Jet Mass Dependent Fragmentation

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Motivation — 1.

- **Goal**
  Hadronisation inside fat jets
- **Proposed model**
  Statistical Model
- **Suggestion**
  Parametrise fragmentation functions as

$$D\left[\tilde{x}=\frac{2P^{jet}_\mu p^\mu_h}{M^2_{jet}},\ \tilde{Q}^2=M^2_{jet}\right]$$

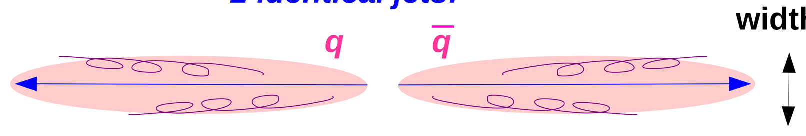
Energy fraction the hadron takes away in the frame co-moving with the jet

Fragmentation scale: jet mass

Problems — 2.

Ideal world: e^+e^- --> 2 jets (factorised picture)

2 identical jets:



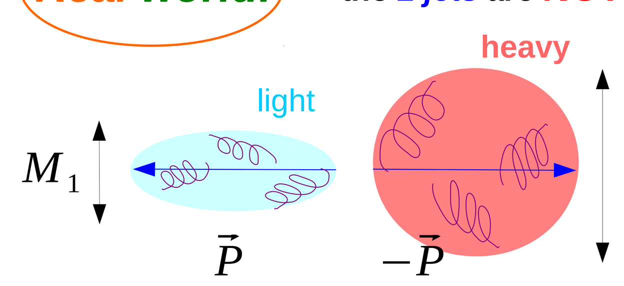
width: $\sim\sqrt{p_q^2}\approx 0 \ll M_{jet}$

$$p^{q,\bar{q}}_\mu=(\sqrt{s}/2,0,0,\pm\sqrt{s}/2)$$

Problem: a real quark ($P_q^2\sim 0$) produces a heavy jet of mass $M_{jet}\sim[0.1-0.5]\sqrt{s}$

- energy fraction the hadron takes away from the energy of the jet: $x=\frac{p_h^0}{\sqrt{s}/2}$
- fragmentation scale: $Q\sim\sqrt{s}$

Real world: the 2 jets are NOT IDENTICAL!



Energy-momentum conservation:

$$P_1^\mu=(P^0,0,0,|\mathbf{P}|)$$
$$P_2^\mu=(\sqrt{s}-P^0,0,0,-|\mathbf{P}|)$$

Problems:

- the energy of a jet $P^0\neq(\sqrt{s}/2)$, so $x=\frac{p_h^0}{\sqrt{s}/2}$ is no longer the energy fraction, the hadron takes away from the energy of the jet.
- The fragmentation scale is no longer $\sqrt{s}$

We propose to use:

- the real energy fraction the hadron takes away from the energy of the jet in the frame co-moving with the jet: $\tilde{x}=\frac{2p^{jet}_h P_\mu^{jet}}{M^2_{jet}}$
- the jet mass as fragmentation scale: $\tilde{Q}\sim M_{jet}$

Statistical jet-fragmentation — 3.

(where x, Q emerge naturally)

The cross-section of the creation of hadrons $h_1,\dots,h_n$ in a jet of n hadrons

$$d\sigma^{h_1,\dots,h_n}=|M|^2\delta^{(4)}\left(\sum_i p^\mu_{h_i}-P^\mu_{jet}\right)d\Omega_{h_1,\dots,h_n}$$

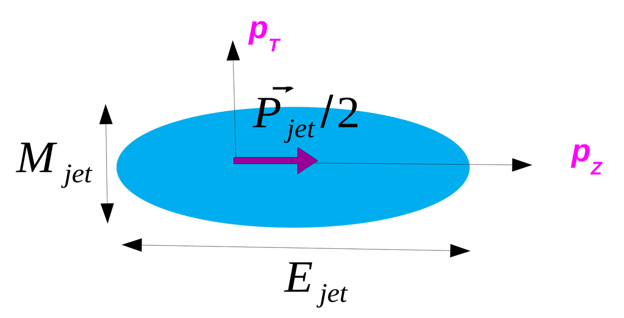
If $|M|\approx$ constans, we arrive at a microcanonical ensemble:

$$d\sigma^{h_1,\dots,h_n}\sim\delta\left(\sum_i p^\mu_{h_i}-P^\mu_{jet}\right)d\Omega_{h_1,\dots,h_n}\propto(P^{jet}_\mu P^\mu_{jet})^{n-2}=M_{jet}^{2n-4}$$

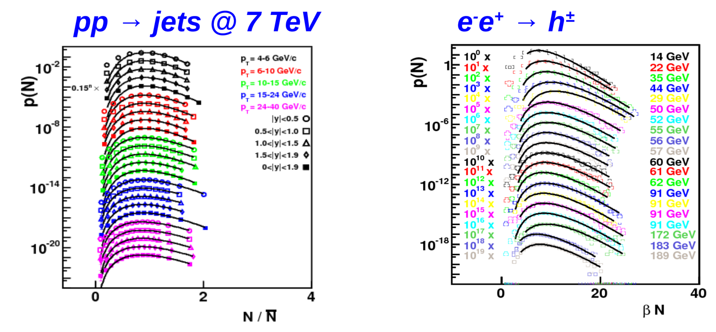
Thus, the haron distribution in a jet of n hadrons becomes

$$p^0\frac{d\sigma}{d^3p}^{n=fix}\propto\frac{\Omega_{n-1}(P^{jet}_\mu-p_\mu)}{\Omega_n(P^{jet}_\mu)}\propto(1-\tilde{x})^{n-3},\quad \tilde{x}=\frac{P^{jet}_\mu p^\mu}{M^2_{jet}/2}$$

Thus, hadrons are inside an ellipsoid:



- The hadron multiplicity in a jet fluctuates according to $P(n)=\binom{n+r-1}{r-1}\tilde{p}^n(1-\tilde{p})^r$



The n-averaged distribution

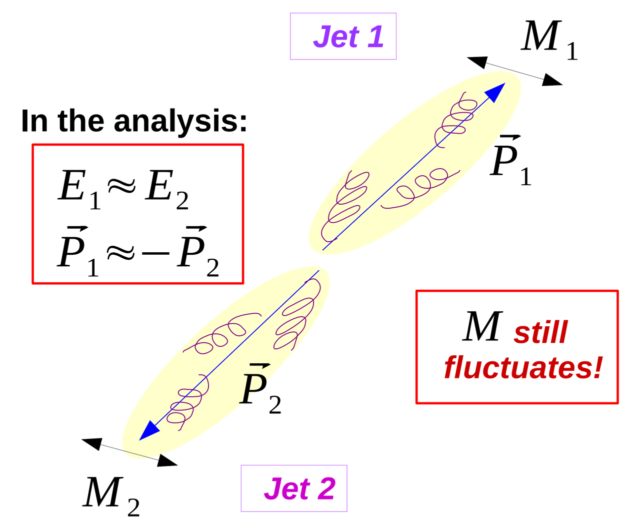
$$p^0\frac{d\sigma}{d^3p}=A\left[1+\frac{q-1}{\tau}\tilde{x}\right]^{-1/(q-1)}$$

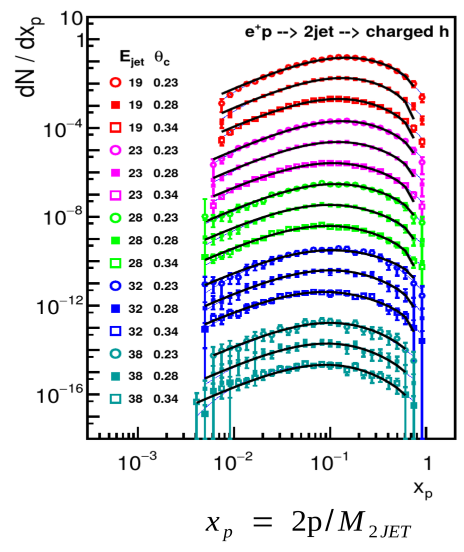
$$\tau=\frac{1-\tilde{p}}{\tilde{p}(r+3)}\qquad q=1+\frac{1}{r+3}$$

Fits — 4.

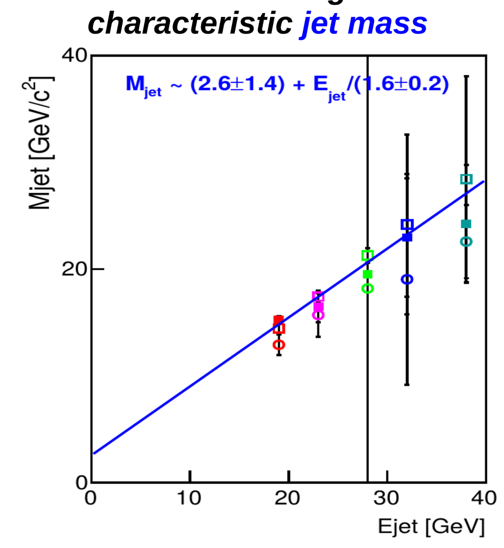
$e^+P\to$ 2 jets $\to h^\pm$ with large rapidity gap

In the analysis:
$E_1\approx E_2$
$\vec{P}_1\approx-\vec{P}_2$



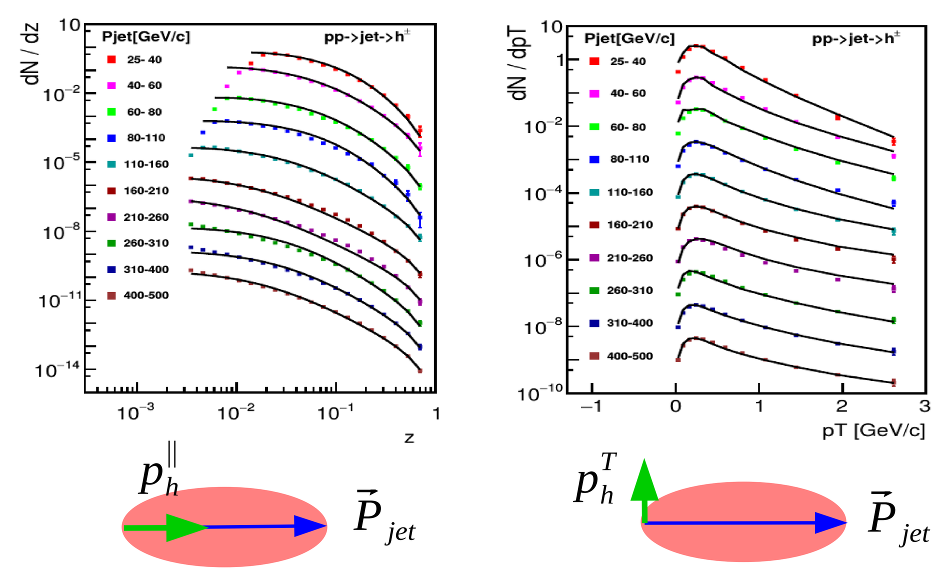


Fitted average characteristic jet mass

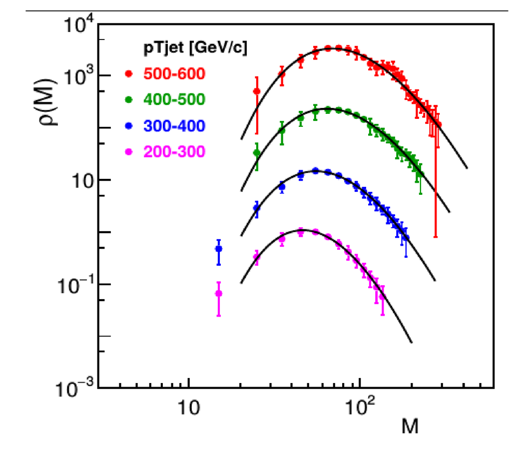


fitted $\langle M_{JET}\rangle = M_0+E_{JET}/E_0$

PP → jet → charged hadrons



Jet mass fluctuations



$$\rho(M)\sim\ln^b(M)\ /\ M^c$$

Scale evolution in the Φ³ theory — 5.

Resummation of branchings with DGLAP

$$\frac{d}{dt}D(x,t)=g^2\int_x^1\frac{dz}{z}P(z)D(x/z,t),\quad t=\ln(Q^2/Q_0^2),\quad g^2=1/(\beta_0 t)$$

with LO splitting function: $P(z)=z(1-z)-\frac{1}{12}\delta(1-z)$

Let the FF preserve its form:

$$D_{apx}(x,t)=\left(1+\frac{q(t)-1}{\tau(t)}x\right)^{-1/(q(t)-1)}\quad\text{with}\quad D(x,0)=\left(1+\frac{q_0-1}{\tau_0}x\right)^{-1/(q_0-1)}$$

From DGLAP (in Mellin space, where $\tilde{f}(\omega)=\int_0^1 x^{\omega-1}f(x)$)

$$\tilde{D}(\omega,t)=\tilde{D}(\omega,0)\exp[b(t)\tilde{P}(\omega)]\quad\text{with}\quad b(t)=\beta_0^{-1}\ln(t/t_0)$$

Let us prescribe the following:

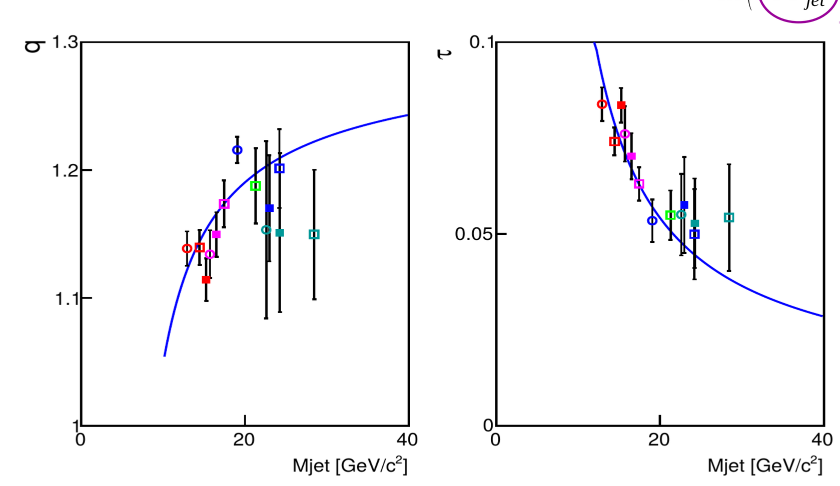
$$\int D_{apx}(x,t)=\int D(x,t)$$
$$\int xD_{apx}(x,t)=\int xD(x,t)=1\ \text{(by definition)}$$
$$\int x^2D_{apx}(x,t)=\int x^2D(x,t)$$

⇒

$$q(t)=\frac{\alpha_1(t/t_0)^{a1}-\alpha_2(t/t_0)^{-a2}}{\alpha_3(t/t_0)^{a1}-\alpha_4(t/t_0)^{-a2}}$$
$$\tau(t)=\frac{\tau_0}{\alpha_4(t/t_0)^{-a2}-\alpha_3(t/t_0)^{a1}}$$
$$a_1=\tilde{P}(1)/\beta_0,\quad a_2=\tilde{P}(3)/\beta_0$$

Scale evolution of the fit parameters

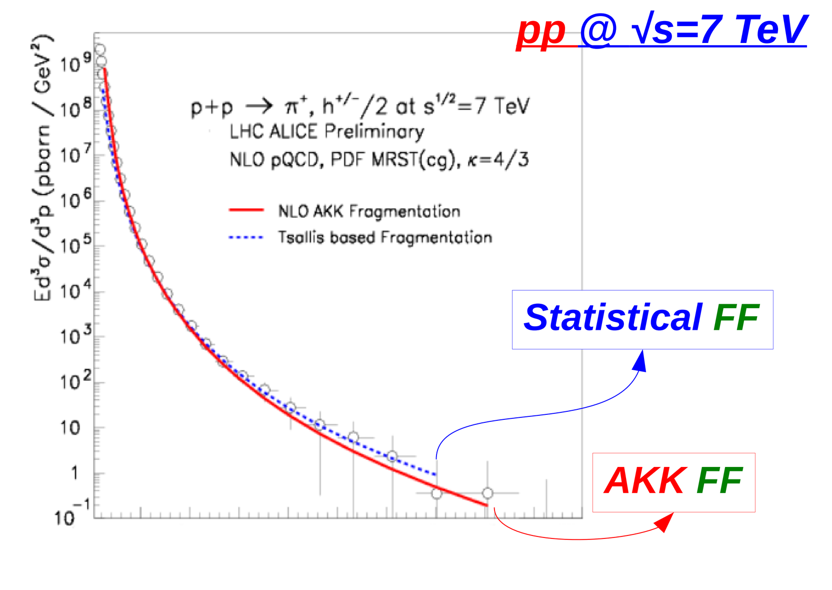
$$t=\ln(M^2_{jet}/\Lambda^2)$$



Application — 6.

π^+ spectrum from NLO pQCD

pp @ √s=7 TeV



Comparison of statistical and AKK FFs in pQCD calculation of charged pion spectra in pp collisions

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