# Two-Particle Momentum Correlation in Jets at Tevatron

**Sergo Jindariani**

**for CDF collaboration**

**PANIC 2005**
**October 24 - 28, 2005, Santa Fe, New Mexico**

# Introduction & Motivation

Relative roles of perturbative and non-perturbative QCD;

- particle multiplicity $N_{partons}$ vs. $N_{hadrons}$ ok
- momentum spectra Partons vs. Hadrons ok

} Experimentally checked ( LEP, CDF )

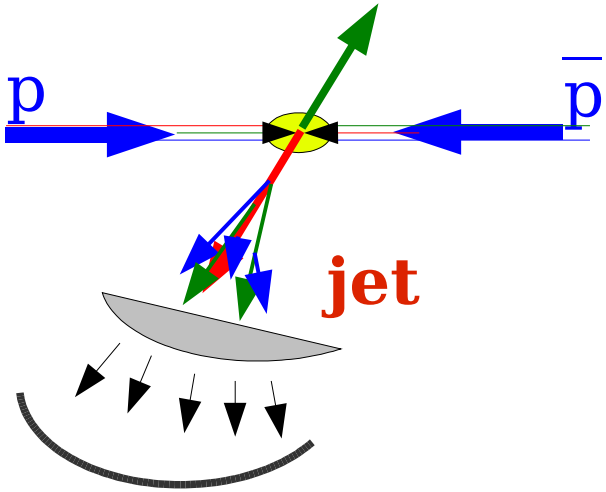
→ Role of perturbative QCD is dominant

- parton-parton correlation $R(\xi_1,\xi_2)$ vs. hadron-hadron $R(\xi_1,\xi_2)$ ?

$$x = \frac{P_{hadron}}{E_{jet}} \qquad \xi = \ln\frac{1}{x}$$

$\xi$=0 means $P_{hadron}=E_{jet}$

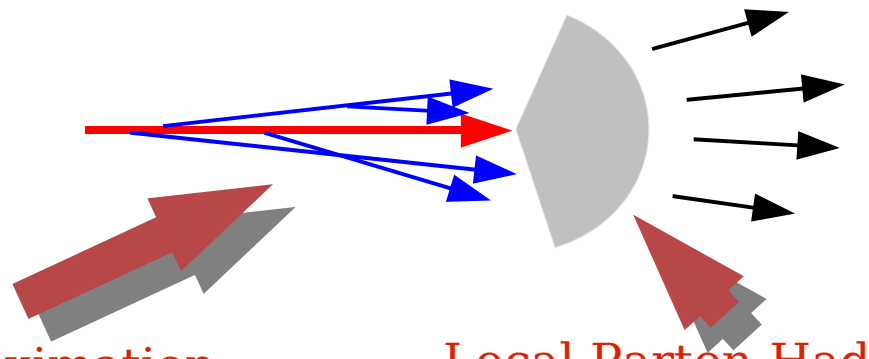
$\xi$=4 means $P_{hadron}$~few GeV



# Jet Fragmentation

## Two stages:

a) Parton shower
b) Hadronization



### Next to Leading Log Approximation:

Sets transverse momentum cutoff parameter ( $k_T > Q_{cut}$)

Allows to calculate soft and collinear gluon emission diagrams with next to leading log precision

Diagrams resumed to all orders

### Local Parton-Hadron Duality:

Hypothesis!

Allows to link theoretical parton level calculations to experimental hadron level measurement

**At the end of parton shower hadron distribution differs from parton distribution by a constant factor - $K_{LPHD}$~1**

CDF measured $K_{LPHD}$ for charged hadrons (~60% of all hadrons)

$K_{meas(\pm)} = 0.58 \pm 0.05 \pm 0.08$

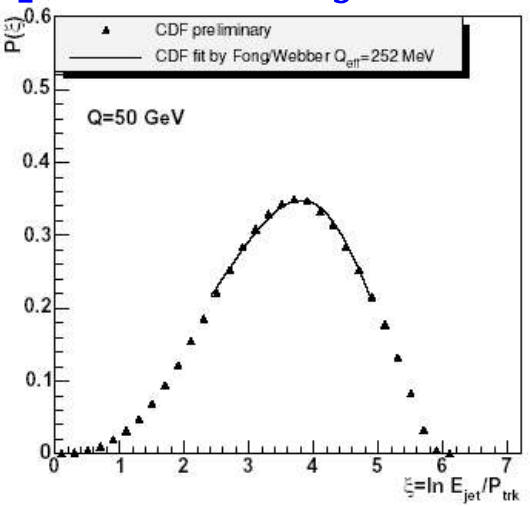
# Correlation

$P(\xi)=dN/d\xi \quad \int P(\xi)d\xi=1$ $\qquad x=\frac{P_{hadron}}{E_{jet}} \qquad \xi=\ln\frac{1}{x}$

inclusive momentum distribution of particles in jets

- skewed "Gaussian" shape

- peak position depends on energy scale
  $Q=E_{jet}\cdot\theta_c$




$P(\xi_1,\xi_2)=d^2N/(d\xi_1\cdot d\xi_2) \quad \int\int P(\xi_1,\xi_2)d\xi_1 d\xi_2=1$

two-particle momentum distribution

$$C(\xi_1,\xi_2)=\frac{P(\xi_1,\xi_2)}{P(\xi_1)P(\xi_2)}$$

two-particle momentum correlation in jets

# Theory

C.Fong, B.Webber (1990)

$$R(\xi_1,\xi_2)=\frac{D(\xi_1,\xi_2)}{D(\xi_1)D(\xi_2)}=\frac{\langle n_{part}(n_{part}-1)\rangle P(\xi_1,\xi_2)}{\langle n_{part}\rangle^2 P(\xi_1)P(\xi_2)}$$

} mixes together:
- momentum correlations
- multiplicity fluctuations

$$C(\xi_1,\xi_2)=\frac{\langle n_{part}\rangle^2}{\langle n_{part}(n_{part}-1)\rangle}R(\xi_1,\xi_2)=\frac{1}{F}R(\xi_1,\xi_2)$$

where $F=\frac{\langle n_{part}(n_{part}-1)\rangle}{\langle n_{part}\rangle^2}$

- by using $C(\xi_1,\xi_2)$ and F taken from theory we eliminate multiplicity fluctuations dependence;

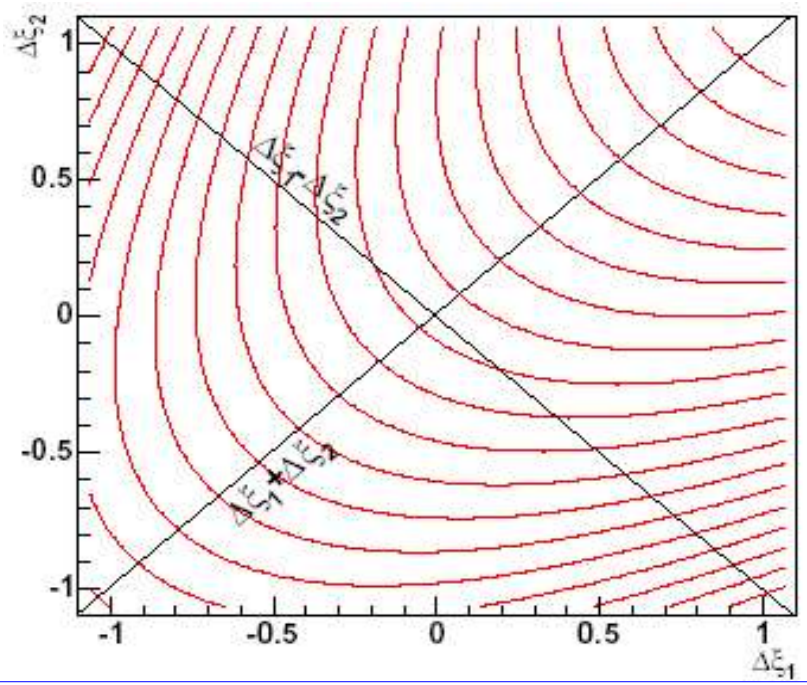
Around the peak of inclusive momentum distribution , $C(\xi_1,\xi_2)$ is predicted by NLLA:

$$C(\xi_1,\xi_2)=C_0+C_1(\Delta\xi_1+\Delta\xi_2)+C_2(\Delta\xi_1-\Delta\xi_2)^2$$

where $\Delta\xi=\xi-\xi_0$

$\xi_0$- position of the peak of inclusive momentum distribution

- $C_0$, $C_1$ and $C_2$ depend on $\ln(Q/Q_{eff})$



# Mixing q/g jets

- In theoretical paper calculations are done for quark and gluon jets separately;

- At Tevatron we can make measurement only for the mixture;

Need to mix quark and gluon jets correlation in theory:

$$C(\xi_1,\xi_2)=A(F_g,f_g,r)C_g(\xi_1,\xi_2)+B(F_q,f_q,r)C_q(\xi_1,\xi_2)$$

$f_g$-fraction of gluon jets;

$F_g$ and $F_q$ – binomial moments of quark and gluon jets (from theory)

$r=\frac{(D_g(\xi))}{(D_q(\xi))}=1.8$ ( CDF measured around $\xi_0$ )

# Measurement

- Cone jet algorithm with R=0.7 used, energy corrected to parton level;

- Central di-jet events with $M_{jj}$ ranging 66-563 GeV;

- Analysis done in the di-jet center-of-mass frame;

- Correlation measured for particles within opening angle 0.5 rad. from the axis of jet;

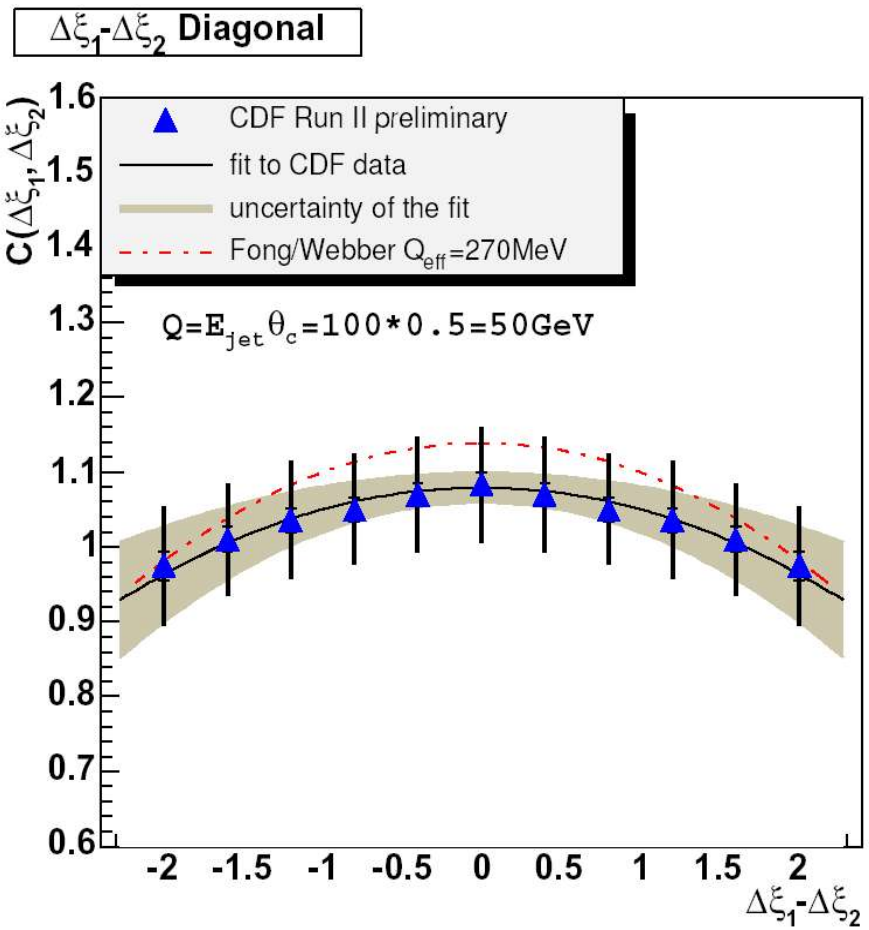
- Contribution of the underlying event subtracted;

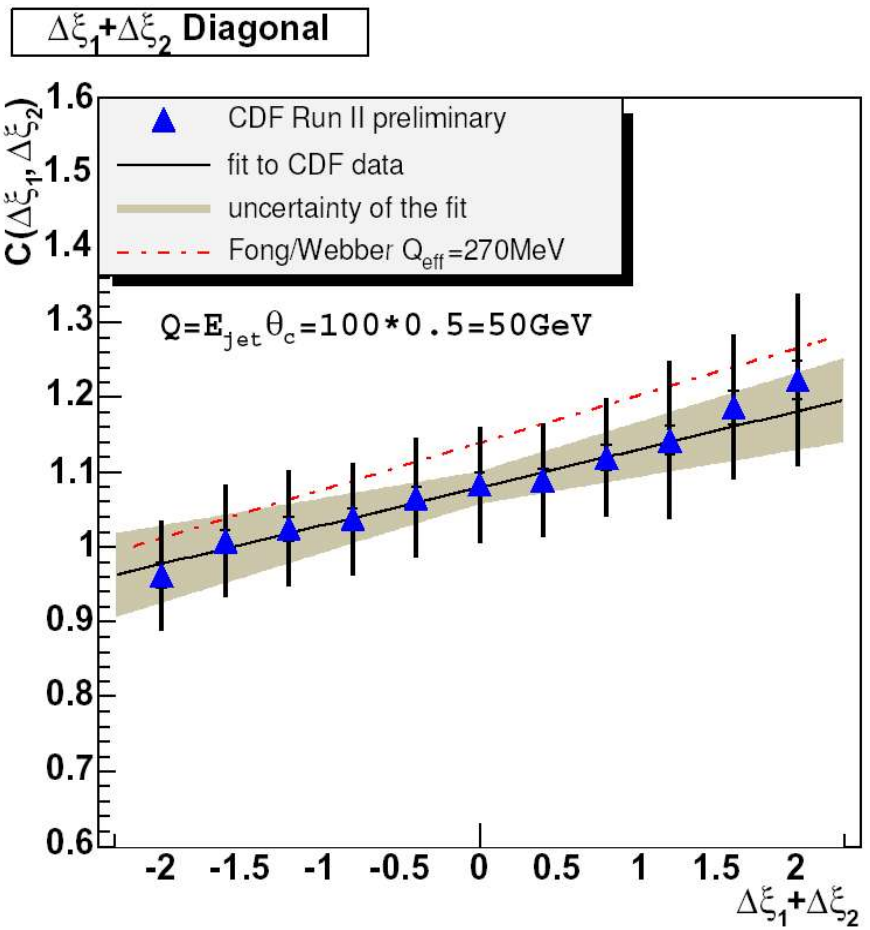
- Energy scale $Q=E_{jet}\theta_c$ (~19-119 GeV)

# CDF results

- Qualitatively data follows NLLA trends;

- NLLA curves for $Q_{eff}$=270MeV obtained from the fit of inclusive momentum distribution slightly overestimate correlation;

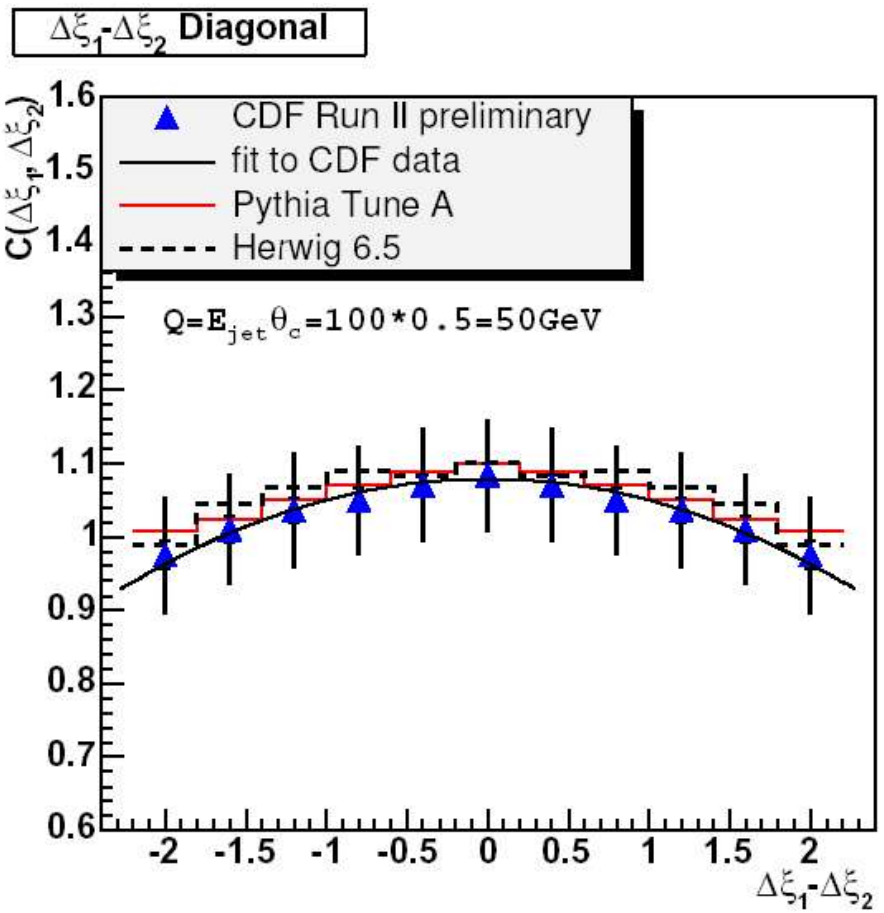


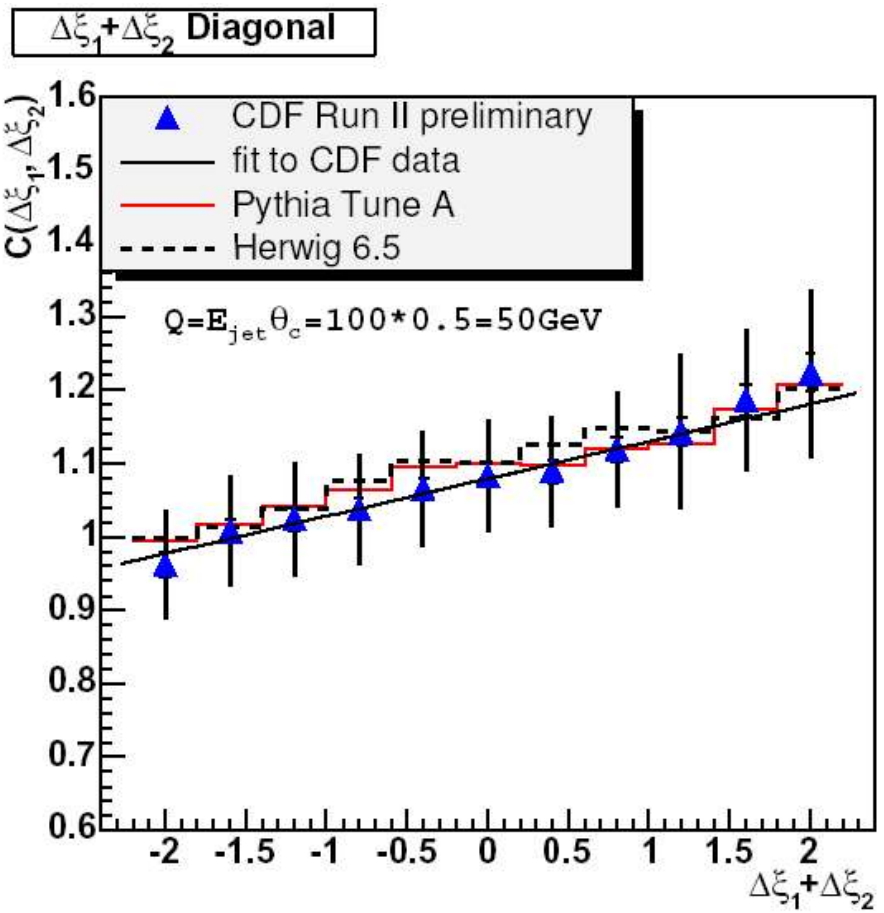



# CDF results

## Pythia Tune A and Herwig 6.5

- MC generators reproduce correlation in data fairly well;



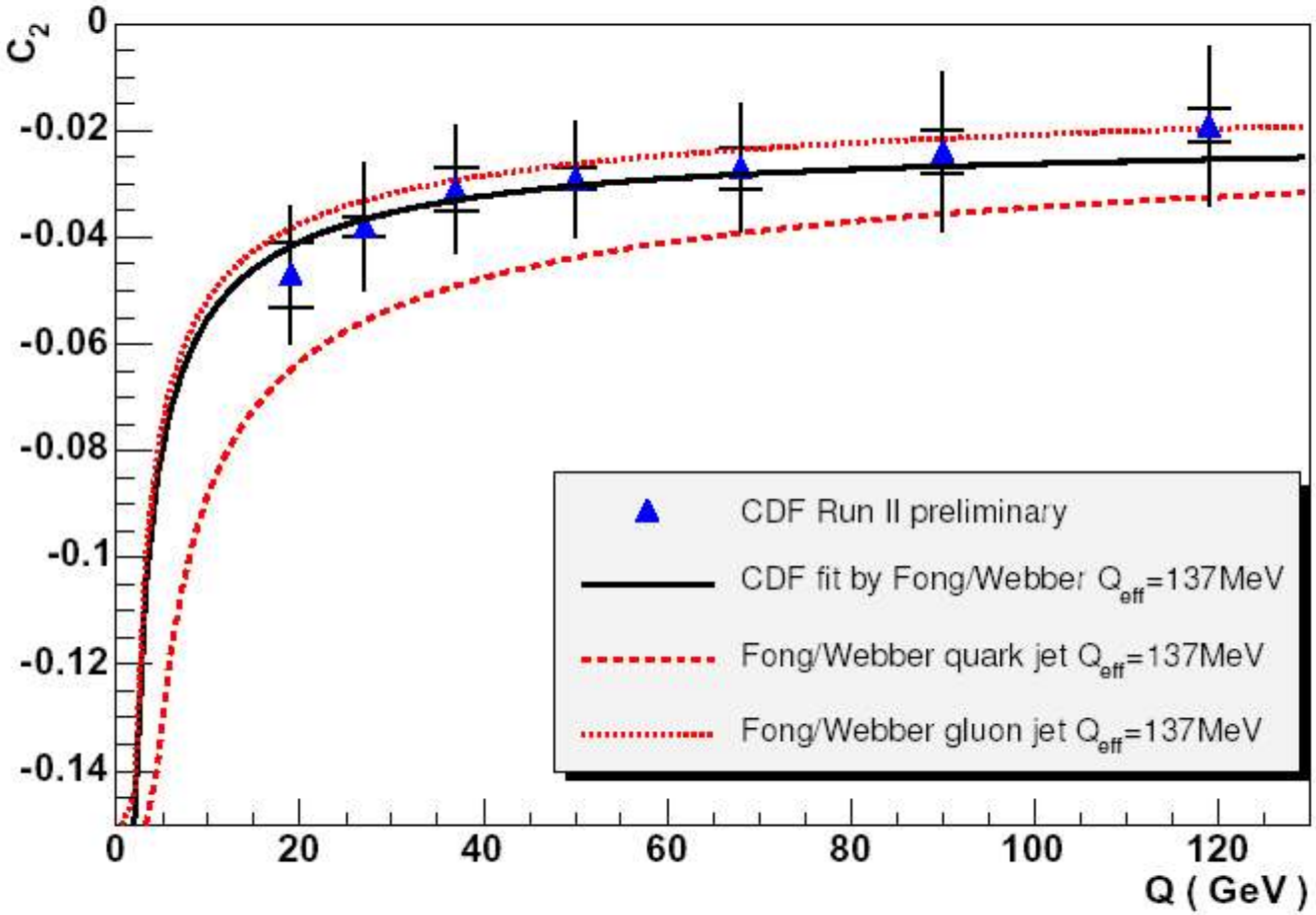



# CDF results

- Start with $C_2$ – parameter that has best (out of three) precision in theory;

- Fit $C_2$ vs. Q with Fong/Webber's function gives $Q_{eff}$=137±53 MeV;

- Data and theory show same trends;



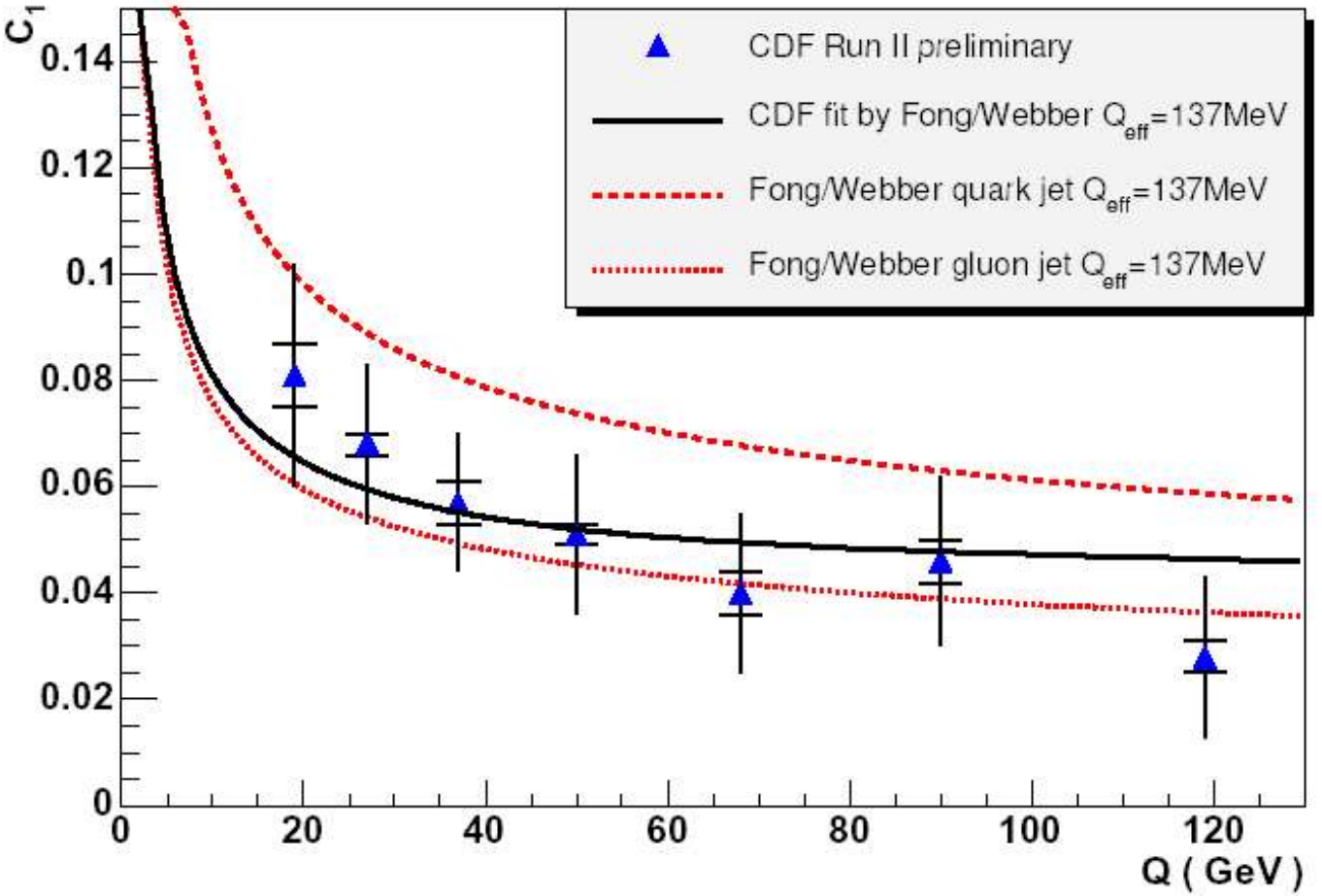

mixed q/g jets

# CDF results

- Parameter $C_1$;

- Fit $C_1$ vs. Q with Fong/Webber's gives same result $Q_{eff}$=137±53 MeV;

- Data and theory show same trends;

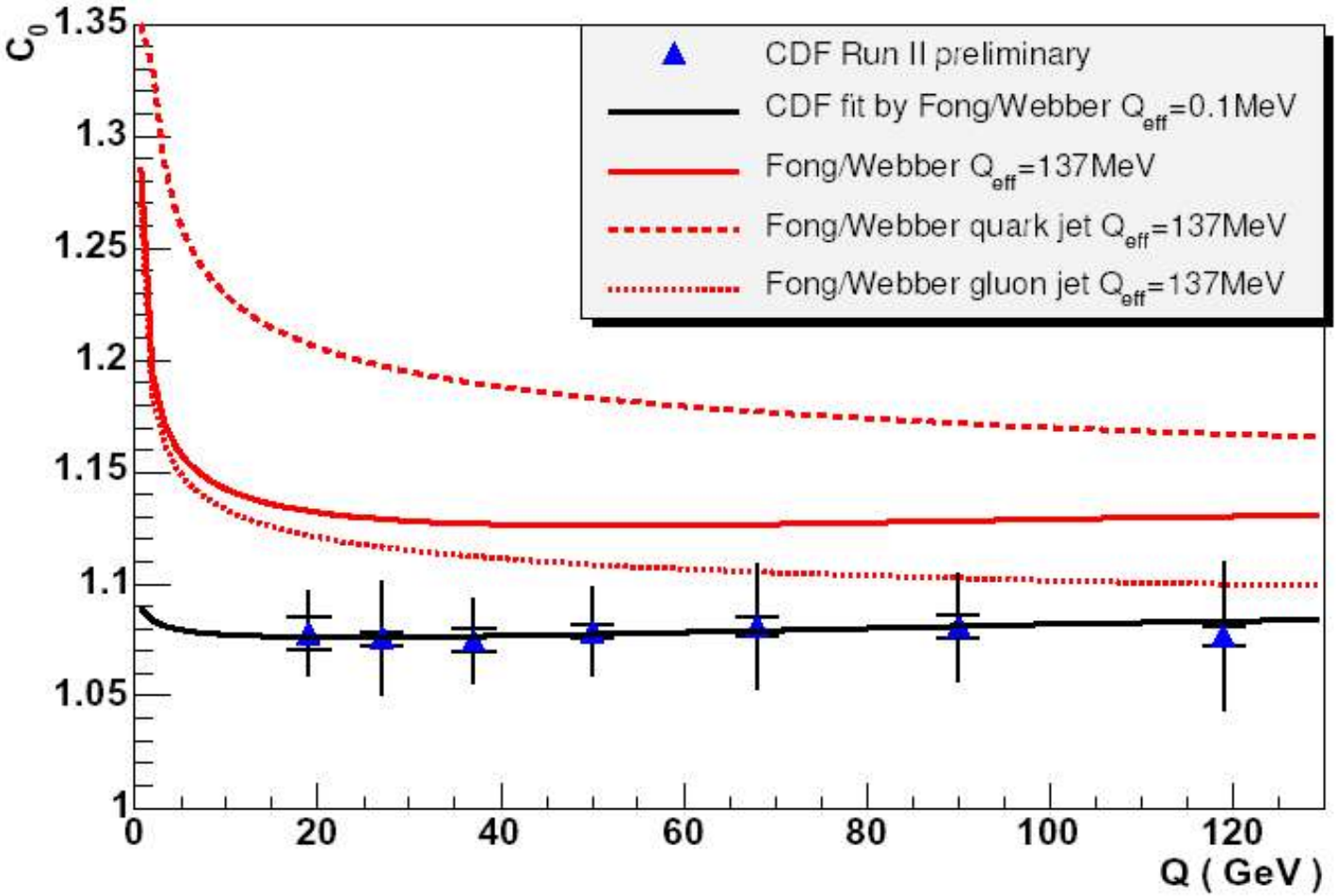


# CDF results

- Parameter $C_0$; ( is sensitive to redefining $\xi_o$ – point of the expansion)

$$C(\Delta\xi_1,\Delta\xi_2)=C_0+C_1(\Delta\xi_1+\Delta\xi_2)+C_2(\Delta\xi_1-\Delta\xi_2)^2$$

- Experiment and theory show the same trends, albeit ~0.06 offset;



# Summary

- First measurements of two-particle momentum correlation in jets in the hadron collider environment;
- Measurements done for di-jet masses ranging 66-563 GeV;
- Trends in data are same as predicted by Next-to-Leading Log approximation calculations. Value of $Q_{eff}$~140±50 MeV obtained from the fits of $C_2$ and $C_1$ is reasonable;
- Monte-Carlo generators Pythia Tune A and Herwig 6.5 reproduce correlation fairly well;
- Correlation clearly survives hadronization stage that gives further support to the hypothesis of LPHD;