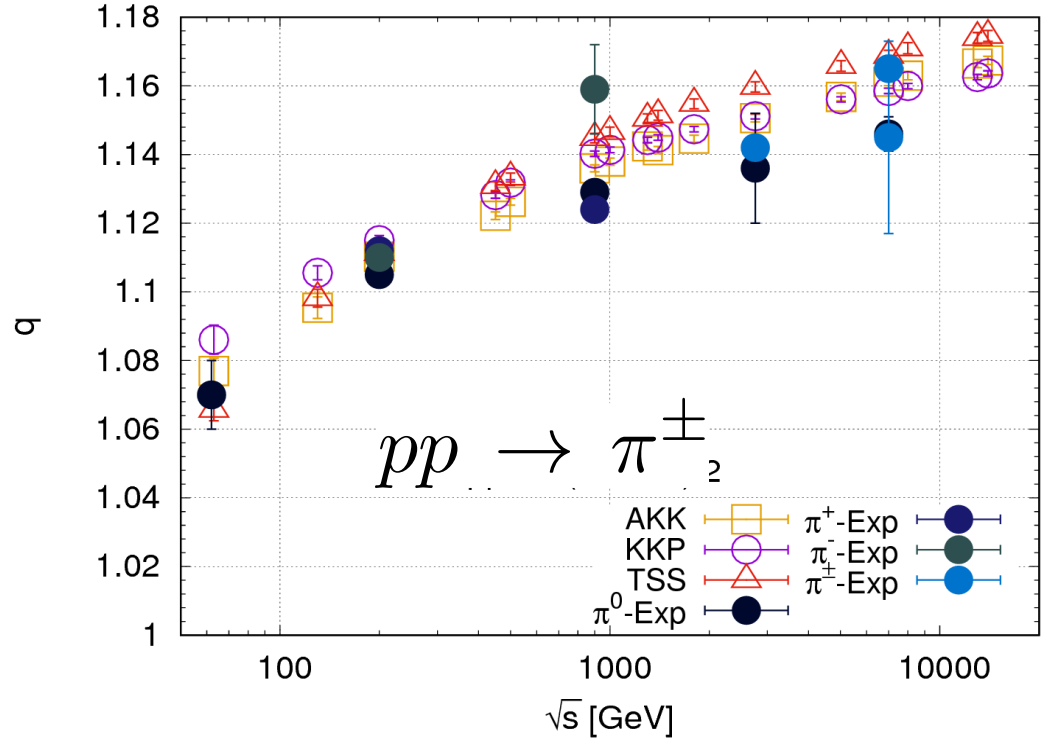

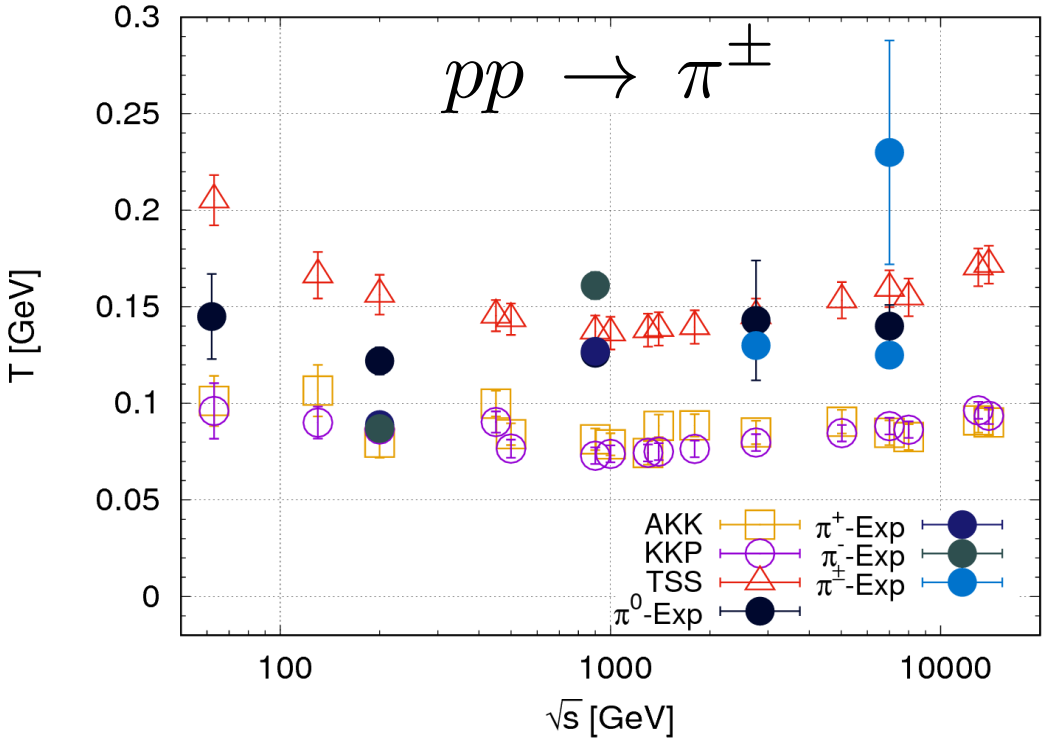

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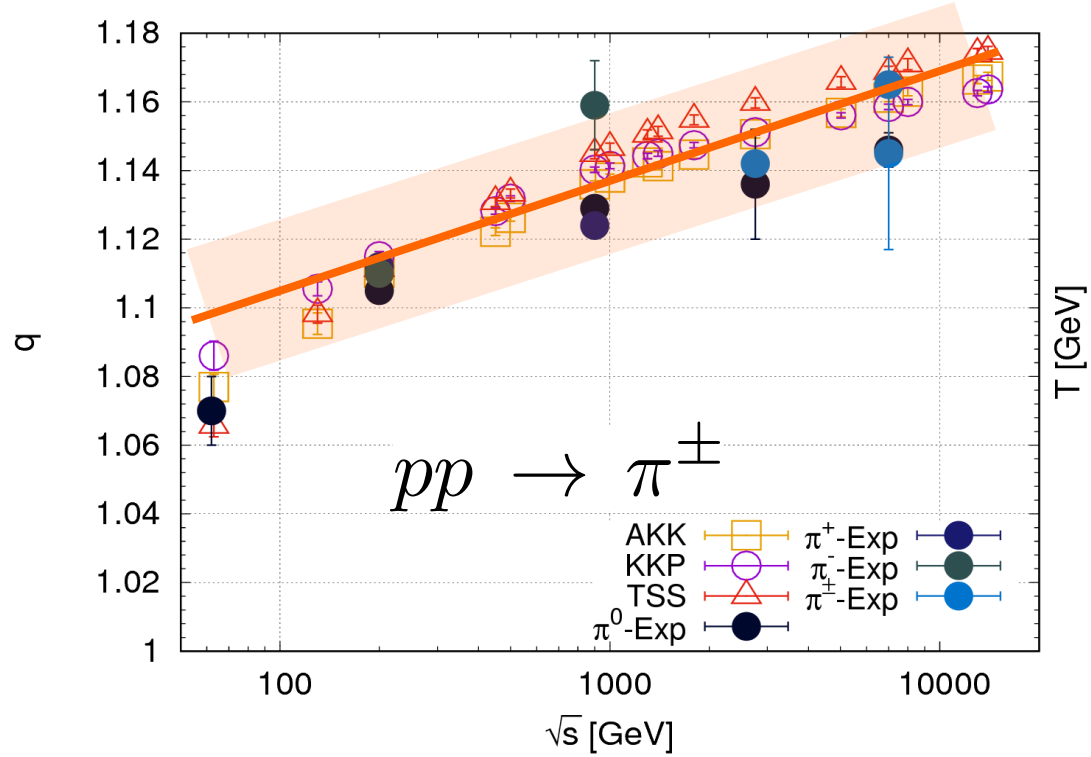
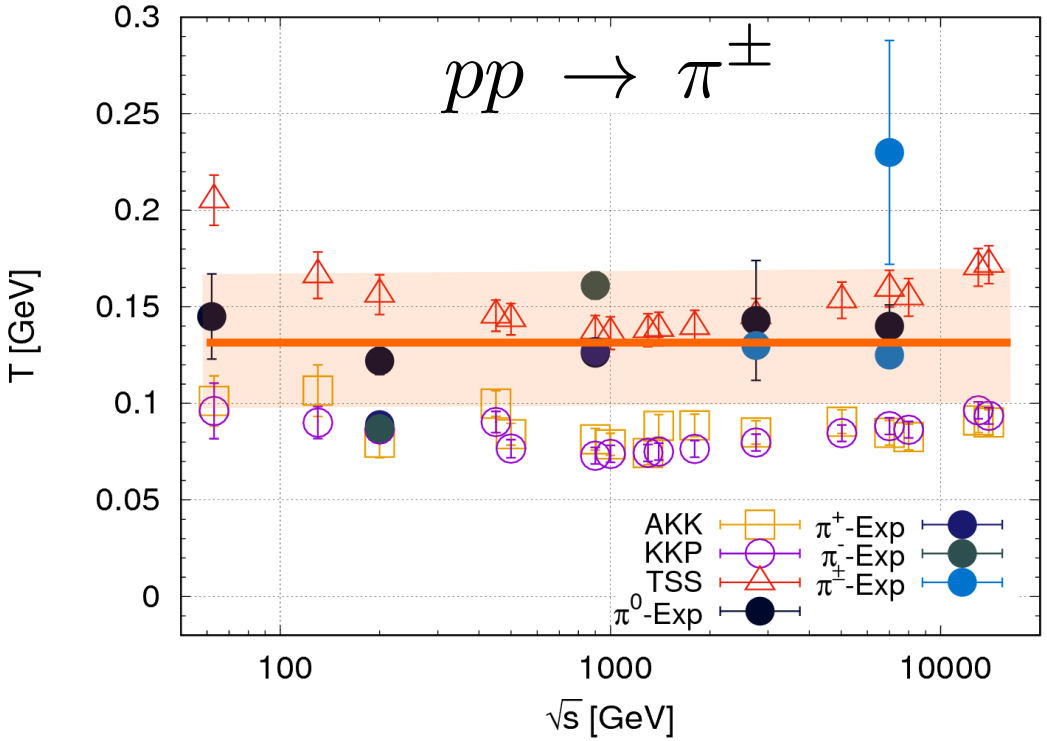




Logarithmic energy scaling
~ QCD like scaling

Constant energy scaling
~ Coalescence like scaling

Summary

0. Non-Extensive Statistical Description for Hadron spectra

1. Tsallis-Pareto Like Fragmentation Function

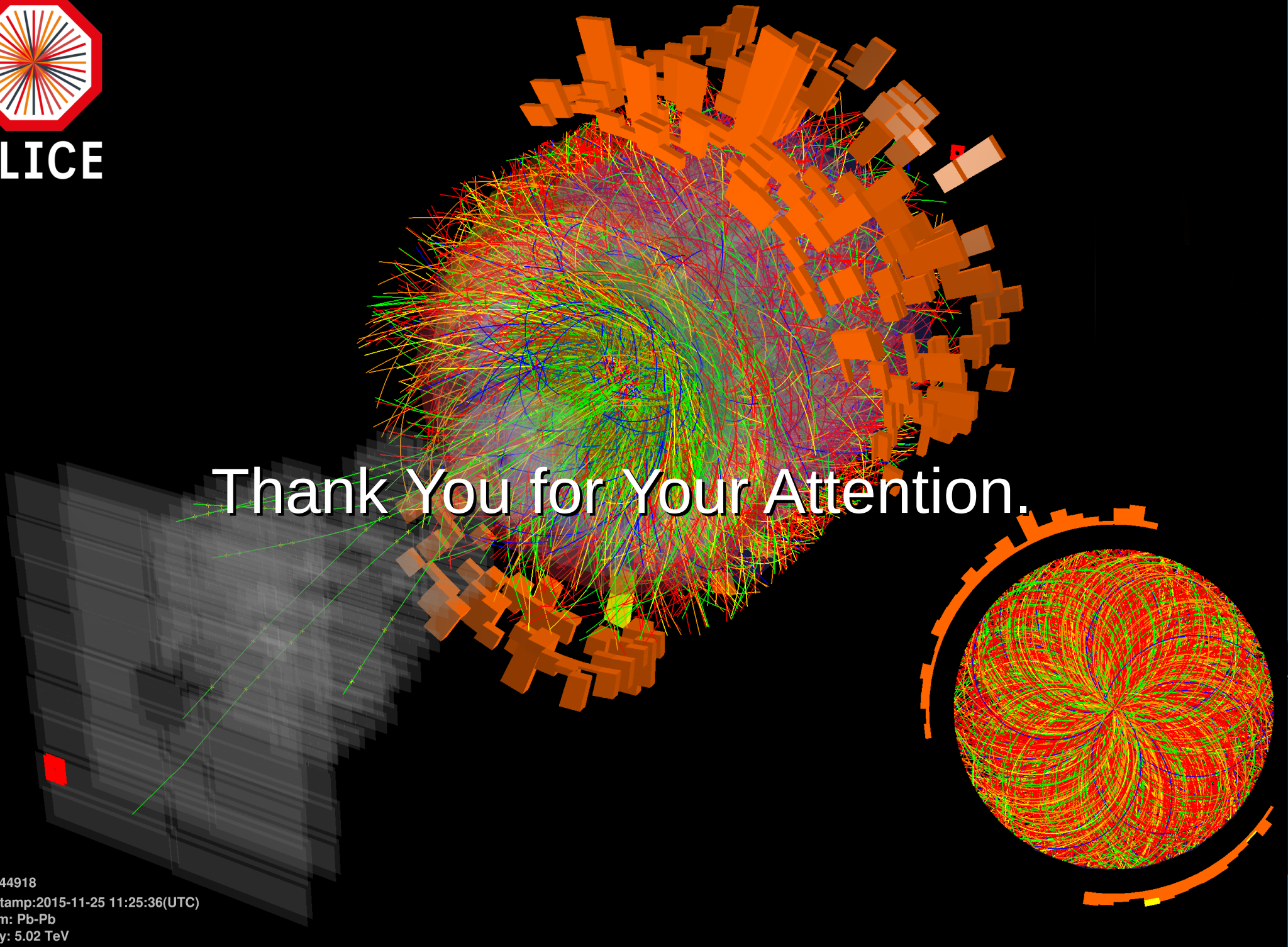
2. Comparism with the Most Common FFs and Experimental Results
   → Better results
   → Physical parameters

+ Errors

+ NLO

+ Microscopical Dynamics (Hadronization)

ALICE



Thank You for Your Attention.

References

[0] Phys. Rev. C 65, 034903 (2002)
[1] Á. Takács et al. Entropy 19 (2017) 88
[2] C. Tsallis, Intr. Nonext. Stat. Mech. (Springer 2009)
[3] Phys.Lett. B689 (2010) 14-17
[4] Phys.Lett. B701 (2011) 111-116
[5] J.Phys.Conf.Ser. 394 (2012) 012002
[6] Phys.Lett. B718 (2012) 125-129
[7] Eur.Phys.J. A49 (2013) 110
[8] Entropy 2014, 16(12), 6497-6514
[9] Physica 417 (2015) 215-220
[10] SLD Phys. Rev. D69, 072003 (2004)
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[14] DELPHI, Nucl. Phys. B444, 3 (1995)
[15] DELPHI, Eur. Phys. J. C5, 585 (1998)

Backup slides

pQCD based Parton Model

pp → *h* inclusive cross section:

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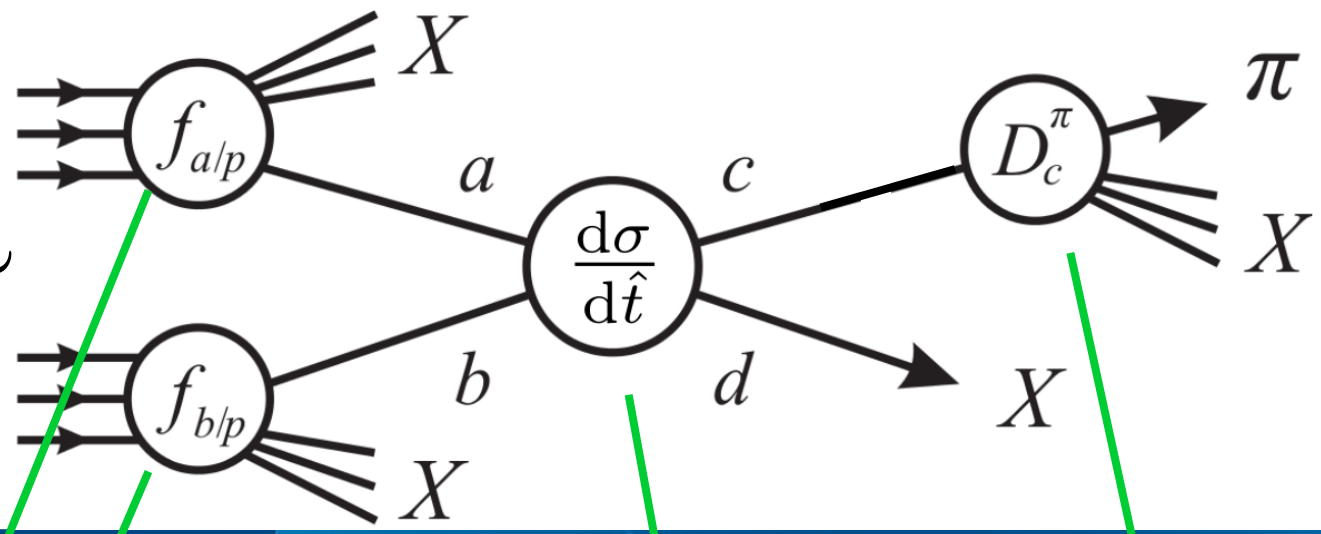


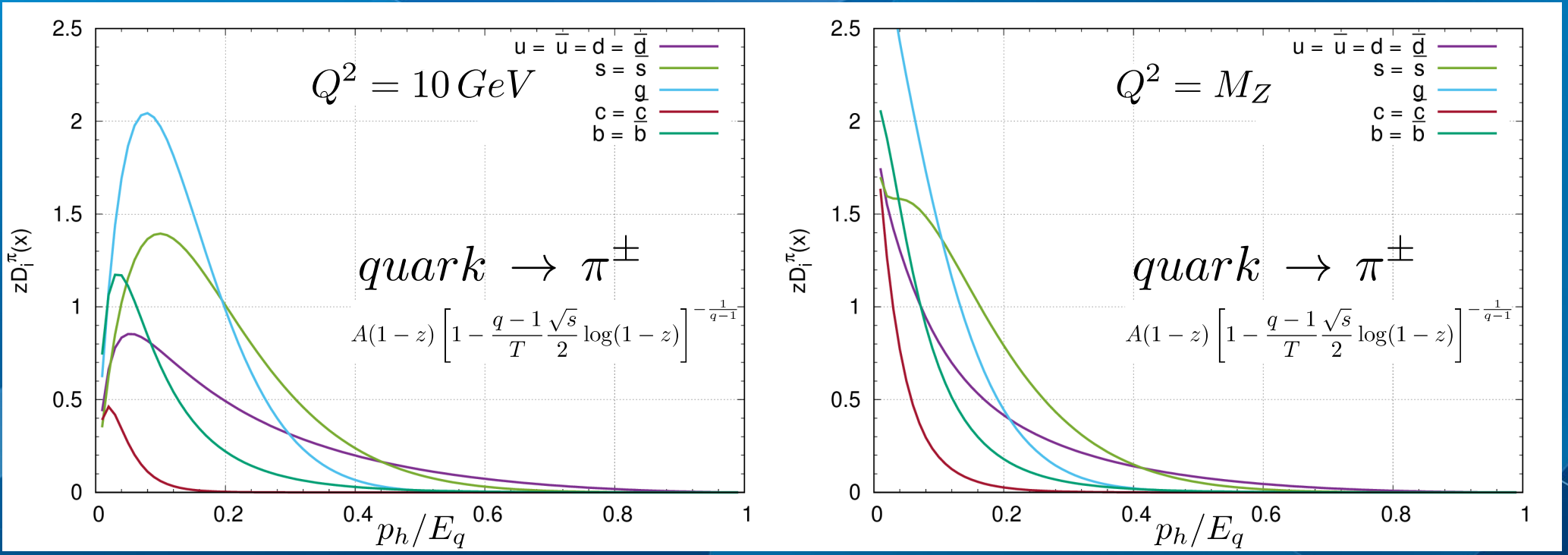
Parton Distribution (PDF)

2-2 QCD Cross section

Fragmentation Function

$$E_h \frac{\mathrm{d}^3\sigma_h^{pp}}{\mathrm{d}^3 p_h} \sim \sum_{\text{processes}}^{\text{all}} f_{a/p}(x_a, Q^2) \otimes f_{b/p}(x_b, Q^2) \otimes \frac{\mathrm{d}\sigma^{ab\to cd}}{\mathrm{d}\hat{t}} \otimes \frac{D_c^h(z_h, \tilde{Q}^2)}{\pi z_h^2}$$

Parametrized Fragmentation Function



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