QCD RESULTS FROM CDF

CHRISTINA MESROPIAN
THE ROCKEFELLER UNIVERSITY

09/10/2009

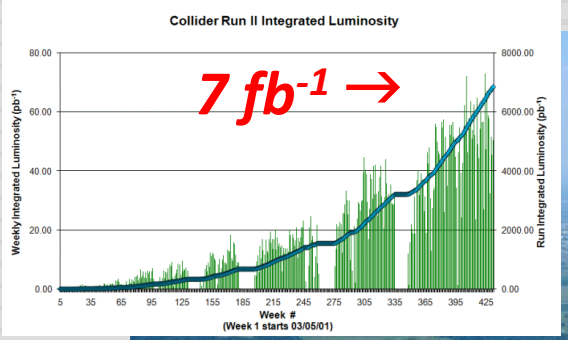
Low x Workshop, Ischia Italy

Contents

- Introduction
- Inclusive Jets and Dijets Production
- W/Z+jets, W/Z+HF
- Photons: inclusive γ, γ +HF
- Underlying Events Studies

- Not included in this talk:
  - Diffractive Studies, talk by K. Goulianos tomorrow
  - Exclusive Charmonium, talk by J. Pinfold tomorrow
  - High mass muon pairs, talk by M. Albrow tomorrow

Collider Run II Integrated Luminosity

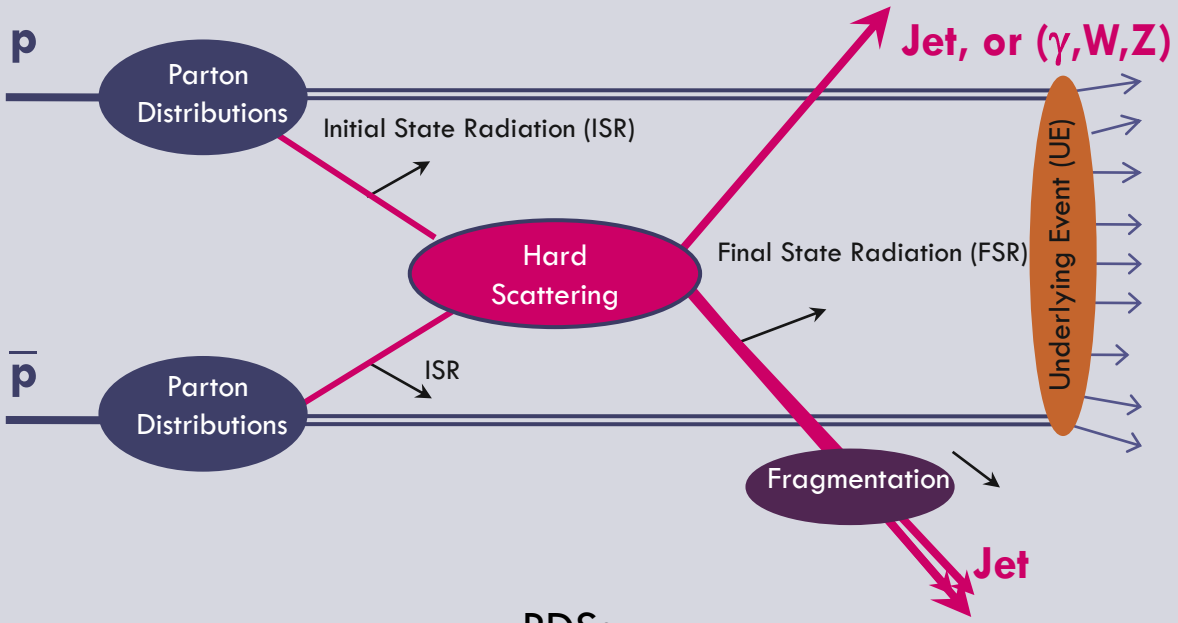


Tevatron $p\bar{p}$ Colider

Run I (1992-1996) $\sqrt{s}$=1.8 TeV (~120 pb^{-1})

Run II (2001-) $\sqrt{s}$= 1.96 TeV

- Test pQCD
- Constrain PDFs, Fragment. functions
- Extract α_s
- Study /test matrix element calculations
- Sensitivity to new physics



PDSs

$$d\sigma = \sum_a \sum_b f_{a/p}(x_p, \mu_F^2)\, f_{b/\bar{p}}(x_{\bar{p}}, \mu_F^2) \otimes \hat{\sigma}_{a,b}(x_p, x_{\bar{p}}, \alpha_s, \mu_R^2)$$

Hard Scatter

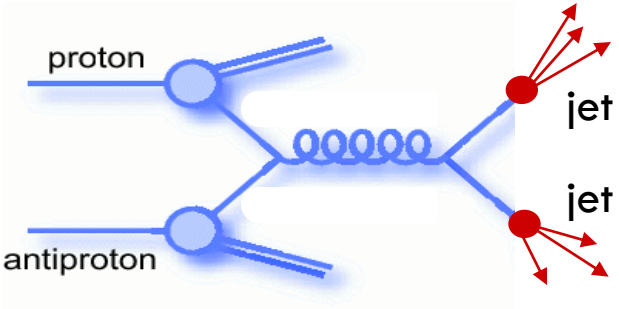
QCD in Hadron-Hadron Colliders

Underlying Event complicates the measurements:

study UE to tune QCD Monte Carlo programs

Jet Production

- Largest high p_T cross-section at a hadron colliders
- highest energy reach

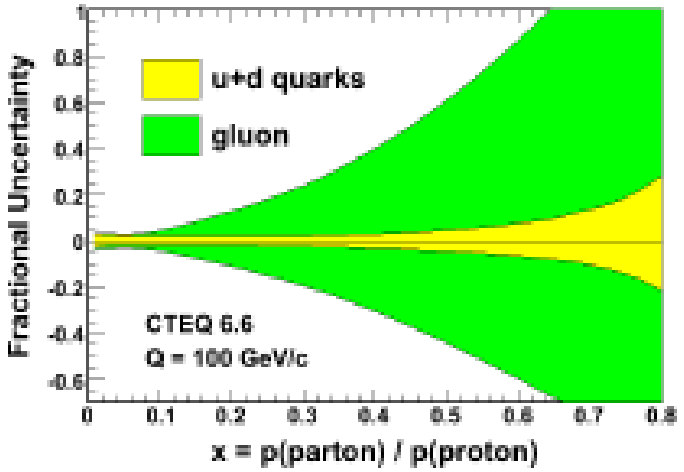


Precision measurements:

- constrain PDFs (especially gluons at high-x)
- α_s

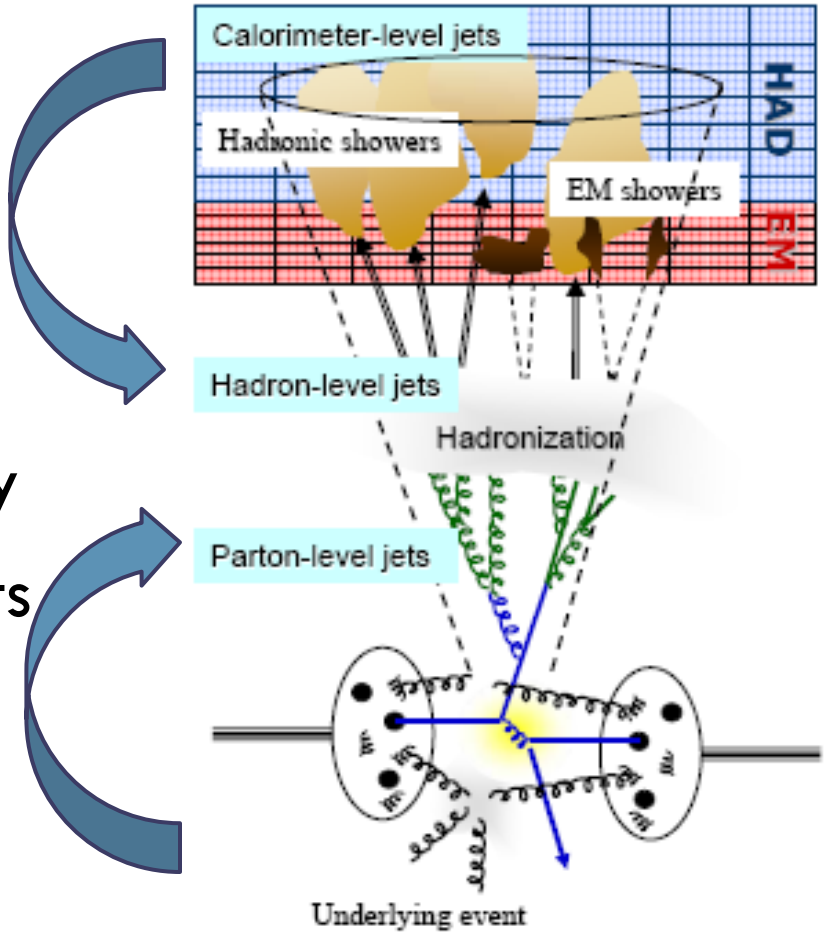
Unique sensitivity to **new physics:**

- new massive particles ,
- quark compositeness,
- extra dimensions,
- …(?)…

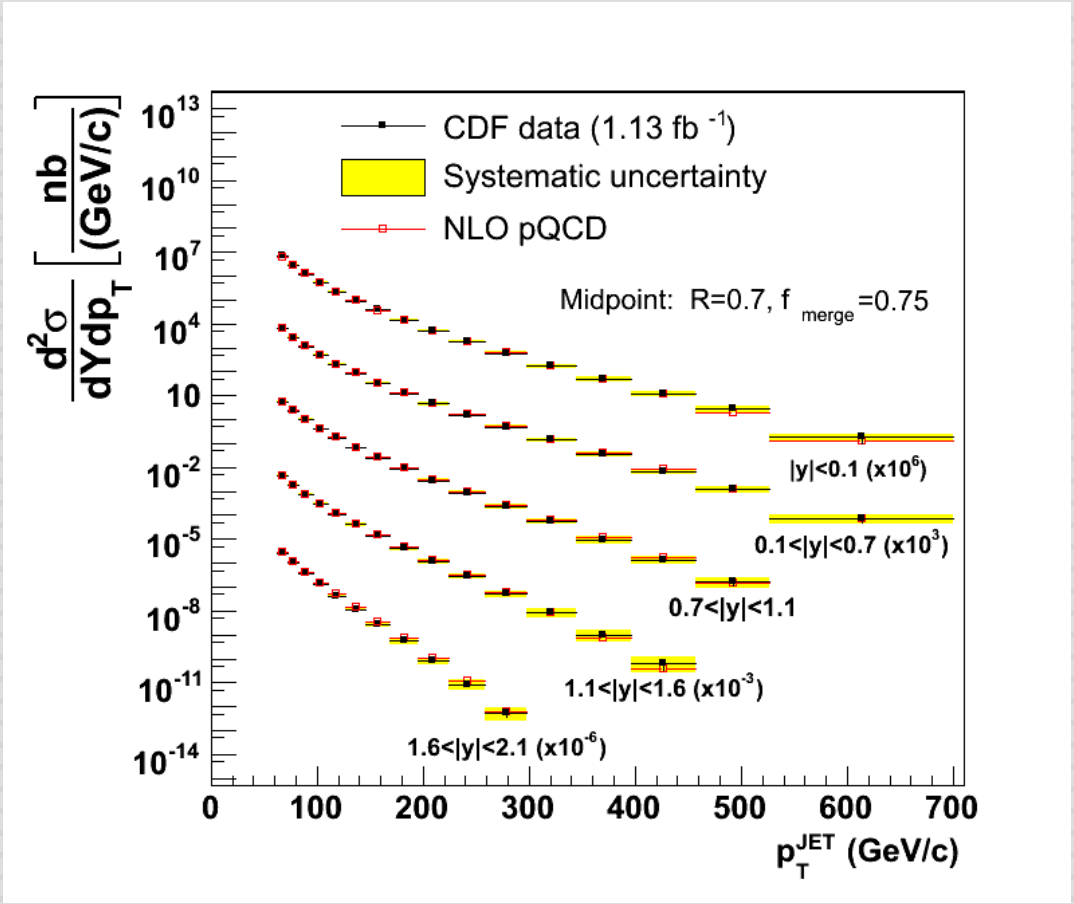


Jet Measurements

- Unfold measurements to the hadron (particle) level
- Correct parton-level theory for non-perturbative effects (hadronization & UE)



PRD 78, 052006 (2008)



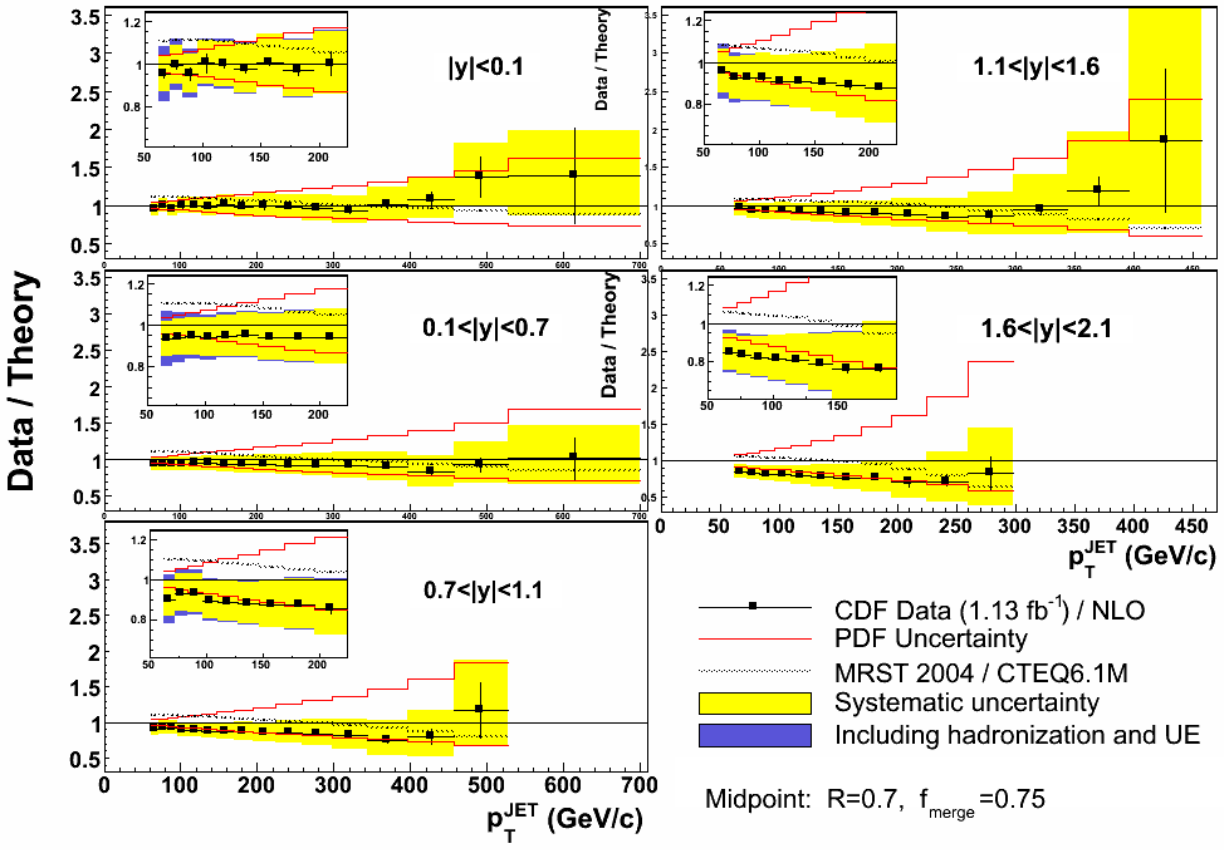
7

Inclusive Jet Cross Section

Tests pQCD over 8 orders of magnitude

highest p_T >600 GeV/c

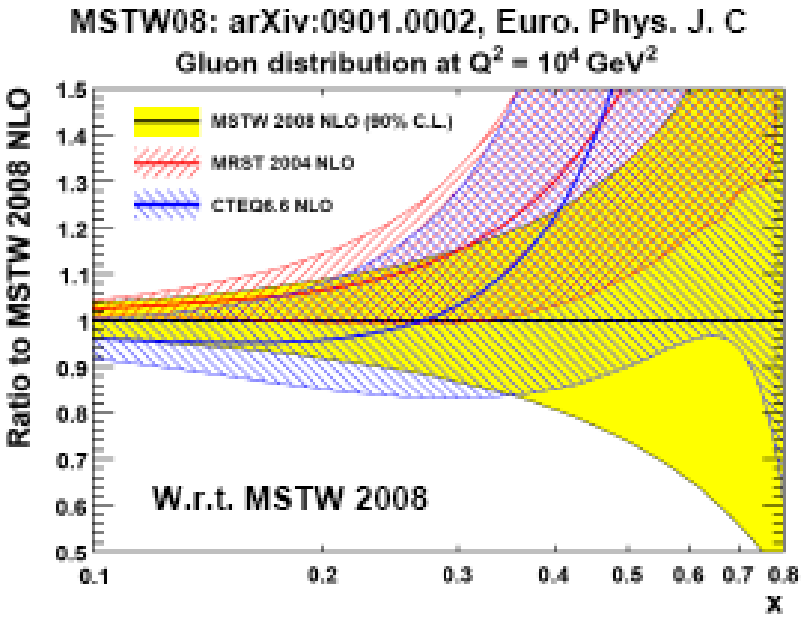
Inclusive Jet Cross Section

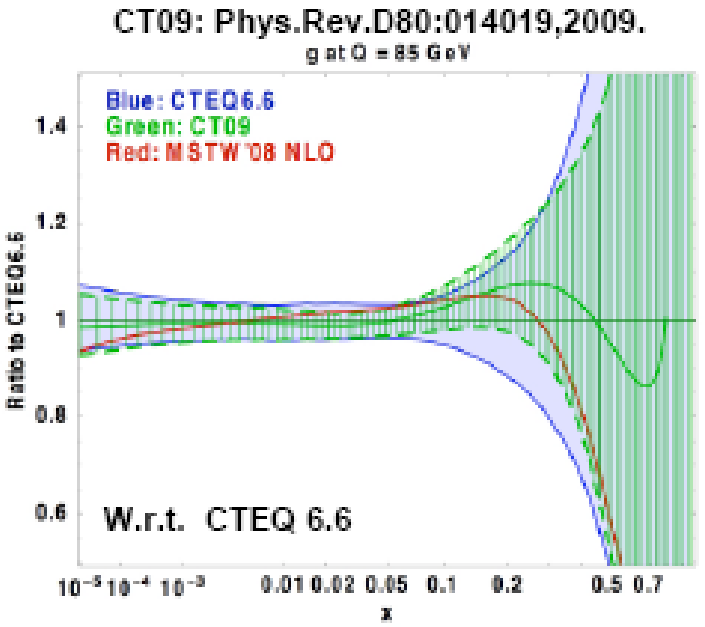


In agreement with NLO predictions

Experimental uncert. are smaller than PDF uncertainties

PDFs with recent Tevatron Jet Data



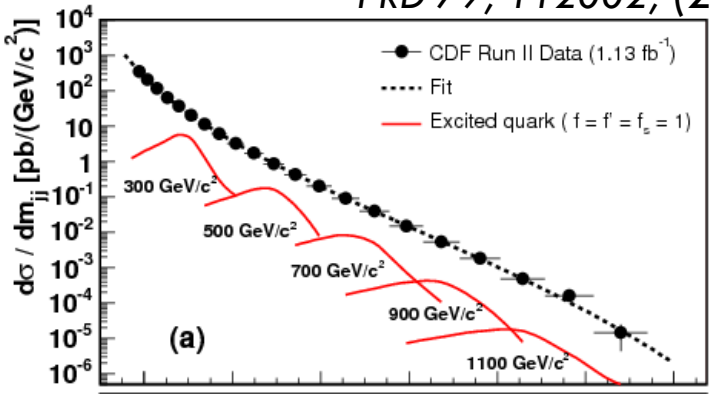


Tevatron Run II data lead to softer high-x gluons (more consistent with DIS data) and help reduce uncertainties

Dijet Mass Distributions

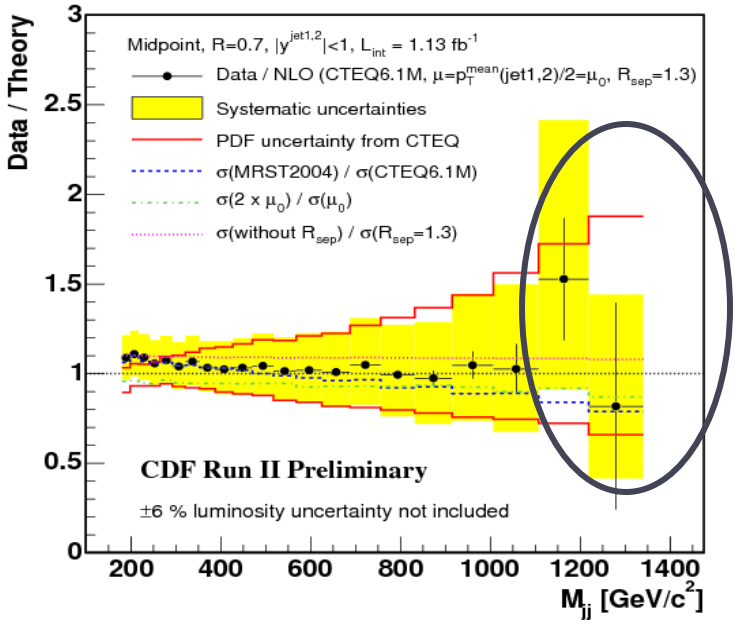
Dijet Mass Distributons test pQCD;
have sensitivity to new physical phenomena

PRD 79, 112002, (2009)



Observ. exclusion	Model description
260-870 GeV/c^2	Excited quark
260-1100 GeV/c^2	Color-octet technirho
260-1250 GeV/c^2	Axigluon & flavor-univ. coloron
290-630 GeV/c^2	E_6 diquark
280-840 GeV/c^2	W' (SM couplings)
320-740 GeV/c^2	Z' (SM couplings)

Mass reach up to ~1.2 TeV/c^2



Consistent with NLO pQCD

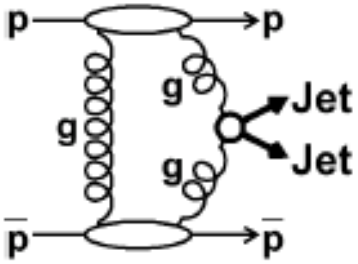
No indications of resonances:

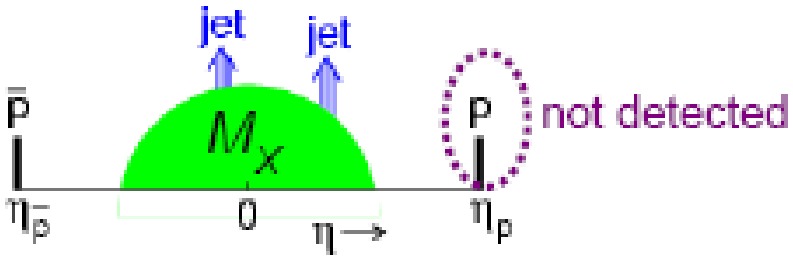
Provides most stringent limits on many new heavy particles

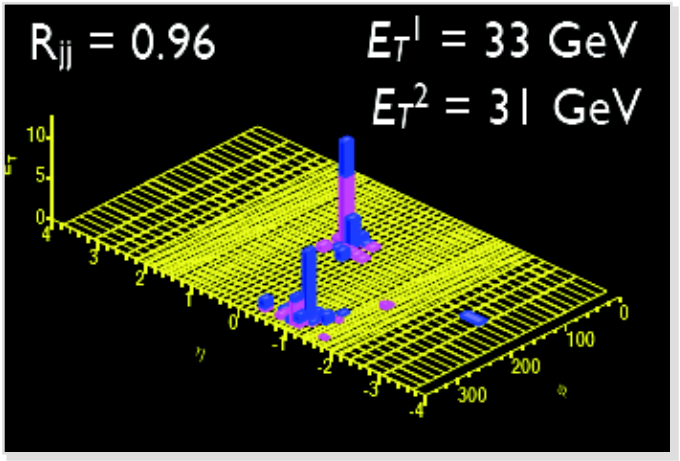
Exclusive Dijet Production

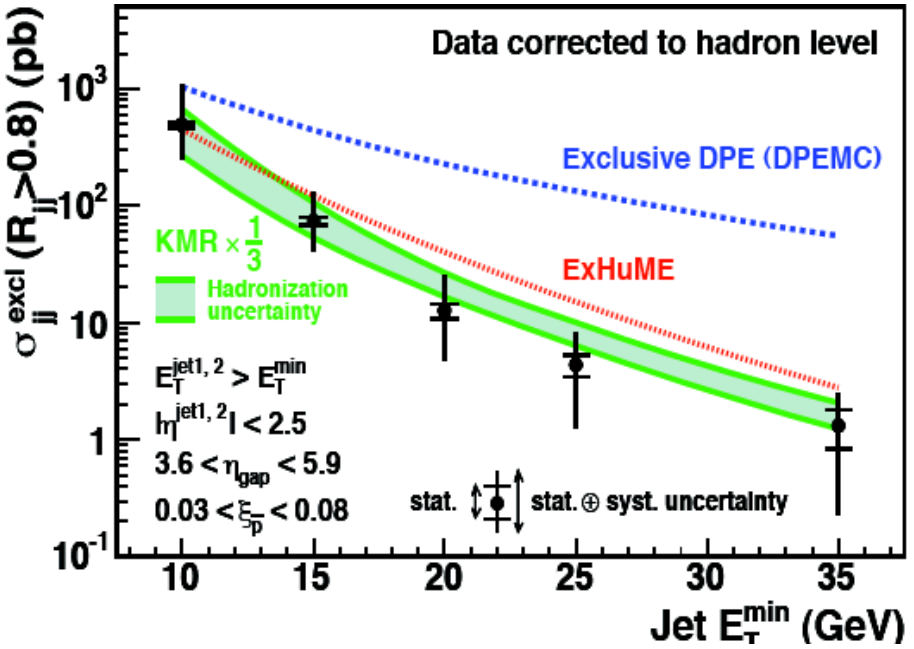
see Dino's talk tomorrow

PRD 77, 052004 (2008)



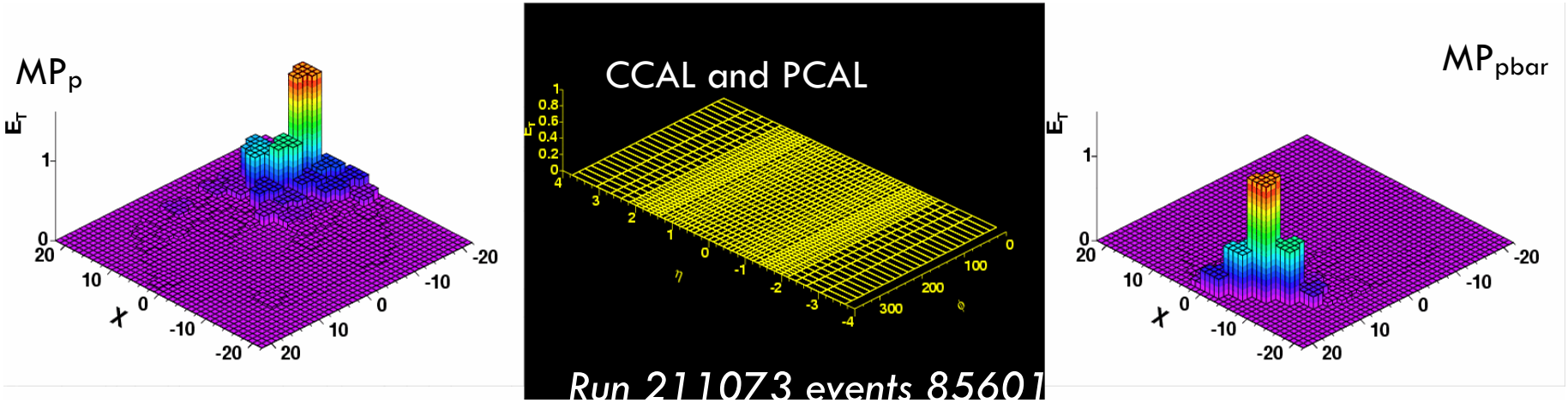




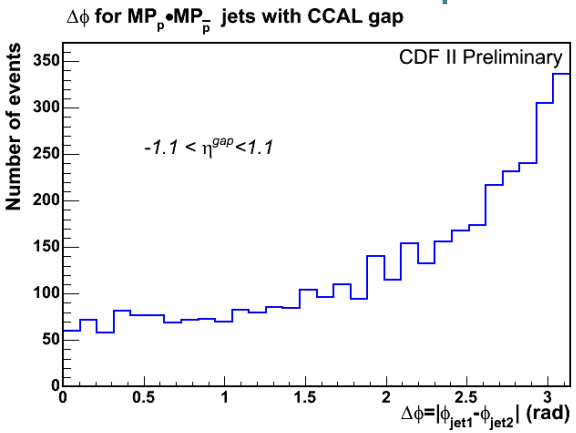


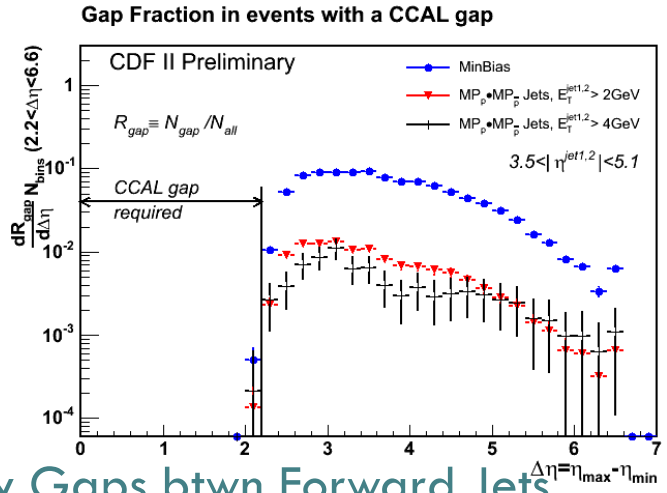
Forward Jets Studies

see Dino's talk tomorrow



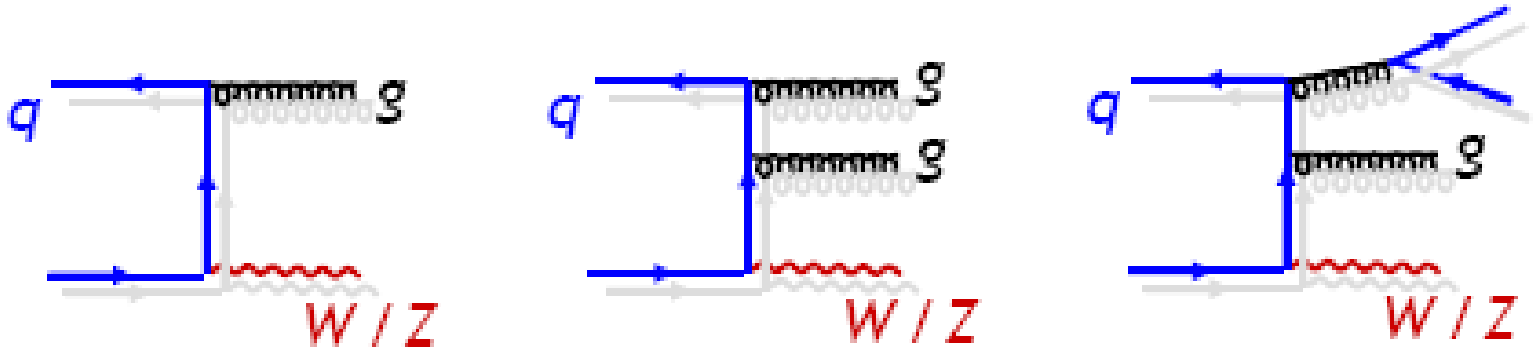
Mueller-Navelet jet studies





Rapidity Gaps btwn Forward Jets

W/Z + Jets Production



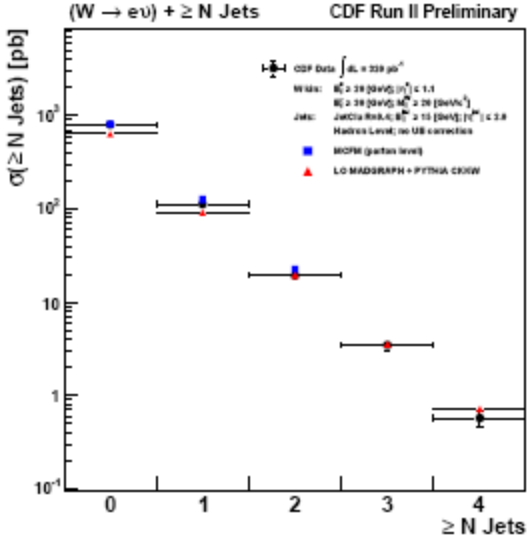
- relevant to other high-multiplicity processes
- background to Higgs,
- test "matched" predictions → critical to Tevatron / LHC physics

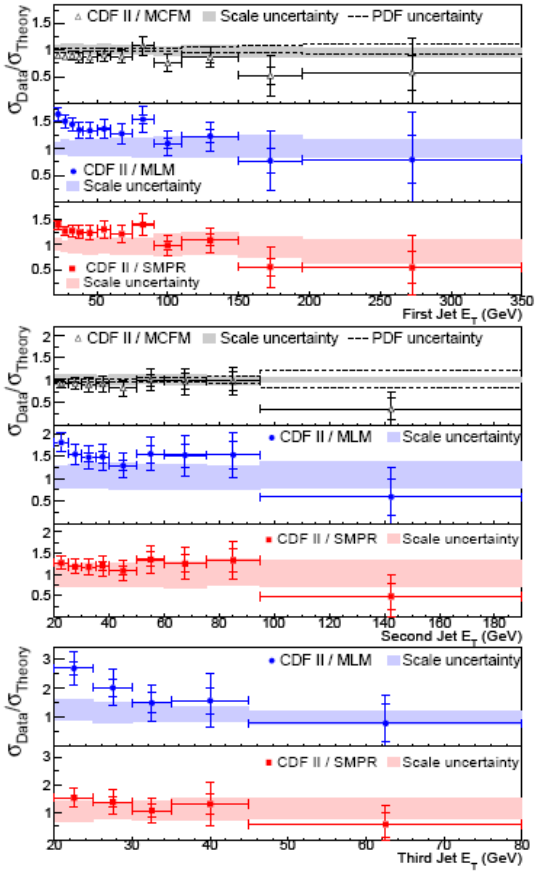
- Many Monte Carlo tools are available:
  - LO+Parton shower Monte Carlo (Pythia, Herwig,)
  - Matched tree level matrix elements +parton shower Monte Carlo (Alpgen, Sherpa,…)
  - These toola and calculations need validation by expem. measurements

W+Jets Production

Phys. Rev. D77, 011108(R)(2008)

- Trigger on high E_T central electron
- Identify W:
  - E_T^e>20 GeV, $|\eta^e|$<1.1
  - Missing E_T>30 GeV
  - m_T>20 GeV/c^2
- Identify Jets:
  - JetClu cone 0.4 with
  - E_T>20 GeV, $|\eta|$<2.0
  - $\Delta R^{e\text{-}jet}$ >0.52
- Measure $\sigma(E_T^{jet})$ at a hadron level
  - cf. LO, NLO predictions





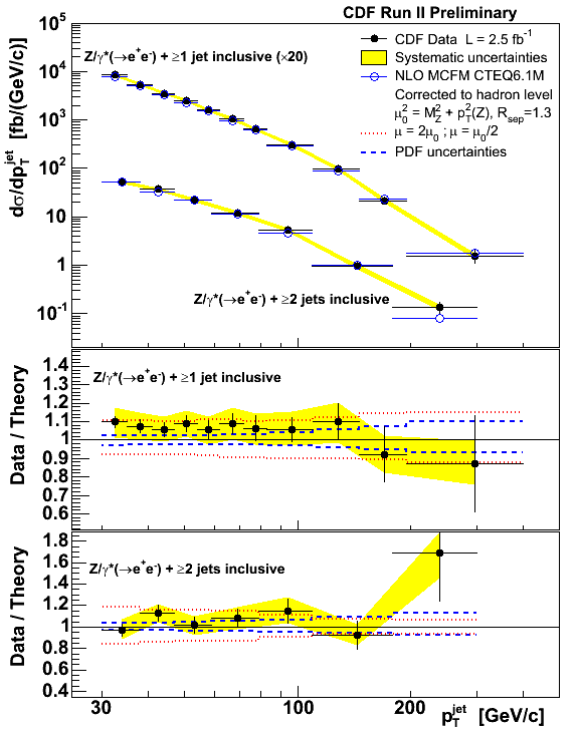
NLO: MCFM (W+1,2 jets available)
LO: ME+PS+nonpQCD correction:
SMPR: Madgraph, CTEQ6L, Pythia
MLM: Alpgen, CTEQ5L, HERWIG

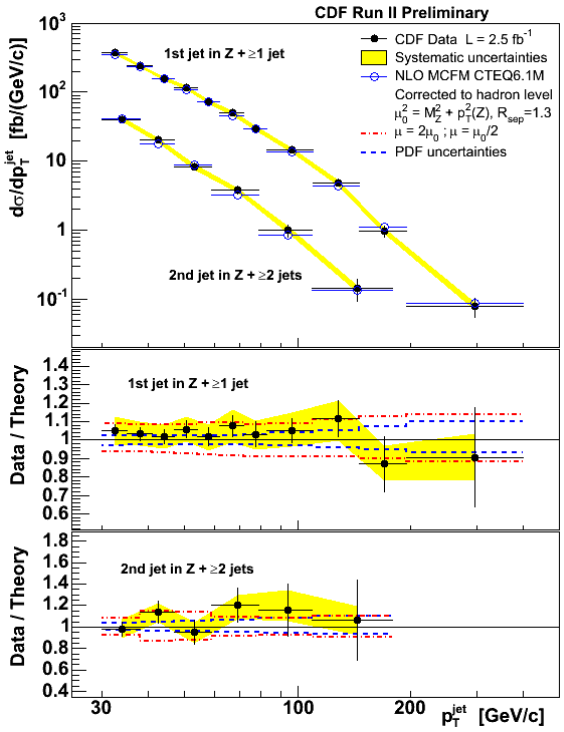
Good agreement with NLO predictions

Z+Jets Production

Phys.Rev. Lett. 100, 102001 & update

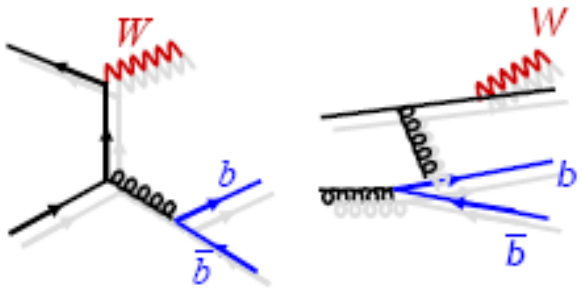
Data and NLO pQCD in agreement
Good control sample for SUSY

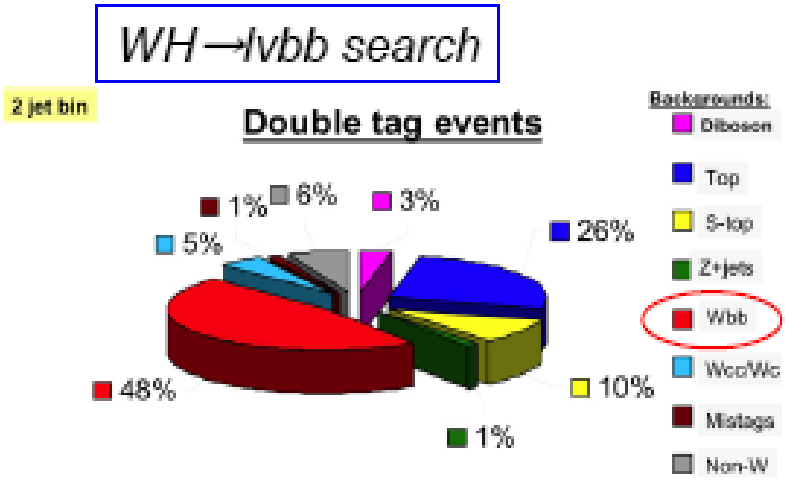




W+b-Jet Production

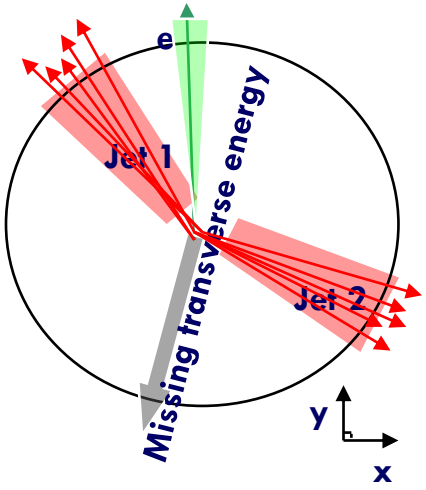
Large background for many rare analysis





Event Selection:

Leptonic W decays



CDF end view
Transverse plane

W→lν, where l=e or μ

Jet E_T >20 GeV

|η|<1.5

σ b-jets (W+b-jets) · BR(W → lν) = 2.74 ± 0.27 (stat) ± 0.42(syst) pb

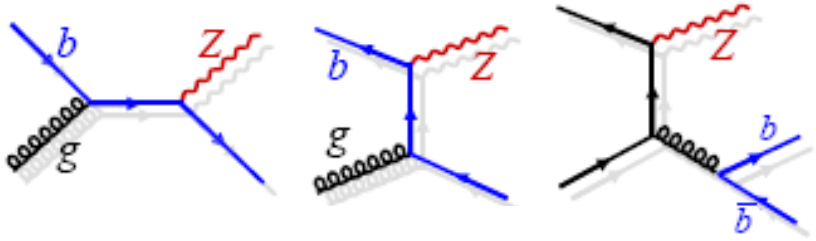
NLO : 1.22±0.14 pb

Alpgen: 0.78pb

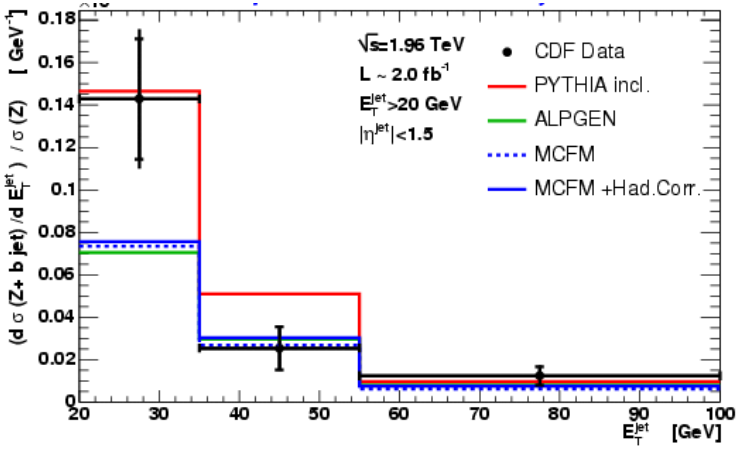
Z+b-Jet Production

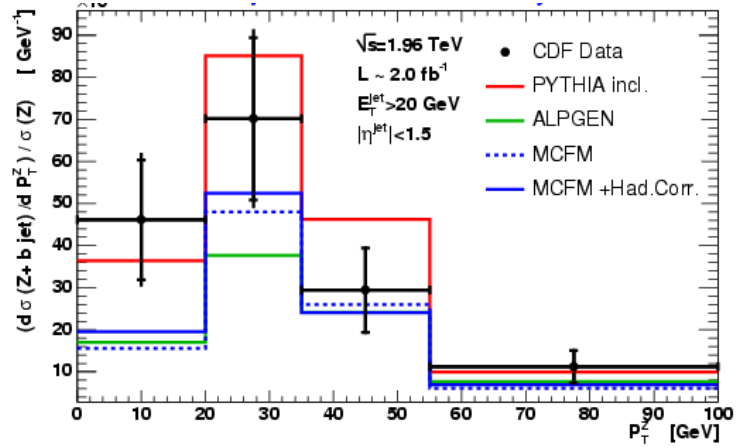
Probe the less-known *b*-content of the proton

Backgrounds for SM Higgs search and SUSY



Phys. Rev. D79, 052008 (2009).





Event Selection:

both electron and muon channels

Jet E_T>20 GeV and $|\eta|$<1.5

$\sigma(Z+b)/\sigma(Z+jets)=2.08\pm0.33\pm0.34(\%)$

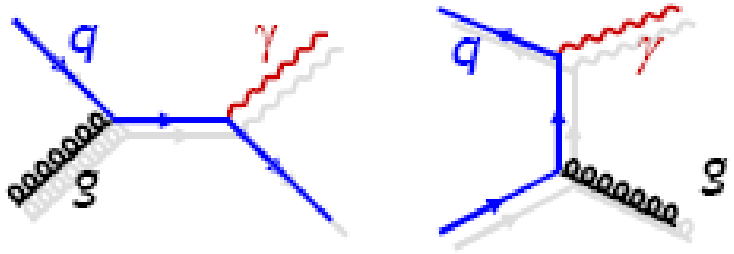
pQCD(MCFM) 1.8(%) for $Q^2=M_Z^2+P_{T,Z}^2$

2.2(%) for $Q^2=\langle P_{T,jet}^2\rangle$

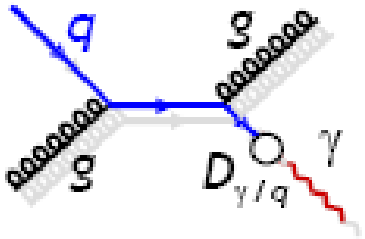
Data and theory are in agreement but both have sizable uncertainties

Direct Photon Production

Direct probe of hard scattering dynamics

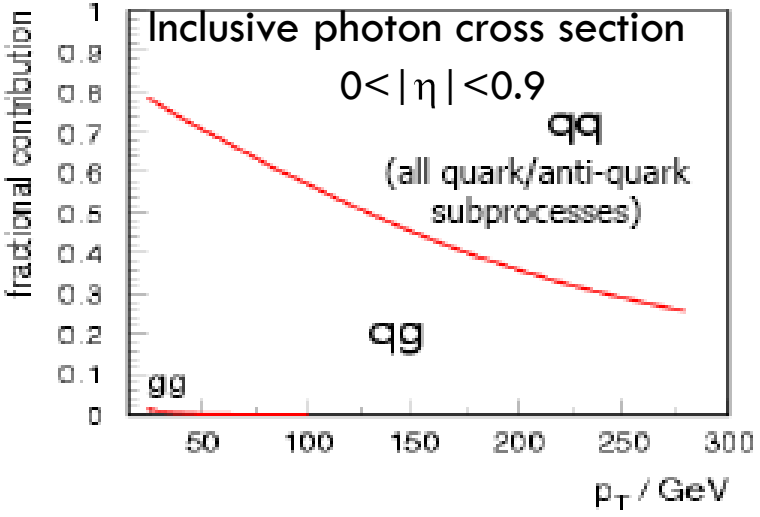


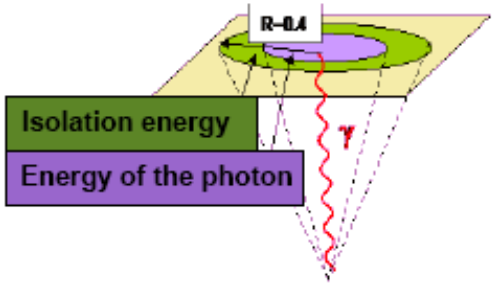
Fragmentation contribution:
Photons accompanied by other particles:
suppressed by ***isolation*** requirements

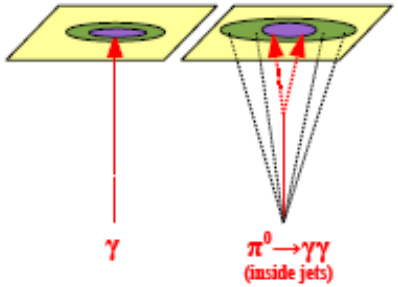


We measure ***isolated photons***:
E_T in R=0.4 < 2 GeV

Potentially sensitive to PDFs



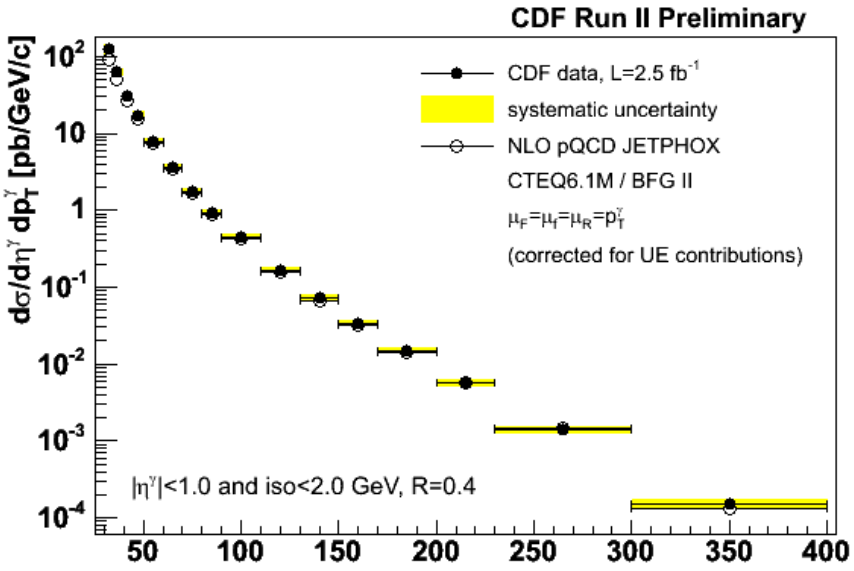


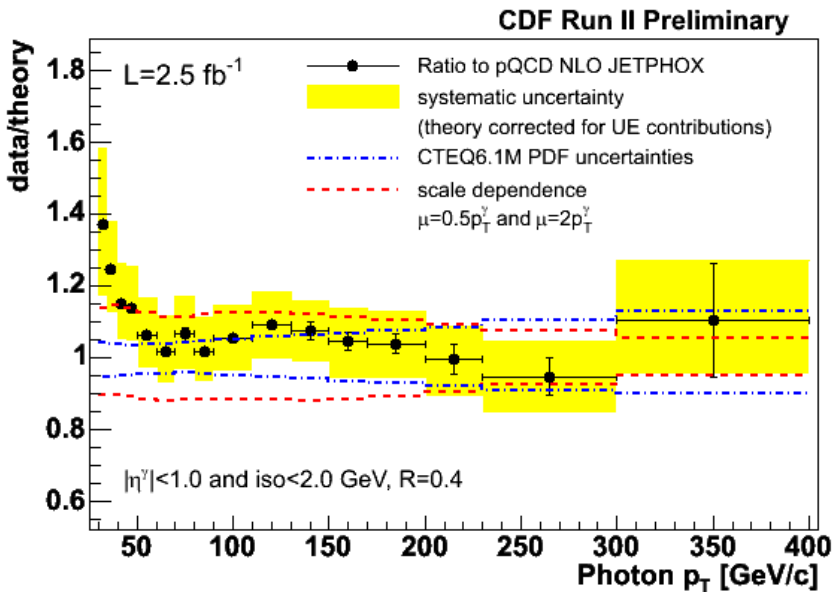


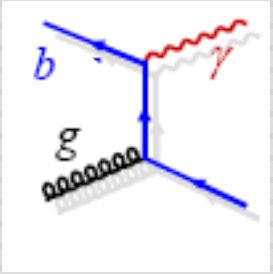
Inclusive Photon Cross Section

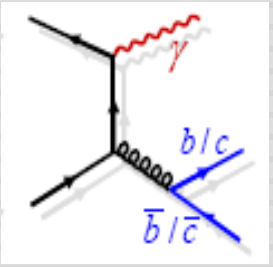
Extends E_T coverage up to 400 GeV
Tests QCD over 6 orders of magnitude

Agreement between data and theory
Different shape at low E_T, as in Run I and UA2







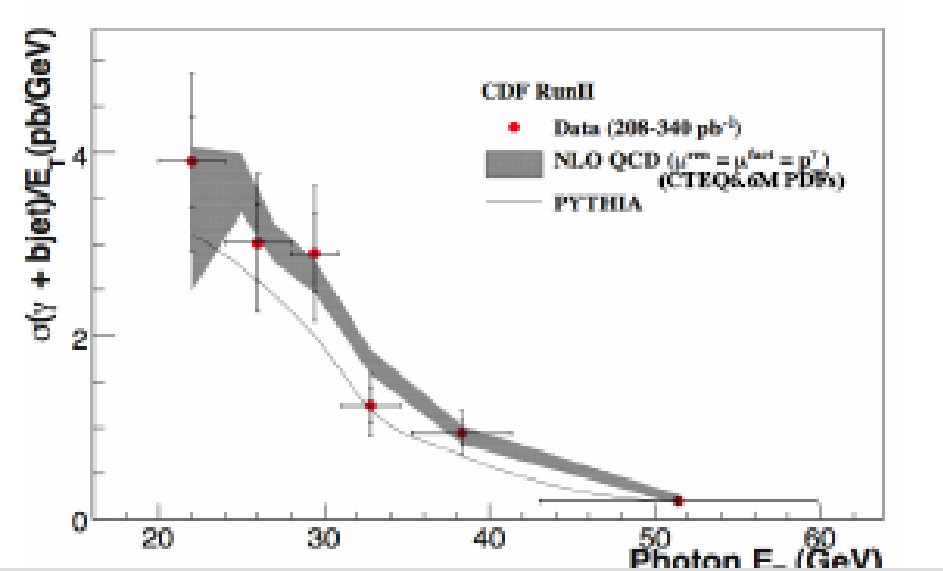


Sensitive to HF of proton

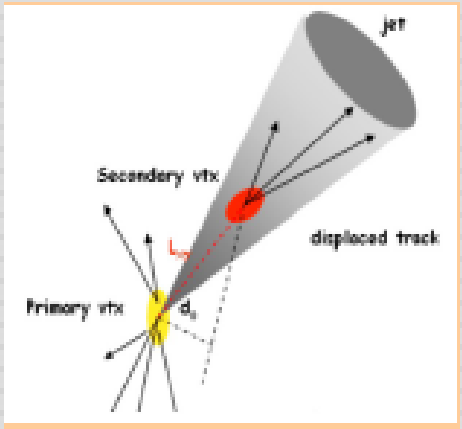
Bkgd for many BSMs

Photon E_T>20 GeV, |y|<1.1

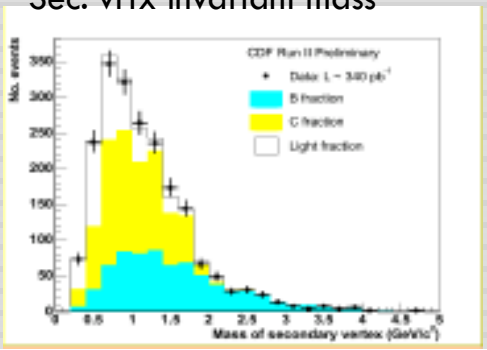
Jet E_T>20 GeV, |y|<1.5, $\Delta R(\gamma,j)$<0.7



B-tagging: Presence of a displaced secondary vertex



B-contribution: extracted using Sec. vrtx invariant mass



Combination of two results with 208 and 340 pb^{-1}

20

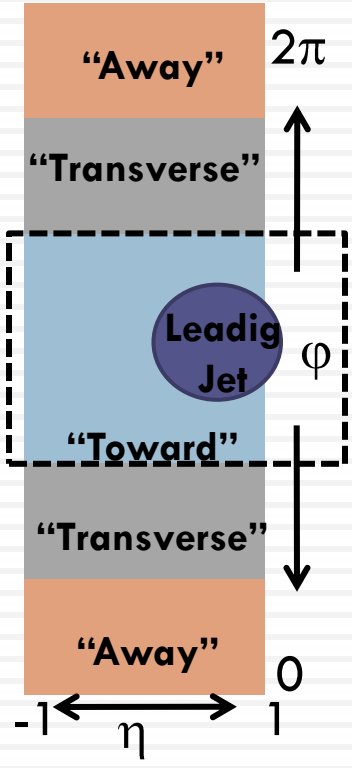
Photon + b-Jet Production

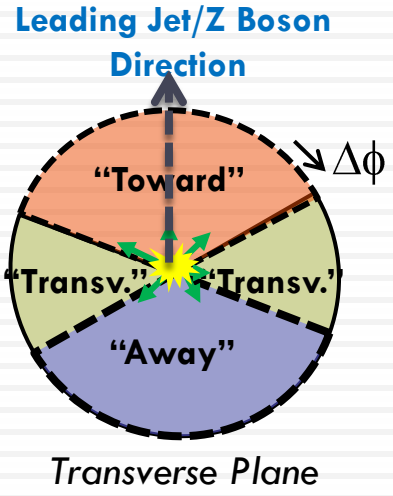
Agreement between data and theory over full p_T^{γ} range

limited statistics

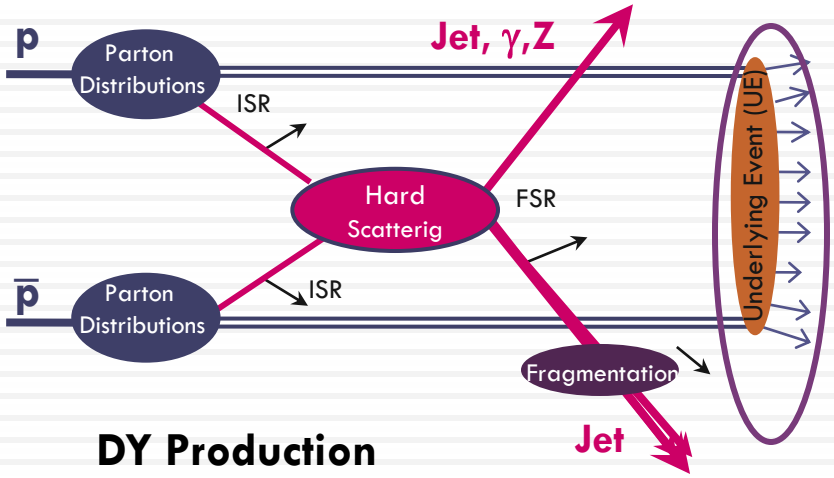
UE: everything except hard scatter

UE in Jet and Drell-Yan Production





Transverse Plane



Jet Production

- Transverse region sensitive to UE
- High statistics jet sample
- Studies in various jet topologies

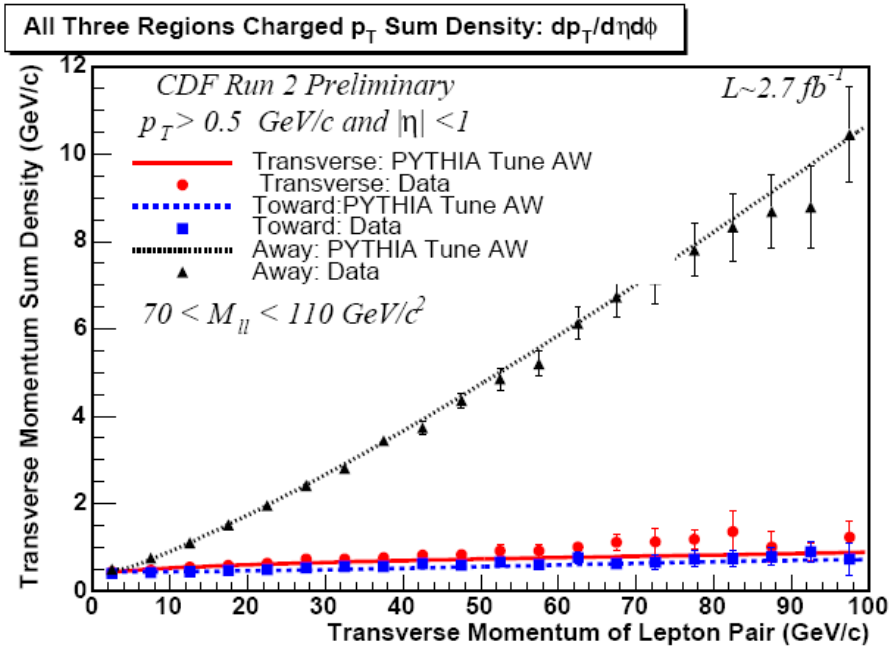
DY Production

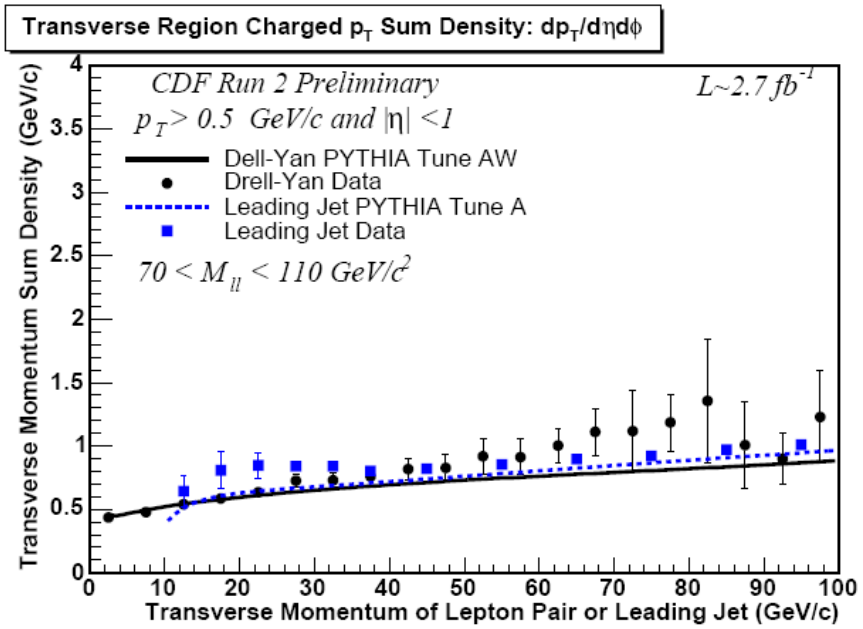
- Transverse and toward regions (excl. lepton pair) sensitive to UE
- Cleaner environment (Z carries no color)
- Limited Statistics

UE in Jet and DY Production

Comparison of 3 regions:

Away region p_T density increases with lepton-pair p_T, whereas transverse and toward region p_T densities mostly flat as a function of lepton-pair p_T





Comparison btwn Jet and DY:

- Similar trend in Jet and DY events: *UE Universality*?
- Tuned PYTHIA describes data reasonably well.

Summary

Precision measurements of fundamental observables @2TeV

- **jet production**

  first look into physics in the TeV regime

  strongest constraints on high-x gluon – for now

- **photon production**

  need to find missing pieces in theory

- **Z/W + jet production**

  many distributions for pQCD tests and for model tuning

- **underlying event**

  strong constraints: tune/improve phenomenological models