New Results from CDF

…plus what I can sneak in from the TeV4LHC workshop

J. Huston

Michigan State University

…thanks to Franco Bedeschi, Florencia Canelli, Giulia Manca, Mario Martinez, Dave Waters, Un-Ki Yang for letting me steal their slides

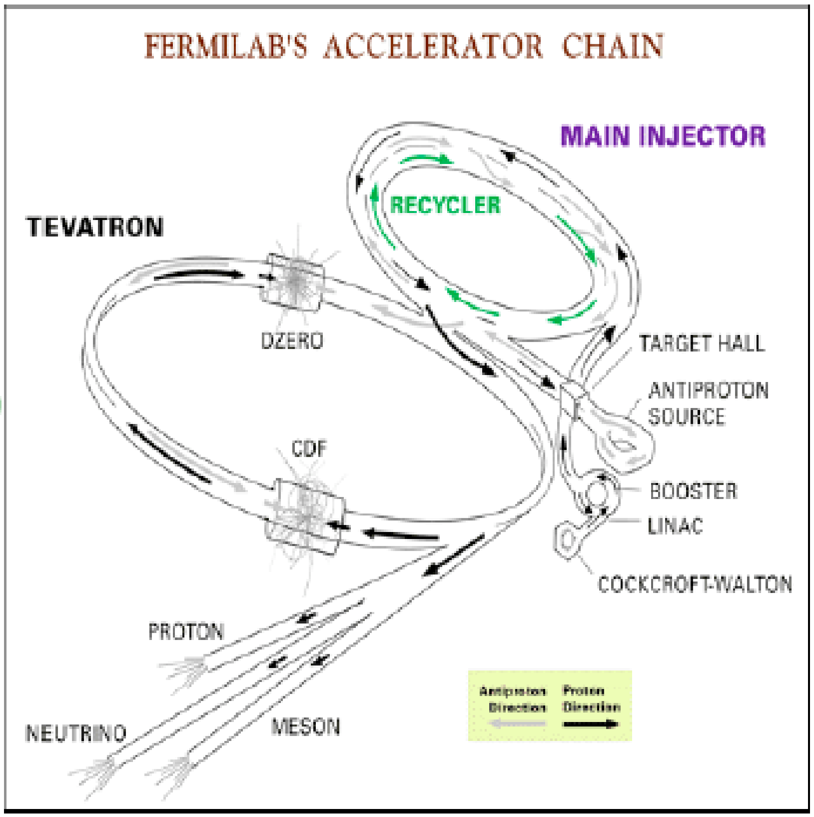
Angels and Demons

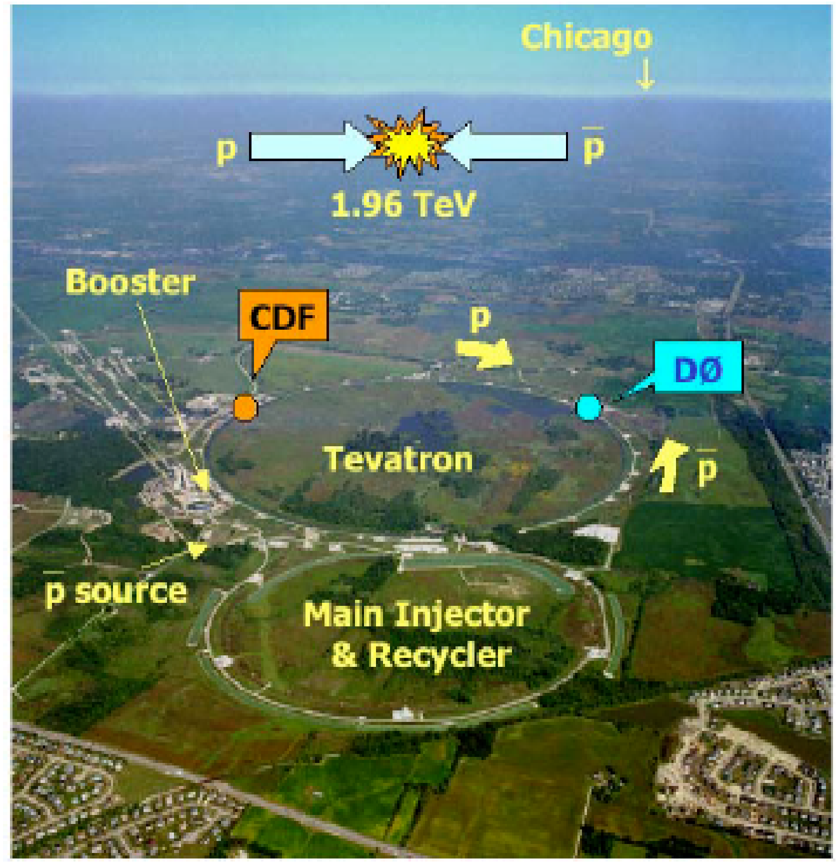
- If I appear to be a bit groggy, it’s because I just arrived this morning
  - after giving my final yesterday
- Of course, this wouldn’t have been a problem if Michelangelo had sent the X-33 like I had asked

Does CERN own an X-33 spaceplane?
Find out what's fact and what's fiction in
Dan Brown's "Angels and Demons"...

Tevatron in Run II

36 bunches (396 ns crossing time)

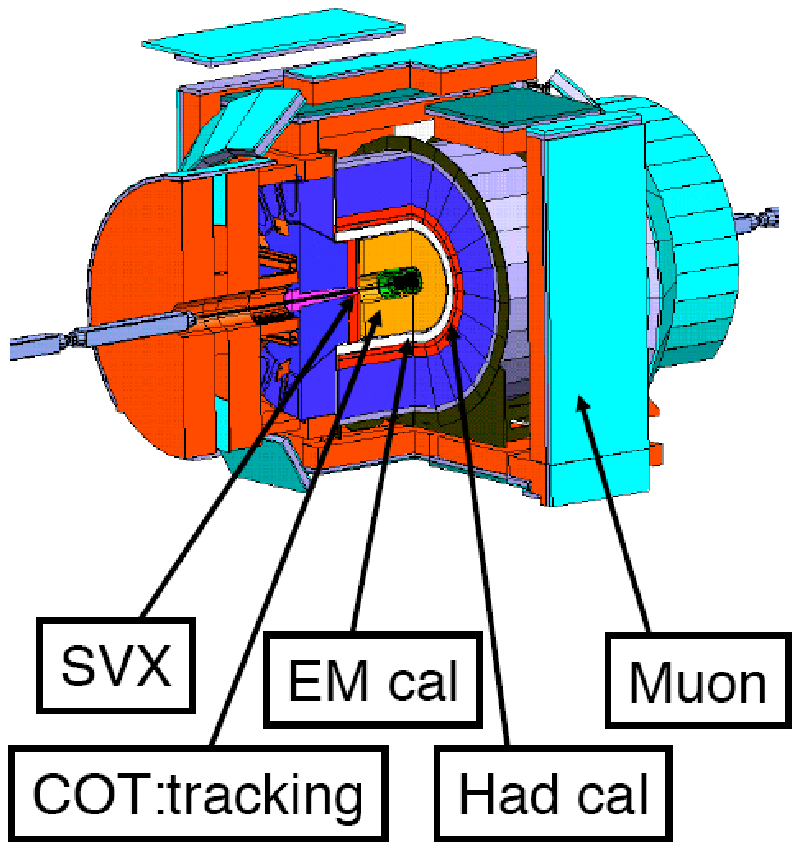




electron cooling this summer → 40% increase in luminosity

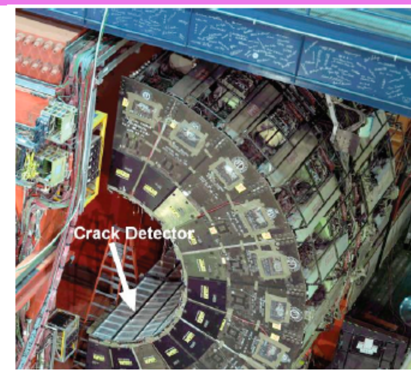
CDF in Run II

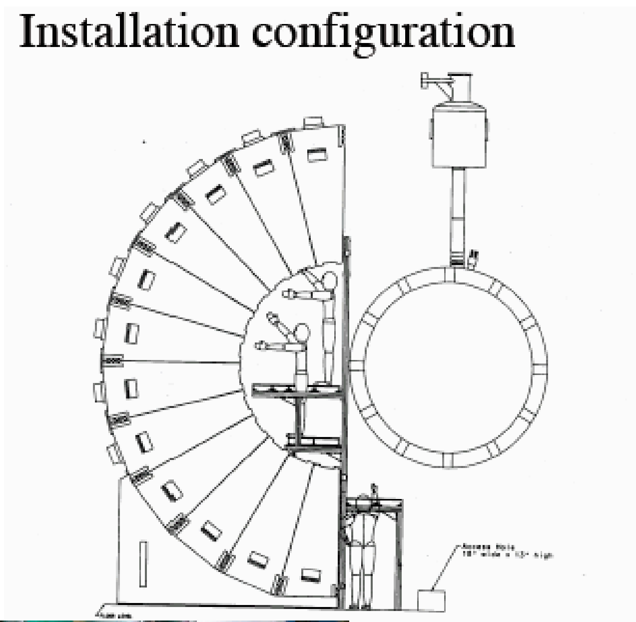
- Silicon detector (SVX):
  - top event b-tag: ~ 55%
- COT: drift chamber
  - Coverage: |η|<1
  - σ_{Pt} / Pt ~ 0.15% P_T
- Calorimeters:
  - Central, wall, plug
  - Coverage: |η|<3.6
  - EM: σ_E / E ~ 14% /√E
  - HAD: σ_E / E ~ 80% /√E
- Muon: scintillator+chamber
  - muon ID up-to |η|=1.5

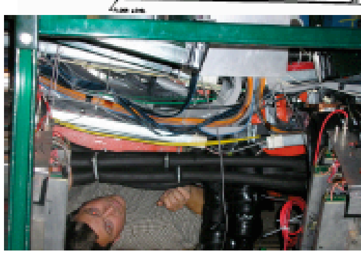


New in 2005 (during fall 2004 shutdown)

- New scintillator-based central preradiator

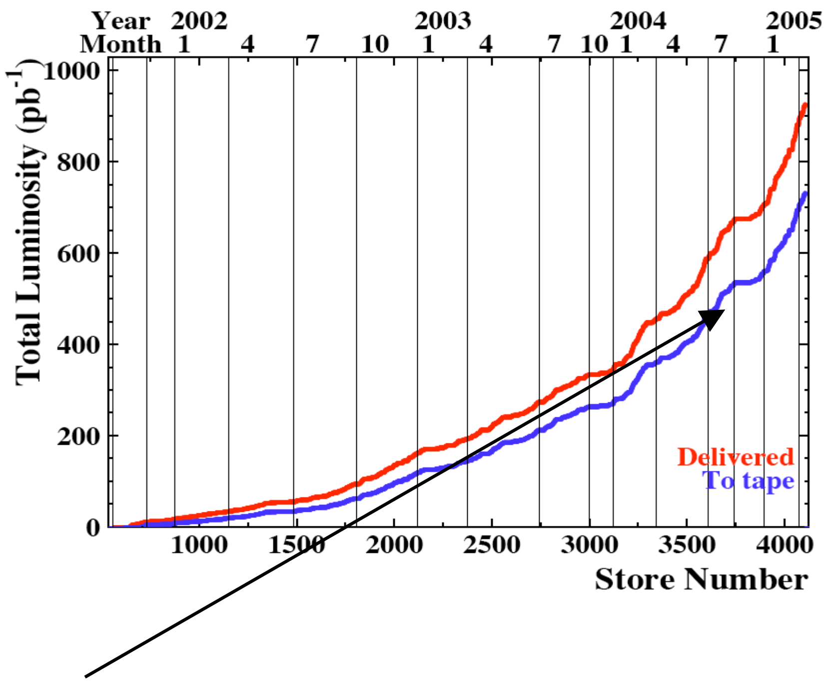






Tevatron Performance

- Theme of this year's Les Houches workshop
  - "From 800 pb^{-1} at the Tevatron to 30 fb^{-1} at the LHC"
- …is accurate, at least for the first part

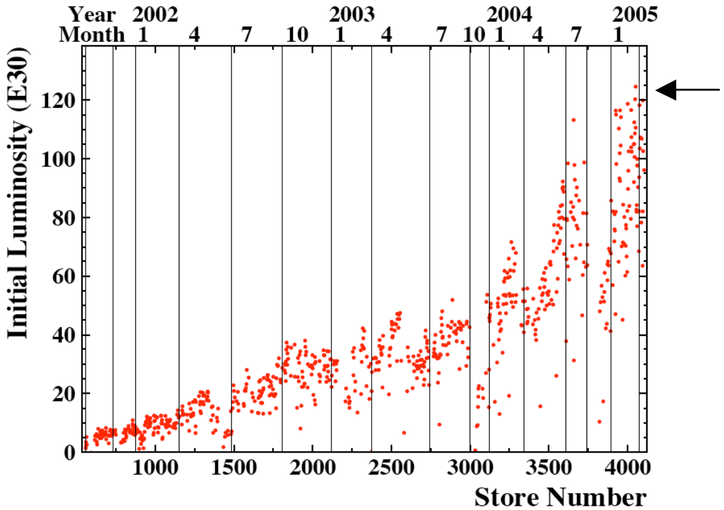


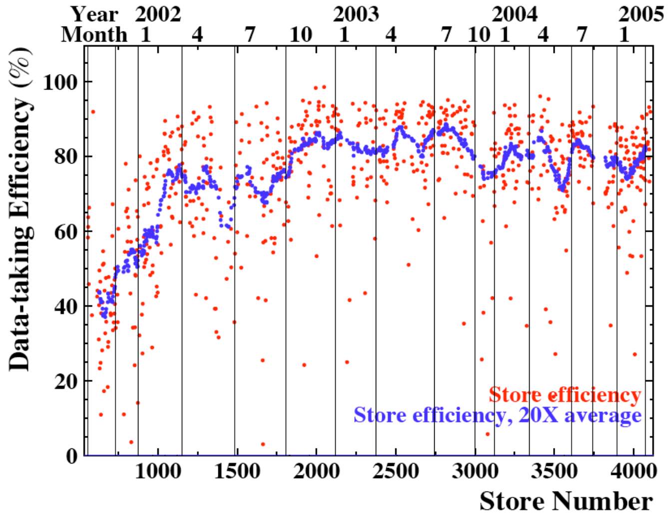
Shutdown: most blessed analyses based on ~400 pb^{-1} before shutdown

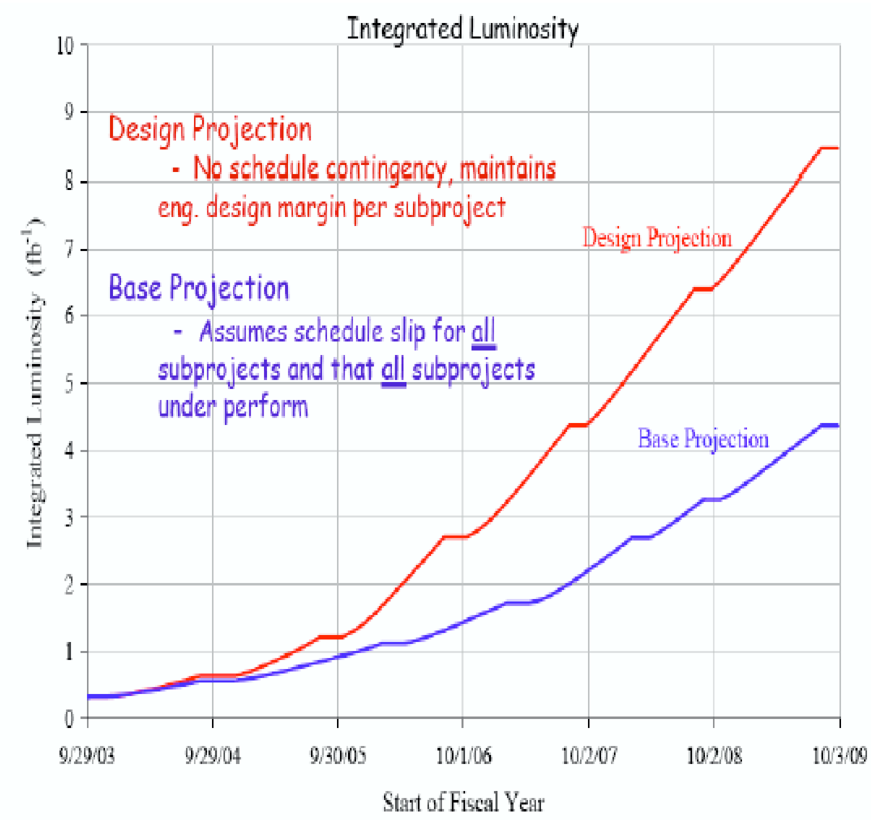
Tevatron Performance

- Tevatron and CDF both peforming well

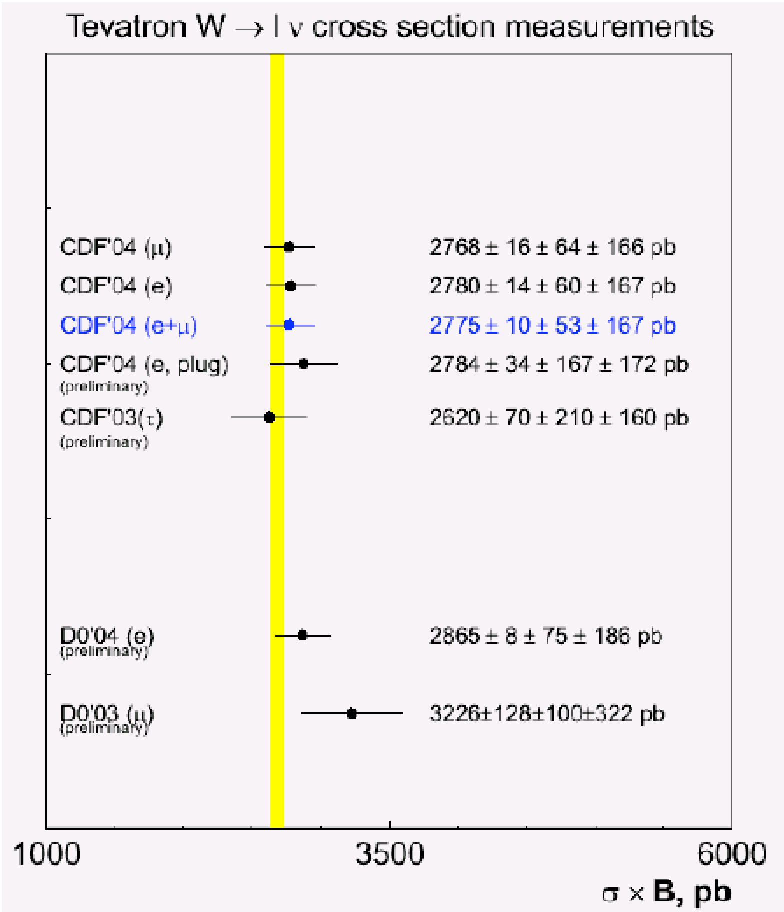
ultimately 4-9 fb^{-1}

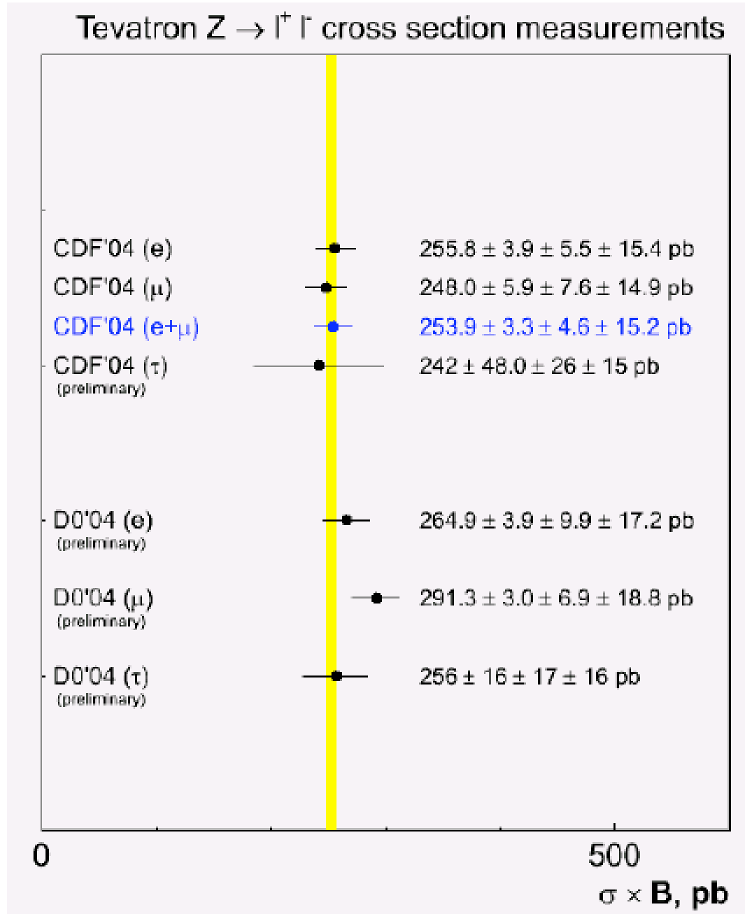






W/Z cross sections at the Tevatron





- good agreement with NNLO predictions
- error dominated by luminosity error (6%)
- 2% systematics (pdf's (acceptance), efficiency) without L error

W cross section as luminosity monitor

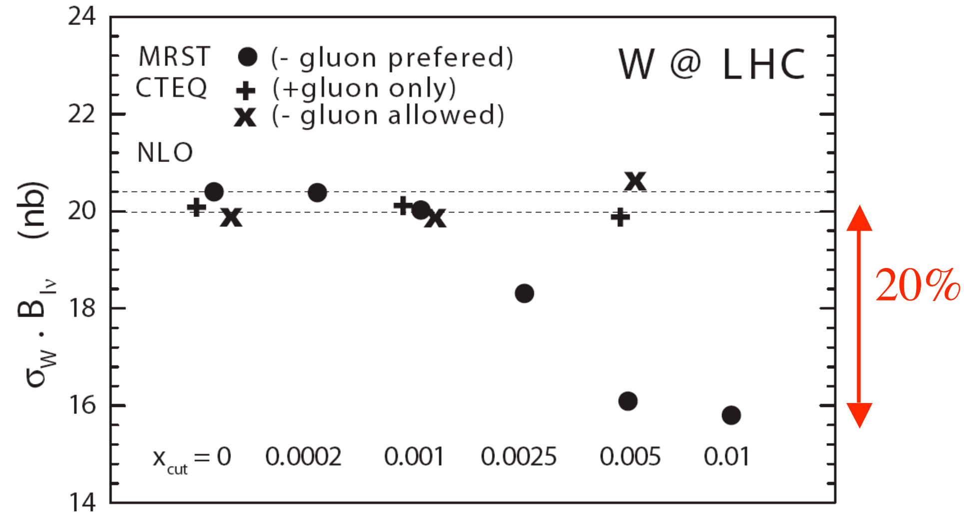
$W \to l\,\nu$ as luminosity monitor

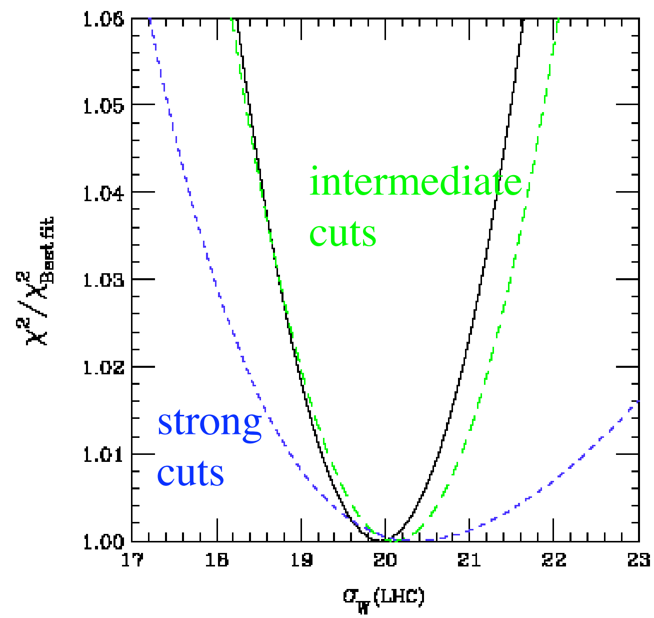
- Current method based on σ_{inel}(ppbar)= 61.7±2.4 mb @ 1.96 TeV (4%)
- Can we do better using the cross section for $W \to l\nu$ measurement?
- Recent paper by Frixione and Mangano (hep-ph/0405130) investigate contributions of uncertainties in acceptance calculation to the $W \to l\nu$ x-sec measurement (currently ~2%)
- Tevatron and LHC would benefit from experimental and theoretical work

…TeV4LHC project

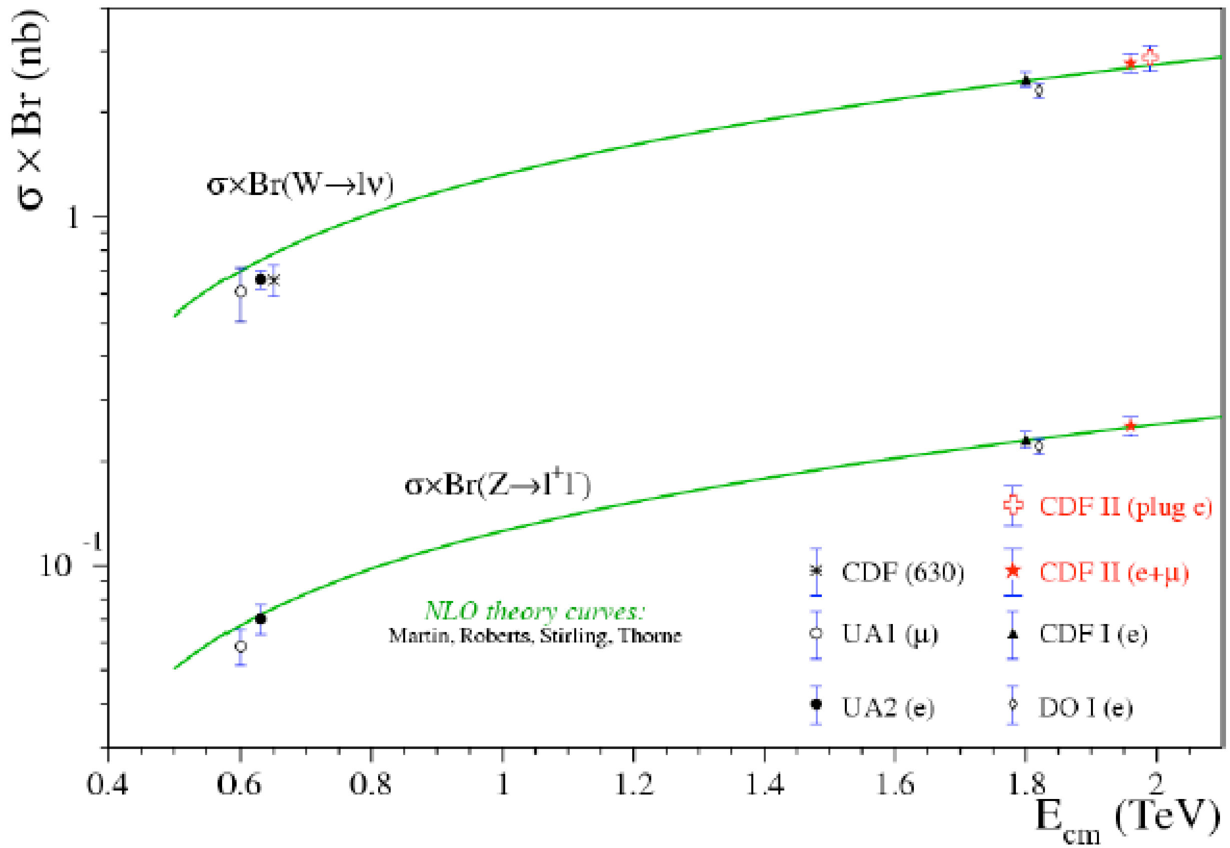
Validity of NLO DGLAP at Tevatron and LHC

- Is there a *tension* between HERA and Tevatron data requiring NNLO DGLAP to resolve?
  - MRST study: hep-ph/0308087
  - W cross section at LHC drops 20% when data below x=.005 are removed from fit
  - implications for use of W σ as luminosity benchmark
- Recent CTEQ study indicates as more severe cuts are made in x and Q^2 in global analysis, uncertainty on W cross section at the LHC increases but central value remains relatively constant
  - hep-ph/0502080
  - accepted by JHEP





W/Z cross sections



$$R = \frac{\sigma_W \times BR(W \to l\nu)}{\sigma_Z \times BR(Z \to l^+ l^-)} = 10.92 \pm 0.15(\text{stat.}) \pm 0.14(\text{syst.})$$

- e, μ combined
- correlated systematics fully taken into account

R(W/Z) and Γ

$$R = \frac{\sigma_W \times BR(W \to l\nu)}{\sigma_Z \times BR(Z \to l^+ l^-)}$$

$$= \frac{\sigma_W}{\sigma_Z} \frac{\Gamma_Z}{\Gamma(Z \to l^+ l^-)} \frac{\Gamma(W \to l\nu)}{\Gamma_W}$$

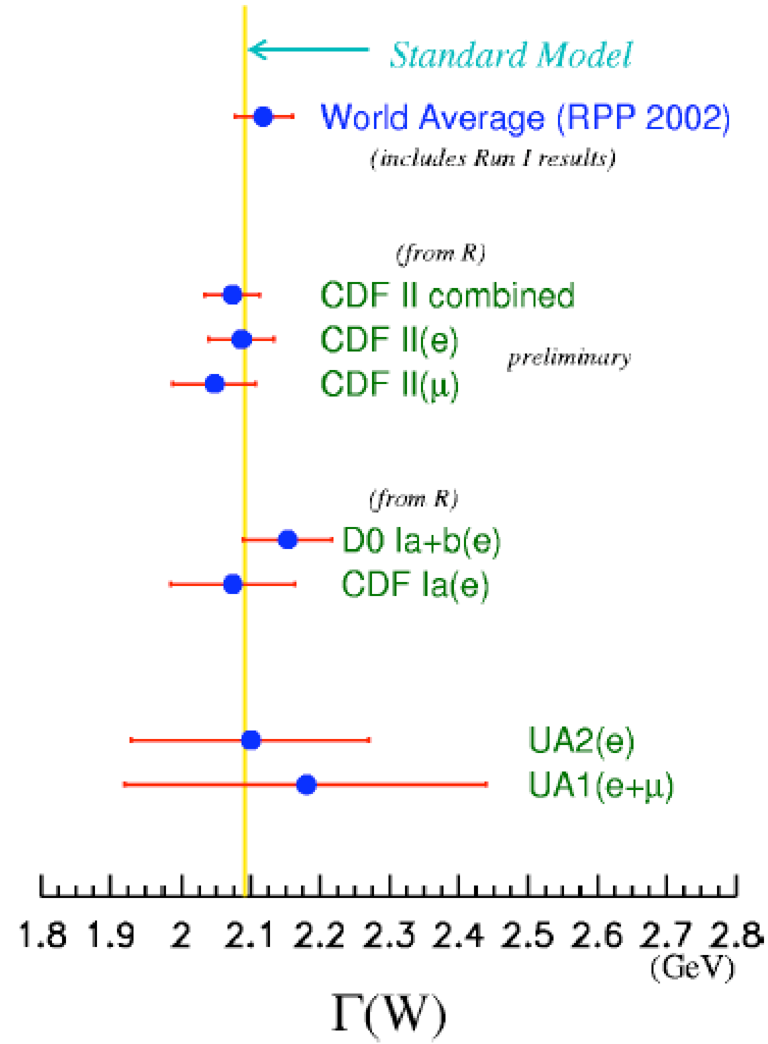
$\frac{\sigma_W}{\sigma_Z}$ → SM : 3.361 ± 0.024

$\frac{\Gamma_Z}{\Gamma(Z \to l^+ l^-)}$ → LEP

$\Gamma(W \to l\nu)$ → SM : 226.4 ± 0.3 MeV

$$\Gamma_W(\text{indirect}) = 2.079 \pm 0.041 \text{ GeV}$$

$$\Gamma_W(\text{WA}) = 2.118 \pm 0.042 \text{ GeV}$$



W charge asymmetry

$$A(y_W) = \frac{d\sigma(W^+)/dy_W - d\sigma(W^-)/dy_W}{d\sigma(W^+)/dy_W + d\sigma(W^-)/dy_W}$$

$$A(y_W) \approx \frac{u(x_1)d(x_2) - d(x_1)u(x_2)}{u(x_1)d(x_2) + d(x_1)u(x_2)}$$

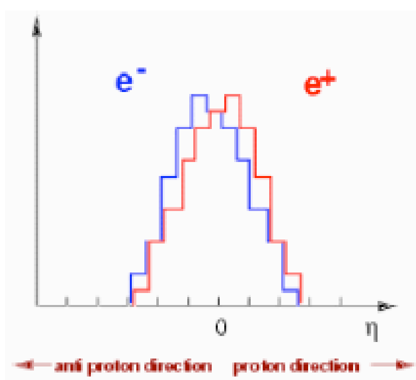
Rapidity charge asymmetry is sensitive to **d(x)/u(x)** ratio at high-**x** → primary interest of PDF fitters.

- cannot reconstruct y_W directly
- measure charged lepton only

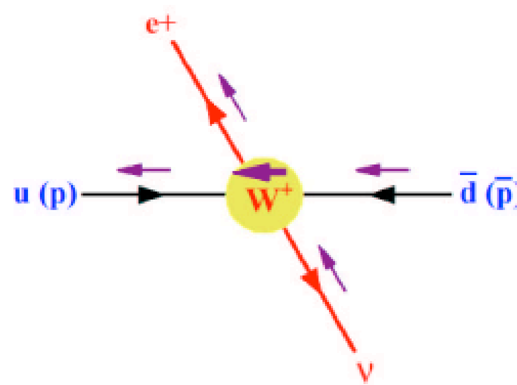
→

$$A(\eta_l) = \frac{d\sigma(l^+)/d\eta_l - d\sigma(l^-)/d\eta_l}{d\sigma(l^+)/d\eta_l + d\sigma(l^-)/d\eta_l}$$

$A(\eta_l) =$

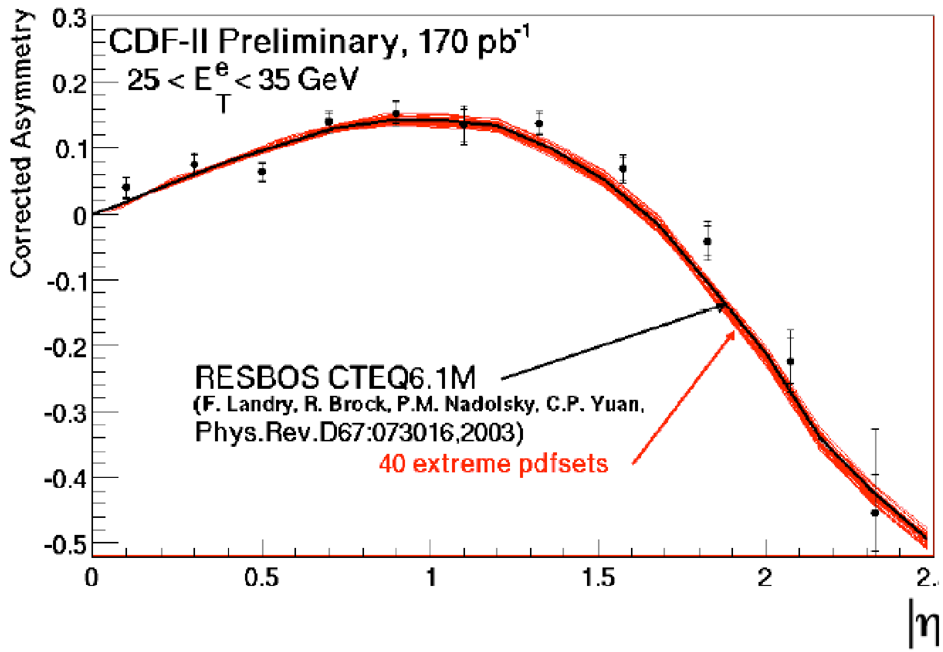


$\otimes$

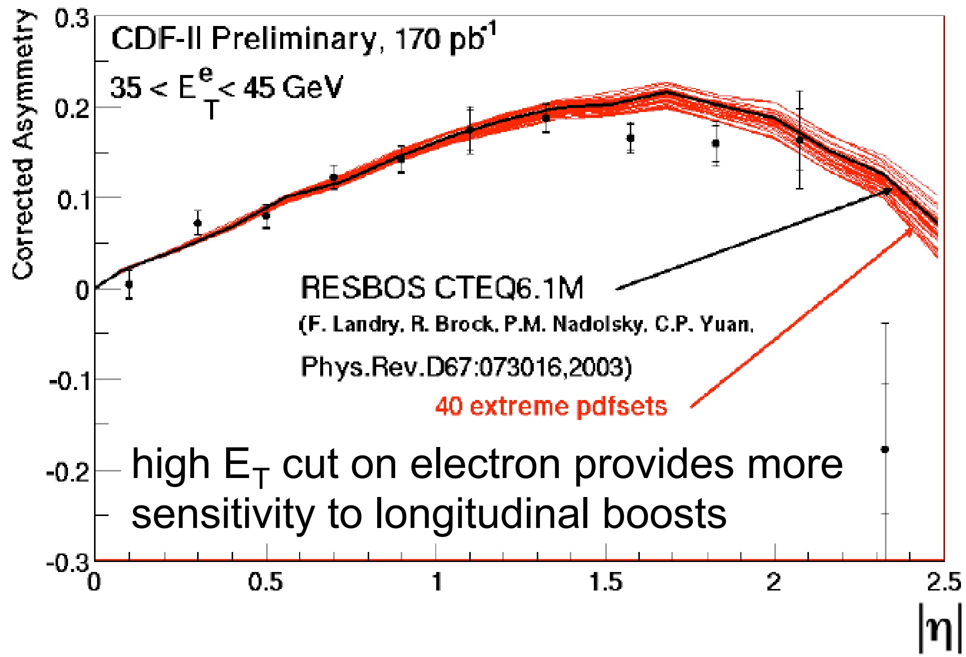


W asymmetry

CTEQ6.1M with RESBOS at NLO

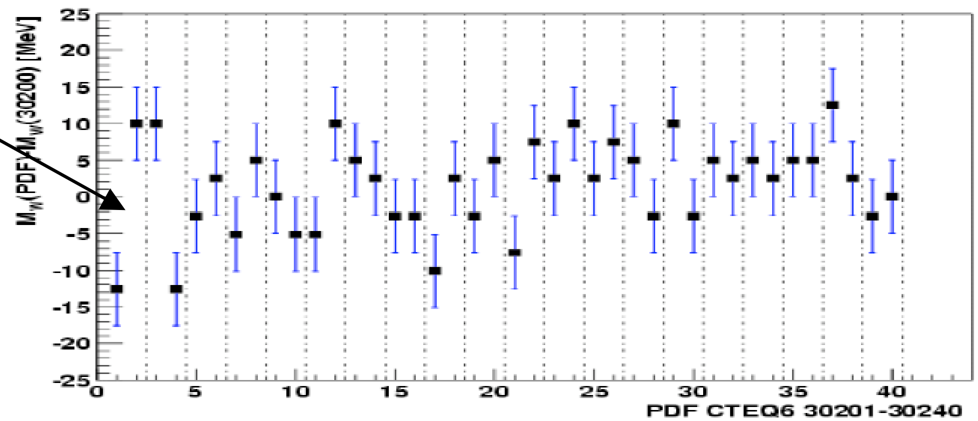


CTEQ6.1M with RESBOS at NLO



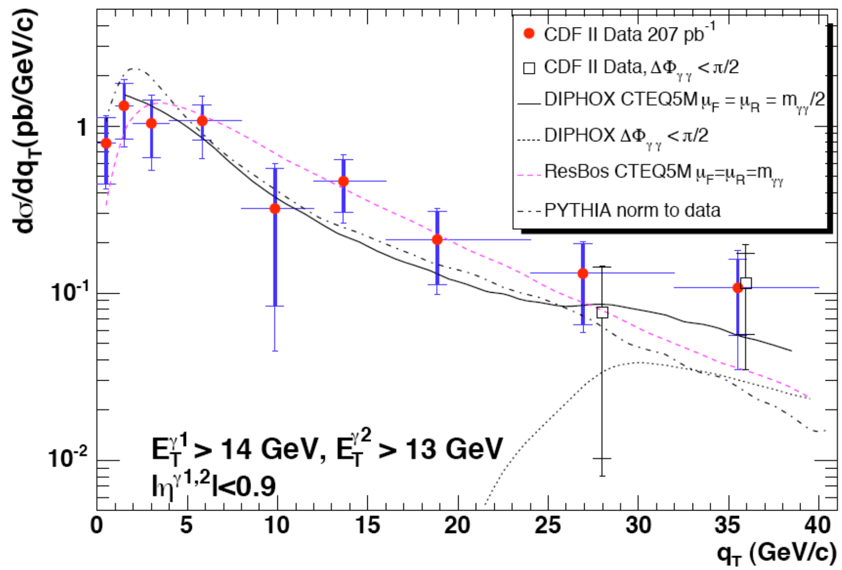
error pdf's that have largest impact on W mass uncertainty also cause large deviations at high η

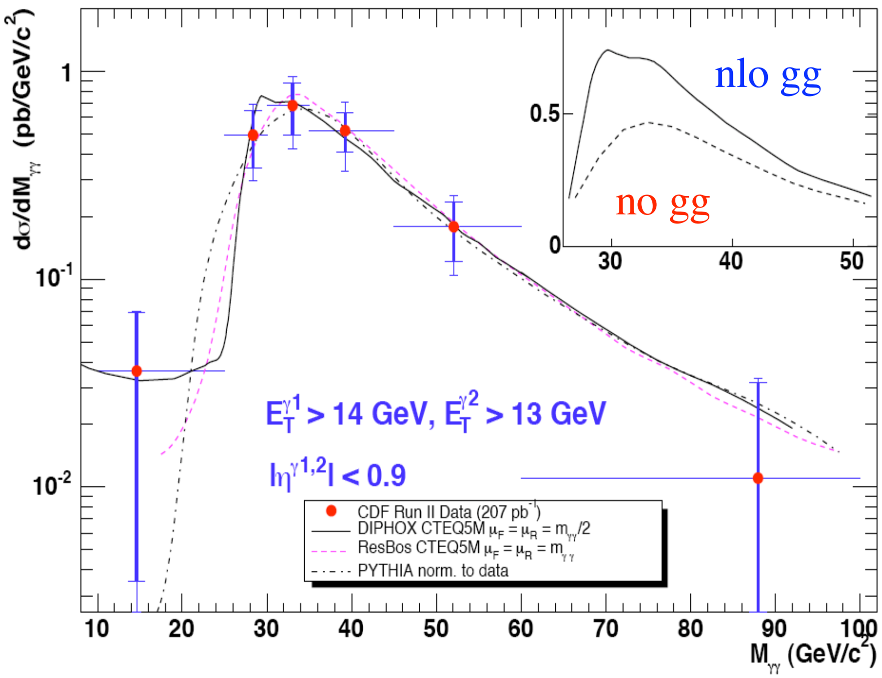
probe u and d valence dists

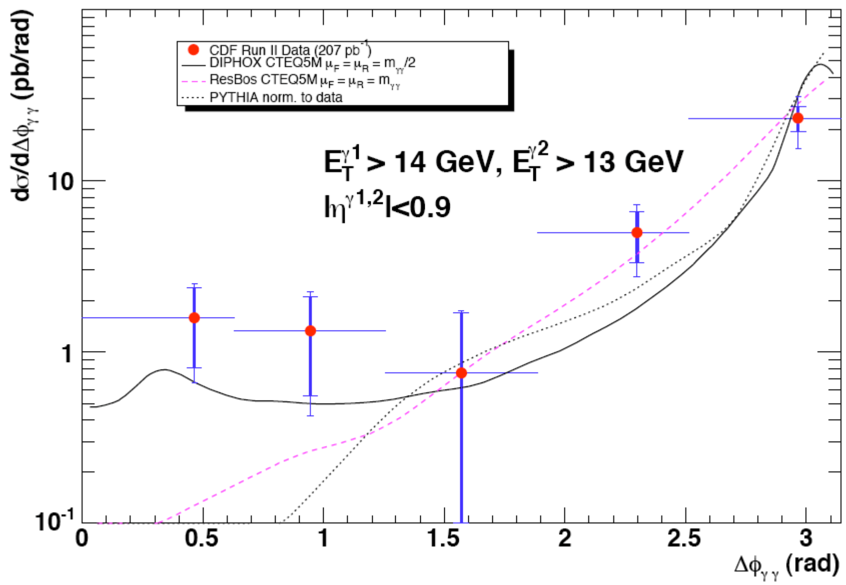


Diphotons in Run II

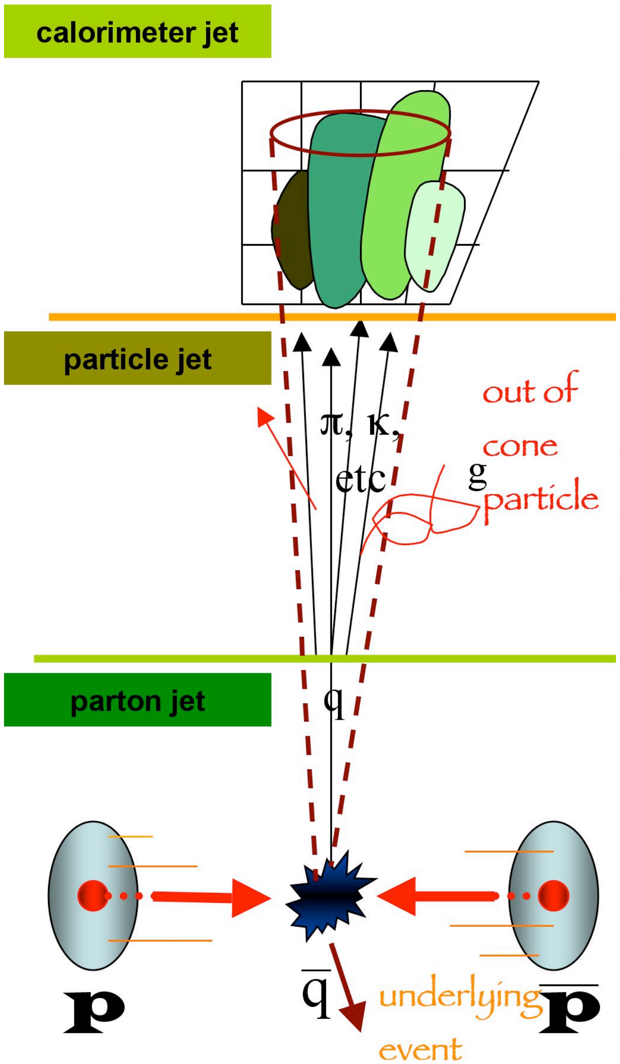
- small q_T, large $\Delta\phi$: effects of gluon resummation evident
- large q_T, small $\Delta\phi$: NLO fragmentation important

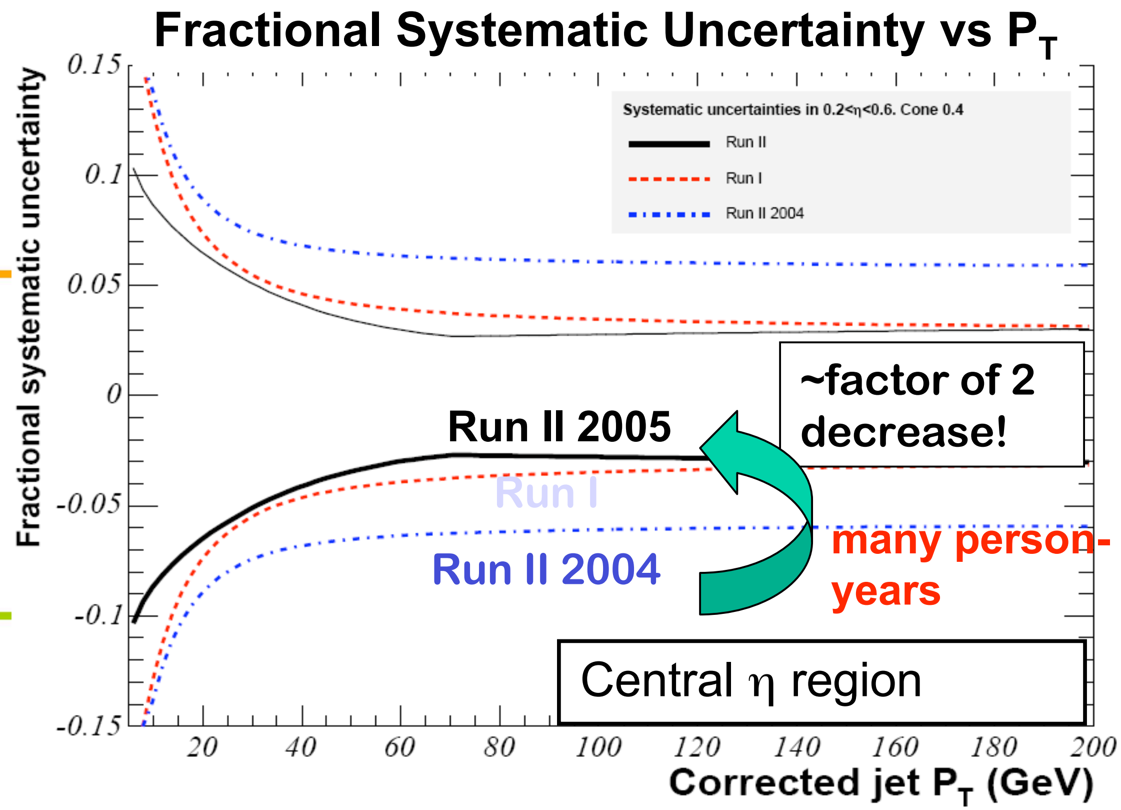






Jet Energy Scale: New

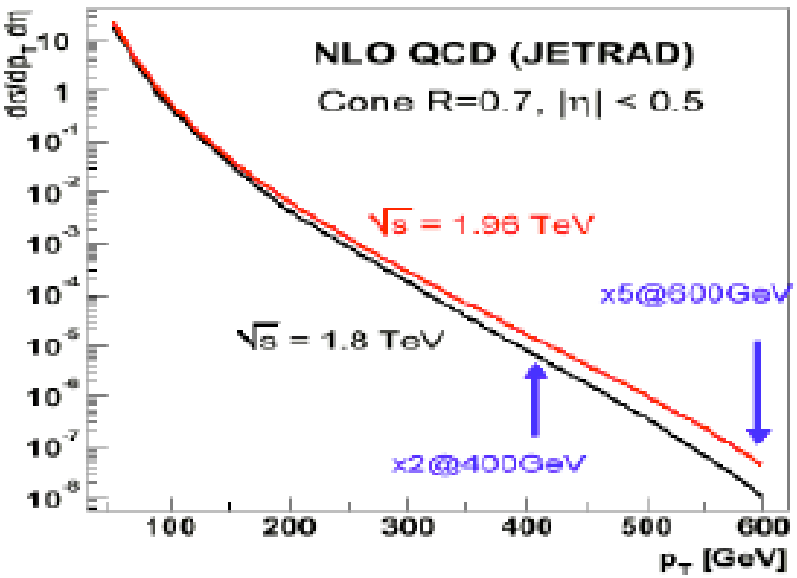




have to correct calorimeter energy depositions for detetector, algorithm and physics effects to obtain "true" jet energy

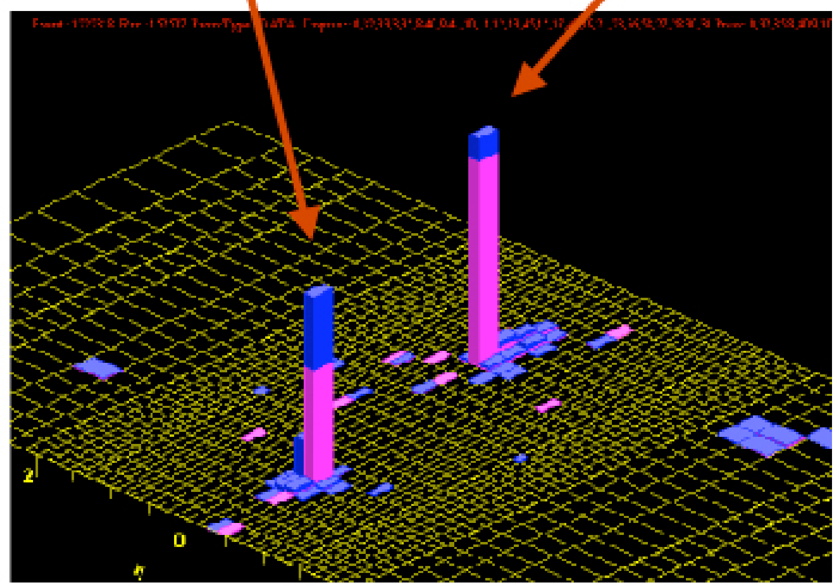
Inclusive Jet Production

- Nowhere is the increase in center-of-mass energy more appreciated



J2 E_T = 633 GeV (corr)
546 GeV (raw)
J2 η = -0.30 (detector)
= -0.19 (correct z)

J1 E_T = 666 GeV (corr)
583 GeV (raw)
J1 η = 0.31 (detector)
= 0.43 (correct z)



CDF Run 2 Preliminary

Jet algorithms

- Run II analyses in CDF use both cone and k_T jet algorithm
  - CDF has used both JetClu (Run I) and midpoint (Run II) cone algorithms

midpoint improves perturbative behavior

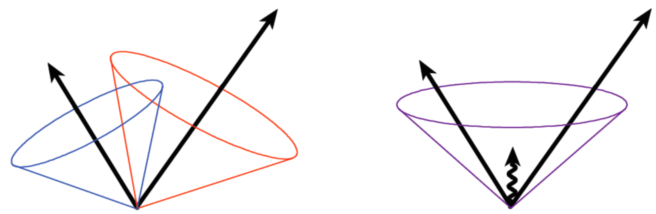
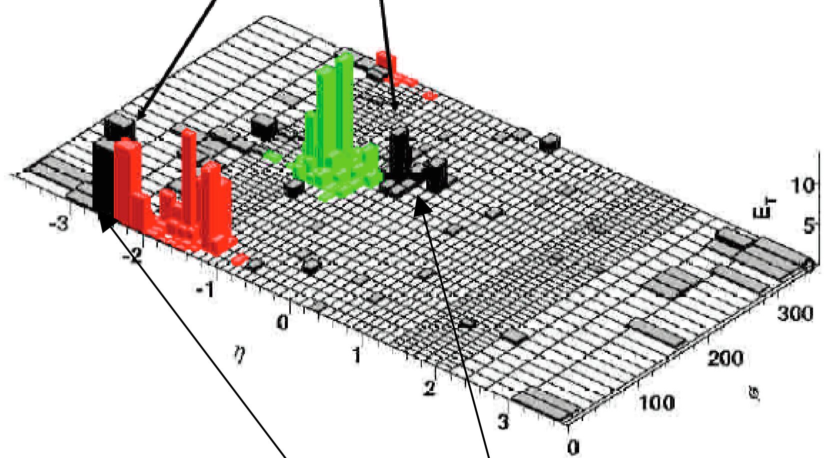
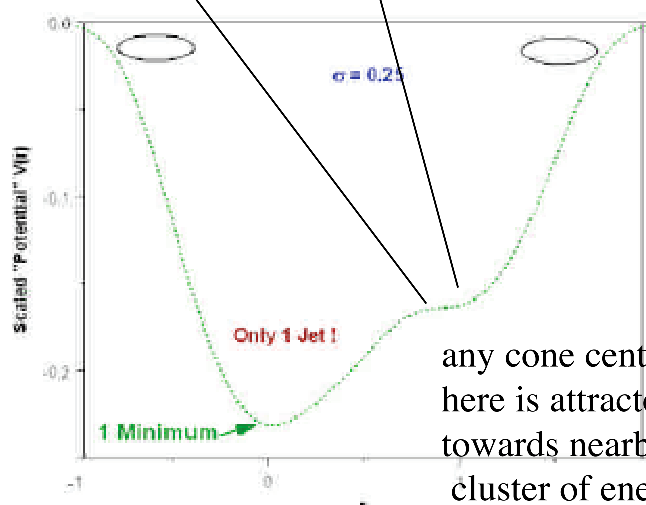


FIG. 1: Two partons in two cones or in one cone with a (soft) seed present.

- subtle issues regarding use of cone algorithms at hadron colliders
  - see hep-ph/0111434, S. Ellis, J. Huston, M. Tonnesmann, *On Building Better Cone Jet Algorithms*
  - under study in both Tevatron and LHC experiments as part of TeV4LHC workshop (and Les Houches)

Missed Towers (not in any stable cone) – How can that happen? Does DØ see this?

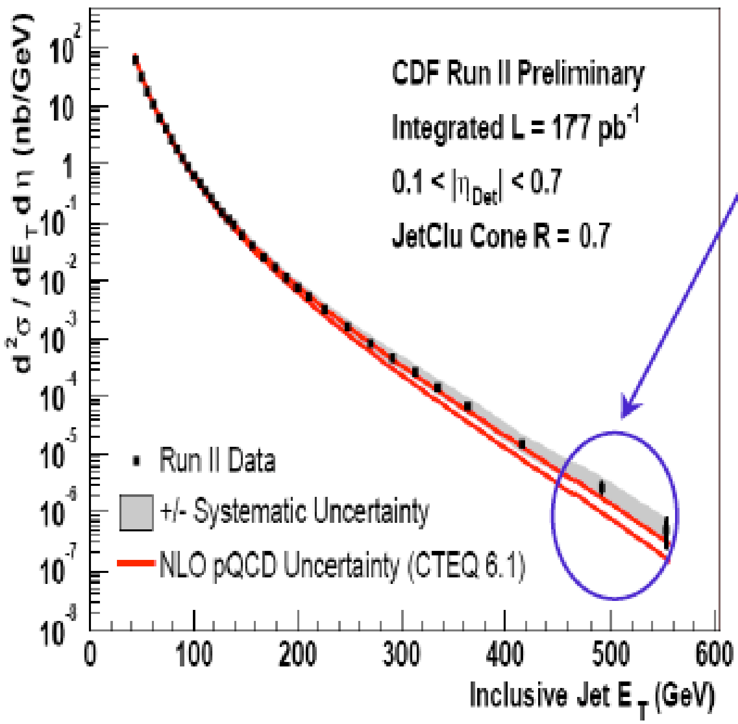




any cone centered here is attracted towards nearby large cluster of energy

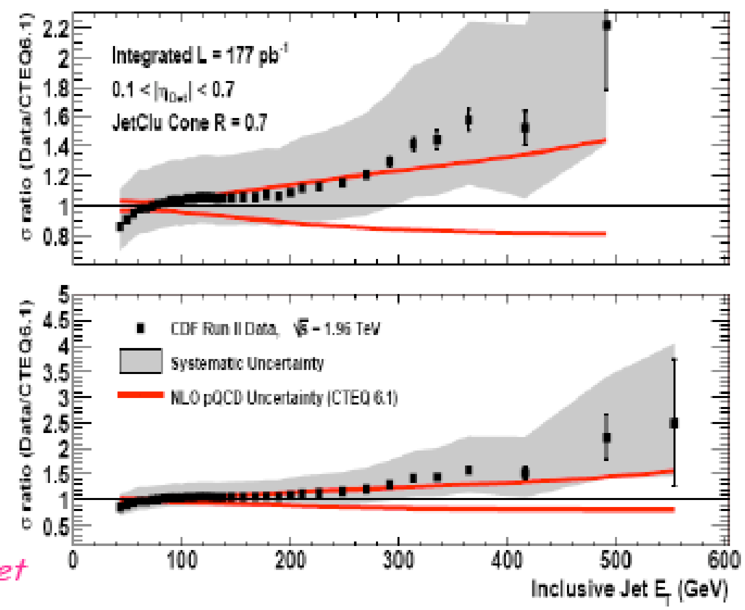
Cone results

…working on blessing midpoint results (corrected to parton level) with ~380 pb^{-1}



- Using Run I cone algorithm & unfolding
  E_T^{jet} range increased by ~150 GeV
- Comparison with pQCD NLO (JETRAD)
  (over almost nine orders of magnitude)

Shape of Data/NLO to be understood



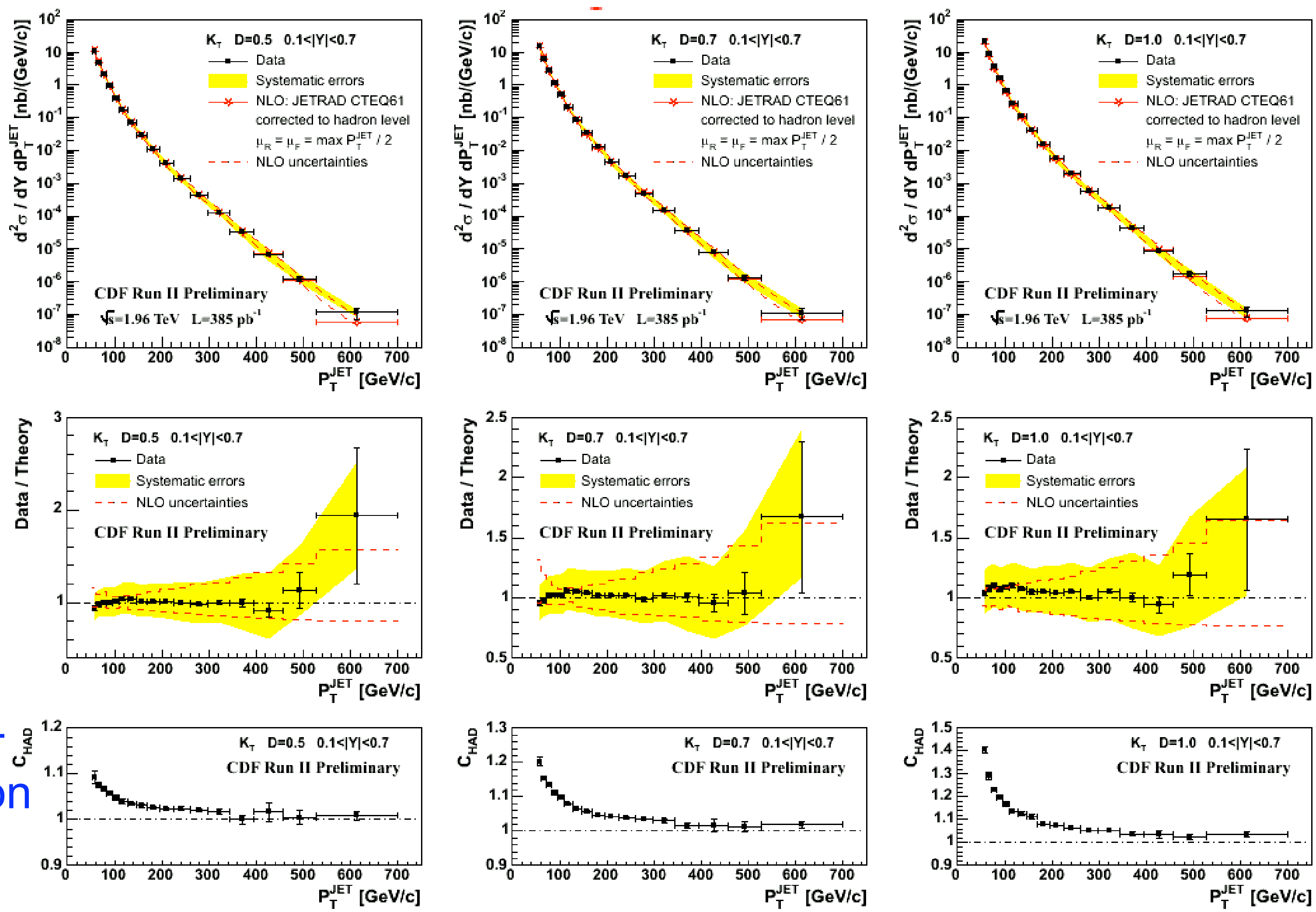
Data dominated by jet energy scale
NLO error mainly from gluon at high x

No hadronization corrections applied to NLO prediction → relevant @ low E_T^{jet}

k_T jet cross section results

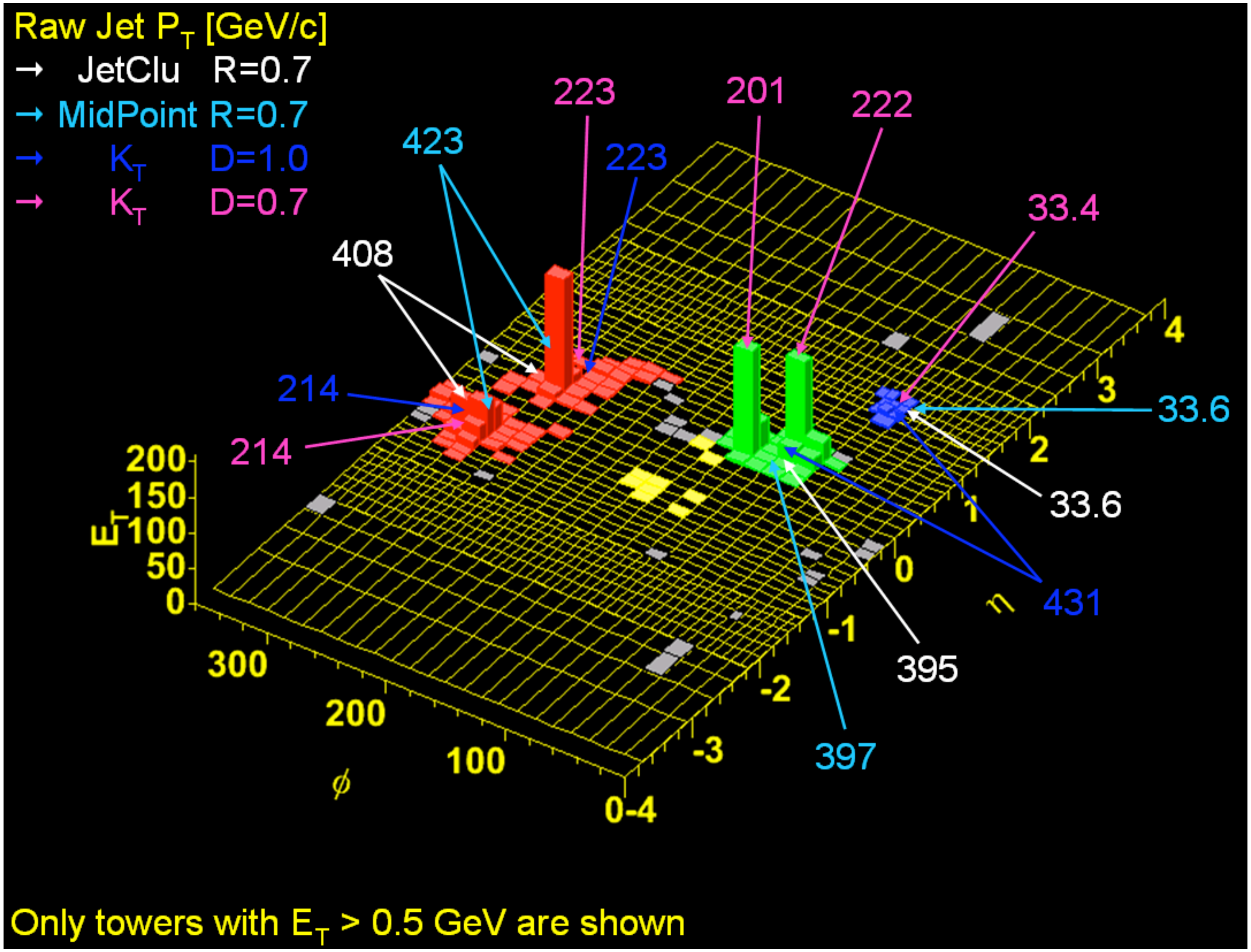
$$d_{ij} = \min(P^2_{T,i}, P^2_{T,j}) \frac{\Delta R^2}{D^2} \qquad d_i = (P_{T,i})^2$$

k_T algorithm seems to work well at a hadron collider



underlying + hadronization correction

Interesting event to study algorithm differences



…project in TeV4LHC to examine what different experimental algorithms (CDF, D0, ATLAS CMS) do with *interesting* events

QCD ≠ SM

- In a recent paper (hep-ph/0503152), Stefano Moretti and Douglas Ross have shown large 1-loop weak corrections to the inclusive jet cross section at the Tevatron
- Up to 20% effect at the Tevatron
  - impact on pdf's and high x gluon?
- Effect goes as $\alpha_W \log^2(E_T^2/M_Z^2)$
  - may be substantially larger for high E_T jets at the LHC
- Other (unsuspected) areas where weak corrections are important?

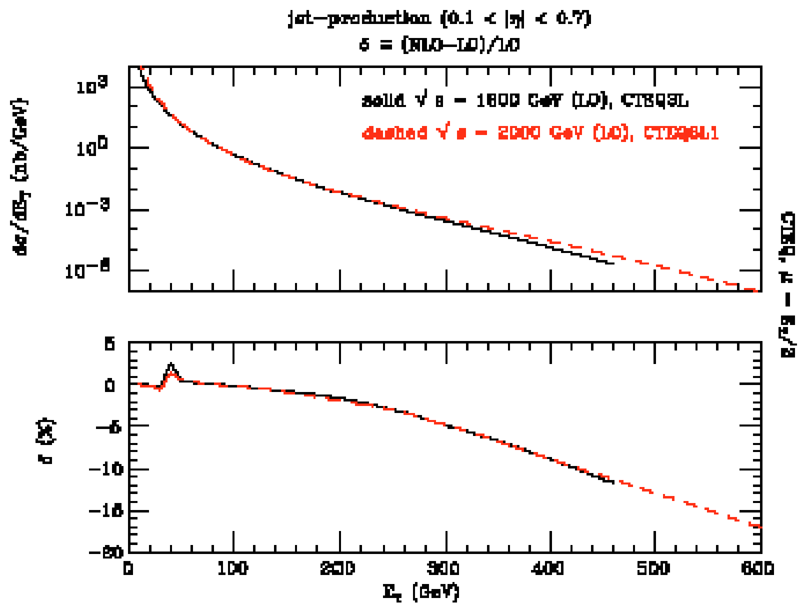
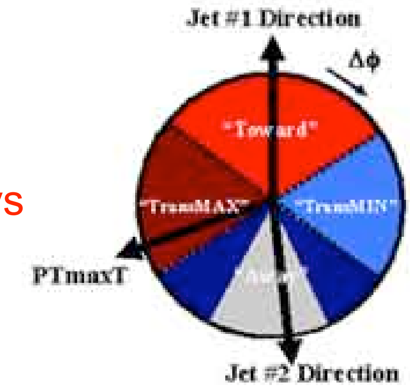


FIG. 1. The effects of the $\mathcal{O}(\alpha_S^2 \alpha_W)$ corrections relative to the LO results for the case of Run 1(Run 2) in the presence of PDFs preceding(following) the gluon re-parameterisation at medium/large Bjorken x, CTEQ3L(CTEQ6L1) [26]([21]). They are plotted as function of E_T for a choice of μ. The cut $0.1 < |\eta| < 0.7$ has been enforced, alongside the standard jet cone requirement $\Delta R > 0.7$.

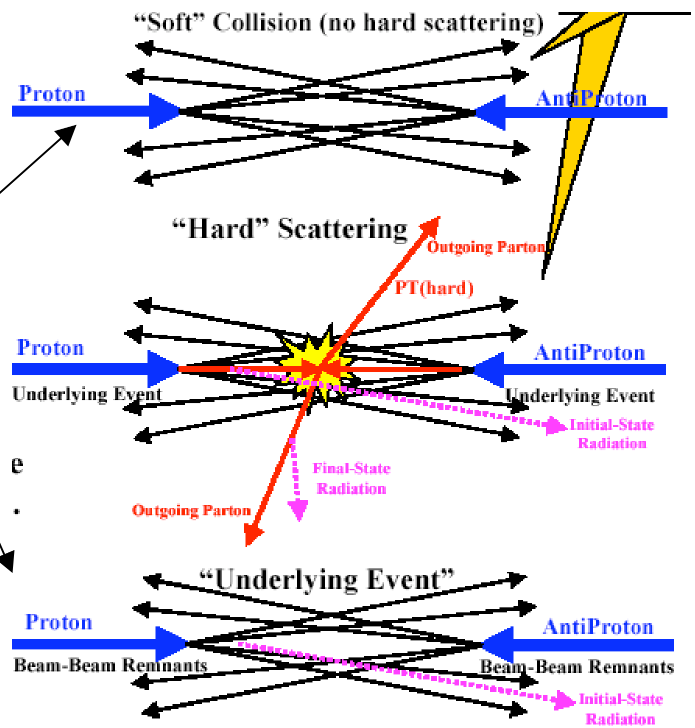
Importance of underlying event

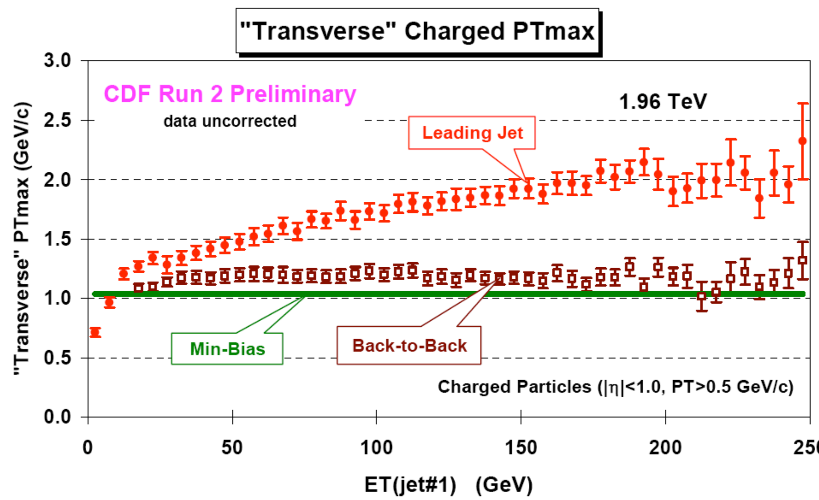
- Have to subtract underlying event from hard scatter in order to compare jet cross sections to parton-level calculations

Σp_T in max region increases as jet E_T increases
Σp_T in min region stays flat, at level similar to min bias



how similar are these two?

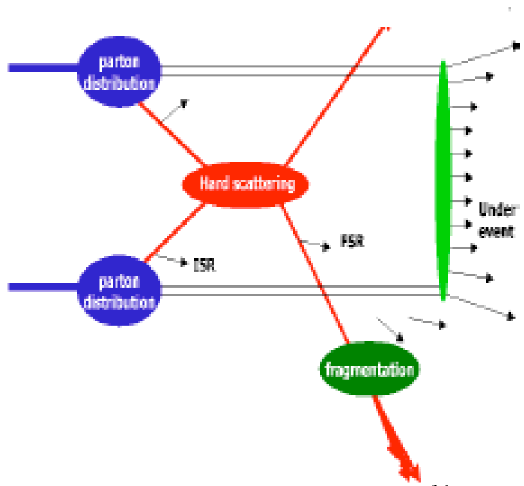


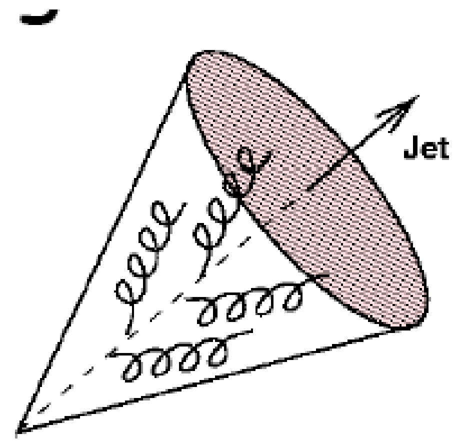


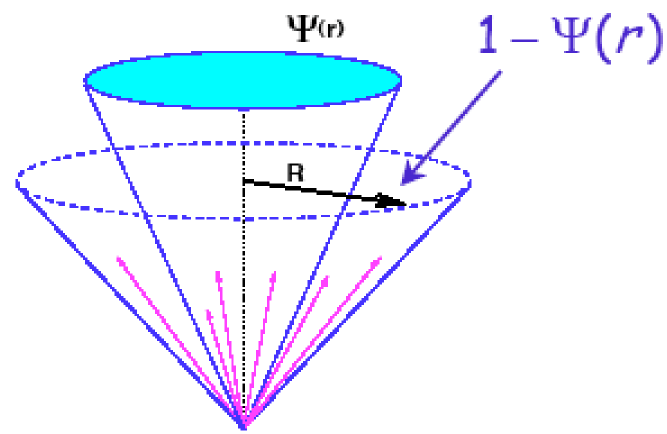
…a Tev4LHC project

need inclusive jet production in MCatNLO->a TeV4LHC/Les Houches project

Jet Fragmentation





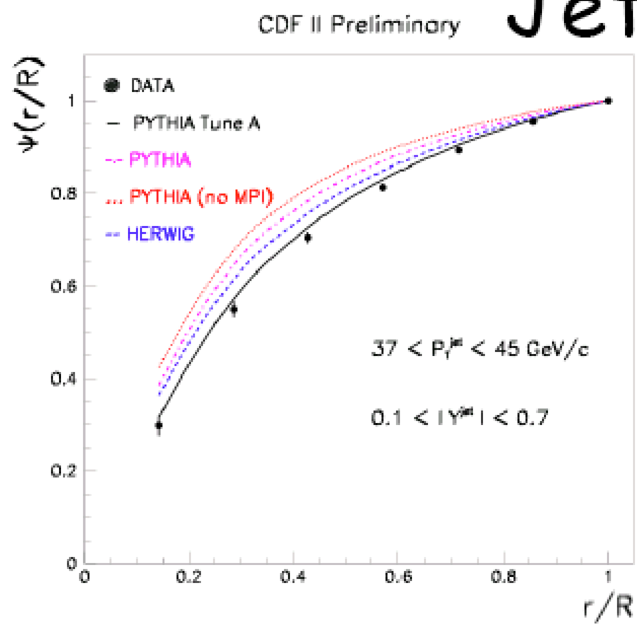


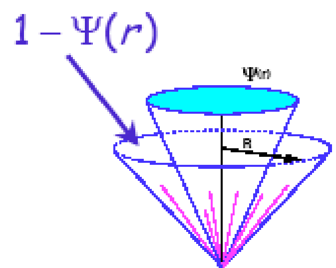
- Jet shape dictated by multi-gluon emission form primary parton
- Test of parton shower models and their implementations
- Sensitive to quark/gluon final state mixture and run of strong coupling
- Sensitive to underlying event structure in the final state

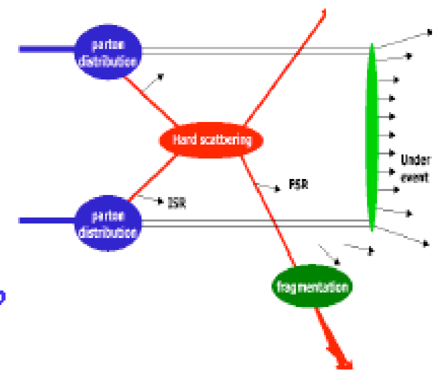
$$\Psi(r) = \frac{1}{N_{jets}} \Sigma_{jets} \frac{P_T(0,r)}{P_T^{jet}(0,R)}$$

Jet Fragmentation

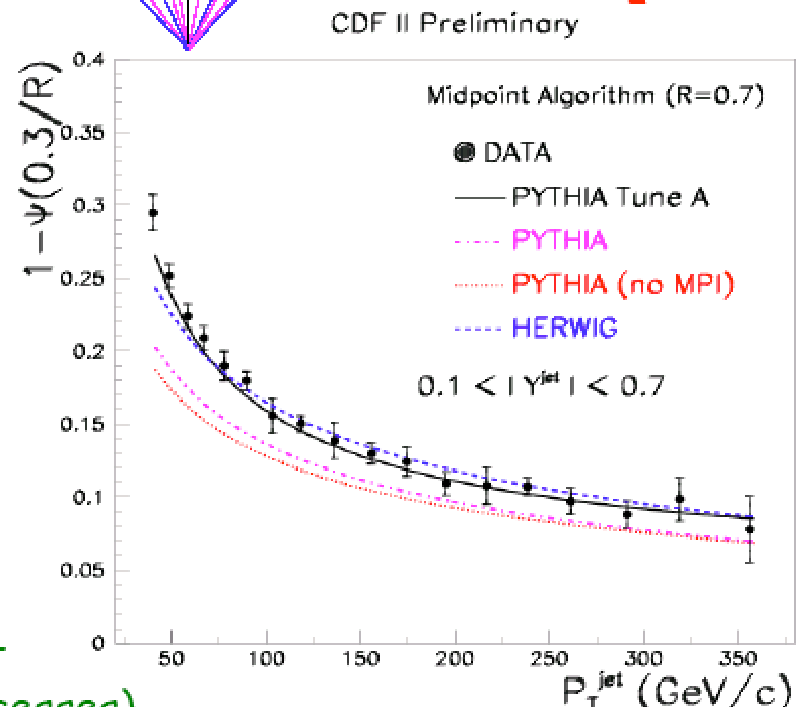
Jet shapes







- PYTHIA Tune A describes the data (enhanced ISR + MPI tuning)
- PYTHIA default too narrow
- MPI are important at low Pt
- HERWIG too narrow at low Pt



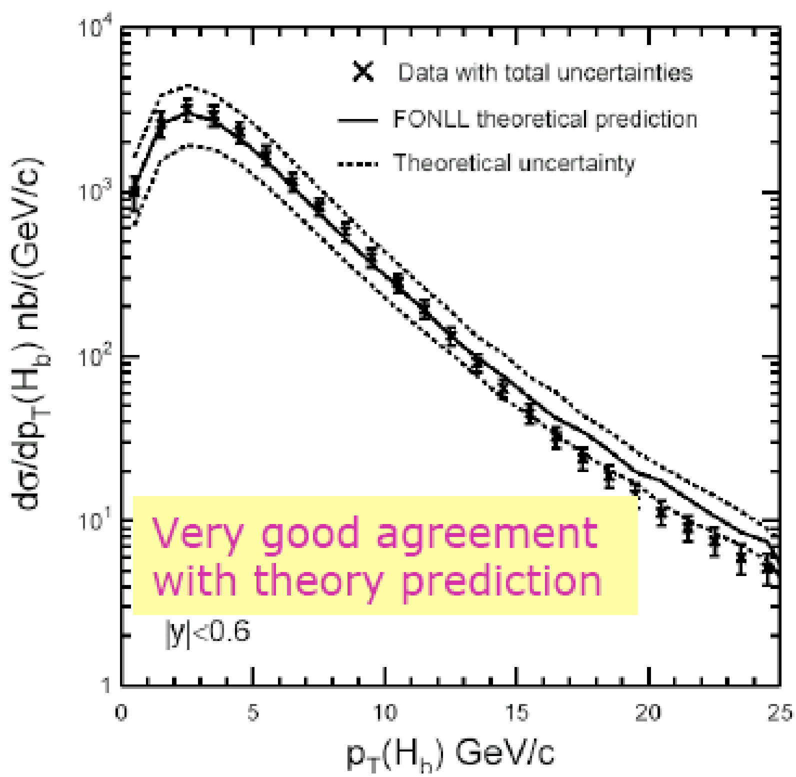
We know how to model the UE at 2 TeV (at least for QCD jet processes)

B-hadron production

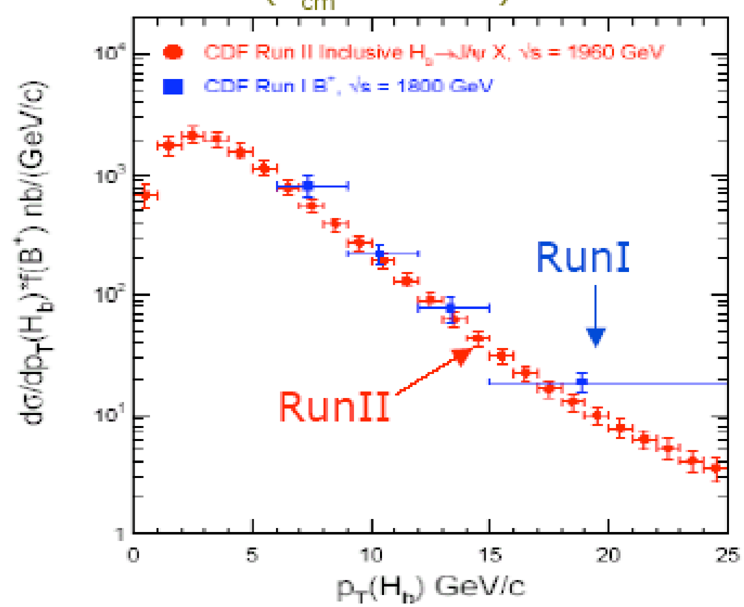
Total inclusive single b-hadron (H_b) cross section

$$\sigma(p\bar{p} \rightarrow H_b X, |y| < 0.6) = 17.6 \pm 0.4(stat)^{+2.5}_{-2.3}(syst)\ \mu\text{b}$$

considering $Br(H_b \rightarrow J/\psi X) = 1.16 \pm 0.10\%$ and $Br(J/\psi \rightarrow \mu\mu) = 5.88 \pm 0.10\%$

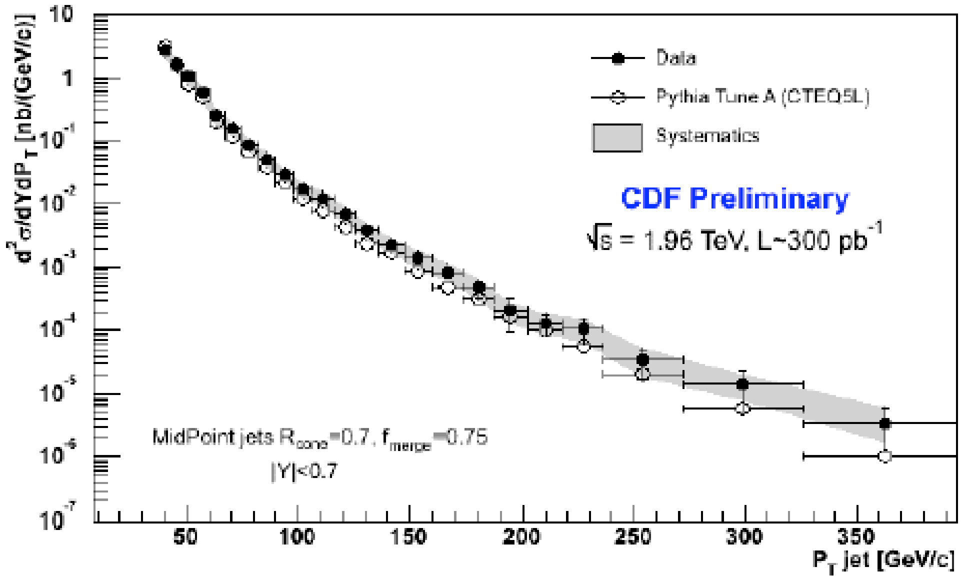


comparison with RunI data
$|y(H_b)| < 1$, σ(RunII) multiplied
by B^+ fragmentation=0.4
(E_{cm} rescaled)



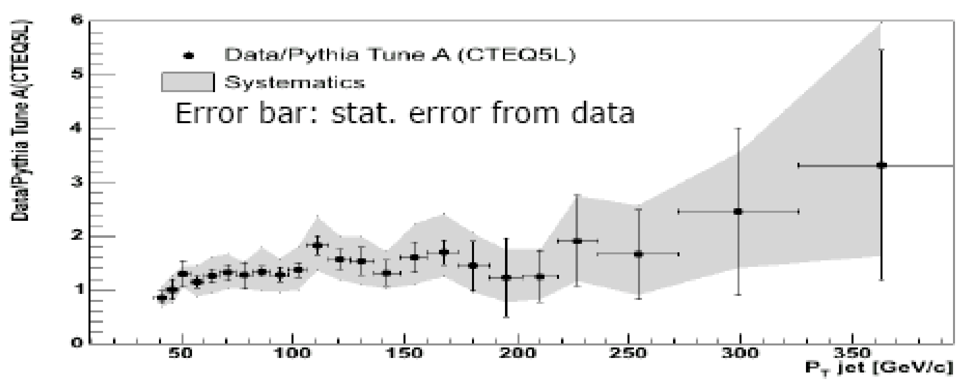
b-jet production

use displaced tracks inside jet to tag heavy flavor; use secondary vertex mass to extract b fraction.



b-jet cross section as function of jet p_T (Range 38-400 GeV/c)

Systematic Error	low P_T	high P_T
Luminosity	6%	6%
Absolute Energy Scale	15-20%	40%
Jet energy resolution	6%	6%
B-tagging efficiency	10%	15%
B-tagged jets fraction	10-15%	40%
Unfolding	8%	8%

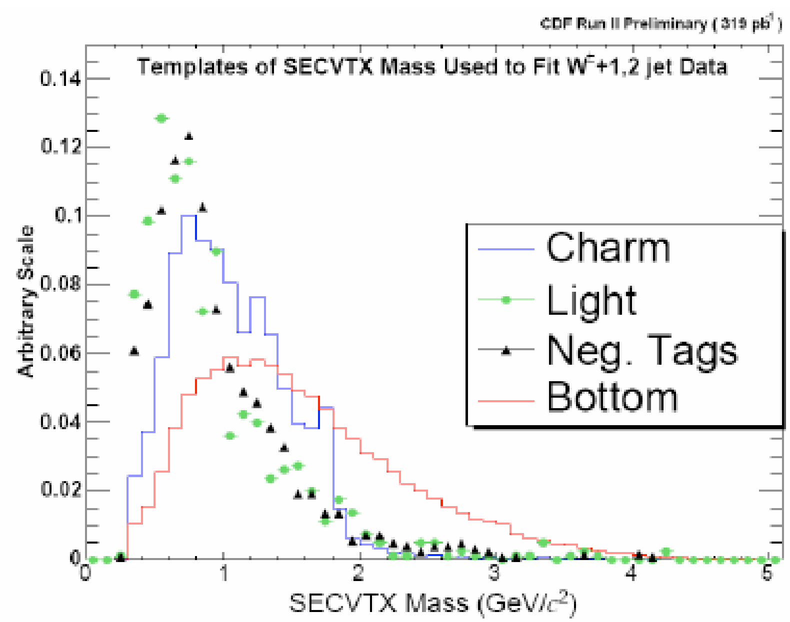


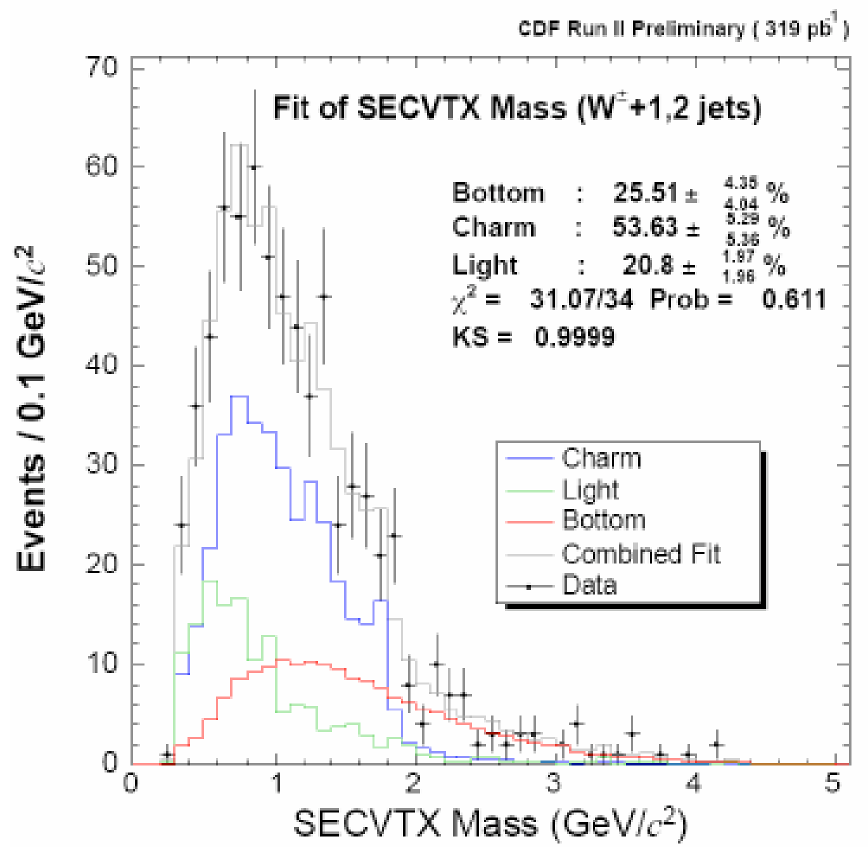
No comparison with NLO yet

Data/Pythia Tune A ~ 1.4
in agreement
with expectations

W+bb/W+j/jj

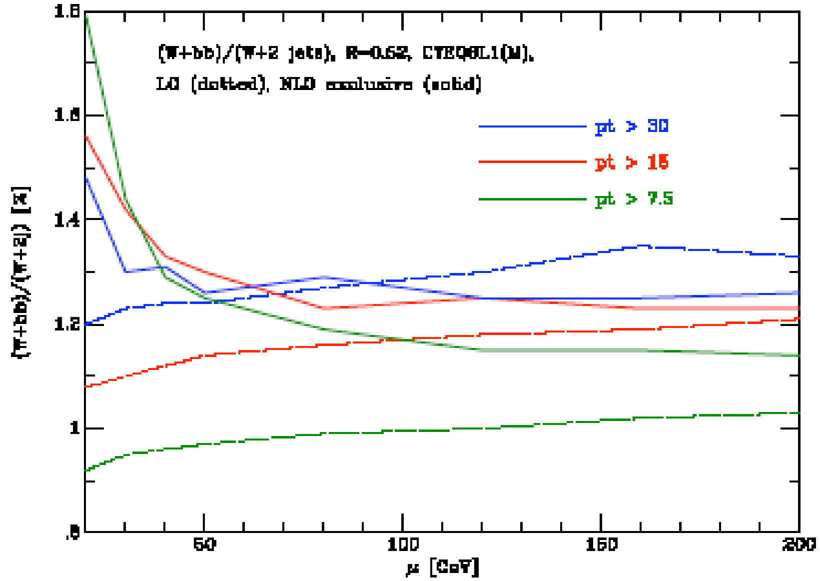
- Use secondary vertex mass to tag heavy flavor
  - Observed rate W+bb)/W+j,jj = 0.0072±0.0024(stat.)±0.0022(syst.)





MCFM prediction for Wbb/Wjj

- At NLO, ratio is stable across a wide range of scales.



- For a p_T cut of 15 GeV and $\mu \sim M_W$, we have:

$$\left[\frac{\sigma(Wb\bar{b})}{\sigma(W+2\text{ jets})}\right]_{LO} = 1.16\%, \qquad \left[\frac{\sigma(Wb\bar{b})}{\sigma(W+2\text{ jets})}\right]_{NLO} = 1.23\%$$

J. Campbell and J. Huston, hep-ph/0405276 [PRD70 094021 (2004)]

Understanding 'Not-Top'

Steve Mrenna:

Understanding W+Jets is Critically Important

- Signature $Wb\bar{b} + X$ is common to unconfirmed Standard Model processes and many new physics processes

$$X \Rightarrow \text{many boxes}$$

- we "know" that Standard Model top is there, thus we can study Not-Top

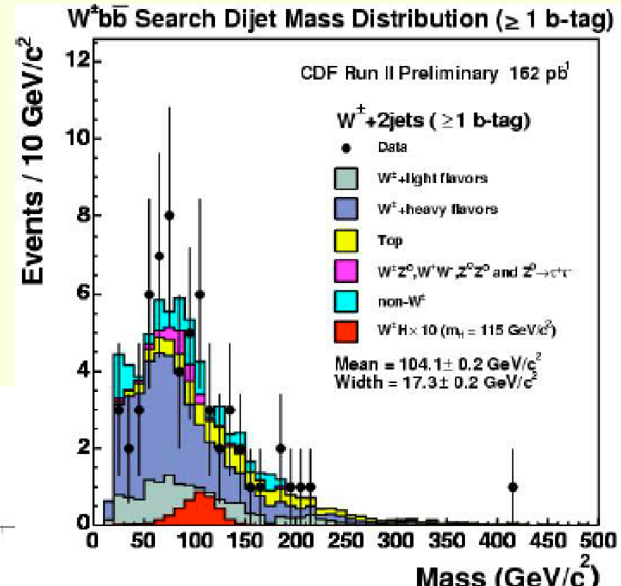
$$\text{Top} \equiv \text{Data} - \text{Not-Top}$$

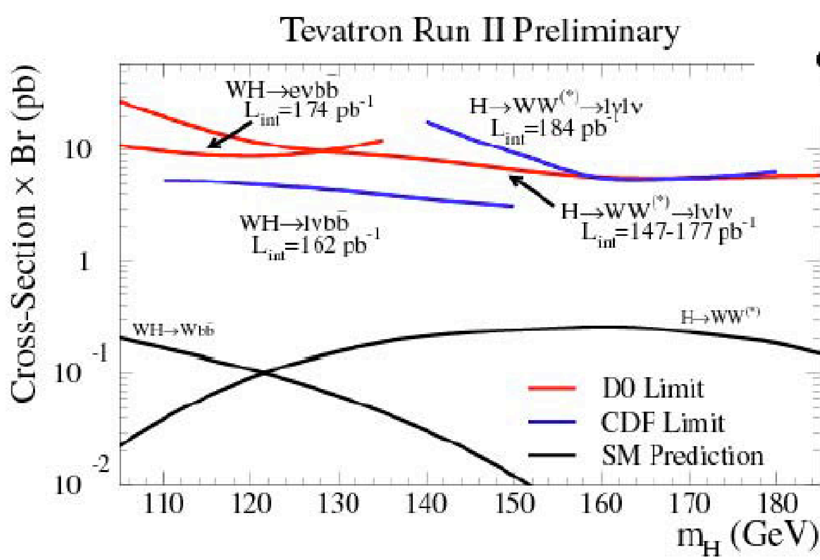
- Claim: understanding Not-Top is more important than understanding Top itself
  - Not-Top challenges our tools
  - Better tools = more challenging questions
- As JES uncertainty is reduced, understanding of Not-Top sets δm_t

A lot of work underway at CDF and in TeV4LHC on 'Not-Top'.

Not-Top: Higgs searches

Current status

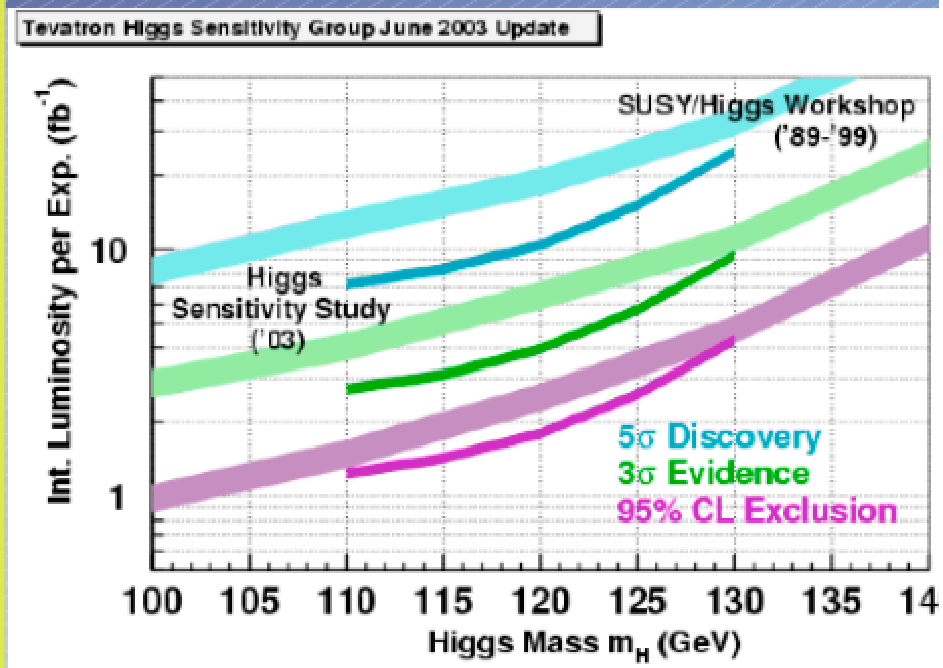




Higgs searches

Combined Results

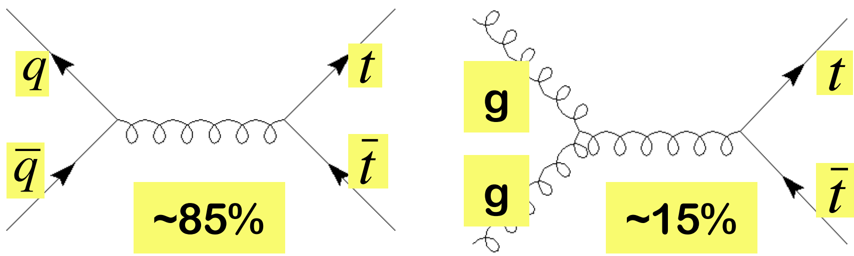
- Combined DØ/CDF result
  - Assumes luminosity from two experiments
- 10% dijet mass resolution
- Run IIB silicon
- Width of HSG bands determined by method uncertainty
  - No systematics included
- Width of SHWG bands given by analysis uncertainty
- SHWG included $H \to WW$
  - contributes at high m_H



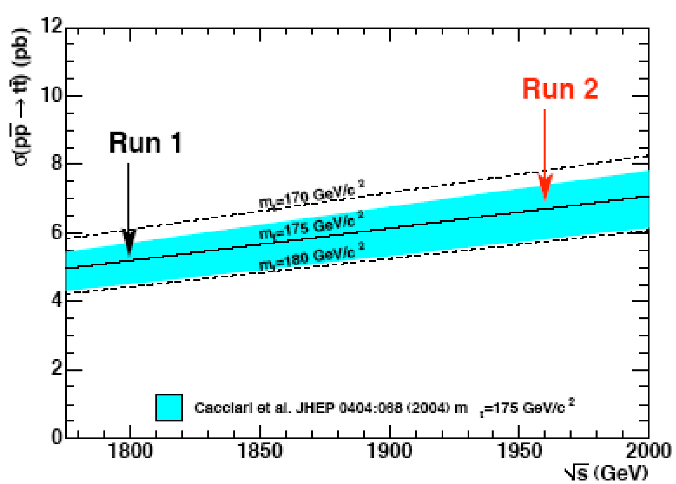
Low mass region 95% excl. or 3σ by 2008
This is difficult region at LHC

Top Physics

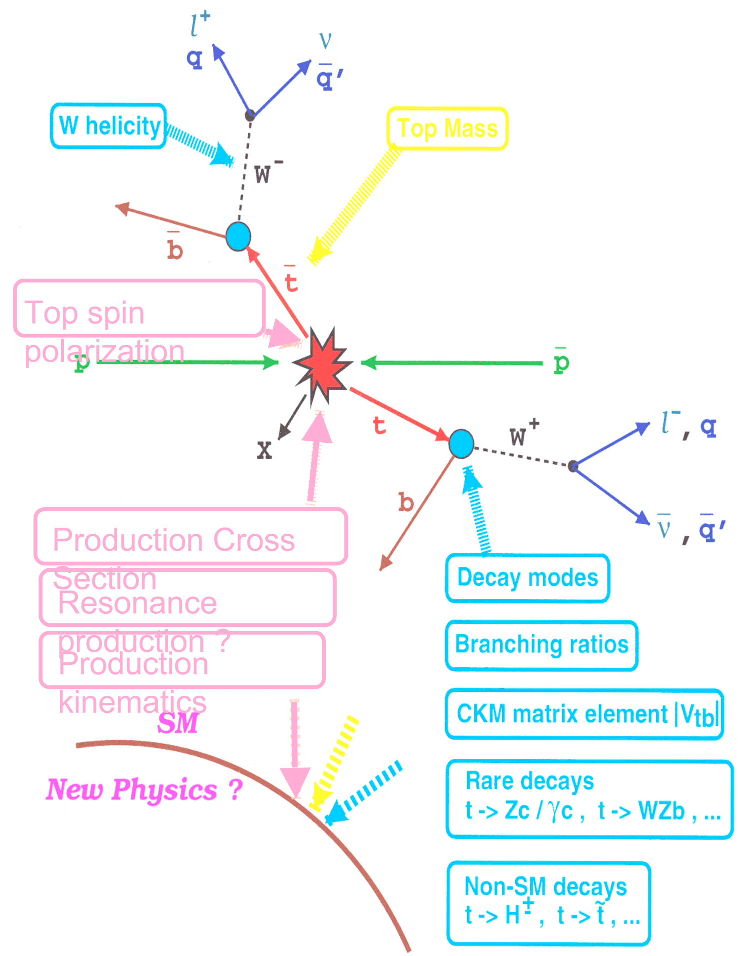
- At Tevatron, top quarks are produced mostly by qq
  - nb: if use Monte Carlos with LO pdf's, only 5% of production comes from gg



$$\sigma(\bar{p}p \rightarrow t\bar{t} @ M_{top} = 178 GeV) \approx 6.1 \text{ pb}$$



- Wealth of physics possible with top quark analyses
  - both SM and probes of BSM

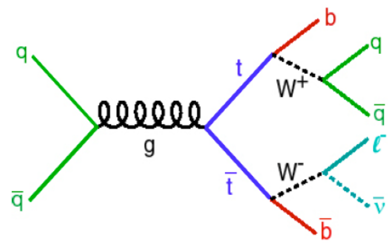


Event signatures

Top quark decays to W and b at a rate of $\sim$100% $\mathrm{Br}(t \to W^+ b) \simeq 1$

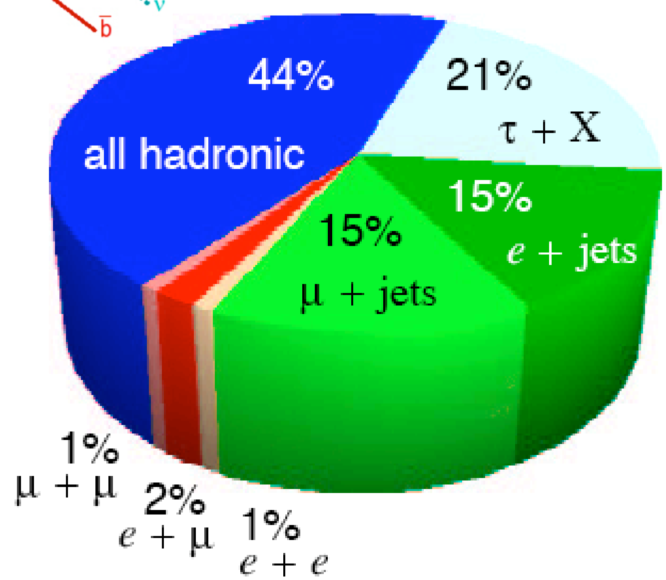
Decay channels of $t\bar{t}$

$t \to W^+ b$	b	b	b	b
$\hookrightarrow$	$\ell^+\nu$	$q\bar{q}'$	$\ell^+\nu$	$q\bar{q}'$
$\bar{t} \to W^- \bar{b}$	$\bar{b}$	$\bar{b}$	$\bar{b}$	$\bar{b}$
$\hookrightarrow$	$\ell^-\bar{\nu}$	$\ell^-\bar{\nu}$	$q\bar{q}'$	$q\bar{q}'$



dilepton channel
$\Rightarrow$ 2 leptons, $\not{E}_T$, 2 b-jets

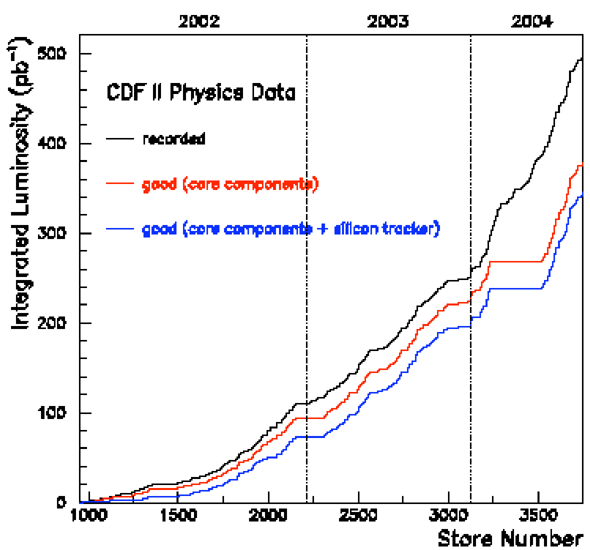
lepton+jets channel
$\Rightarrow$ 1 lepton, $\not{E}_T$, 4 jets (including 2 b-jets)



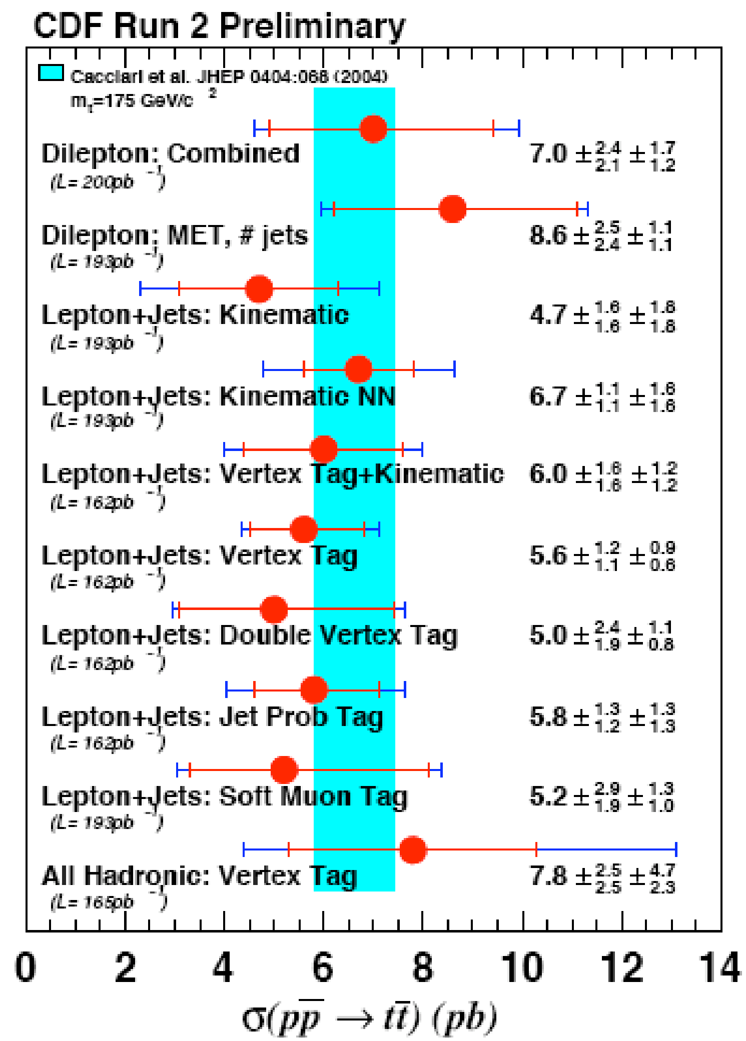
all hadronic channel
$\Rightarrow$ 6 jets (including 2 b-jets)

Cross section results

- Variety of analyses
  - counting experiments
  - kinematic fits/neural networks
  - w/wo b-tagging (silicon available for most of data)

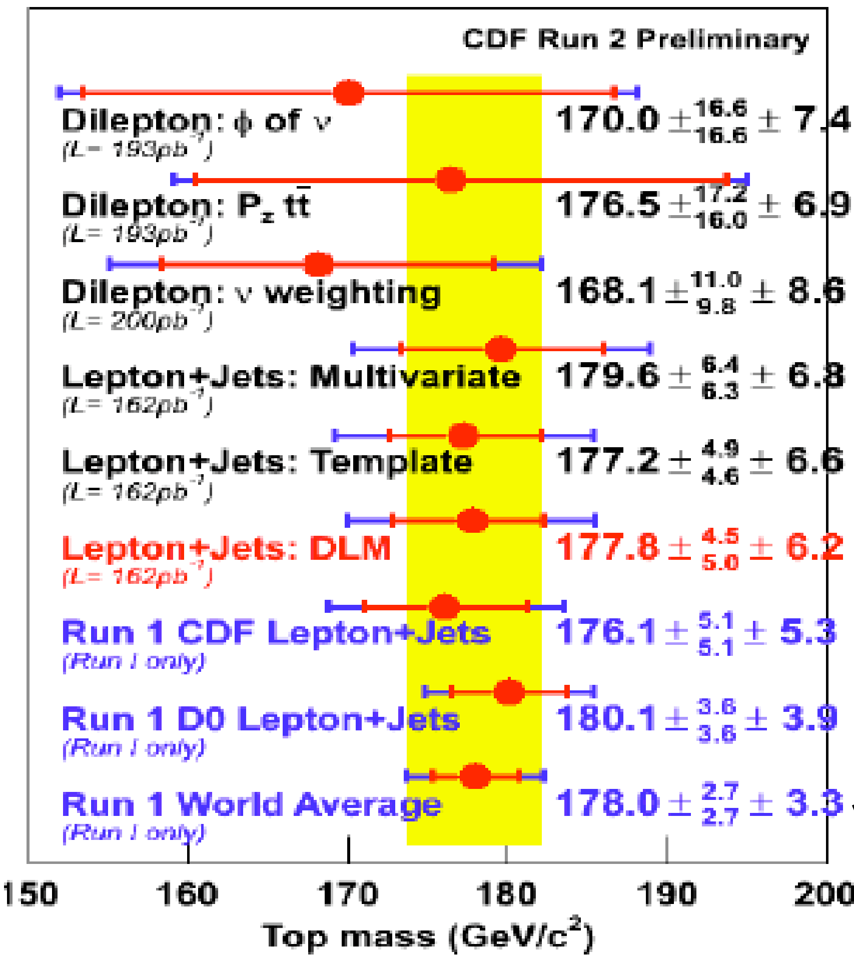


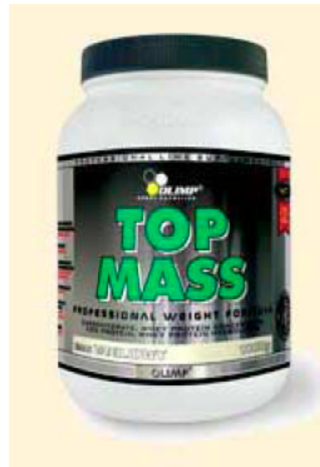
- All results consistent with each other and with theory prediction

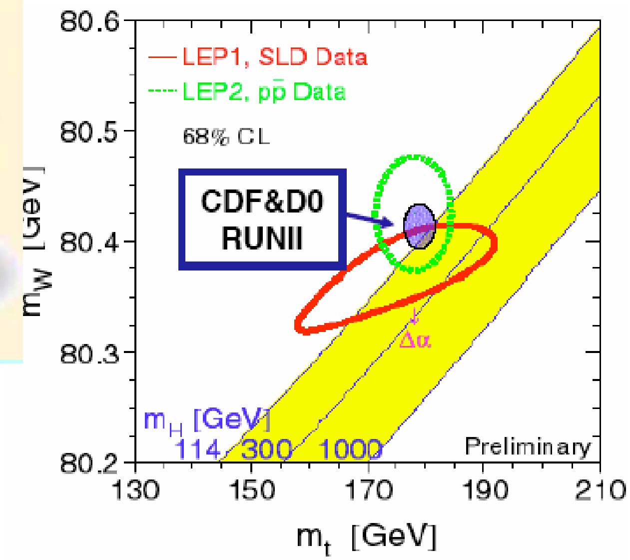


Top Mass

- Results as of 2004







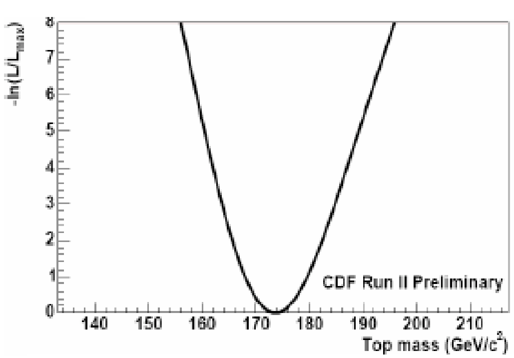
$m_H = 114 \, ^{+65}_{-45}$ GeV/c^2

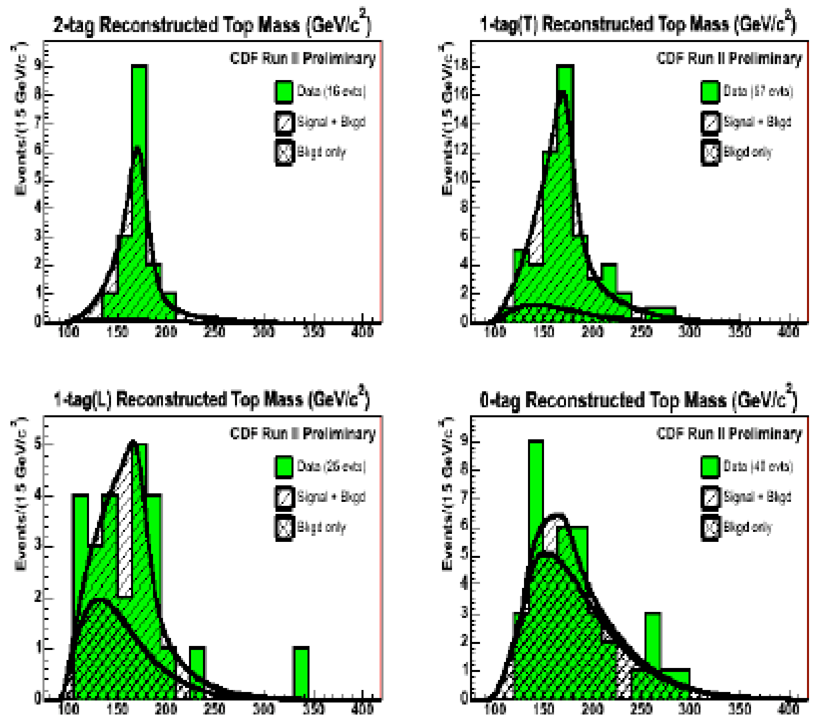
goal with 2fb^{-1}: δM_{top} = 2-3 GeV

Run 2 template method

- Lepton + jets final state
  - E_T>15 GeV (8 GeV on 4th jet), $|\eta|$<2.0
  - 318 pb^{-1} data sample
- χ^2 mass fitter
  - find top mass that fits event best with 2 constraints (W mass, top mass)
- Likelihood fit
  - best signal + background templates to fit data with constraint on background

Comb. –Log Likelihood





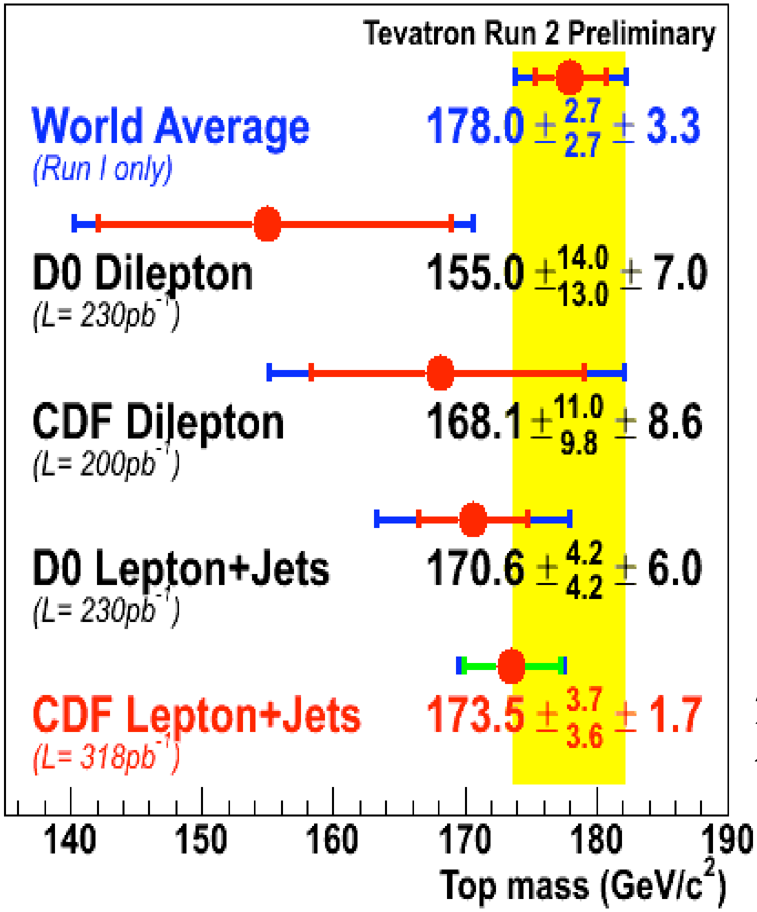
$$M_{top} = 173.2^{+2.9}_{-2.8}\,(stat)\ GeV/c^2$$

The best single measurement

1-D template fit
(+/- 3.4 GeV syst)

Top Mass Results

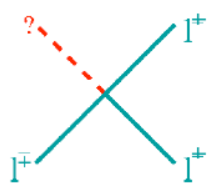
- World's best top mass measurement has been made in the lepton + jets channel at CDF
  - world average will drop slightly as will predictions for Higgs mass
- Systematics due to jet energy scale and background shape to improve further



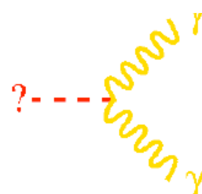
2-D template fit

Supersymmetry

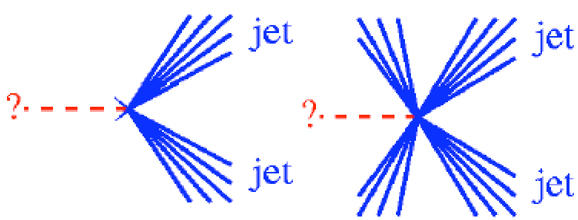
- Wide range of signatures
  - look for SUSY-specific signatures or excess in SM ones
  - RP: large missing E_T from LSP's
  - isolated leptons



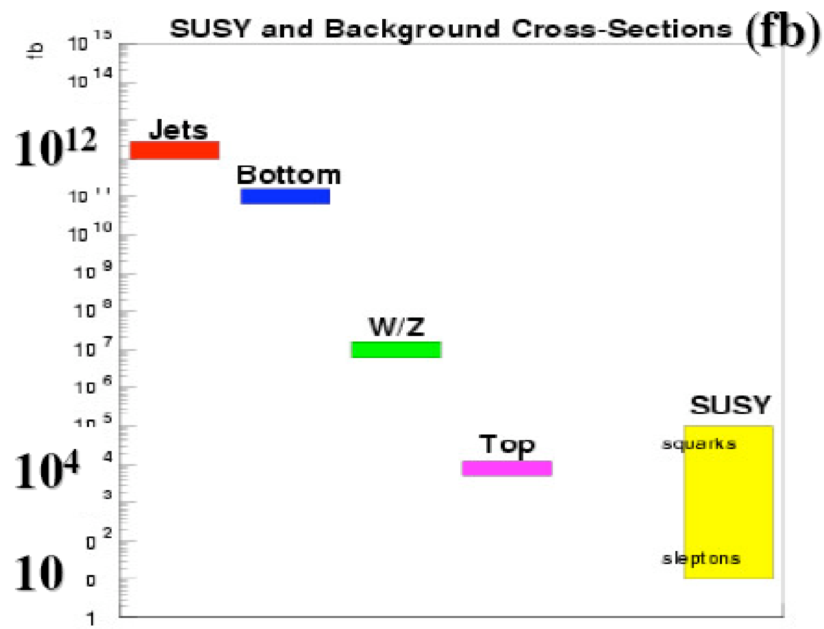
  - diphotons



  - multijets



very small cross sections



detector response has to be well-understood; detectors have to be highly efficient

Example: chargino and neutralino in 3l + $\not{E}_T$

PRELIMINARY !!

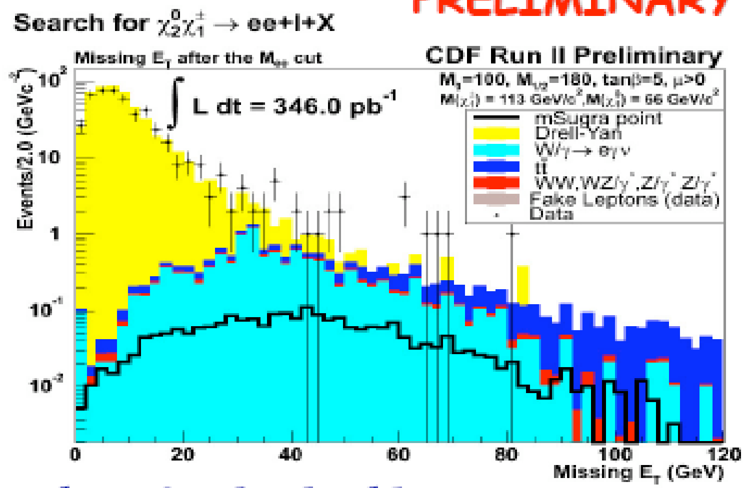
In mSUGRA: 3 leptons+$\not{E}_T$

➡ σxBR~0.1 pb

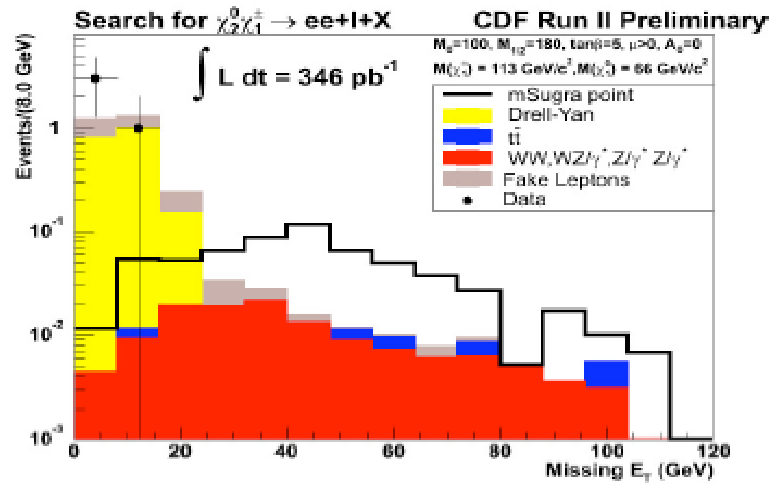
SELECTION:

- 2 electrons+ ℓ (ℓ =e,μ) |η|< 1
- large $\not{E}_T$
- $15<M_{ll}<76$, >106 GeV/c^2
- $|\Delta\phi| < 160°$
- Njets(20 GeV) <2

ee+l (SUSY signal)	0.5
TOT SM Expected	0.16±0.07
OBSERVED	0



Asking for the third lepton:



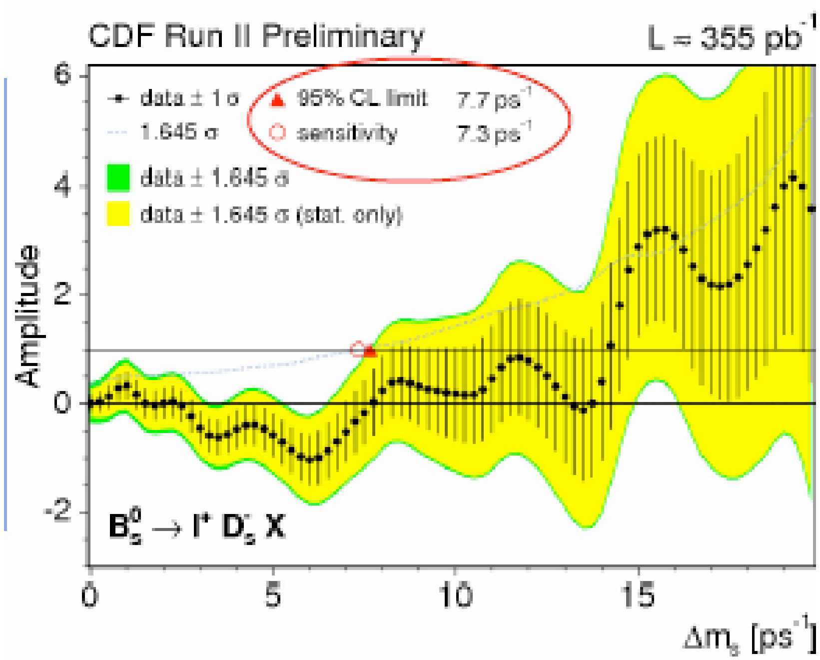
VERY FIRST LOOK AT THE DATA!!

Still to do:

- improve acceptance adding the plug
- add the other channels (almost ready)

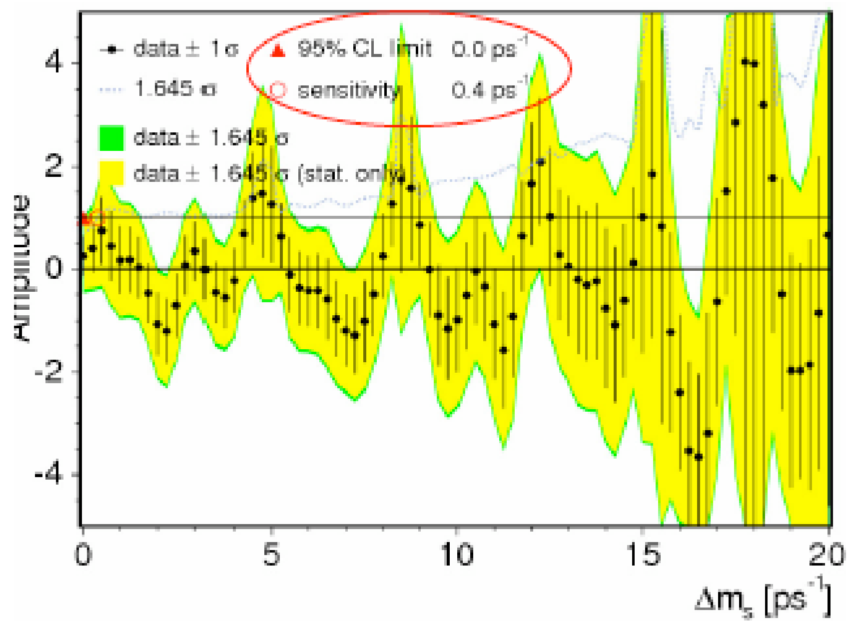
B_s mixing

$$B_s^0 \rightarrow \ell^+ D_s^- X$$



	N	S/B
$D_s^- \rightarrow \phi\pi^-$	4355 ± 94	3.12
$D_s^- \rightarrow K^{*0}K^-$	1750 ± 83	0.42
$D_s^- \rightarrow \pi^+\pi^-\pi^-$	1573 ± 88	0.32

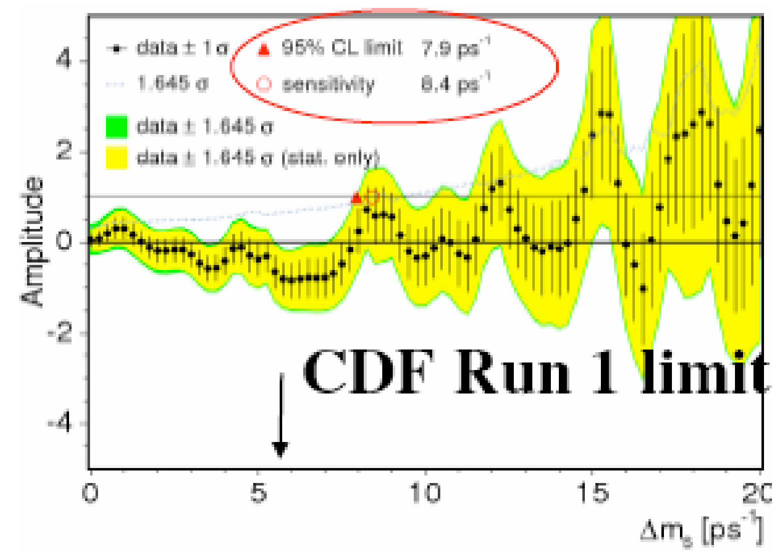
$$B_s^0 \rightarrow D_s^- \pi^+$$

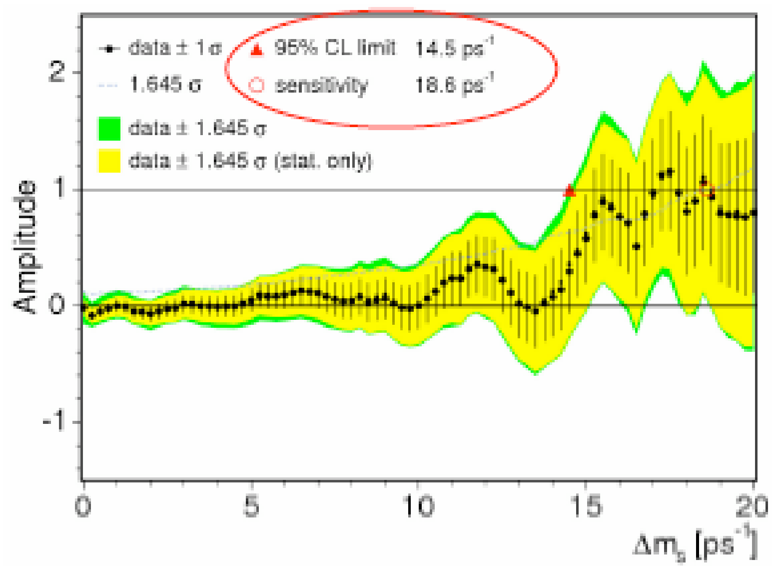


Subsample	Yield	S/B
$D_s^- \rightarrow \phi\pi$	526.2 ± 33.2	1.80
$D_s^- \rightarrow K^*K$	253.6 ± 20.5	1.69
$D_s^- \rightarrow \pi\pi\pi$	115.7 ± 18.0	1.01

Impact on world average sensitivity

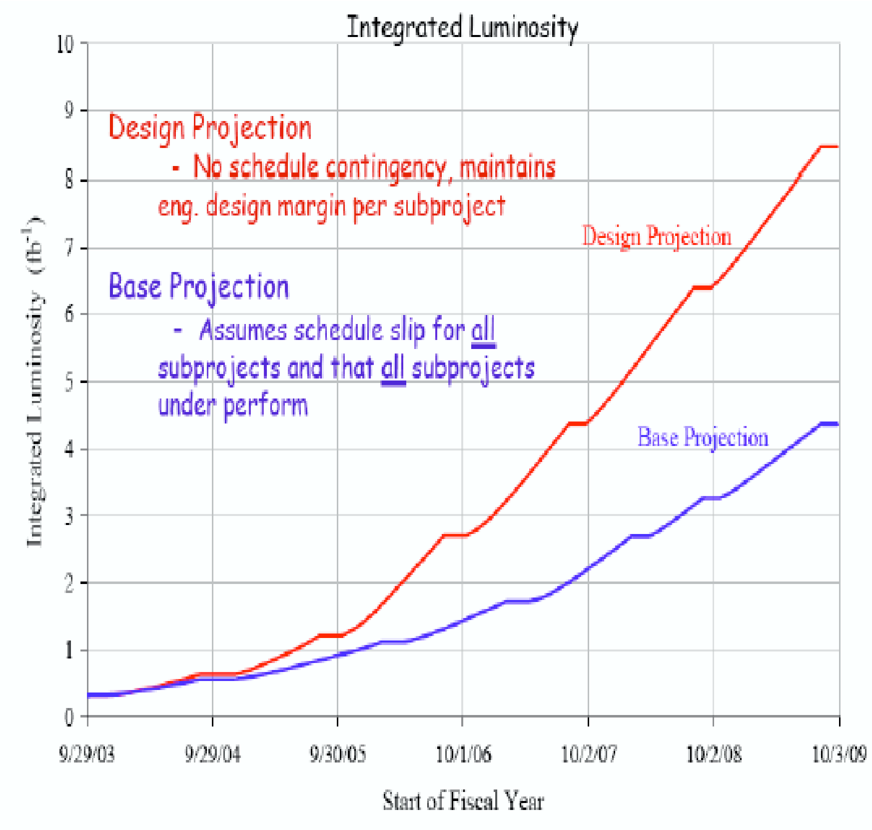
- Combined scan results
  - 7.9 ps^{-1} 95% CL limit
  - sensitivity: 8.4 ps^{-1}
  - additional improvements could reduce statistical error by up to a factor of 2 with the same dataset
- Effect on world average:
  - limit: 14.5->14.5 ps^{-1}
  - sensitivity: 18.2->18.6 ps^{-1}





Summary

- Tevatron and CDF both working well
- ~800 pb^{-1} down and > 8 fb^{-1} to go



Websites and future meetings

- TeV4LHC: conferences.fnal.gov/tev4lhc/
- QCD
  - www.pa.msu.edu/~huston/tev4lhc/wg.htm
  - see also www.pa.msu.edu/~huston/tevqcdwg/wg.htm
- TopEW
  - www.hep.anl.gov/tait/tev4lhc/topew.html
- Higgs
  - www-clued0.fnal.gov/~iashvili/TeV4LHC_higgs/higgs.html
- Landscape

- Final meeting at Fermilab in the fall of 2005

You're all wondering, How can I enlist?

- Four listserver mailing groups have been set up:

  tev4lhc-qcd
  tev4lhc-higgs
  tev4lhc-topew
  tev4lhc-landscape

- If you would like to subscribe to the working groups, here are the instructions:
  - To subscribe to a mailing list called MYLIST

    1. Send an e-mail message to listserv@fnal.gov

    2. Leave the subject line blank

    3. Type "SUBSCRIBE MYLIST FIRSTNAME LASTNAME" (without the quotation marks) in the body of your message.

See (some of you) at Les Houches 2005

- Physics at TeV Colliders
  - From 800 pb^{-1} at the Tevatron to 30 fb^{-1} at the LHC
  - May 2-20
    - right after CERN meeting of TeV4LHC
- 2 main working groups
  - SM and Higgs
  - BSM and Higgs modeling