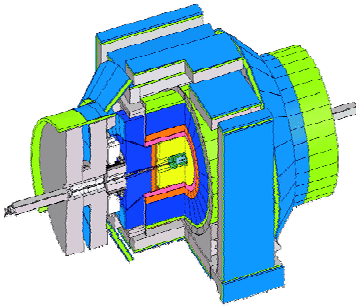


QCD Results at CDF

Olga Norniella

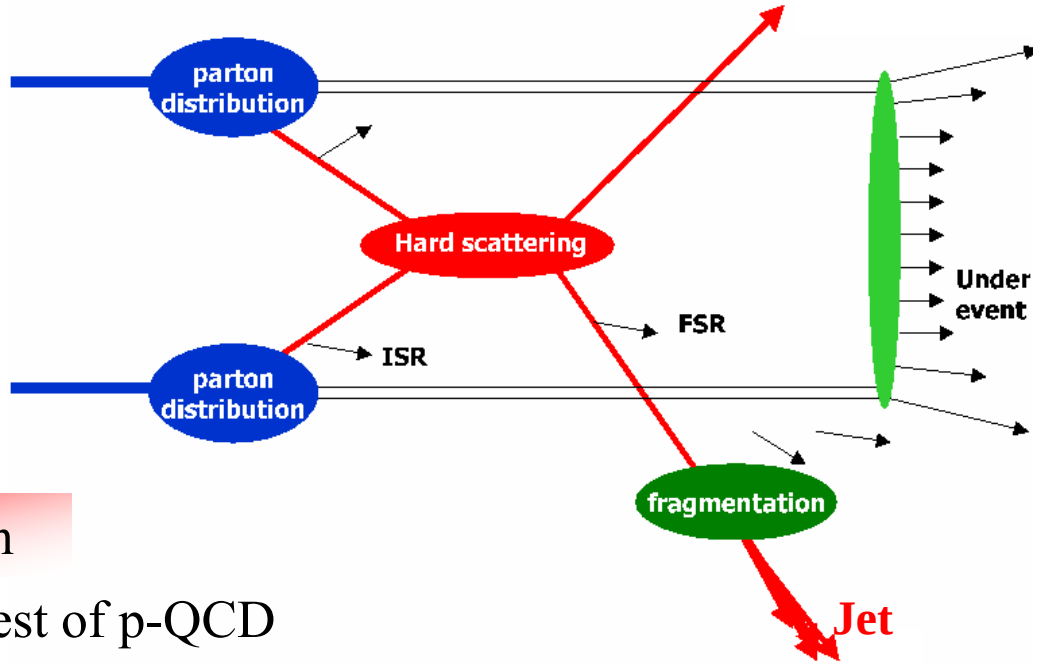
IFAE-Barcelona

On behalf of the CDF Collaboration

Lake Louise Winter Institute 2005

QCD at Tevatron

✓All production processes are QCD related



★ Jet Production

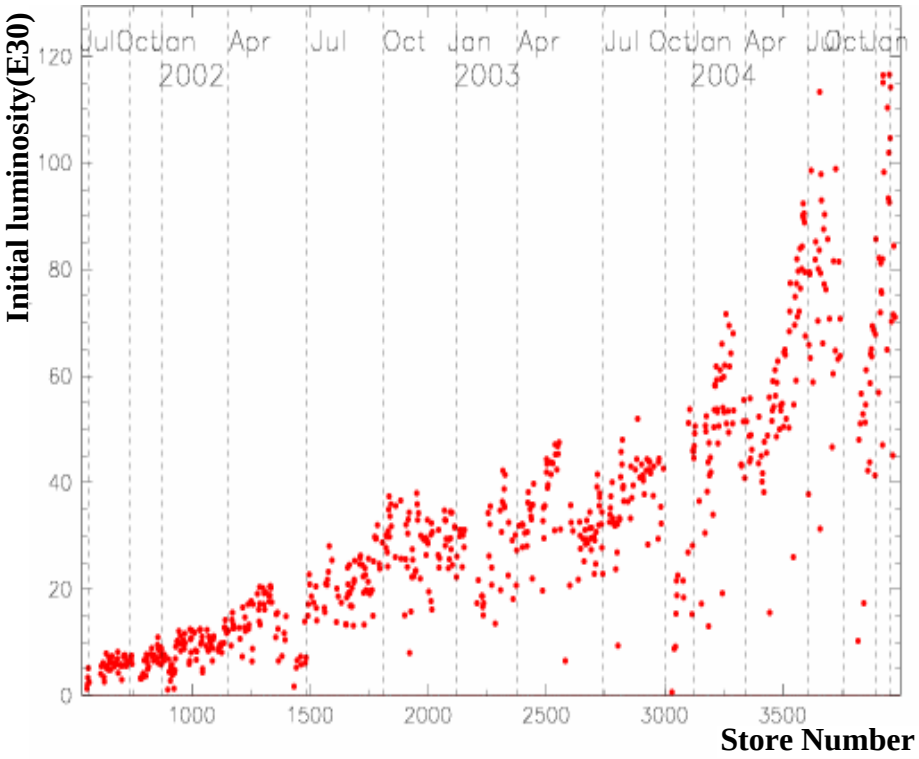
- ✓Stringent test of p-QCD
- ✓High-p_T tail sensitive to new physics and PDFs

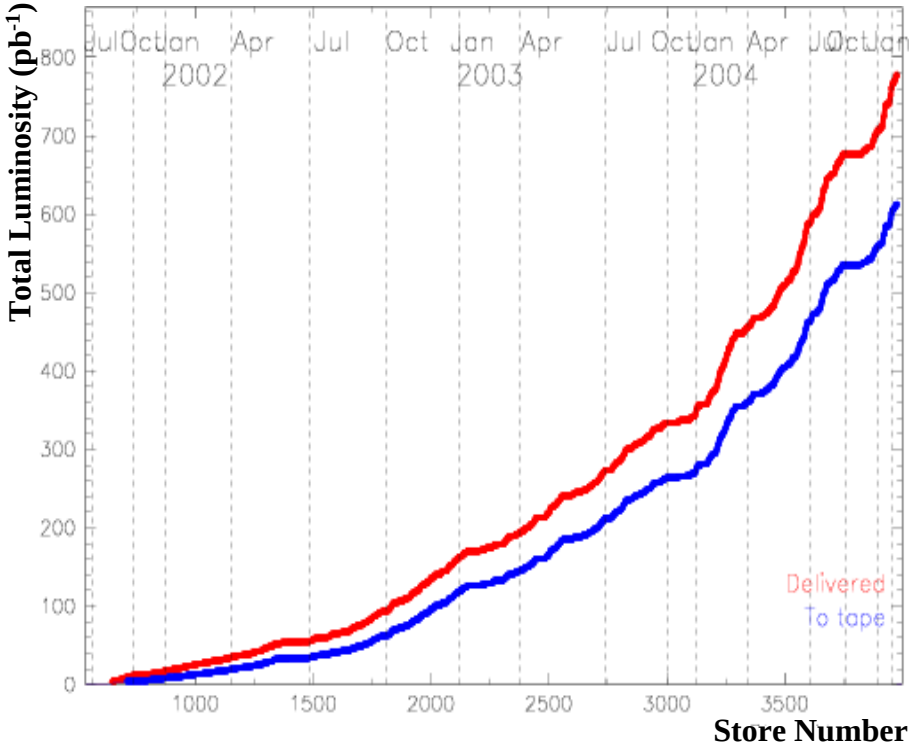
★ Non-perturbative QCD contributions: Underlying event
Jet Fragmentation

Other studies of interest: W+jets, diphoton, γ + heavy quark, inclusive b-jet production, hadron spectroscopy, diffraction

Tevatron

✓Tevatron is the $p\bar{p}$ collider at the highest $\sqrt{s}$ ever reached



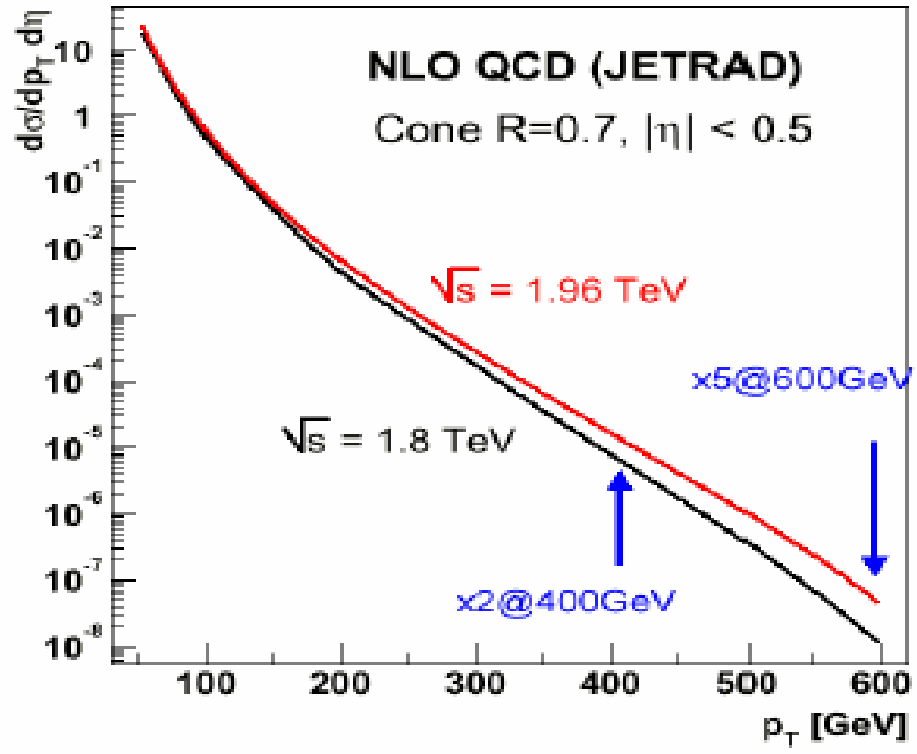


Initial record luminosity
116.5 E30$cm^{-2}s^{-1}$

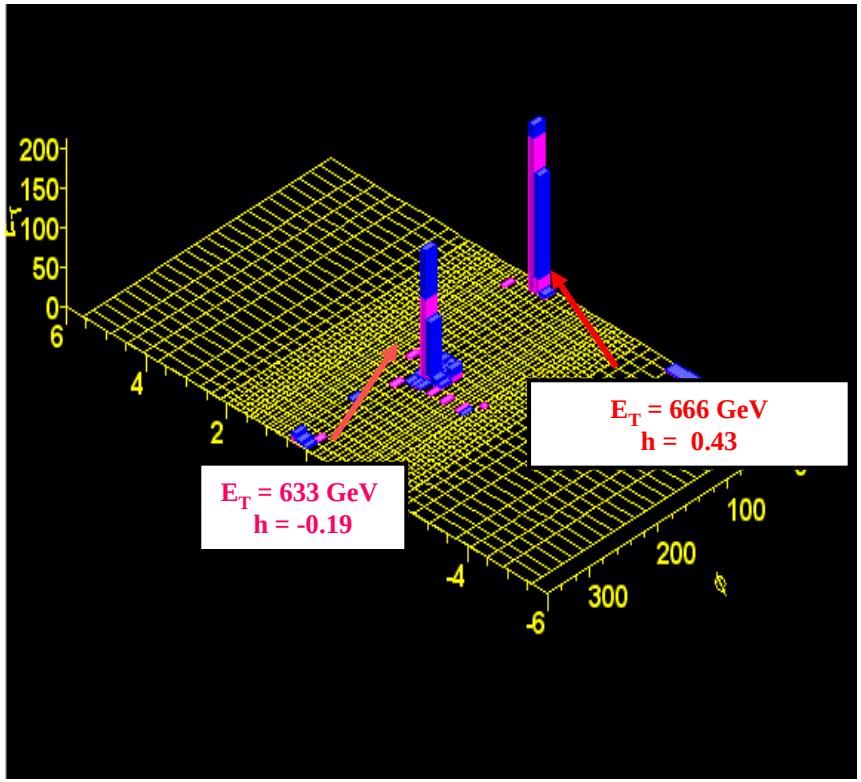
On tape ~600 pb^{-1}

Jet Physics at Tevatron

Inclusive Jet Cross Section



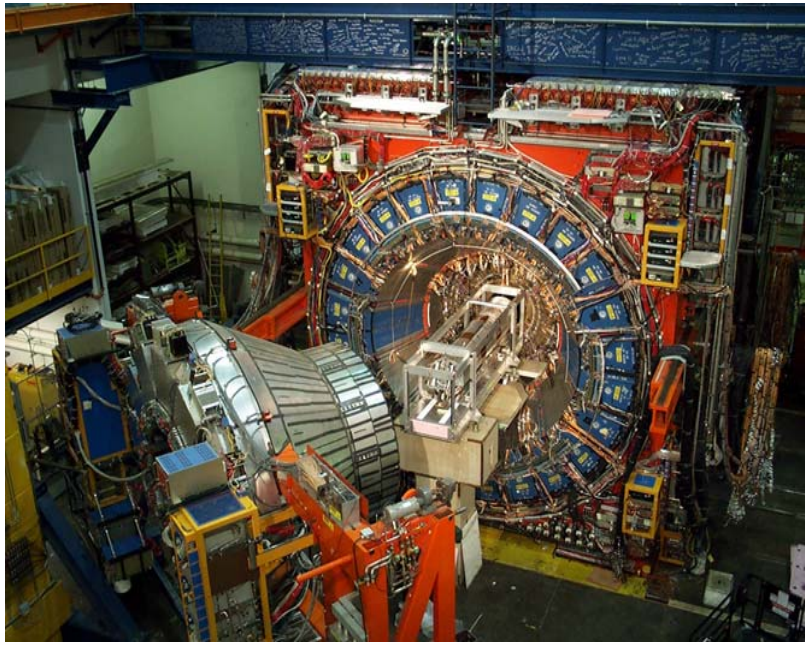
Highest dijet mass so far
Mass ≅1.3 TeV



Higher σ_{jet} with respect to RunI

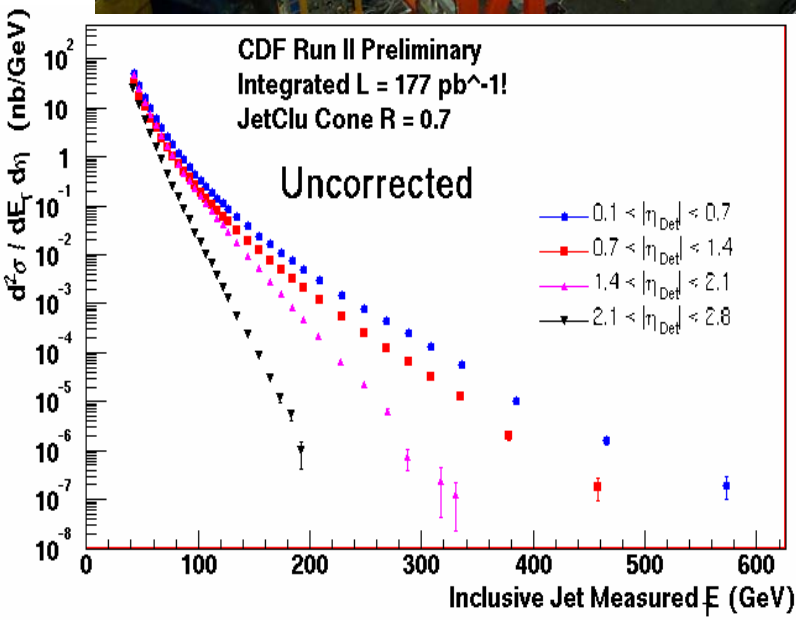
Increase p_T range for jet production

CDF Detector

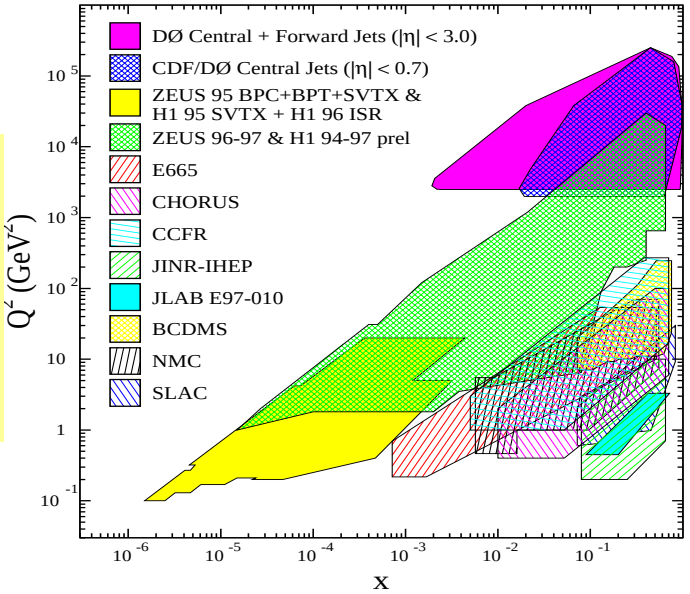


Upgrades

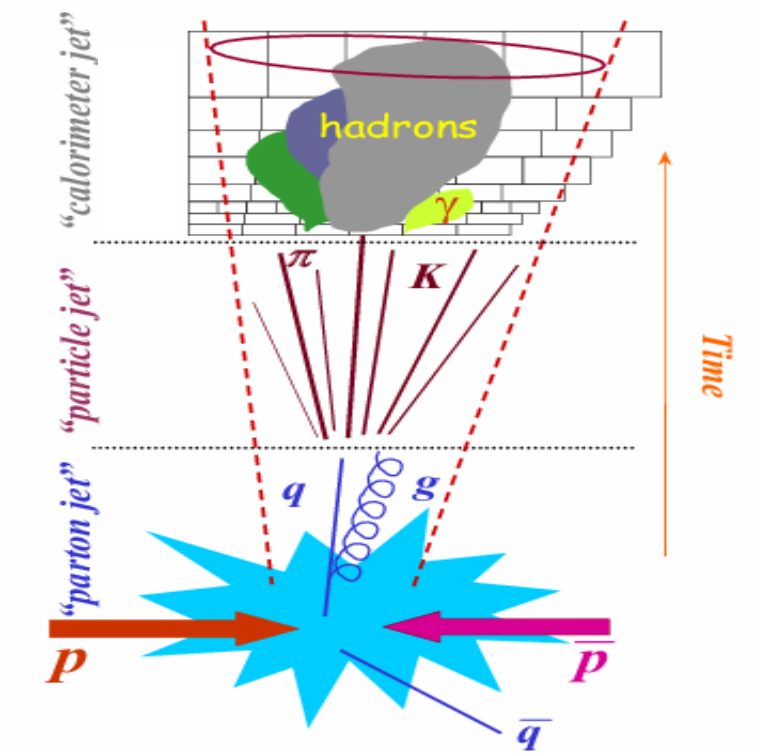
- ✓ Si detector & Tracking
- ✓ Time of Flight detector
- ★ Plug Calorimeters
- ✓ Forward detectors
- ✓ Muon system
- ✓ DAQ electronics & Trigger

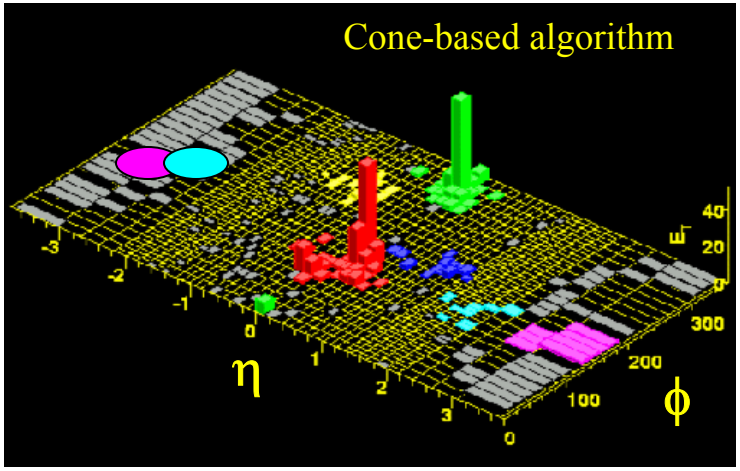


Measurements in different regions allow to further constrain the PDFs



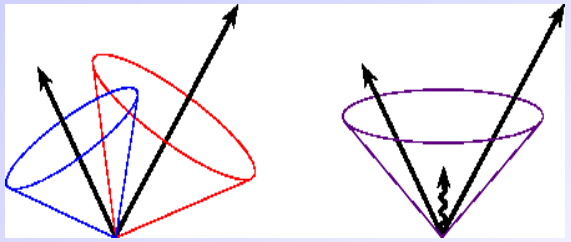
Jet Algorithms and physics





✓Precise jet search algorithm necessary to compare with theory

✓ Run I cone-based algorithm is not infrared and collinear safe to all orders in p-QCD



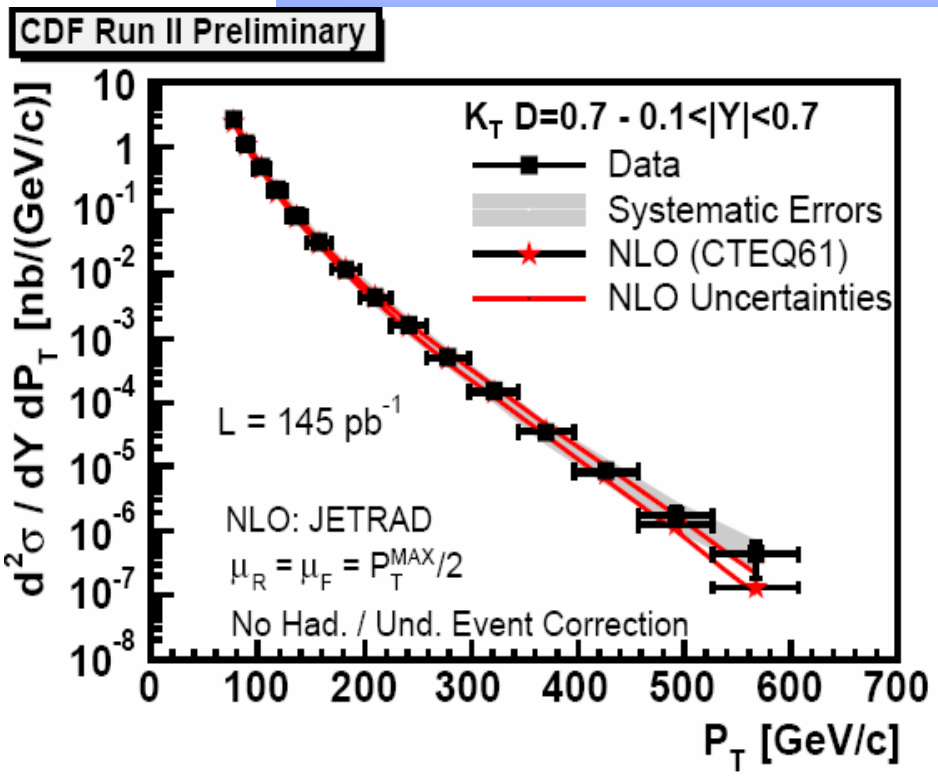
The jet multiplicity changed after emission of a soft parton

✓ Run II ⇒ new cone-based algorithm: **MidPoint**

✓ Cone-based jet algorithms include an "experimental" prescription to resolve situations with overlapping cones

✓ Theory suggests to separate jets according to their relative transverse momentum ⇒ **K_T algorithm**

Inclusive Jet Cross Section with K_T

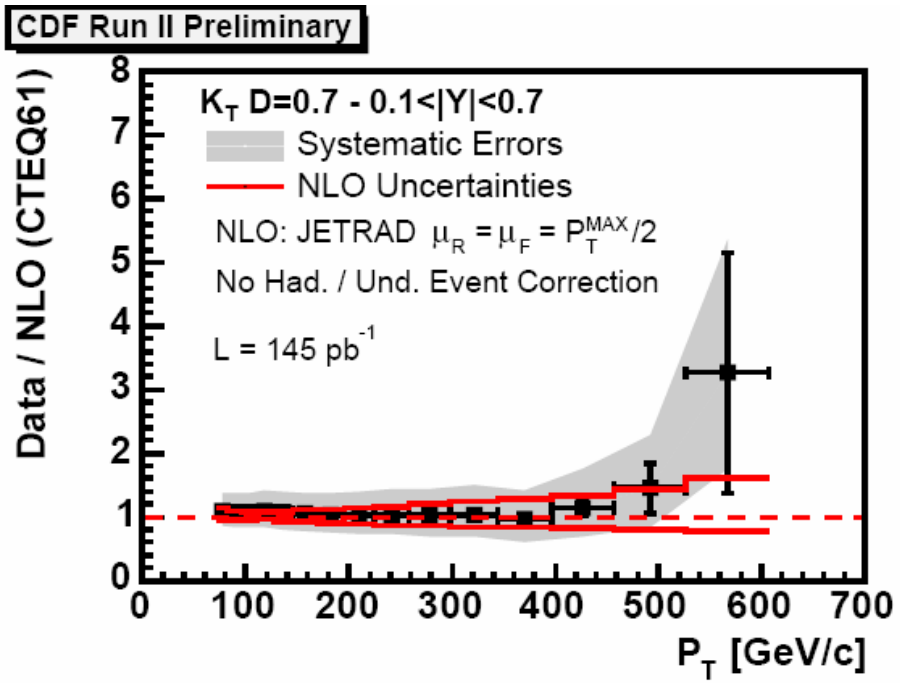


K_T Algorithm

$$d_{ij} = \min(P^2_{T,i}, P^2_{T,j})\frac{\Delta R^2}{D^2}$$
$$d_i = (P_{T,i})^2$$

✓Infrared and collinear safe to all orders in p-QCD (relevant for NNLO)

✓No merging/splitting parameter



Good data-theory agreement

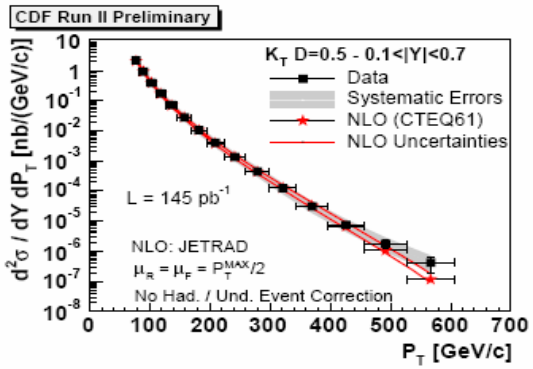
- Data uncertanties dominated by energy scale (5% energy scale systematic)
- NLO error mainly from PDFs (high x gluon)

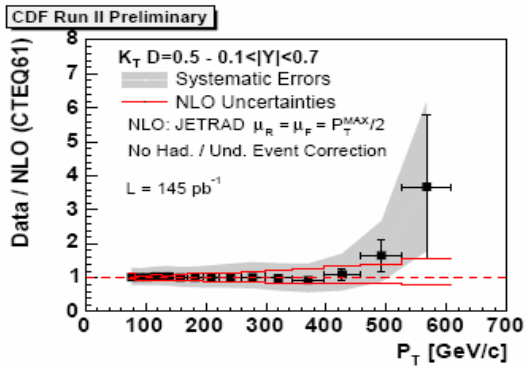
No hadronization and Underlying event corrections applied to NLO prediction

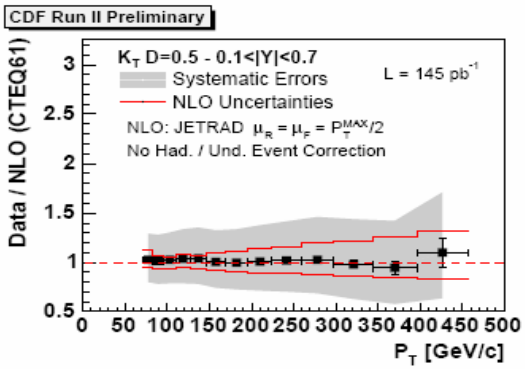
$$d_{ij} = \min(P^2_{T,i}, P^2_{T,j}) \frac{\Delta R^2}{D^2}$$

K_T Jets vs D

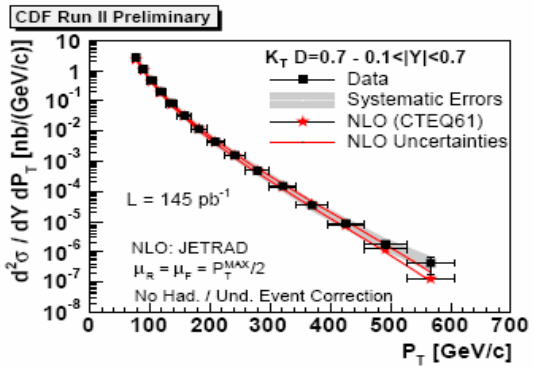
D=0.5

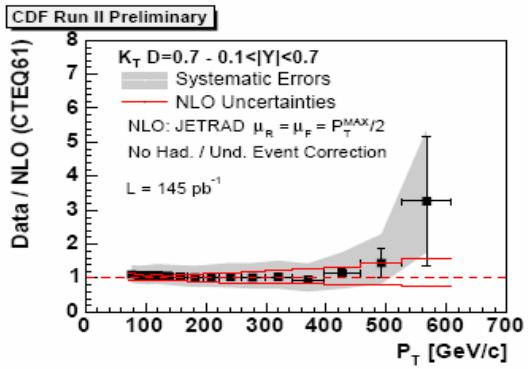


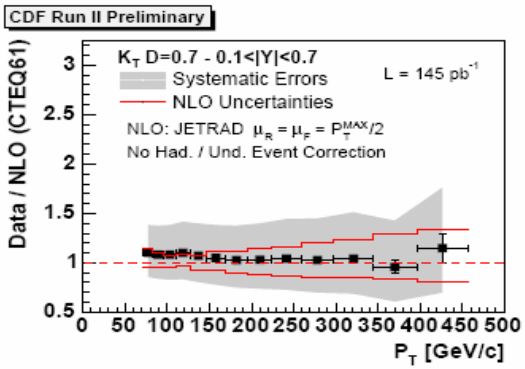




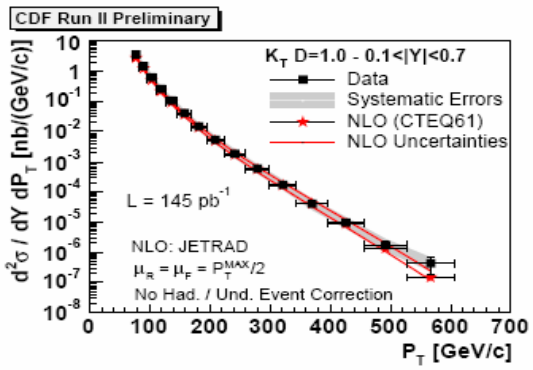
D=0.7

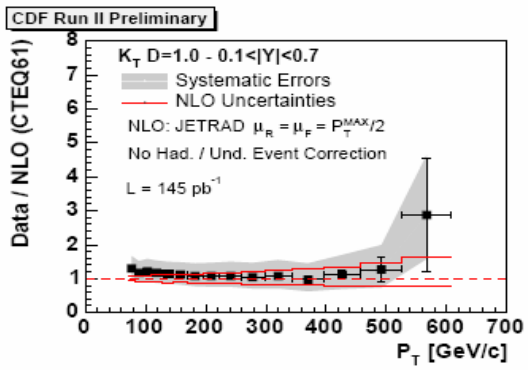


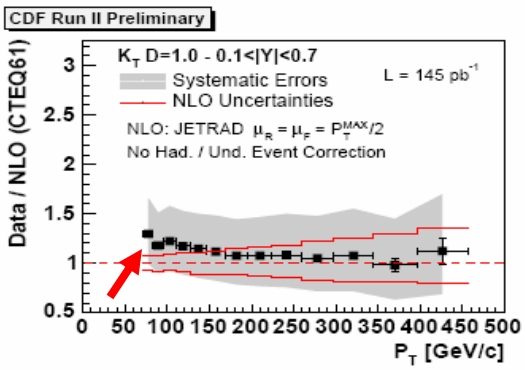




D=1.0



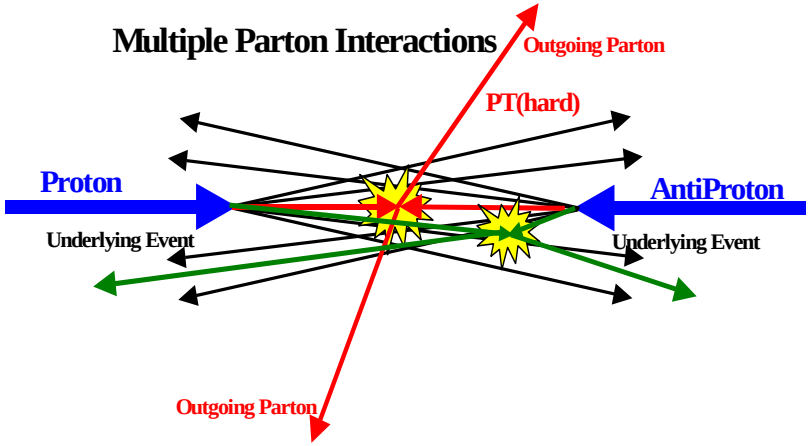




Underlying event contribution important at low $p_T \Rightarrow$ need to be modeled in MC

Underlying Event

Final states in hadron collision are affected by the underlying event contribution:

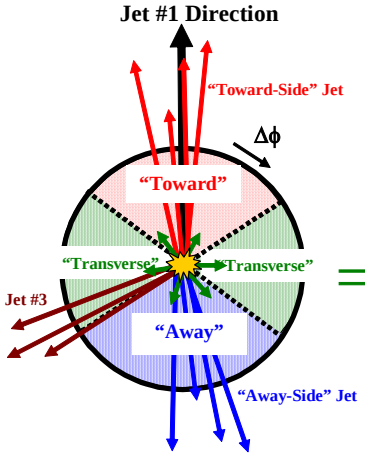


- ✓Initial-and-final-state soft gluon radiation
- ✓Beam-beam remnants
- ✓Multiple parton interaction

The UE contribution is modeled using MC tuned to describe the data

Studies in Inclusive jet events

- ✓ Leading jet (Jet cone algorithm R=0.7,|η|<2)
- ✓Two different event topologies

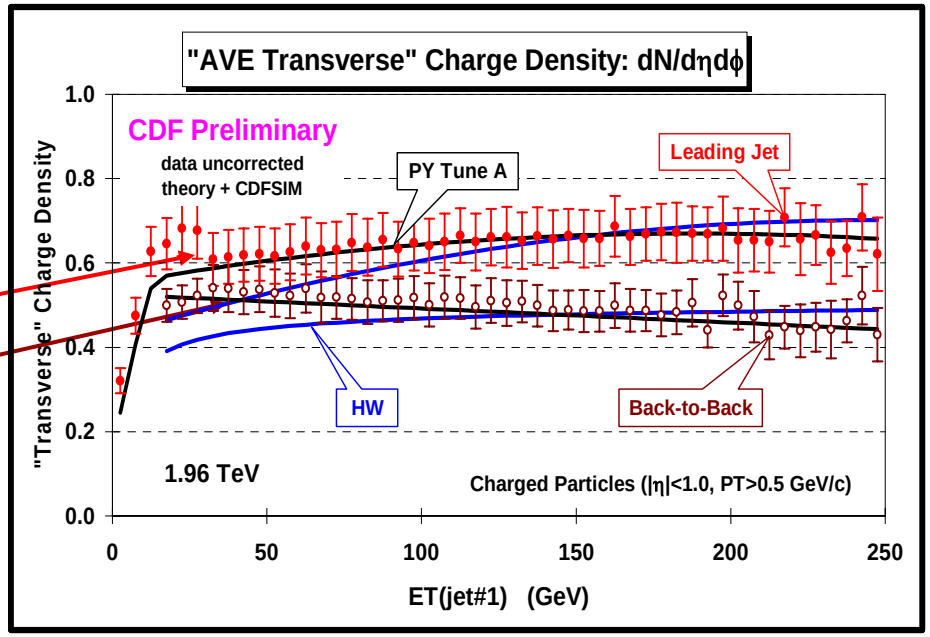


"leading jet"

"back-to-back"

(Suppression of hard radiation)

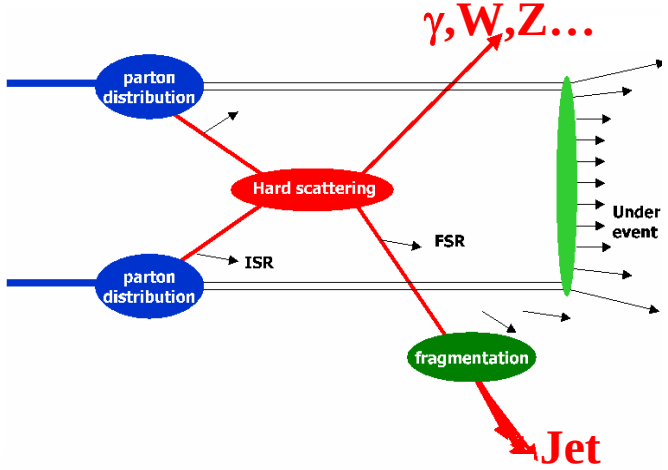
⇒very sensitive to U.E



Pythia Tune A good description of measurements

(tuned using similar studies on RunI data)

Studies on Jet Shapes

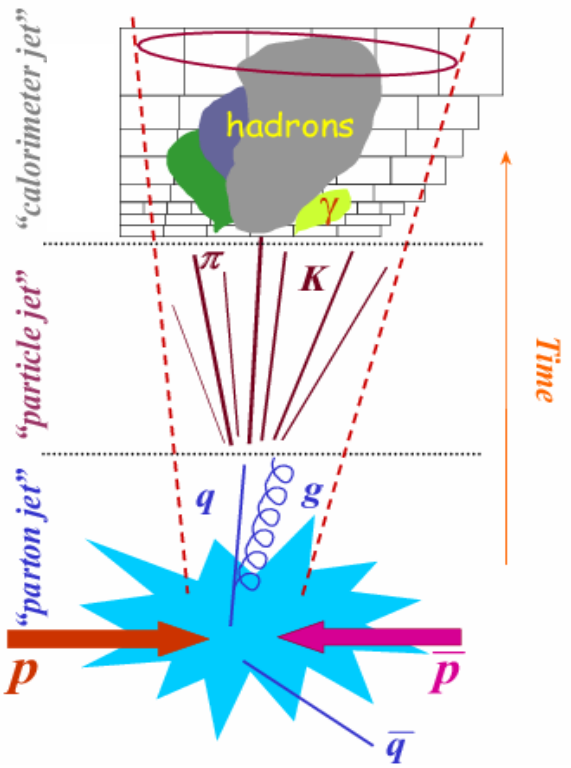


Jet Shapes

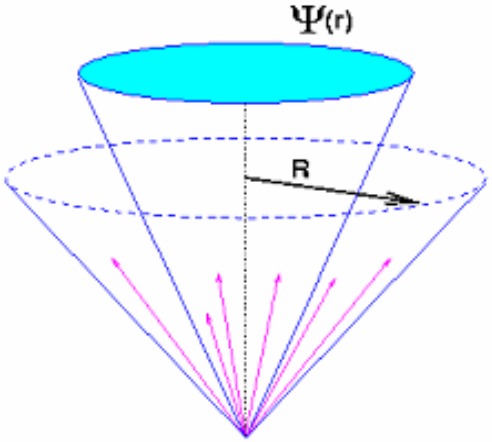
✓ Driven by multi-gluon emission from primary parton

✓ Test of **parton shower** models

✓ Sensitive to the **underlying event**

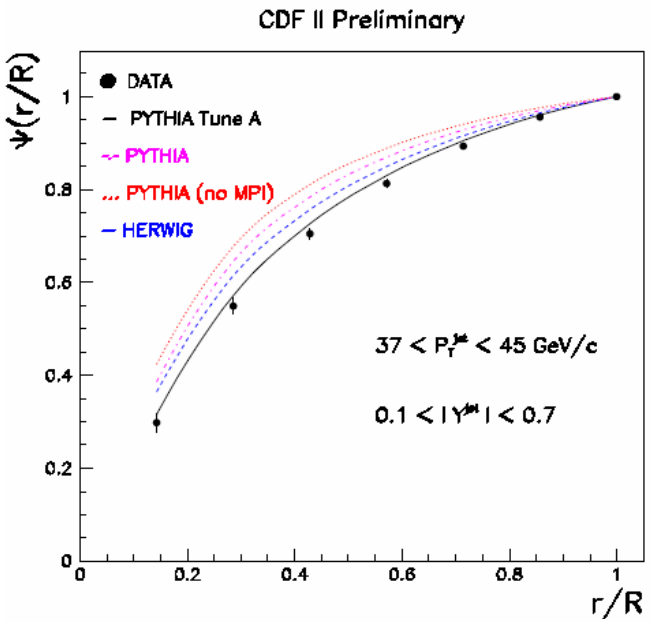


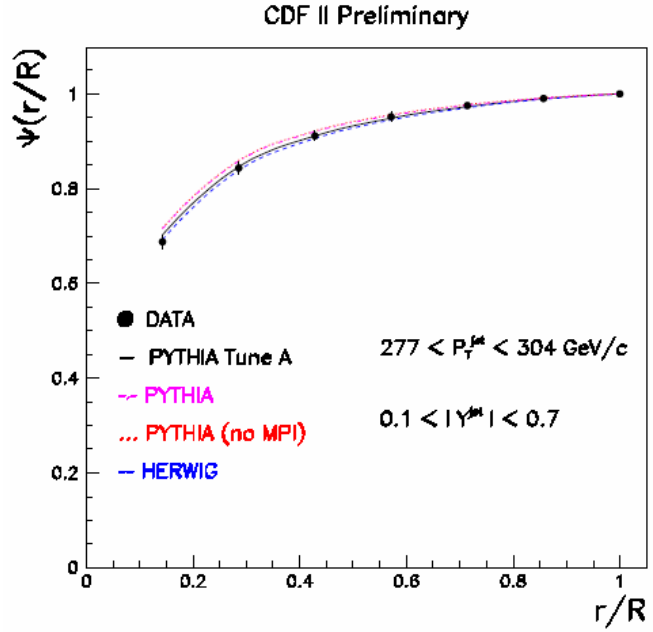
Jet Shape definition



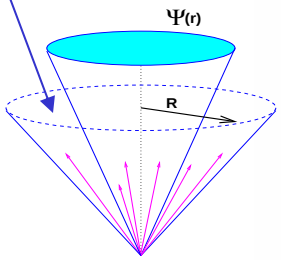
$$\Psi(r) = \frac{1}{N_{jets}} \sum_{jets} \frac{P_T(0,r)}{P_T(0,\mathrm{R})}$$

Jet Shape: Evolution with P_T(jet)

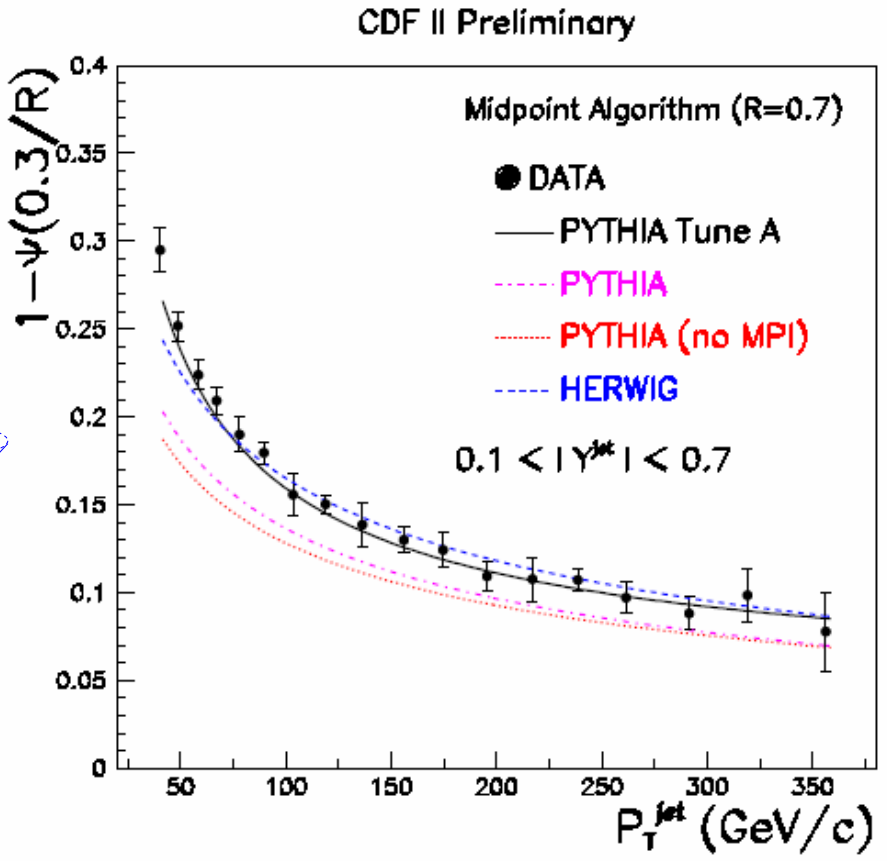




$1-\Psi(r)$



Taking (1-Ψ) a fixed r (r=0.3) for all P_T range:



- **Pythia Tune A** describes the data
- **Pythia default** produces too narrow jets
- MPI contribution important at low p_T
- **Herwig** is OK but too narrow at low p_T

Summary and Conclusions

RunII at Tevatron will define a new level of precision for QCD studies in hadron-hadron collisions

CDF has a rich program: Inclusive jet cross section, W+jets, diphoton, γ + heavy quark, b-jet production, Underlying event studies, hadron spectroscopy, diffraction.

Jet production studies with the K_T algorithm

- Good agreement between data and NLO
- Working on hadronization and Underlying event corrections and, on a better understanding of the jet energy scale
- Working on Jet Cross Section measurements in the Forward region

Studies of the underlying events are crucial for a proper comparison with pQCD

- Pythia Tune A provides a good description of the measurements in all p_T region

$\Rightarrow$ gives us a proper modeling of the underlying event contributions

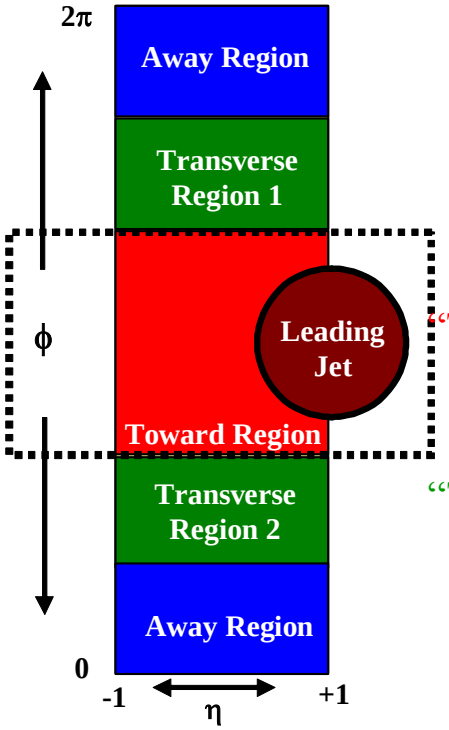
Back-up

Underlying Event

✓ Look at charged particle correlations in the azimuthal angle Df relative to the leading calorimeter jet (JetClu R = 0.7, $|\eta| < 2$).

Charged Particle $\Delta\phi$ Correlations $p_T > 0.5$ GeV/c $|\eta| < 1$

✓ Define 3 regions of same size in ϕ-η space

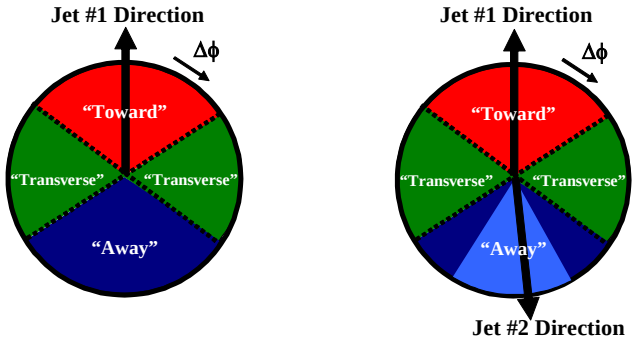


"Toward" region $\Rightarrow |\Delta\phi| < 60^o$

"Away" region $\Rightarrow |\Delta\phi| > 120^o$

"Transverse" regions $\Rightarrow 60^o > |\Delta\phi| < 120^o$

✓ Two different event topologies



"leading jet"

No prescription on the jet#2

"back-to-back"

E_T(jet#2)/E_T(jet#1) > 0.8

$\Delta\phi_{12} > 150^o$

Pythia – Tune A

- Smoothed out probability of Multi-Parton Interaction (MPI) vs impact
- Enhanced Initial State Radiation
- MPIs are more likely to produce gluons than quark-antiquark pairs and MPI gluons are more likely to have color connection to p-pbar remnants

PYTHIA 6.206 Tune Set A (CTEQ5L)			
Parameter	**Default**	**Tune**	**Description**
PARP(67)	1.0	**4.0**	Scale factor that governs the amount of initial-state radiation.
MSTP(81)	1	**1**	Turns on multiple parton interactions (MPI).
MSTP(82)	1	**4**	Double Gaussian matter distribution.
PARP(82)	1.9	**2.0**	Cut-off for multiple parton interactions, $P_{T0.}$
PARP(83)	0.5	**0.5**	Warm Core: 50% of matter in radius 0.4.
PARP(84)	0.2	**0.4**	Warm Core: 50% of matter in radius 0.4.
PARP(85)	0.33	**0.9**	Probability that the MPI produces two gluons with color connections to the "nearest neighbors".
PARP(86)	0.66	**0.95**	Probability that the MPI produces two gluons either as described by PARP(85) or as a closed gluon loop. The remaining fraction consists of quark-antiquark pairs.
PARP(89)	1,000.0	**1,800.0**	Determines the reference energy $E_{0.}$
PARP(90)	0.16	**0.25**	Determines the energy dependence of the cut-off P_{T0} as follows $P_{T0(Ecm) = PT0(Ecm/E0)^{PARP(90)}}$.

Inclusive Jet Cross Section

- Plan :

✓ Correct the NLO for Hadronization and Underlying Event in order to compare to data

–Use Pythia “Tune A”: Underlying Event tuned on Run I data

✓ Hadronization / UE correction factor:

$$C_i = \frac{\sigma\ (\text{Hadron Level - Pythia Tune A with MPI})}{\sigma\ (\text{Parton Level - Pythia Tune A no MPI})}$$

Jet Shapes

- Jet defined with MidPoint Algorithm R=0.7 Merging at 75%
- At least one central jet $0.1 < |Y^{Jet}| < 0.7$; $P_T > 30$ GeV
- Number of vertex =1