Jet Fragmentation at CDF

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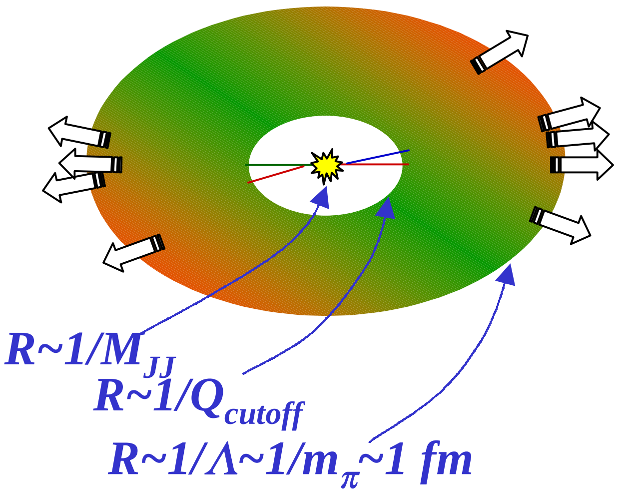
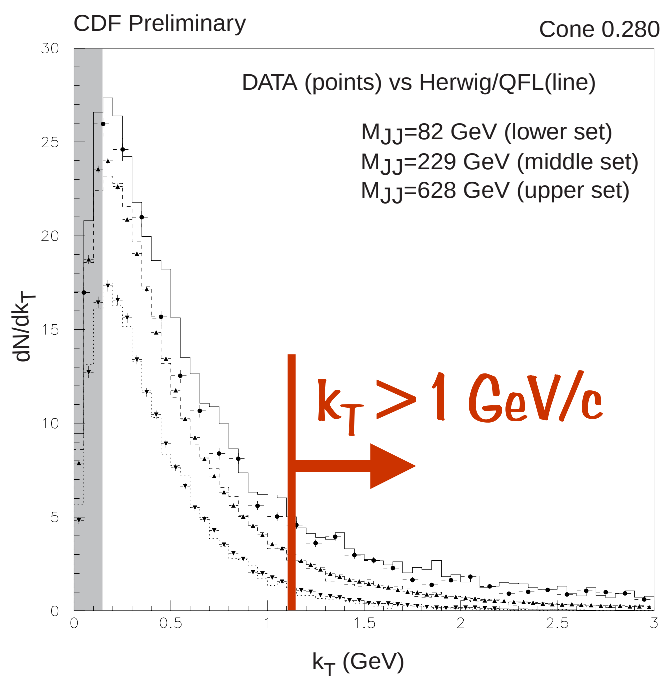
Jet Fragmentation: pQCD + hadronization



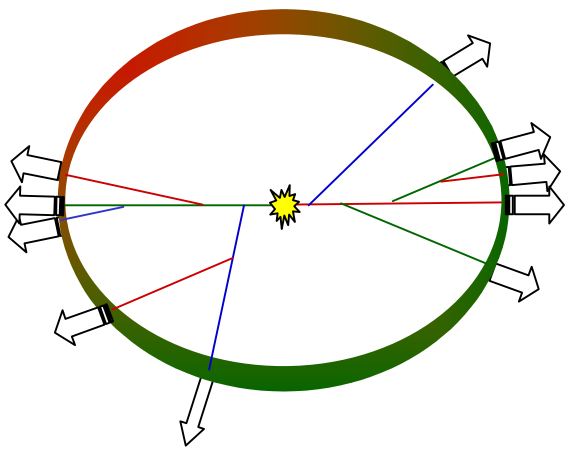


Fragmentation can be thought of as the two-stage process:

- pQCD stage that governs development of a parton shower
- phenomenological hadronization that converts partons into hadrons
- the fuzzy border between the two stages is usually associated with a k_T cut-off scale Q_{cutoff}

pQCD with comfortably high $k_T > 1$ GeV ($R < 0.2$ fm) inevitably implies the dominance of the phenomenological hadronization stage

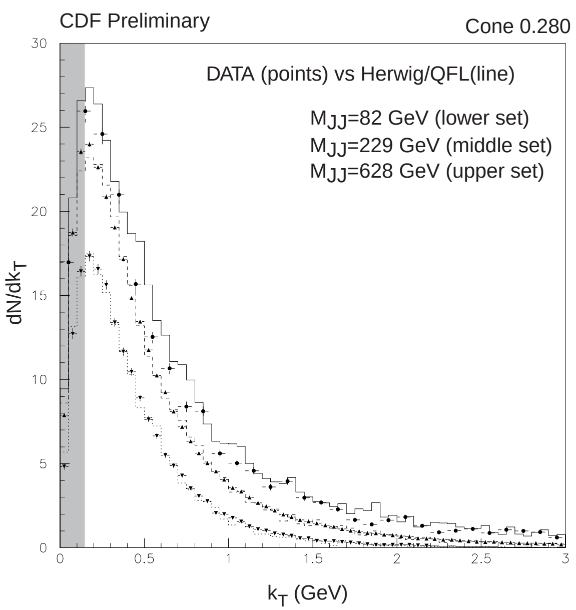
Jet Fragmentation: pQCD dominance scenario



MLLA, Modified Leading Log Approximation, after re-summing pQCD terms in all orders, gives analytical infrared stable expressions where one can set $Q_{cutoff}=\Lambda_{QCD} = Q_{eff}$ (~200 MeV?);

it explicitly accounts for soft partons $x_p=p/E_{jet}<<1$.

Mueller (1983); Dokshitzer, Troyan (1984); Malaza, Webber (1984)



LPHD, Local Parton Hadron Duality, hypothesis assumes that hadronization occurs locally at the very last moment and, therefore, hadrons "remember" parton distributions: e.g., $N_{hadrons}=K_{LPHD} \bullet N_{partons}$

- if all hadrons are accounted for, $K_{LPHD(all\ hadrons)} \sim 1$
- if only charged hadrons are observed, $K_{LPHD(\pm)} \sim 2/3$ (adding I=1/2 particles, e.g., K^+K^o, and particles with predominantly neutral decay modes, e.g., η, may somewhat reduce this number)

Azimov, Dokshitzer, Khoze, Troyan (1985)

MLLA: Modified Leading Log Approximation

Gluon Jets:

- Multiplicity: $N_g(Y)$, $Y=\ln(E_{jet}\sin\theta/Q_{eff})$
- Momentum distribution: $dN_g(\xi,Y)/d\xi$, $\xi=\log(1/x_p)$, $x_p=p/E_{jet}$

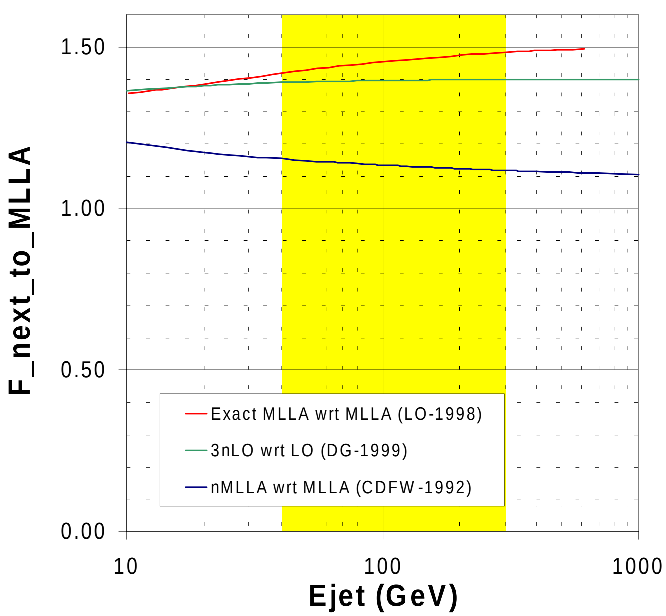
Quark Jets:

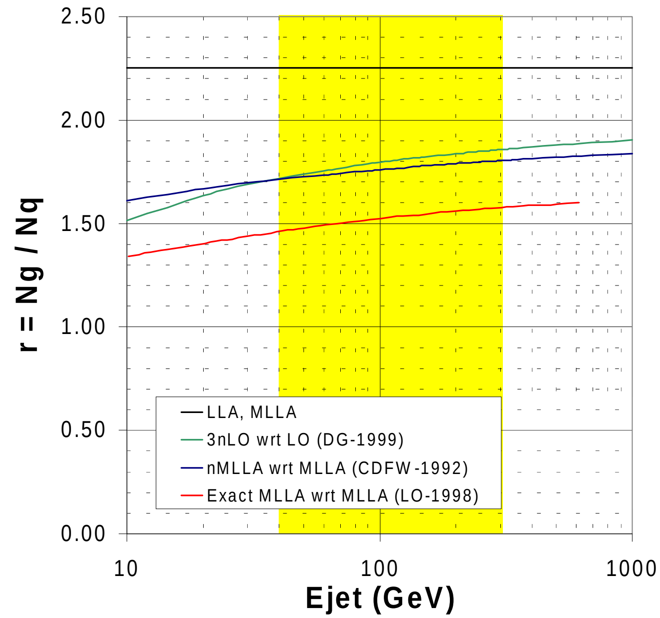
- quark jet is different by a normalization factor 1/r, $r = C_A/C_F=9/4$
- Multiplicity: $N_q(Y)=(1/r)\cdot N_g(Y)$
- Momentum distribution: $dN_q/d\xi=(1/r)\cdot dN_g/d\xi$

Next-to-MLLA corrections

Next-to-MLLA corrections to multiplicity of parton in gluon and quark jets:

- $N_{next\text{-}to\text{-}MLLA} = F_{next\text{-}to\text{-}MLLA} \times N_{MLLA}$ (gluon jet)
- $r \neq 9/4$





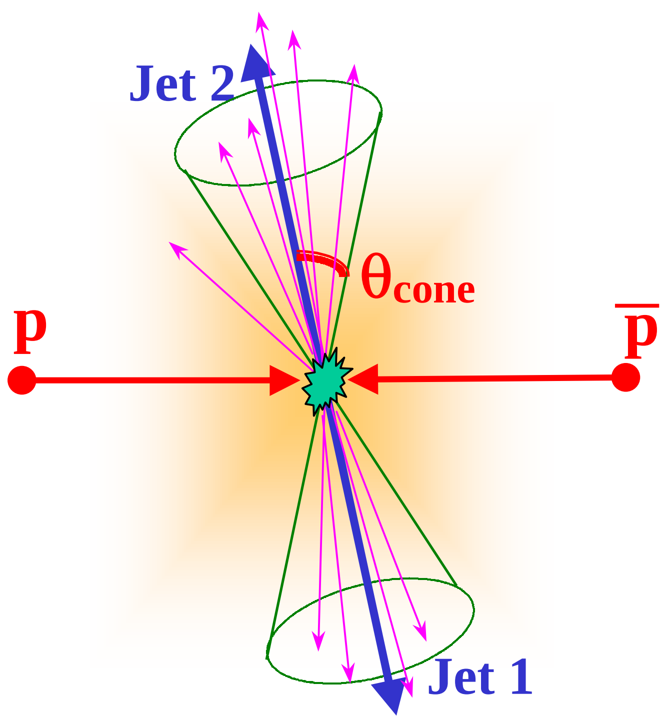
CDFW-1992 Catani, Dokshitzer, Fiorani, Webber, Nucl.Phys. B377(1992)445

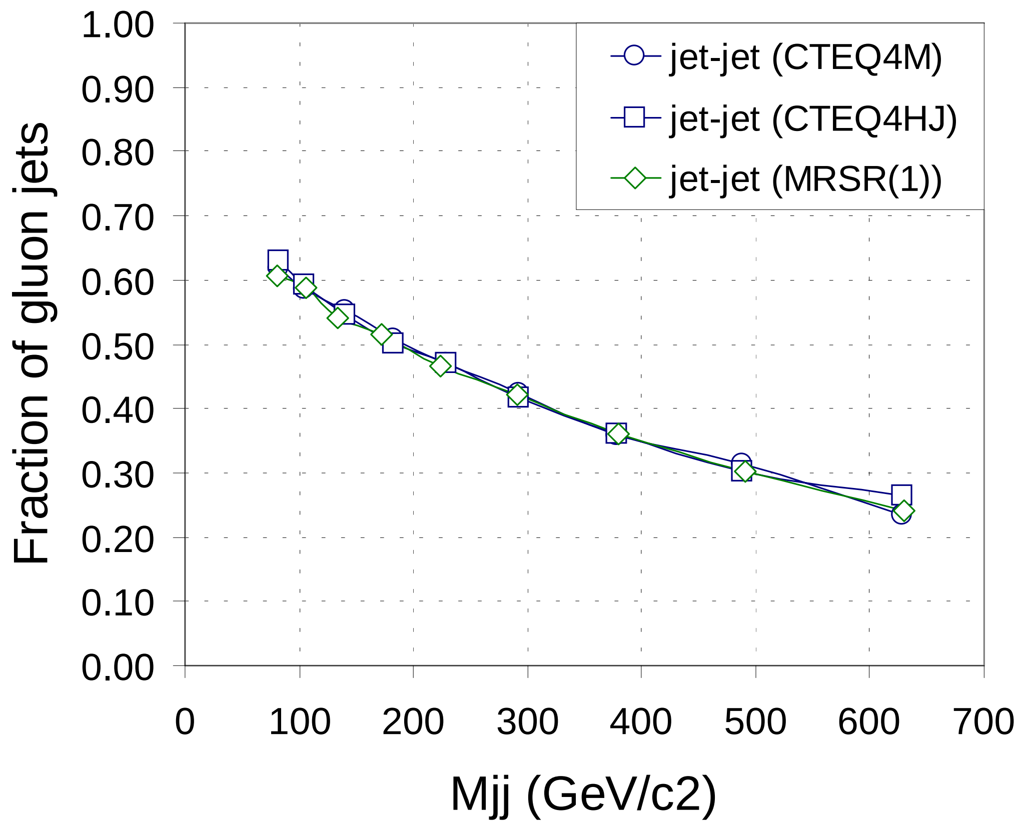
LO-1998 Lupia, Ochs, Phys.Lett. B418(1998)214 and Nucl.Phys.B (Proc. Suppl.) 64(1998)74

DG-1999 Dremin, Gary, hep-ph/9905477v2, 3 Sep 1999

Analysis at CDF

- dijet events with $80 < M_{JJ} < 630\ GeV/c^2$
- both jets are in central region, well balanced
- opening angle $0.17 < \theta_{cone} < 0.47$

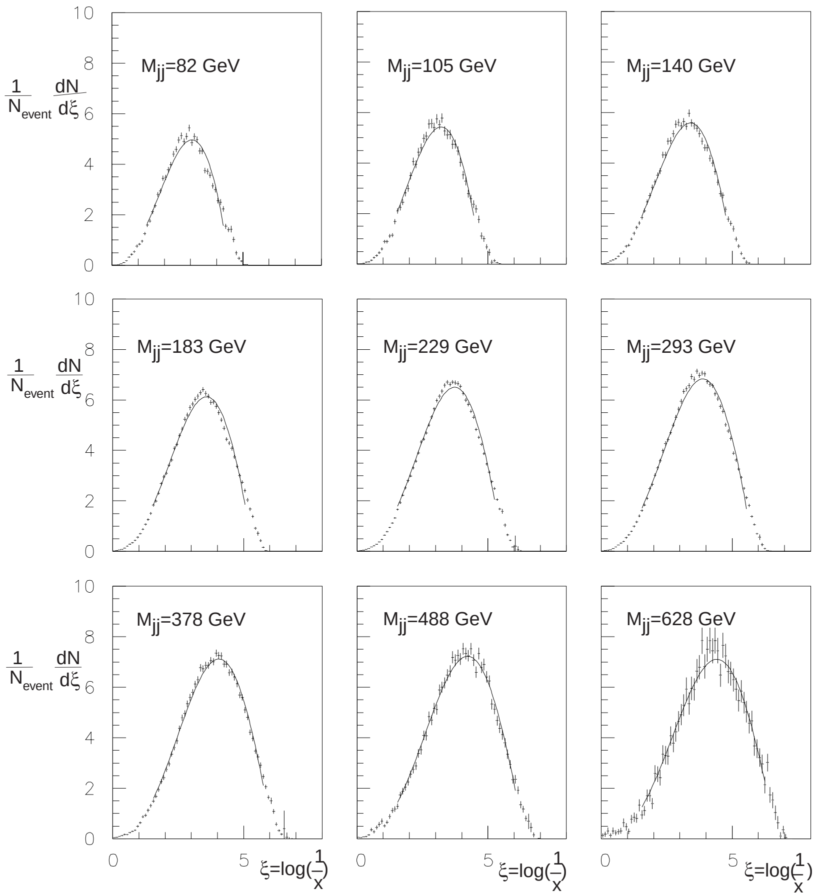




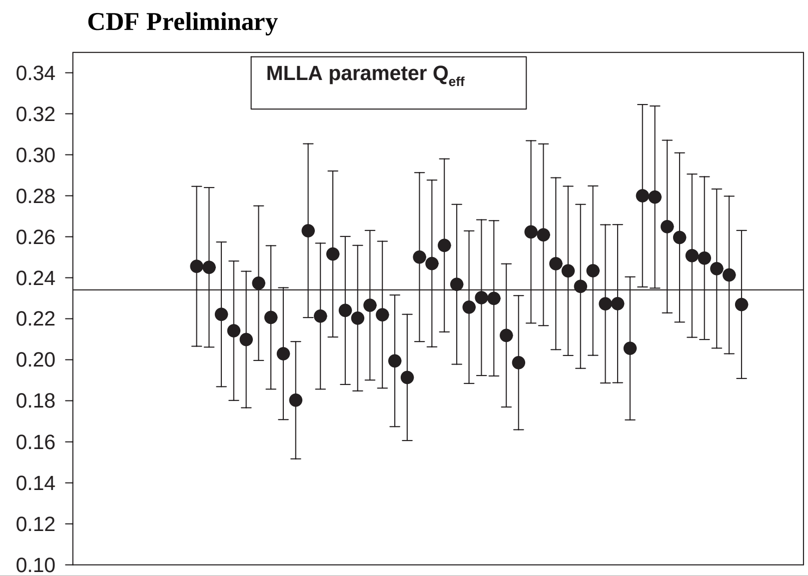
Momentum distribution of tracks

M_{jj}-scan (θ_{cone}=0.47), MLLA fit

CDF preliminary



Q_{eff} for all 9 M_{jj}'s and 5 opening angles θ_{cone}'s

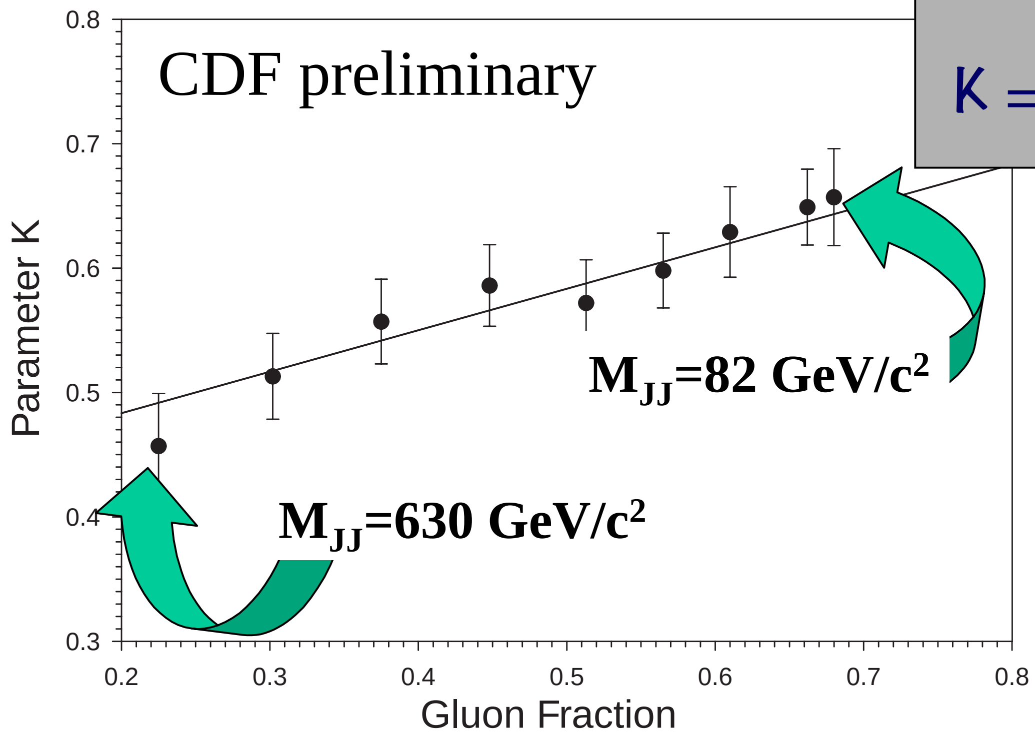


MLLA fit $dN(\xi,Y)/d\xi$

$Q_{eff} \approx$ constant=240±40 MeV

Momentum distribution of tracks

$$N_{hadrons} = K_{LPHD} \times N_{partons} = K_{LPHD} \times (\varepsilon_g N^{g\text{-}jet} + \varepsilon_q N^{q\text{-}jet}) =$$
$$= K_{LPHD} \times (\varepsilon_g + (1-\varepsilon_g)/r) \times N^{g\text{-}jet} =$$
$$= K_{LPHD} \times (\varepsilon_g + (1-\varepsilon_g)/r) \times F_{next\text{-}to\text{-}MLLA} \times N^{g\text{-}jet} = K \times N^{g\text{-}jet}$$



$$N_{hadrons} = K \times N^{g\text{-}jet}$$
$$K = K_{LPHD} \times (1/r + (1-1/r)\varepsilon_g) \times F_{next\text{-}to\text{-}MLLA}$$

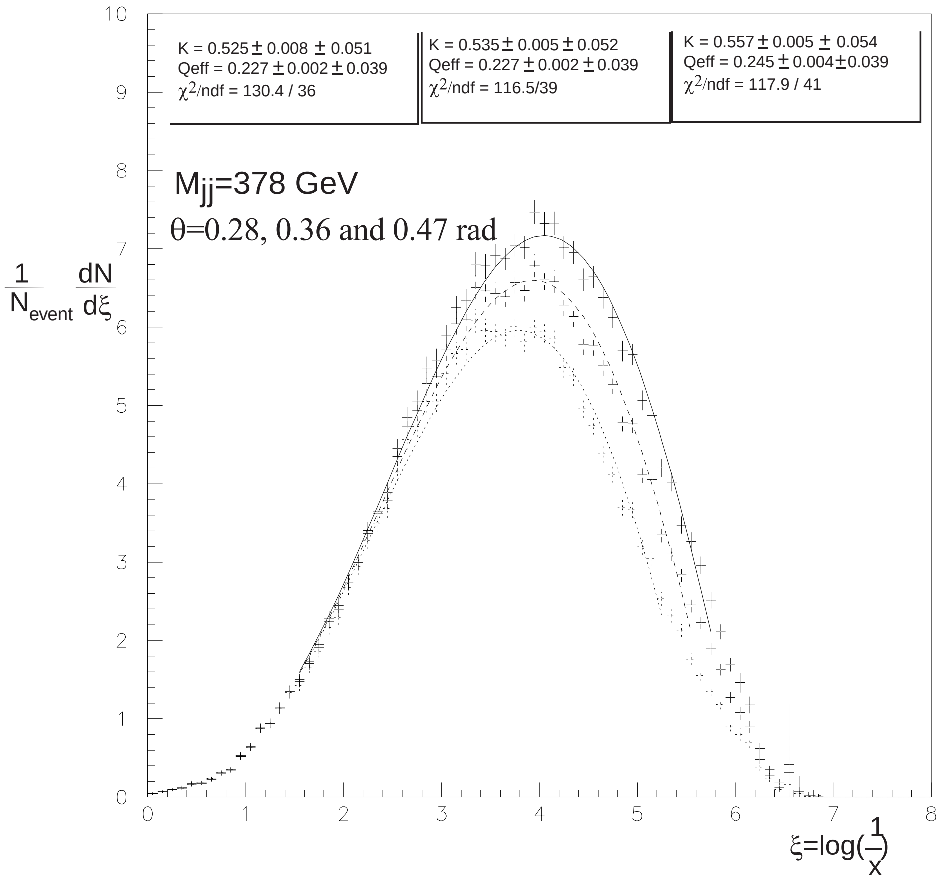
K vs. gluon jet fraction fit:

- r=1.8±0.4 (indirect)
- K_{LPHD}=0.58±0.05 ±0.08

the measurement is "indirect":
the result relies on MLLA-predicted $dN_g(\xi, E_{Jet})/d\xi$

Momentum distribution of tracks

CDF preliminary



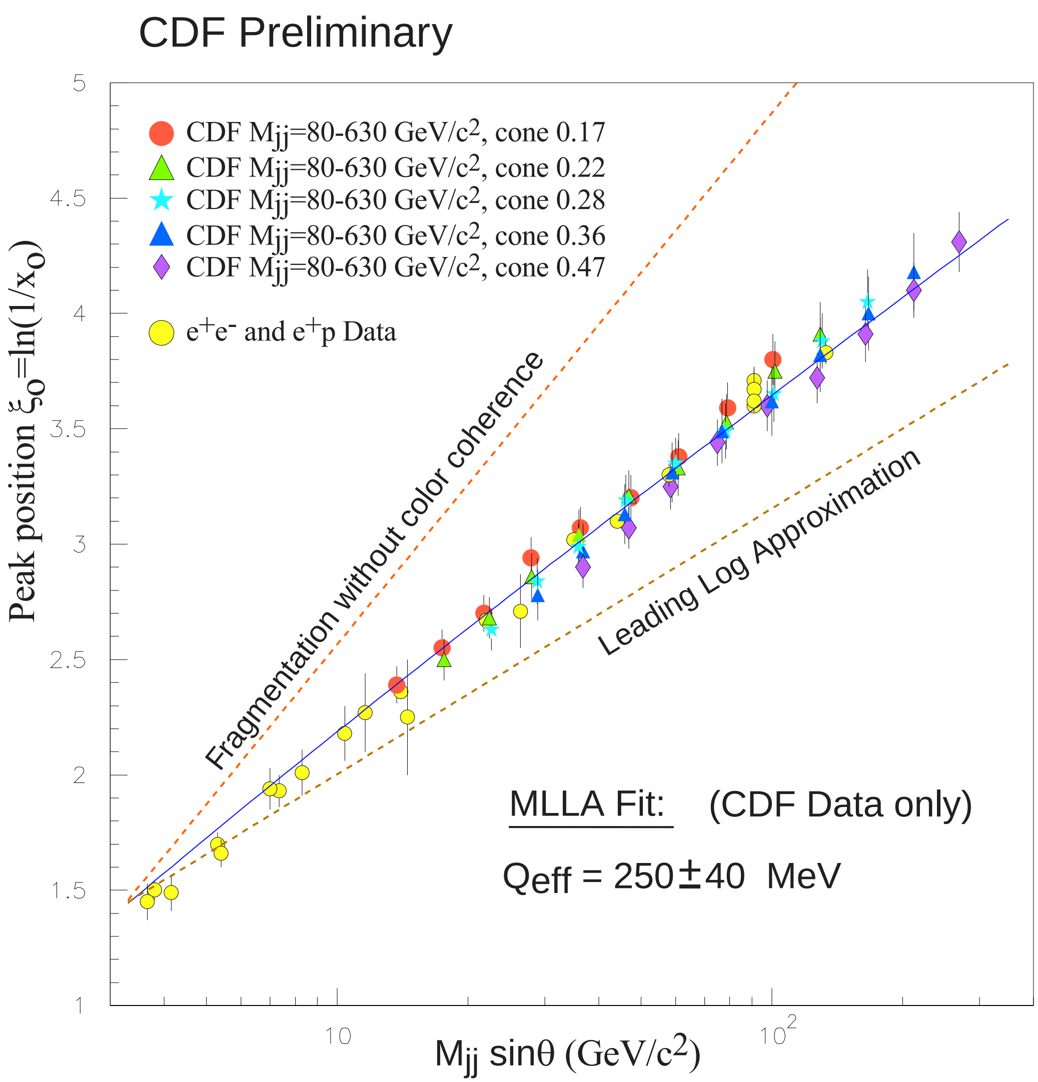
For fixed M_{jj},

K should be angle independent

MLLA-fitted values of K:

- θ_{cone}=0.47 K=0.56 ±0.05
- θ_{cone}=0.36 K=0.54± 0.05
- θ_{cone}=0.28 K=0.53 ±0.05

Peak of momentum distribution of tracks



In MLLA peak ξ_0 vs. M_{JJ}:

$\xi_0 = 1/2\, Y + (cY)^{1/2} - c,$

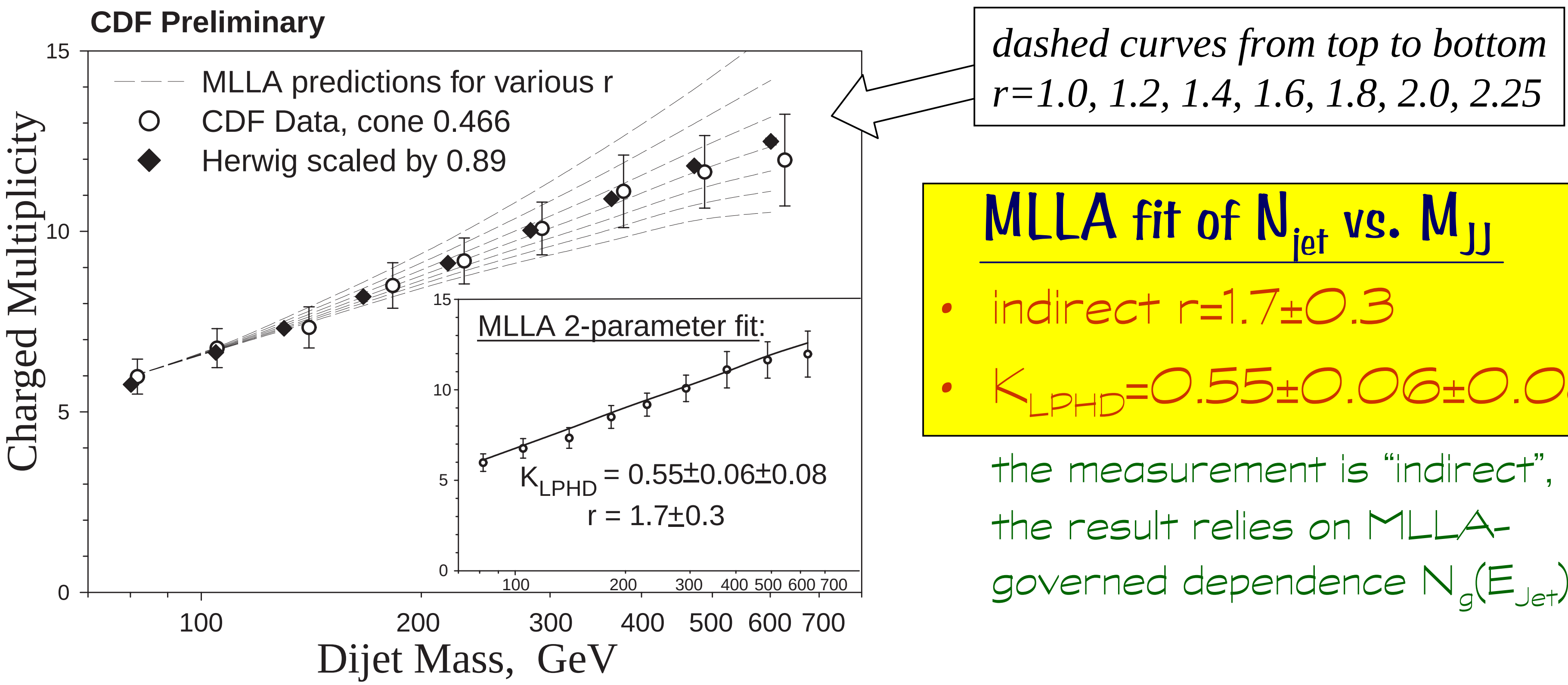
$Y = \ln(E_{jet} \sin\theta / Q_{eff})$

$c = 0.29$ for $n_f = 3$

Peak ξ_0 vs. M_{JJ} fit:

$Q_{eff} = 250 \pm 40$ MeV

Multiplicity in dijet events



MLLA fit of N_{jet} vs. M_{JJ}

- indirect r=1.7±0.3
- K_{LPHD}=0.55±0.06±0.08

the measurement is "indirect", i.e. the result relies on MLLA-governed dependence $N_g(E_{Jet})$

Intermediate Summary

Analysis in the framework of MLLA

- Q_{eff} = 240 ± 40 MeV
- K_{LPHD} = 0.56 ± 0.10 (assuming next-to-MLLA correction 1.30 ± 0.20)
- r = 1.7 ± 0.3
  - r, though being treated as a free parameter, is measured in MLLA-context, i.e. strictly speaking it is an indirect measurement
  - r is self-consistent with the next-to-MLLA predictions

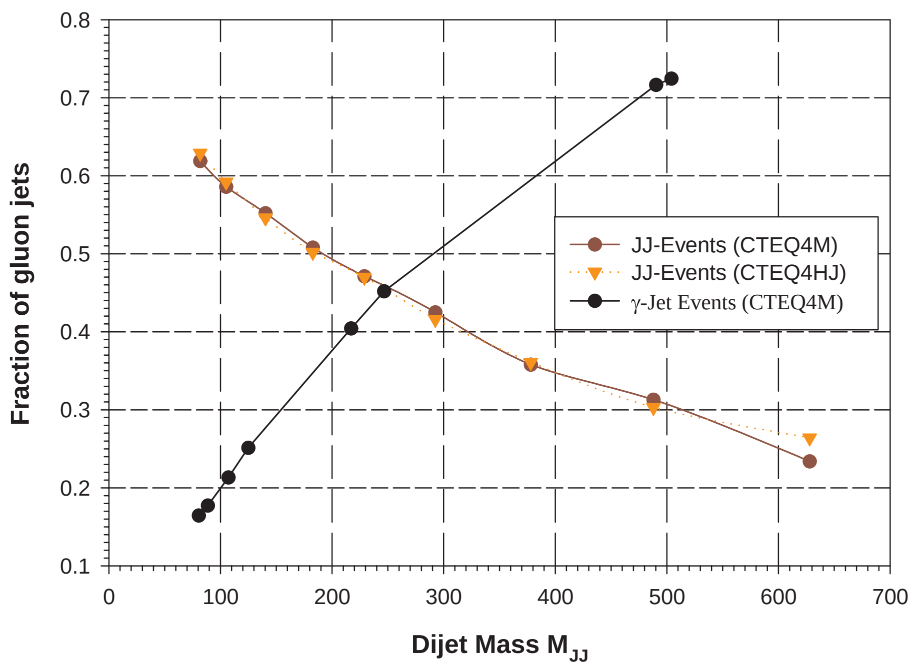
Does it all make sense?

r, K_{LPHD}, Q_{eff}?

Model-independent measurement of r

Jet-jet sample: $N_{hadrons} = K_{LPHD} \times (\varepsilon_g + (1-\varepsilon_g)/r) \times F_{next-to-MLLA} \times N^{g-jet}$

γ-jet sample: $N'_{hadrons} = K_{LPHD} \times (\varepsilon'_g + (1-\varepsilon'_g)/r) \times F_{next-to-MLLA} \times N^{g-jet}$

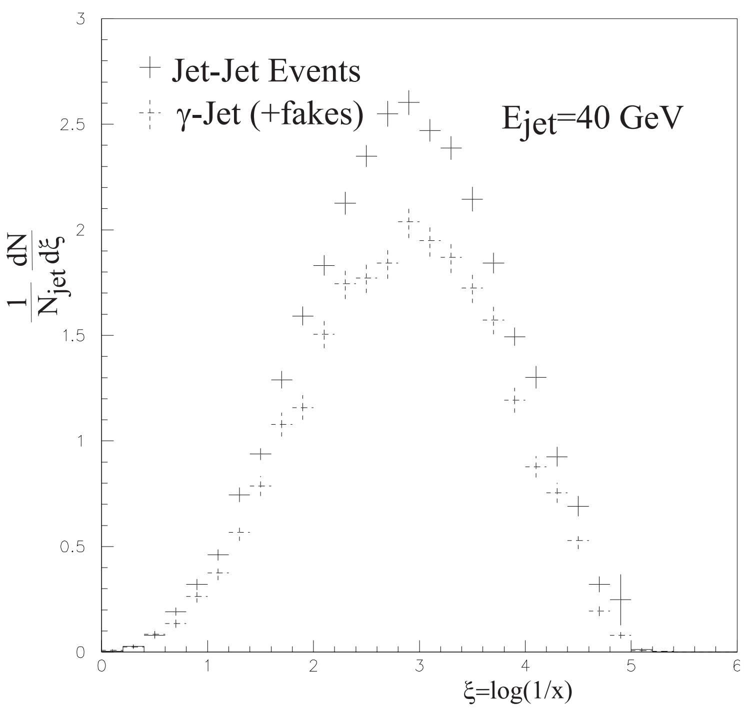


Model-independent measurement of r

Jet-jet sample: $N_{hadrons} = K_{LPHD} \times (\varepsilon_g + (1-\varepsilon_g)/r) \times F_{next\text{-}to\text{-}MLLA} \times N^{g\text{-}jet}$

γ-jet sample: $N'_{hadrons} = K_{LPHD} \times (\varepsilon'_g + (1-\varepsilon'_g)/r) \times F_{next\text{-}to\text{-}MLLA} \times N^{g\text{-}jet}$

CDF preliminary

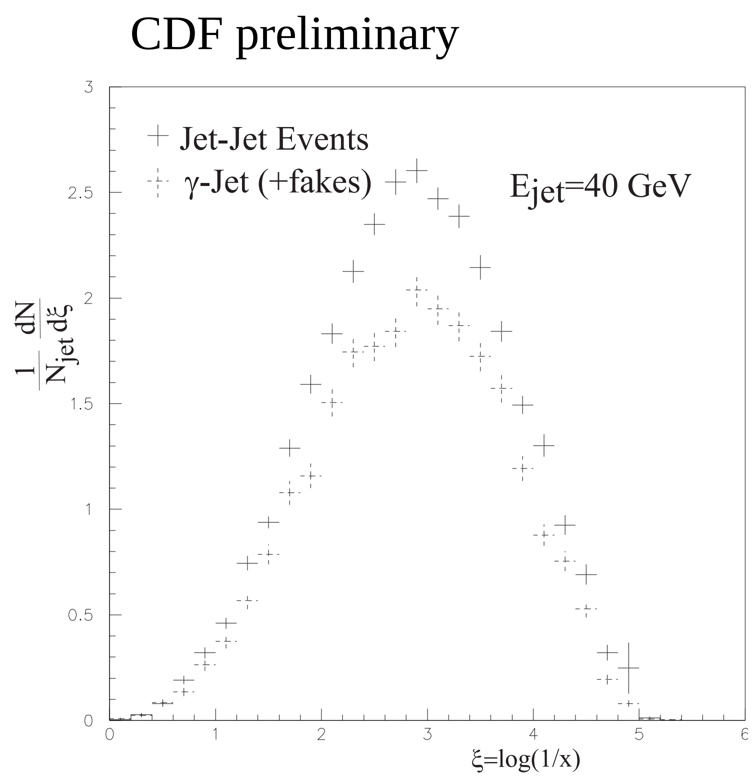


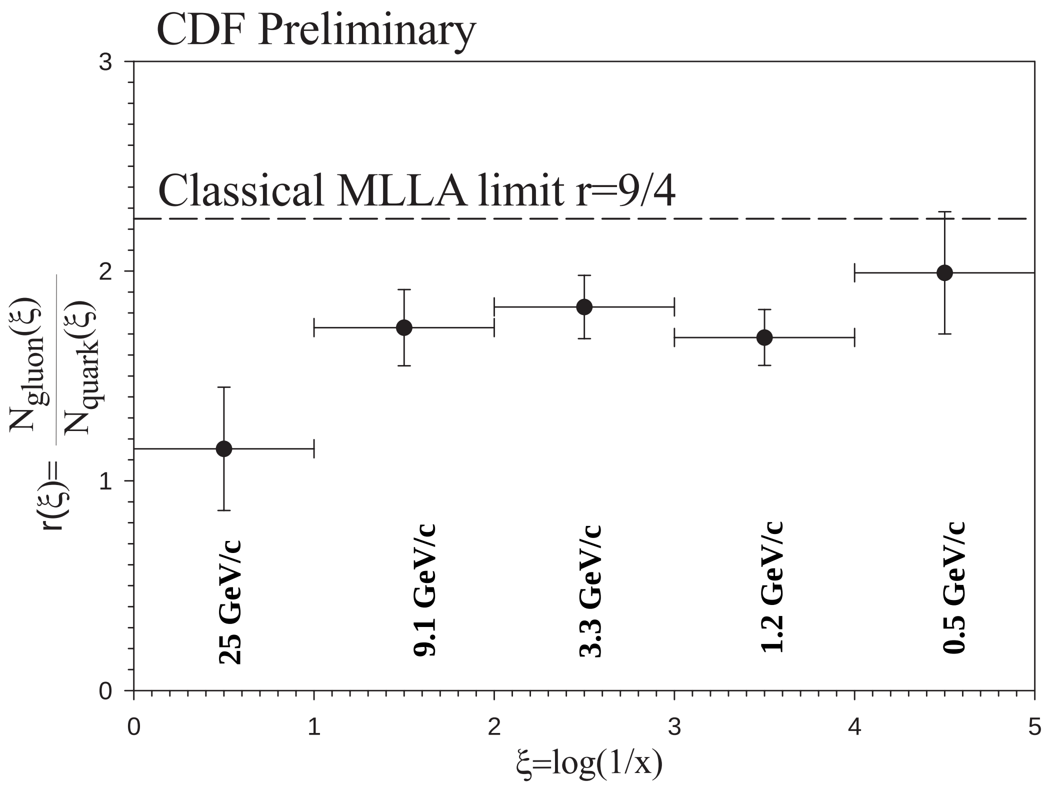
- Dijets with M_{jj}=80 GeV/c^2:
  N = 5.77±0.03 tracks/jet
- Gamma-jets with $M_{\gamma j}$=80 GeV/c^2:
  N'_{jet} = 4.83 ±0.05 tracks/jet
  (gamma-jet sample has ~70% of true γ-jets and ~30% of fakes--dijets)

direct measurement of r

r = 1.74 ± 0.11 ± 0.07

Does r depend on particle momenta?





r may depend on particle momentum, being larger for soft particles, but errors are too large for conclusive judgements

Does $K_{LPHD(+/-)}$ make sense?

LPHD:

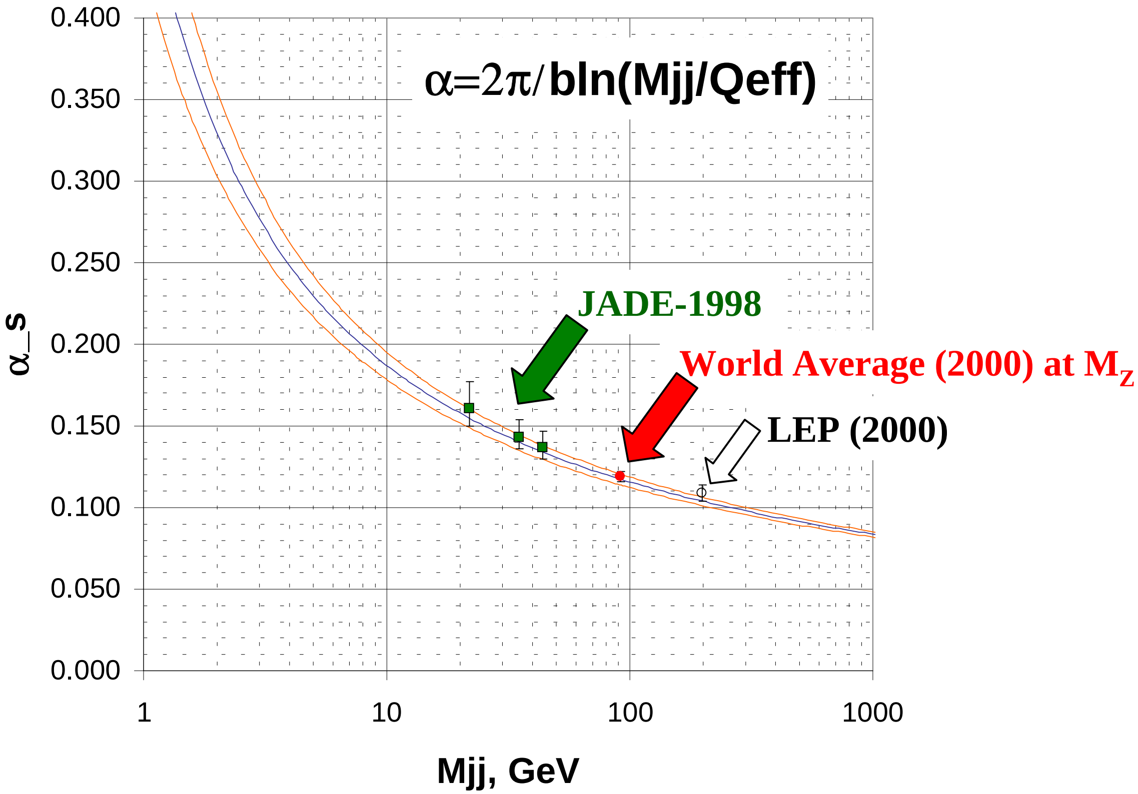
- We measured $K_{LPHD\ (+/-)} = N_{hadrons(+/-)} / N_{partons} = 0.56 \pm 0.10$
- Energy fraction carried by charged particles:

  TASSO: 0.59±0.01 for Q=12-42 GeV -- Z.Phys.C22(1984)307

Does Q_{eff} make sense?

MLLA Q_{eff}:

- MLLA $\alpha_s = 2\pi/(b \cdot \ln(k_T/\Lambda_{QCD}))$
- $Q_{cutoff} = \Lambda_{QCD} = Q_{eff}$
- Measured Q_{eff} = 240±40 MeV



Jet Fragmentation at CDF: conclusions

Momentum distribution of tracks at $80 < M_{jj} < 630$ GeV/c^2:

Qeff = 240 ± 40 MeV

r = 1.8 ± 0.4 (in the framework of MLLA)

K_{LPHD} = 0.58 ± 0.10 (assuming next-to-MLLA corrections)

Peak position vs M_{jj}:

Qeff = 250 ± 40 MeV

Multiplicity in dijet events vs. M_{jj} ($80 < M_{jj} < 630$ GeV/c^2):

r = 1.7 ± 0.3 (in the framework of MLLA)

K_{LPHD} = 0.55 ± 0.10 (assuming next-to-MLLA corrections)

Multiplicity in dijet events vs. gamma-jet events at $M_{jj} = 82$ GeV/c^2:

r = 1.74 ± 0.11 ± 0.07 (model independent)