Tevatron Latest Results

XL International Meeting in Fundamental Physics

Benasque 25th May – 2nd June 2012

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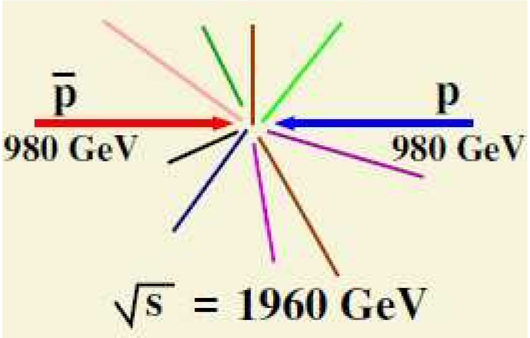
Outline

- ❑ The Tevatron collider and the experiments
- ❑ QCD
- ❑ Heavy Flavor Physics
- ❑ Electroweak Physics
- ❑ Top Quark Physics
- ❑ Beyond the SM

The Tevatron Collider

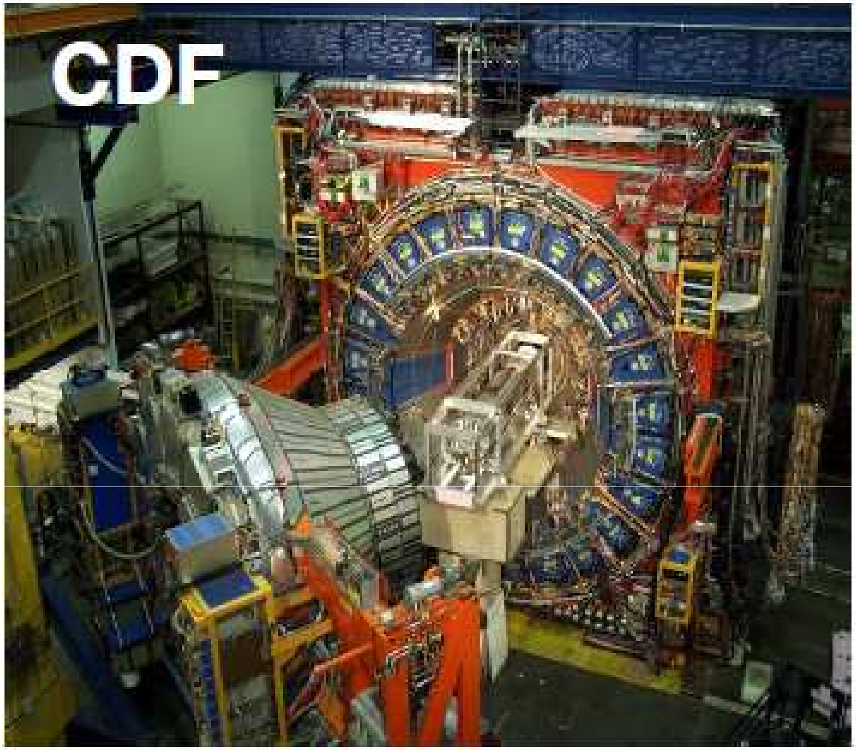


- Proton-Antiproton collider at ***$\sqrt{s}$=1.96 TeV***
- Located at Fermilab, Illinois (USA)
- Operated between 1985 until September of 2011
- Beams collided at 2 locations where ***CDF*** and ***D0*** experiments collected their data
- ***~12 fb^{-1}*** delivered. ***~10 fb^{-1}*** collected by each experiment

Physics Runs

1987	**Run 0 - 4 pb^{-1}**
1992-1996	Run 1 - 120 pb^{-1}
2001-2011	Run 2 – 12 fb^{-1}

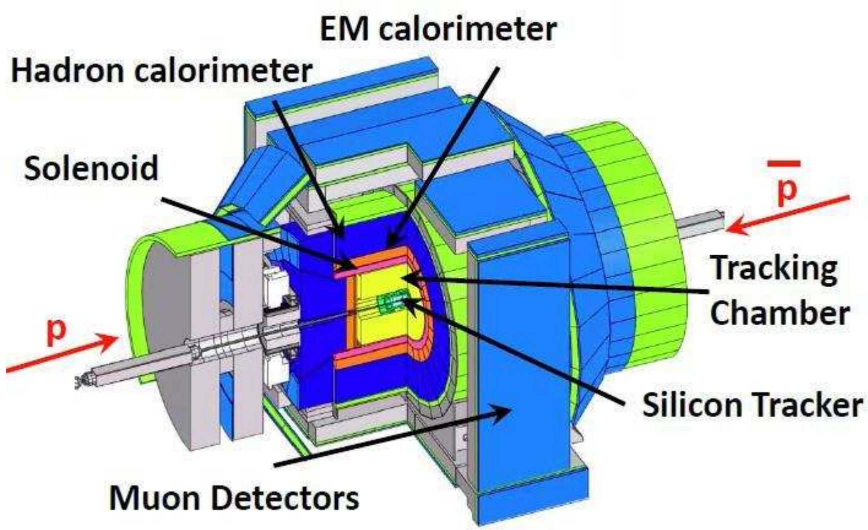
CDF and D0

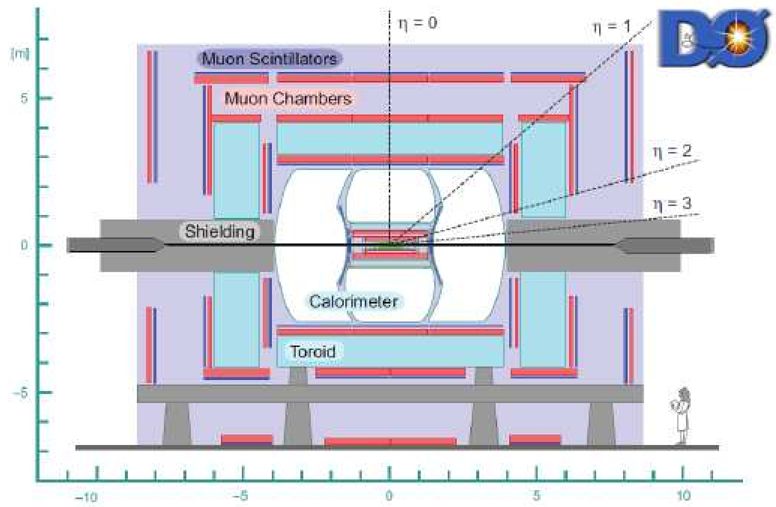


Major detector
upgrades for Run 2

CDF and D0

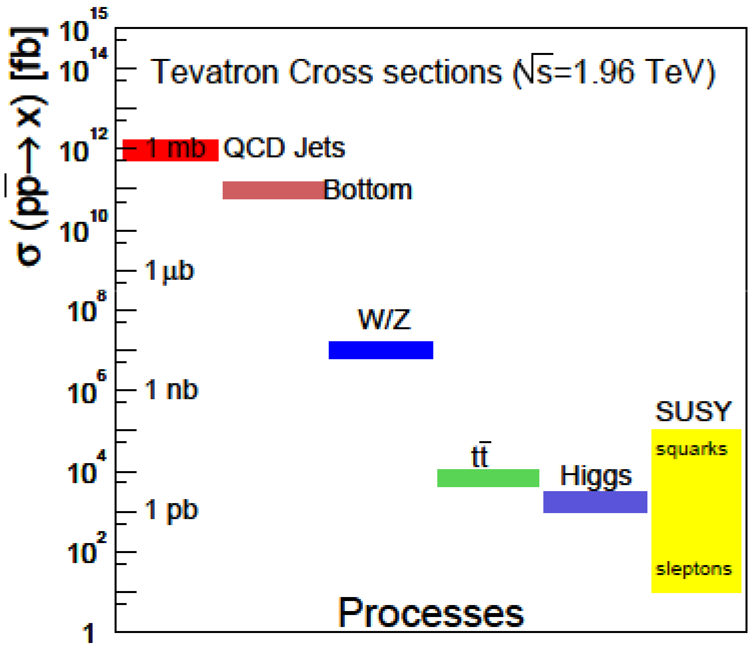
- ❑ Clasical design for multipurpose detectors
  - ➢ Silicon high precision vertex detectors
  - ➢ Tracking chambers in magnetic field
  - ➢ 4π calorimetry with EM preshowers
  - ➢ Muon detectors (outside)
  - ➢ Axial and forward-backward symmetry





Tevatron Physics Program

- ❑ Vast physics program at Tevatron
  - ➢ +80 new results since the Tevatron shutdown



- ❑ Multijet production
- ❑ Heavy-flavour production
- ❑ Electroweak boson production
- ❑ Top production
- ❑ Higgs
  - ➢ Will be covered in Higgs session tomorrow
- ❑ Searches

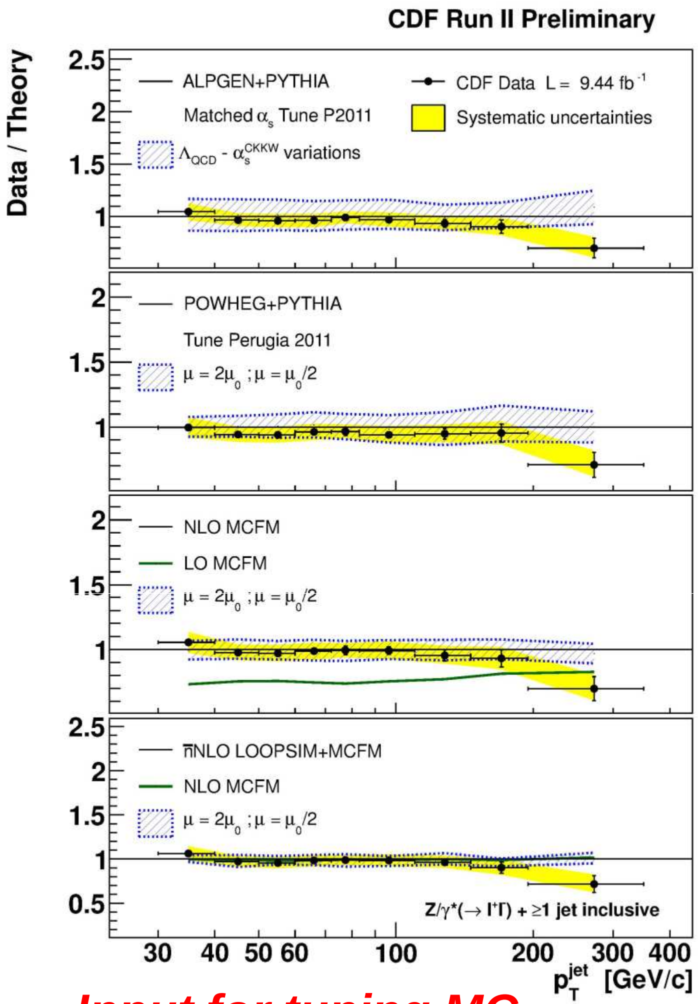
QCD

- Important tests of the SM
  - Test pQCD
  - Jet properties: internal structure, models for Parton shower and Underlying Event models
- showing results on
  - Z+ jets, γ + jets
  - W+jets in back-up slides

D0: ***http://www-d0.fnal.gov/Run2Physics/qcd/D0_public_QCD.html***

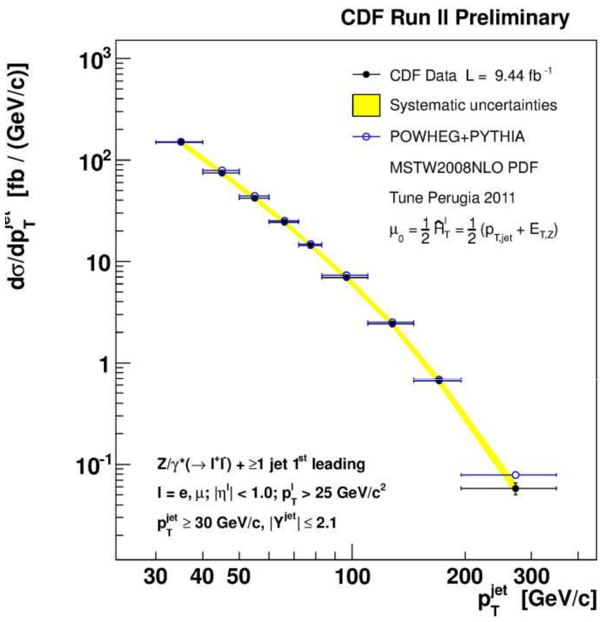
CDF: ***http://www-cdf.fnal.gov/physics/new/qcd/QCD.html***

QCD: Z+jet



Input for tuning MC

- **Boson + jet production**
  - Large theoretical uncertainties
  - Test QCD predictions
  - Background to new physics searches



In good agreement with NLO

- 2 Central μ or e with $|\eta|<1.0$, $P_T>25$ GeV
- Jets: MidPoint Cone R=0.7, $|y|<2.1$, $P_T>30$ GeV
- Compare to theory using jet P_T, y, multiplicity, M_{jj}, ΔR_{jj}, $\Delta\phi_{jj}$, M_{Zjj}, $P_{T\,jj}$,

Full CDF Dataset preliminary

Z+n-jet data vs (approx. nNLO) LOOPSIM+MCFM, (LO and NLO) MCFM, (LO and NLO) BLACKHAT+SHERPA, (ME+PS) ALPGEN+PYTHIA, (NLO+PS) POWHEG+PYTHIA

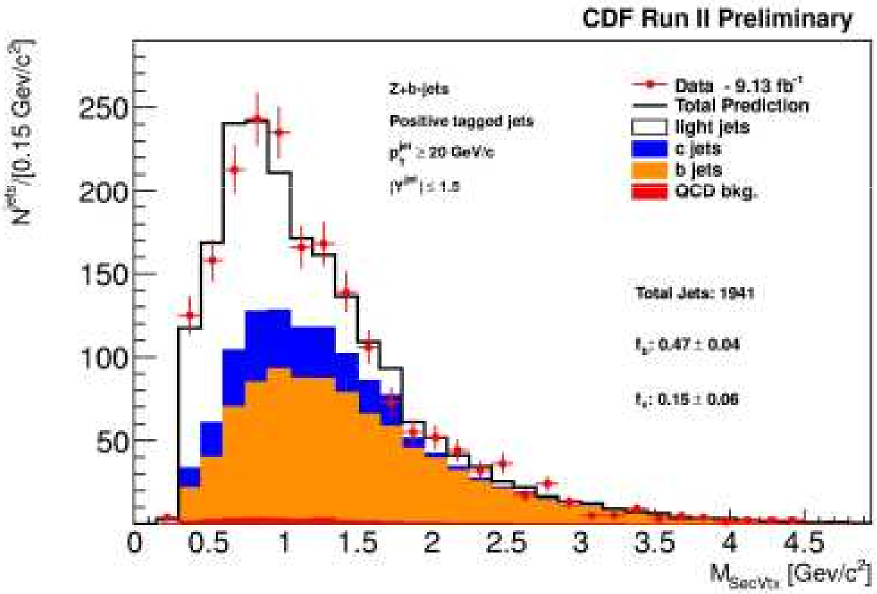
QCD: σ(Z+b)/ σ(Z+jet)

- At least one central muon or electron with $|\eta|<1.0$, $P_T>20$ GeV
- Jets: MidPoint Cone R=0.7, $|y|<1.5$, $P_T>20$ GeV
- ΔR(lepton,jet) > 0.7
- Comparison to NLO MCFM
- Measured as ratios **σ(Z+b)/ σ(Z), σ(Z+b)/ σ(Z+jet)**

Full CDF Dataset

preliminary

CDF conf. note 10594



DATA:

$$\frac{\sigma_{Z\_bjet}}{\sigma_Z} = 0.261 \pm 0.023^{stat} \pm 0.029^{syst}\%$$

$$\frac{\sigma_{Z\_bjet}}{\sigma_{Zjet}} = 2.08 \pm 0.18^{stat} \pm 0.27^{syst}\%$$

MCFM	$Q^2 = m_Z^2 + p_{T,Z}^2$	$Q^2 = < p_{T,jet}^2 >$
$\frac{\sigma_{Z\_bjet}}{\sigma_Z}$	0.23 %	0.29 %
$\frac{\sigma_{Z\_bjet}}{\sigma_{Zjet}}$	1.8 %	2.2%

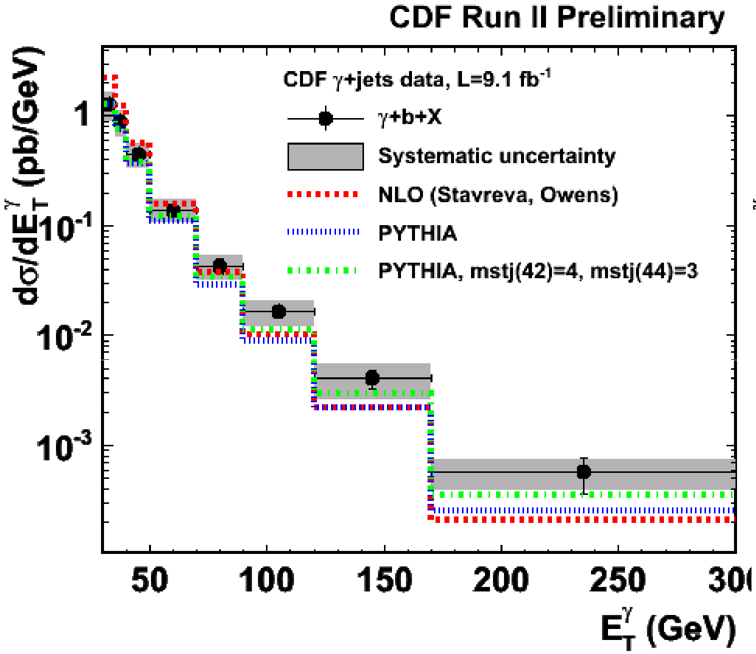
In good agreement with NLO

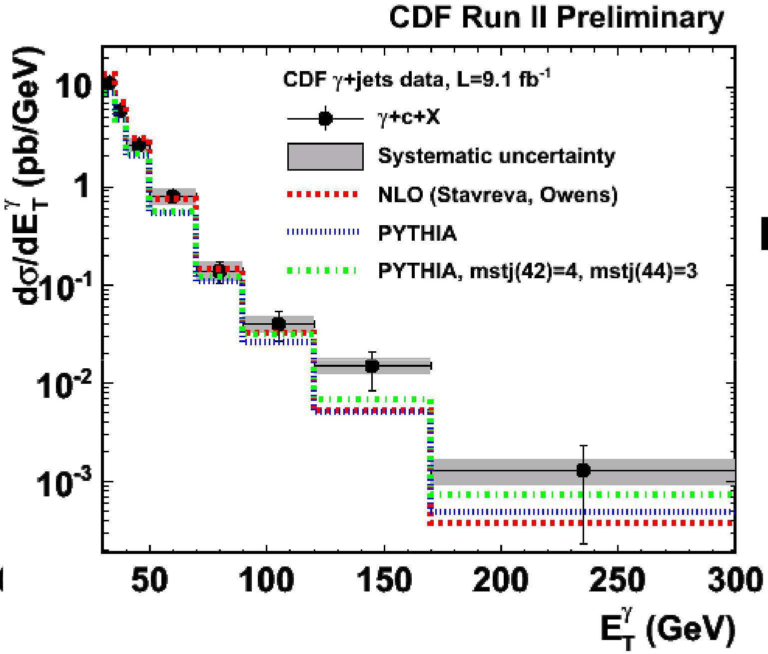
QCD: Direct γ in association with heavy quark

- Measured **σ(γ + c + X)** and **σ(γ + b + X)** as a function of E_T^γ
- $30 < E_T^\gamma < 300$ GeV, $|y^\gamma| < 1.0$
- Jets: $|y|<1.5$, $E_T>20$ GeV

Reasonably good agreement at NLO for low E_T^γ

Data σ higher than NLO at high are higher with NLO





Full CDF Dataset Preliminary

CDF note 10818

σ(pp→γ + b + X; $30 < E_T^\gamma < 300$ GeV, $P_T^b > 20$ GeV) **= 19.7±0.7(stat)±5.0(syst) pb**

σ(pp→γ + c + X; $30 < E_T^\gamma < 300$ GeV, $P_T^c > 20$ GeV) **= 132.2±4.6(stat)±19.2(syst) pb**

NLO prediction σ(γ + b + X) = $27.3^{+2.3}_{-1.5}$ **pb ;σ(γ + c + X) =** $152.6^{+12.2}_{-9.6}$ **pb**

Heavy Flavor

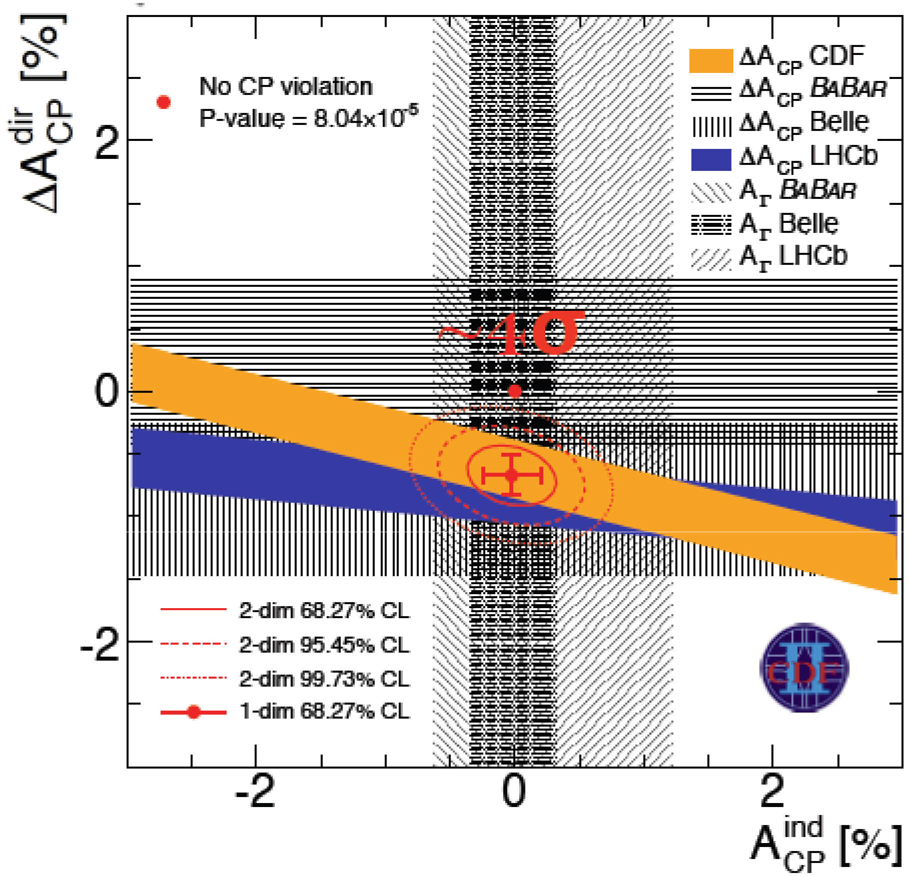
- Large production cross sections, datasamples
- Broad heavy flavour physics program
- Latest results
  - CPV in charm with Full CDF Run II dataset
  - Search for $B \rightarrow \mu\mu$ with Full CDF Run II dataset
  - CPV in B_S mixing CDF and D0
  - D0 new state decaying into $\Upsilon(1S)+\gamma$

D0: http://www-d0.fnal.gov/Run2Physics/WWW/results/b.html

CDF: http://www-cdf.fnal.gov/physics/new/bottom/bottom.html

HF: CP violation in charm

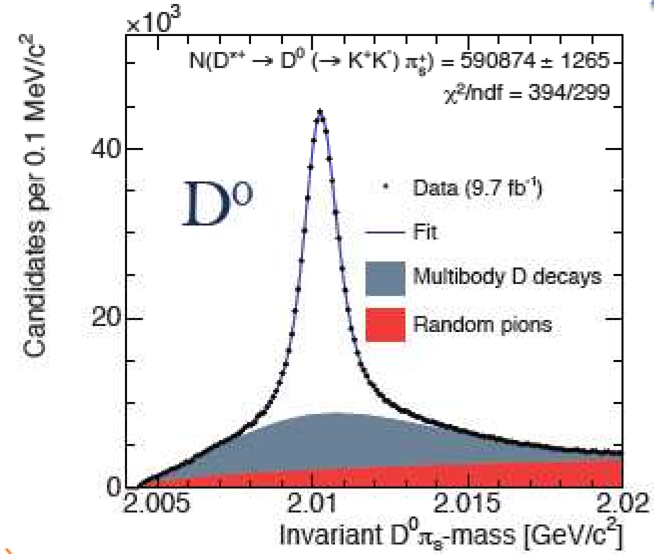
Full CDF Dataset
Preliminary
CDF Note 10784



- Trigger on displaced tracks
- Huge charm sample in $D^0 \rightarrow K^+K^-$, $D^0 \rightarrow \pi^+\pi^-$
- Optimize off-line selection for ΔA_{CP}

$$\Delta A_{CP} = A_{CP}(D^0 \rightarrow K^+K^-) - A_{CP}(D^0 \rightarrow \pi^+\pi^-)$$

- D^0 flavor through $D^* \rightarrow D^0 \pi_s$



$$\Delta A_{CP} = (-0.62 \pm 0.21(\text{stat}) \pm 0.10(\text{syst}))\%$$

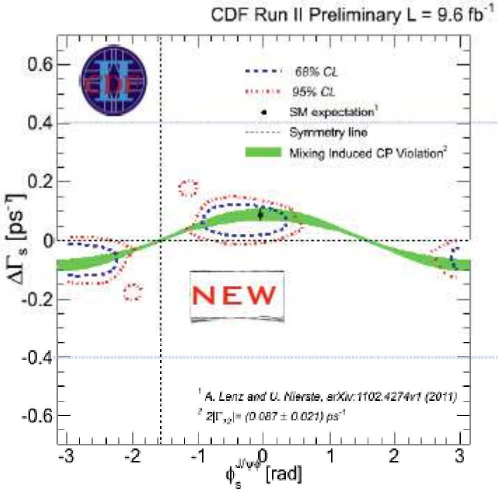
Inconsistent with no CP violation at 2.7σ

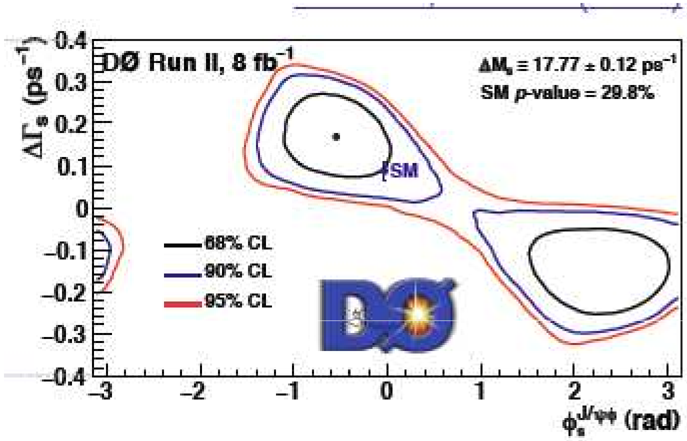
Confirm LHCb result (first evidencd of CPV in charm 3.5σ from zero)

HF: Search for new physics in B_S mixing

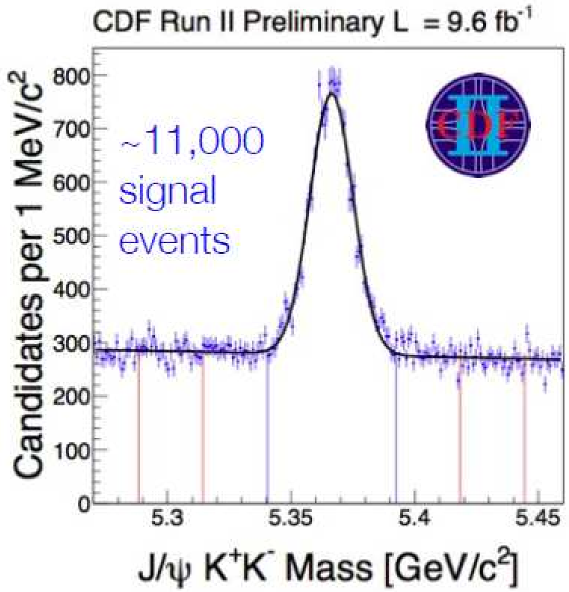
- A broad class of BSM models can introduce significant CP violation in Bs mixing
- Mixing phase through $B_S \rightarrow J/\psi\ \phi$ decays

D0 $\phi_s = -0.55^{+0.38}_{-0.36}$ rad CDF ϕ_s in [-0.60, 0.12] rad @ 68% C.L.





- Both experiments consistent with SM (<1σ)



with 8.0 fb^{-1} of data

$$\Delta\Gamma_s = 0.163^{+0.065}_{-0.064}\,\text{ps}^{-1}$$

$$\tau_s = 1.443^{+0.038}_{-0.035}\,\text{ps}$$

with 9.6 fb^{-1} of data

Assuming SM CP - violation

$$\Delta\Gamma_s = 0.068 \pm 0.027(\text{stat+syst})\,\text{ps}^{-1}$$

$$\tau_s = 1.528 \pm 0.021(\text{stat+syst})\,\text{ps}$$

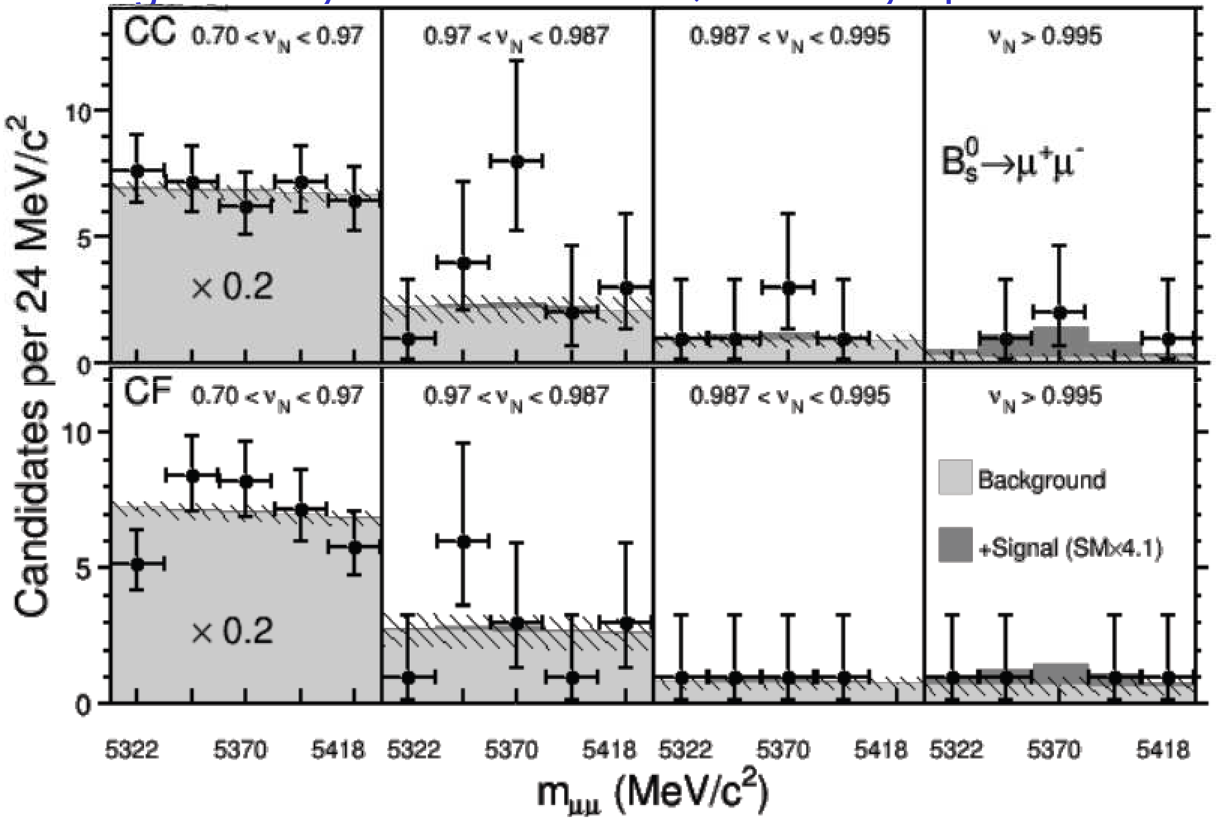
HF: B→ μμ

SM rates well understood

$BR(B_s^0 \to \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$, $BR(B^0 \to \mu^+\mu^-) = (1.0 \pm 0.1) \times 10^{-10}$

- ❑ Interesting 2.5σ deviation from bkg seen by CDF with 7 fb^{-1}→Recently updated with full dataset (10 fb^{-1})

oClean Signature
  - Trigger on 2 μ P_T>1.5-2 GeV
oChallenge: reject 10^6 larger bkg.
  - Use NN classifier (uses 14 input variables)
oCombinatorial bkg predicted from mass sideband (dominant) and fake rates for B→h^+h^-



- ❑ Limits on BR(B→μμ) consistent with SM

$0.8 \times 10^{-9} < BR(B_s \to \mu\mu) < 3.4 \times 10^{-8}$ @95% C.L. [$BR = (1.3^{+0.9}_{-0.7}) \times 10^{-8}$]

>2σ for bkg only hypothesis. p-value 0.94% (bkg only) 7.1% bkg + SM signal

HF: New state decaying into Υ(1S)+γ

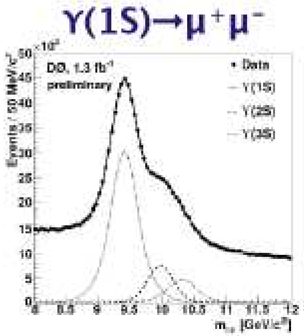
- Confirm ATLAS observation of $\chi_b(3P) \rightarrow \Upsilon(1S) + \gamma$

$$M[\chi_b(3P)] = 10.551 \pm 0.014 \pm 0.017 \text{ GeV}$$

1.3 fb^{-1} D0 Dataset

Submitted to Phys. Lett. B

arXiv: 1203.6034



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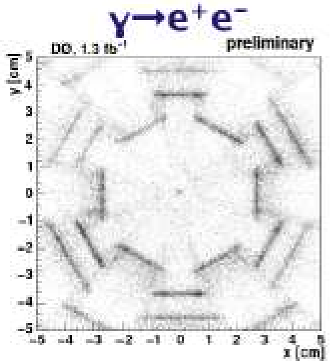
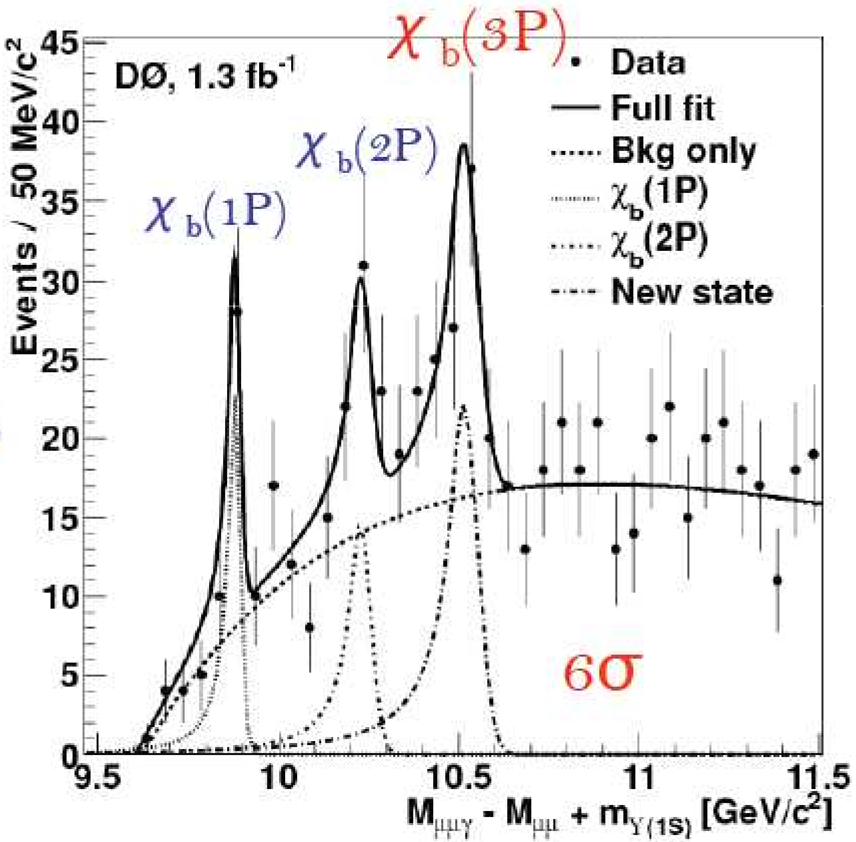




Electroweak

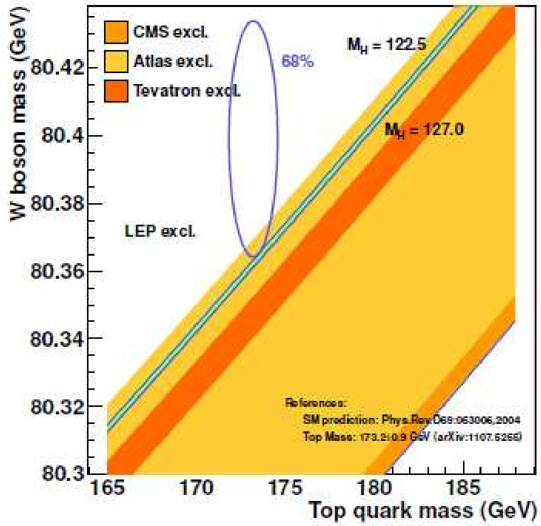
- Focus mainly on
  - W mass CDF and D0 results
  - Dibosons at Tevatron

D0: http://www-d0.fnal.gov/Run2Physics/WWW/results/ew.htm

CDF: http://www-cdf.fnal.gov/physics/ewk/

W Mass: Introduction

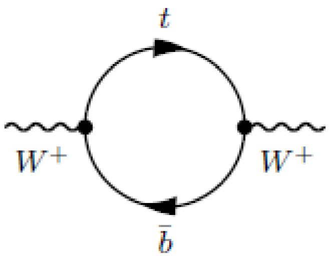
Before Feb. 2012

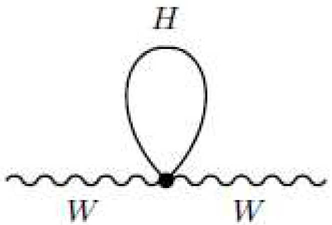


- The W boson mass is not an input parameter, but can be calculated

$$M_W\left(1-\frac{M_W^2}{M_Z^2}\right)=\frac{\pi\alpha}{\sqrt{2}G_\mu}(1+\Delta r)$$

  - Radiative corrections Δr dominated by top and Higgs Loops





Indirect dependence	δM_W
$\delta M_H = 13\,GeV[114 \rightarrow 127]$	$-6.2\,MeV$
$\delta m_t = 1.8\,GeV[172.4 \rightarrow 174.1]$	$10.8\,MeV$
Current theoretical uncertainty	$4\,MeV$

- Precision measurements in m_W and m_{top} constrain SM Higgs mass

W Mass

- Impossible to know the parton system initial longitudinal momentum and thus P_Z^ν
- Transverse momenta carry part of the mass info. Use bin likelihood fits to extract M_W from different kinematical distributions: m_T, P_T^l, P_T^ν

Event Selection

CDF analysis	DØ analysis
• Analyzed $2.2\,fb^{-1}$.	• Analyzed $4.3\,fb^{-1}$ ($1\,fb^{-1}$ analyzed before)
• Uses $W \to e\nu$ and $W \to \mu\nu$ decay channels.	• Uses $W \to e\nu$ decay channel.
• Central leptons $\|\eta\| < 1$ with $30 < p_T < 55\,GeV$	• Central electrons $\|\eta\| < 1.05$ with $p_T > 25\,GeV$
• Missing transverse energy $30 < \not{E}_T < 55\,GeV$	• Missing transverse energy $\not{E}_T > 25\,GeV$
• Transverse mass $60 < m_T < 100\,GeV$	• Transverse mass $50 < m_T < 200\,GeV$
• Hadronic recoil momentum $u_T < 15\,GeV$	• Hadronic recoil momentum $u_T < 15\,GeV$

W Mass: Calibration strategy

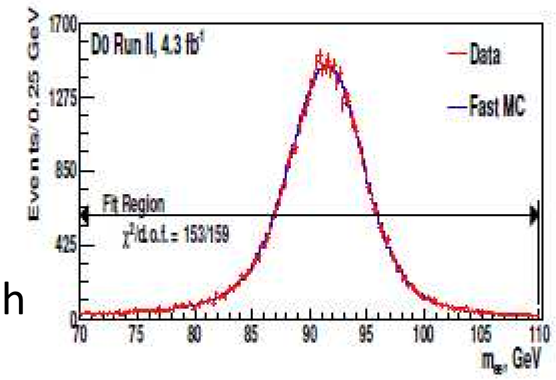
- Parametrize fast simulations of the detector response to W→lν
- Parametrizations are calibrated with data, using different strategies

CDF strategy

- Detailed model of lepton interactions at the central tracker.
- Precise alignment using cosmic rays.
- Momentum scale calibrated using $J/\psi \to \mu\mu$, $\Upsilon \to \mu\mu$ and $Z \to \mu\mu$ mass fits.
- Use calibrated momentum scale and E/p distribution in $W \to e\nu$ events to calibrate the calorimeter energy scale.

DØ strategy

- Detailed model of the calorimeter response to electrons and photons.
- Detailed model of the underlying energy flow.
- Detailed model of efficiencies.
- Calibrate the calorimeter energy scale using the dielectron invariant mass and angular distribution in $Z \to ee$ decays (electron energy scale α and energy offset β).

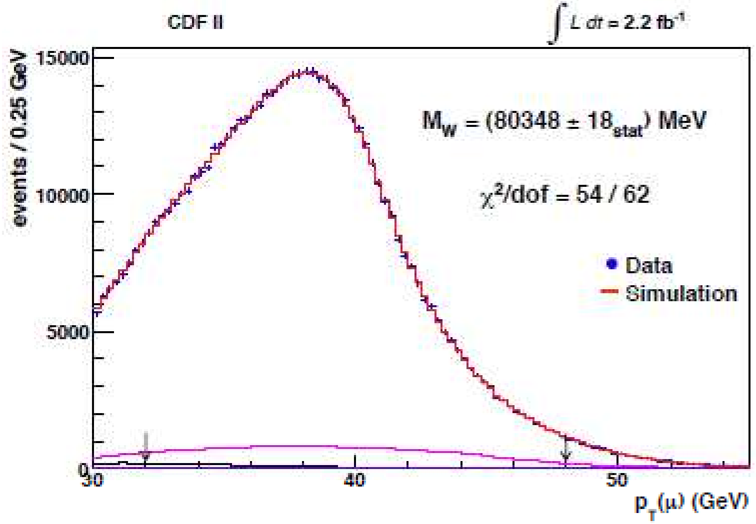


$$M_Z(ee) = 91193 \pm 17(\text{stat})\, MeV$$

- CDF momentum and D0 energy scale precision ~0.01%
- Z mass fits to test the calibrations . All values consistent with LEP measurements: M_Z = 91188 ± 2 MeV

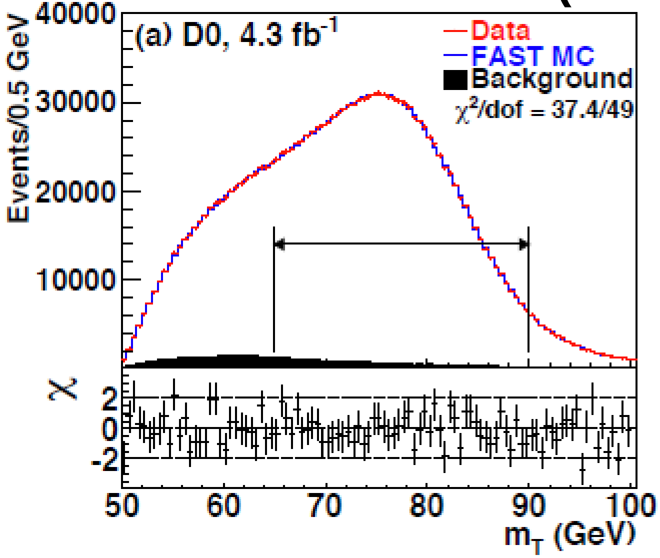
W Mass: Results

PRL 108 151803 (2012)

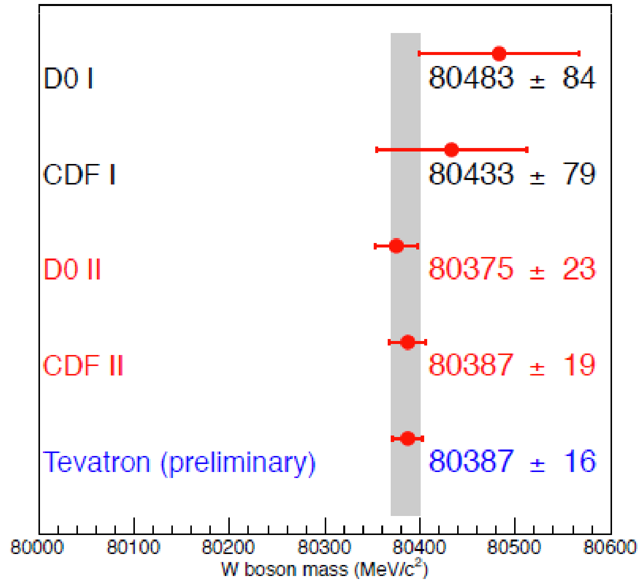


M_W = 80387 ± 19 MeV (CDF, 2.2 fb^{-1})

PRL 108 151804 (2012)



M_W = 80367 ± 26 MeV (DØ, 4.3 fb^{-1})

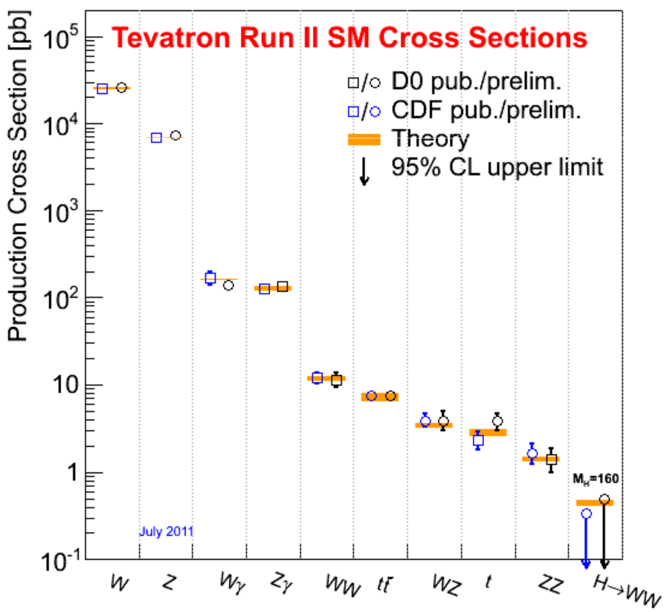


- Fits performed to m_T, P_T^l, P_T^ν
- Combine all three in *e* and μ channels in CDF and in m_T, P_T^l in *e* channel (D0), taking into account correlations

- ❑ CDF and D0 results in excellent agreement
- ❑ Most precise measurement in the world

Dibosons: Introduction

- Diboson production represents an important test of the EWK sector of the SM
  - Sensitive to anomalous gauge boson couplings
  - New particles in extensions of the SM
- Important background to top, Higgs, SUSY
- ***Proving ground for combined Tevatron search for low mass Higgs (H→bb modes)***
- WW, WZ, and ZZ production are among the smallest standard model cross sections

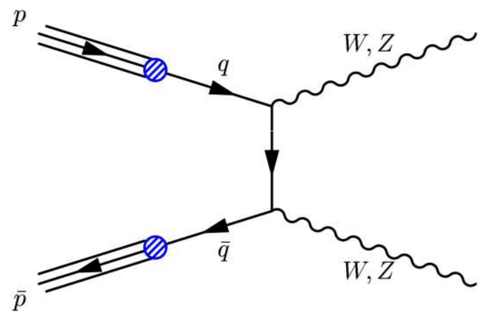


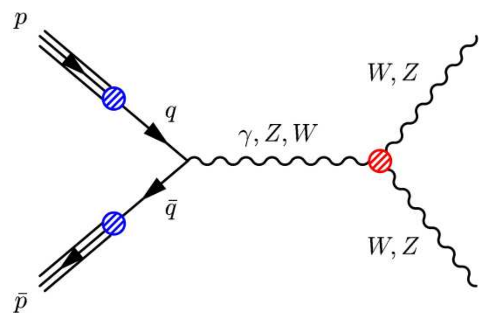
Extremely rare processes:

$$\sigma_{p\bar{p}\to W^+W^-}$$
$$11.34 \pm 0.7 \text{ pb}$$

$$\sigma_{p\bar{p}\to W^\pm Z^0}$$
$$3.22 \pm 0.2 \text{ pb}$$

$$\sigma_{p\bar{p}\to Z^0Z^0}$$
$$1.2 \pm 0.07 \text{ pb}$$

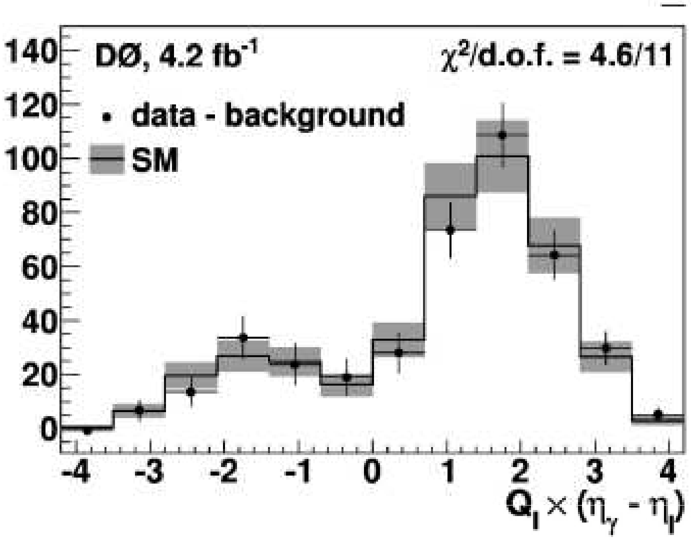




- TeVatron experiments already observed all modes

Dibosons: W/Z + γ

$W\gamma \rightarrow l\nu\, \gamma$



➢ PRL 107, 241803 (2011)

➢ $Q_l(\eta_\gamma - \eta_l)$ in agreement with SM

$-0.4 < \Delta\kappa_\gamma < 0.4, -0.08 < \lambda_\gamma < 0.07$

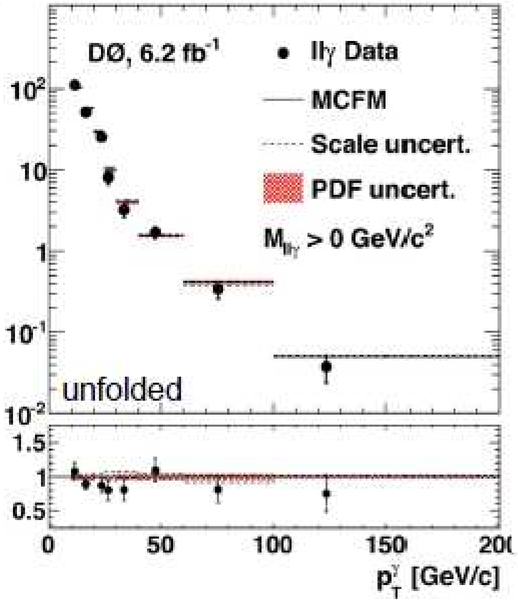
➢ ***95% C.L. TGC limits for Λ = 2 TeV***

$\sigma_{W\gamma} \times BR(W \rightarrow l\nu) = 7.6 \pm 0.4(stat) \pm 0.6(syst)$ pb

SM@NLO $\sigma(W\gamma) \times BR(W \rightarrow l\nu) = 7.6 \pm 0.2$ pb

$E_T^\gamma > 15$GeV, $\Delta R^{l\gamma} > 0.7$

$Z\gamma \rightarrow ll\gamma$



➢ PRD 85 052001 (2012)

$\sigma_{Z\gamma} \times BR(Z \rightarrow ll) = 1089 \pm 40(stat) \pm 65(syst)$ fb

SM@NLO $\sigma(Z\gamma) \times BR(Z \rightarrow ll) = 1096 \pm 34$ fb

$M_{ll\gamma} > 110$ GeV (FSR removal):

$\sigma_{Z\gamma} \times BR(Z \rightarrow ll) = 288 \pm 15(stat) \pm 11(syst)$ fb

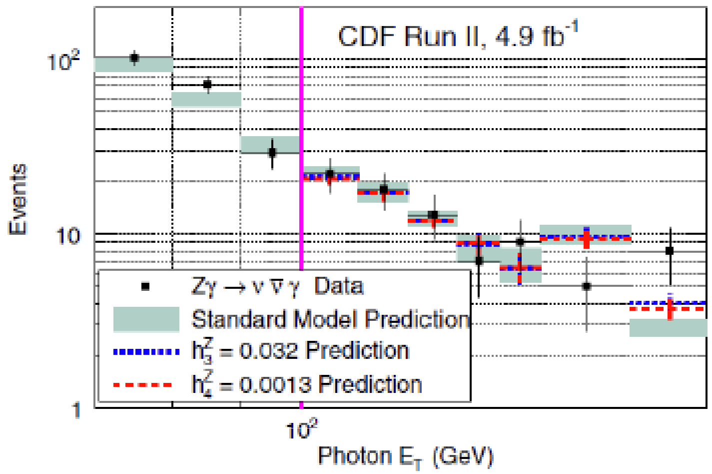
SM@NLO $\sigma(Z\gamma) \times BR(Z \rightarrow ll) = 294 \pm 10$ fb

$P_T^\gamma > 10$GeV, $\Delta R^{l\gamma} > 0.7$, $|\eta^\gamma| < 1$

➢ diff. cross section ($d\sigma/dp_T^\gamma$) in agreement with SM

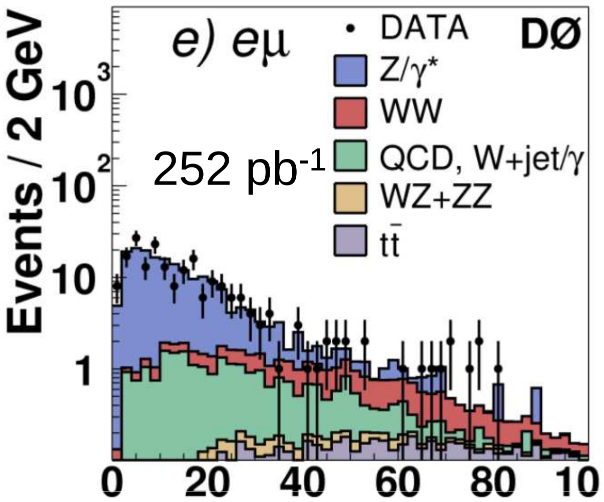
$Z\gamma \rightarrow ll\gamma$, $\nu\nu\gamma$

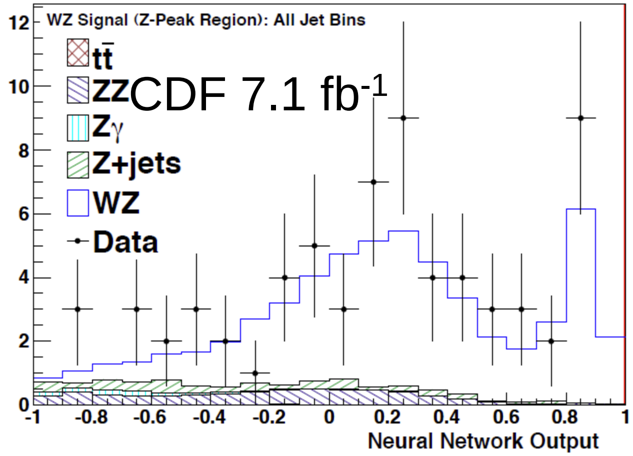
$\nu\nu\gamma$: photon $E_T > 100$ GeV

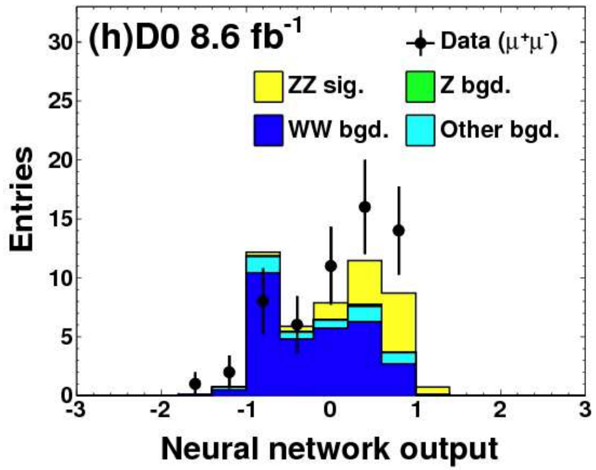


Parameter	(Λ = 1.5 TeV)
h_3^Z	−0.020, 0.021
h_4^Z	−0.0009, 0.0009
h_3^γ	−0.022, 0.020
h_4^γ	−0.0008, 0.0008

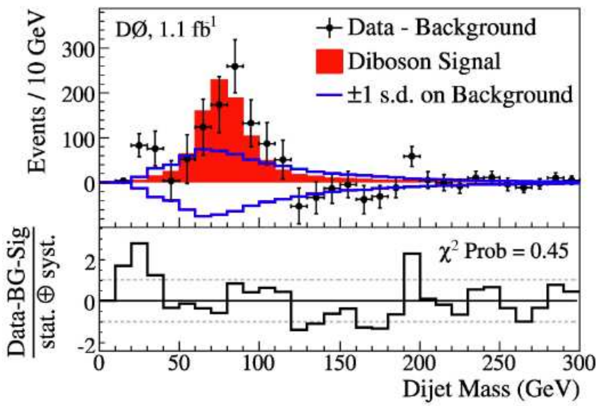
Dibosons: VV in dileptons and semileptons

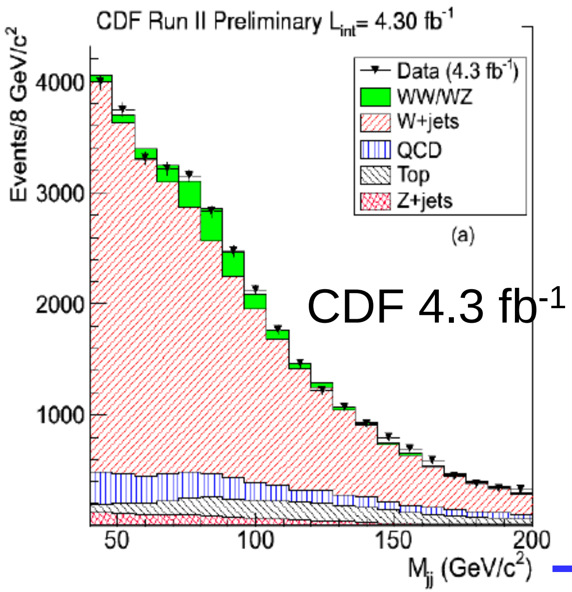




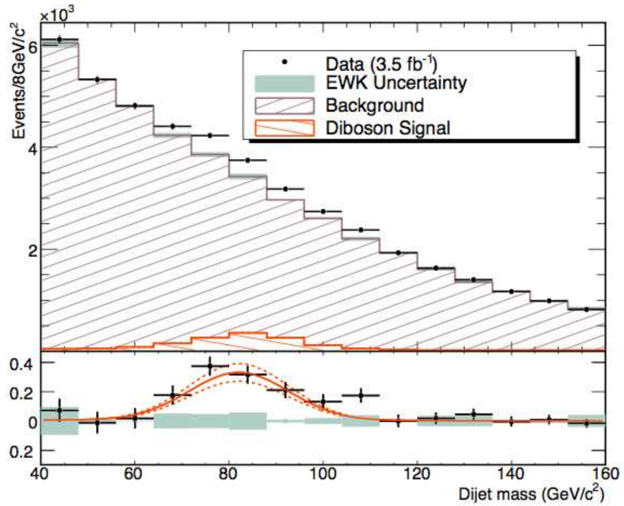


D0 1.1 fb-1





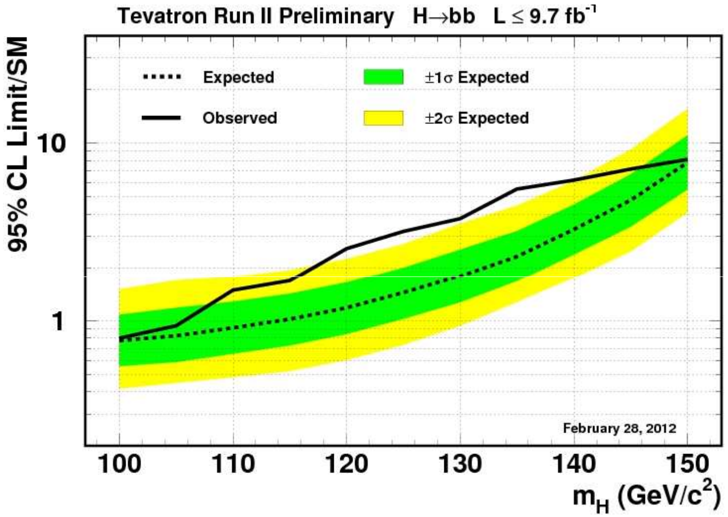
CDF 3.5 fb-1



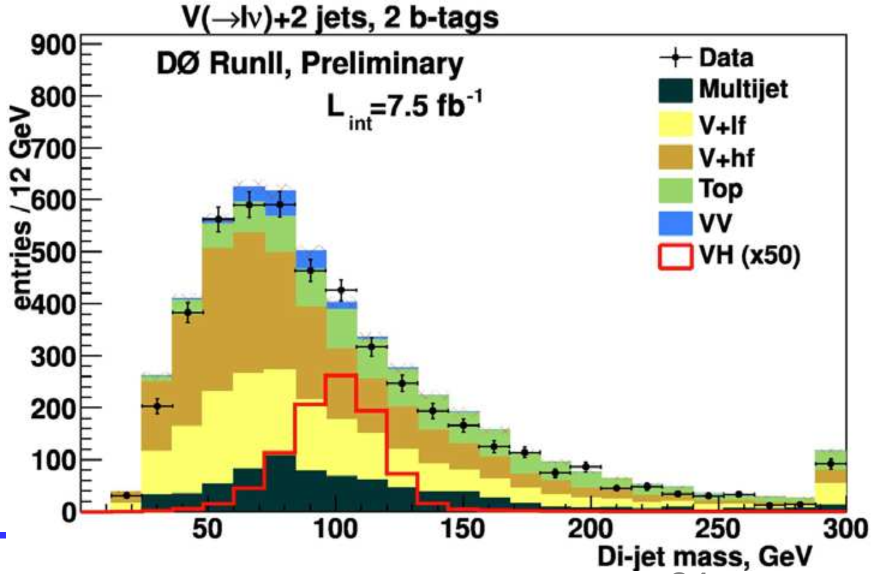
Phys. Rev. Lett. **102**, 161801 (2009) Ph

WZ/ZZ with heavy flavor jets

- WZ/ZZ with HF jets probing ground for H→bb searches
  - WZ/ZZ →llbb, lvbb, vvbb same final states as most important channels for low-mass Higgs searches at Tevatron (WH/ZH)



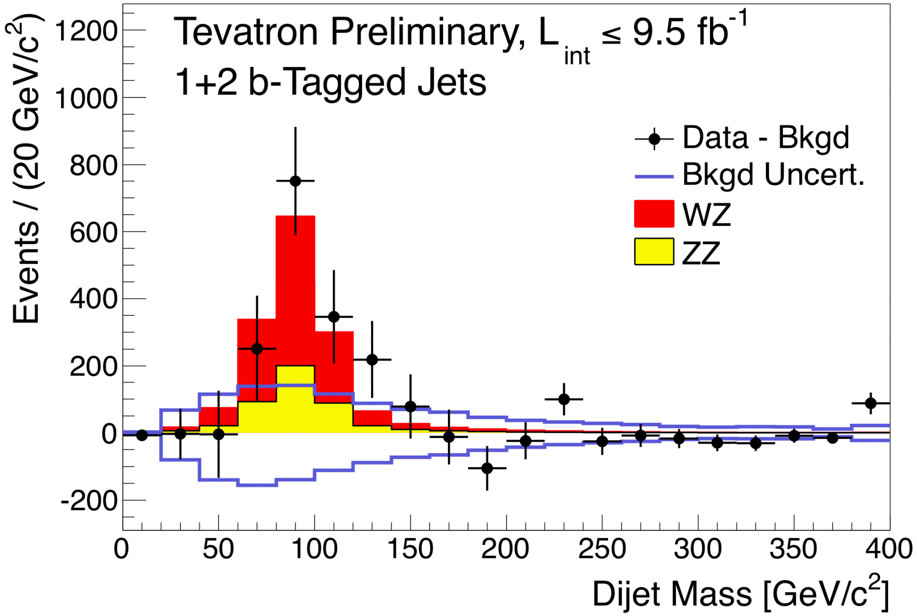
Final State	(W/Z)***H* (115 GeV)**	(W/Z)*Z*
lvbb	**27 fb**	**105 fb**
llbb	**5 fb**	**24 fb**
vvbb	**15 fb**	**73 fb**

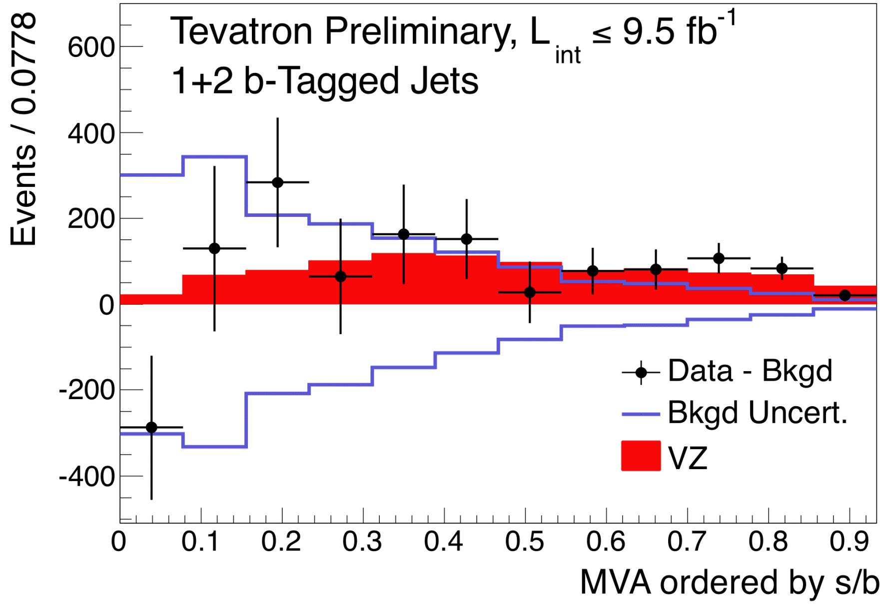


- WZ/WZ ~ 4-5 times larger cross section than WH/ZH
- WZ/ZZ harder to distinguish from large irreducible background (WW…)

Diboson: b-tagged final state

$\sigma(VZ)_{SM}$= 4.42 pb





Tevatron Combination

- VZ in final states with b-tagged jets
  - WW is considered a background
- Validates low mass Higgs searches
  - Replicate Higgs-low-mass analyses
- ***σ(VZ)=4.47 ± 0.64 ± 0.73 pb***
- Evidence with ***4.6σ***

Top Physics

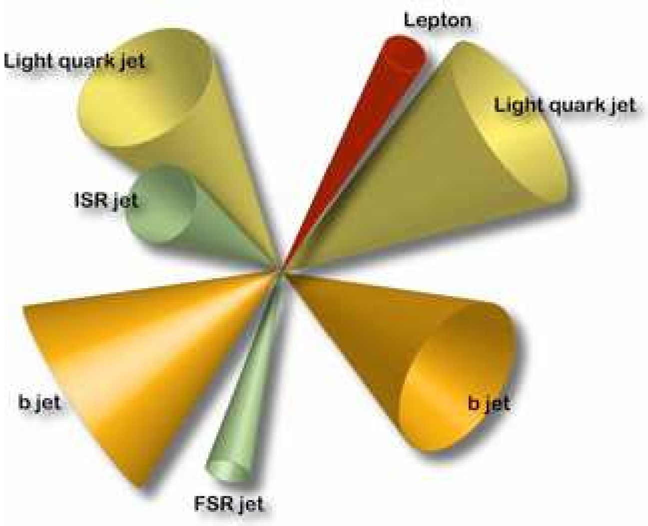
- Focus mainly on
  - Top mass CDF and D0 results
  - Single top
  - Forward-Backward asymmetry

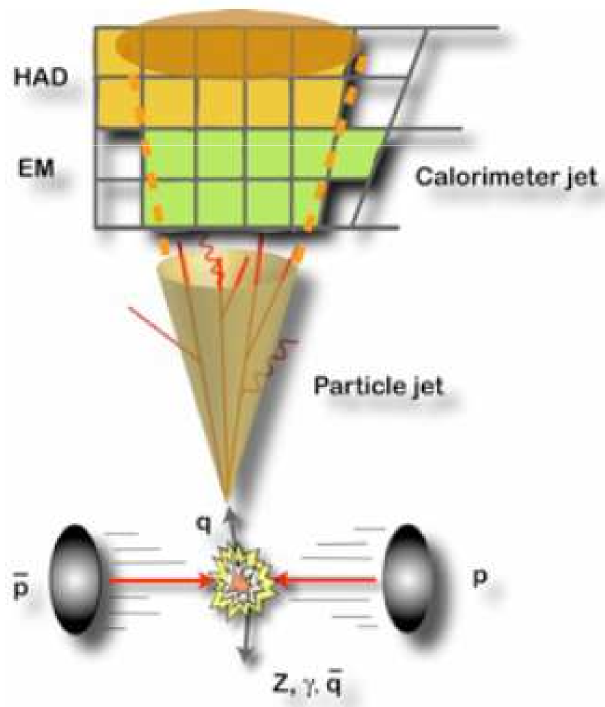
Many other results:

D0: ***http://www-d0.fnal.gov/top/top_public_web_pages/top_public.html***
CDF: ***http://www-cdf.fnal.gov/internal/physics/top/topnew.shtml***

Top mass overview

- Difficult measurement
- Most information carried in quarks
  - But can only measure resulting jets
  - Jet-parton assignment
  - QCD radiation
- Jet energy scale (JES) uncertainty dominates [~3%]
  - Can be reduced via *in situ* measurement from hadronic *W*
- Mass measurement techniques
  - *Matrix element: form probabilities as function*
  - *Template: form templates as function of mt* and JES from fully simulated events



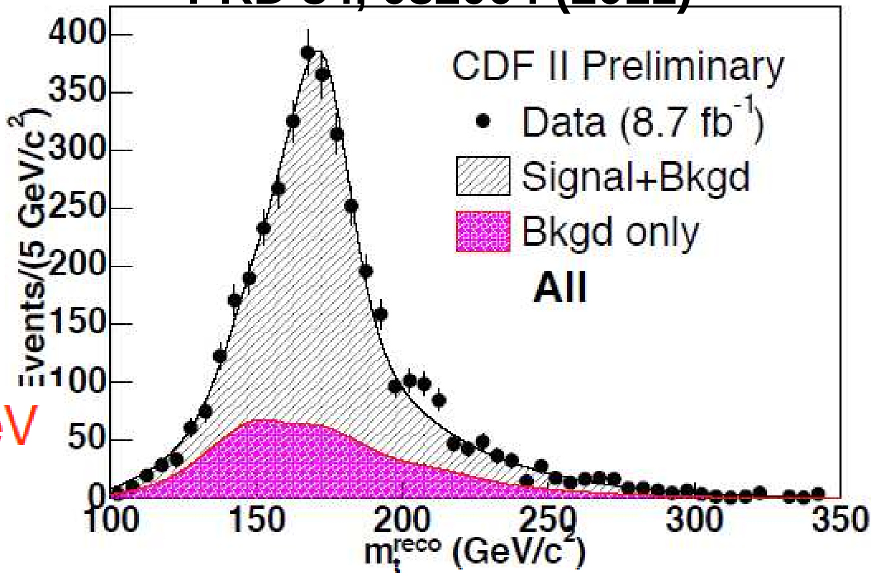


Top mass: Analysis Strategy

- Semileptonic channel
  - Reconstruct top mass per event
    - Determine χ^2 for each jet-parton pairing
  - Final state separated according to number of b-tags
  - 2D fit to mt and ΔJES
  - ***Single best measurement to date***

m_t=172.85±0.71(stat+JES)±0.84(syst) GeV

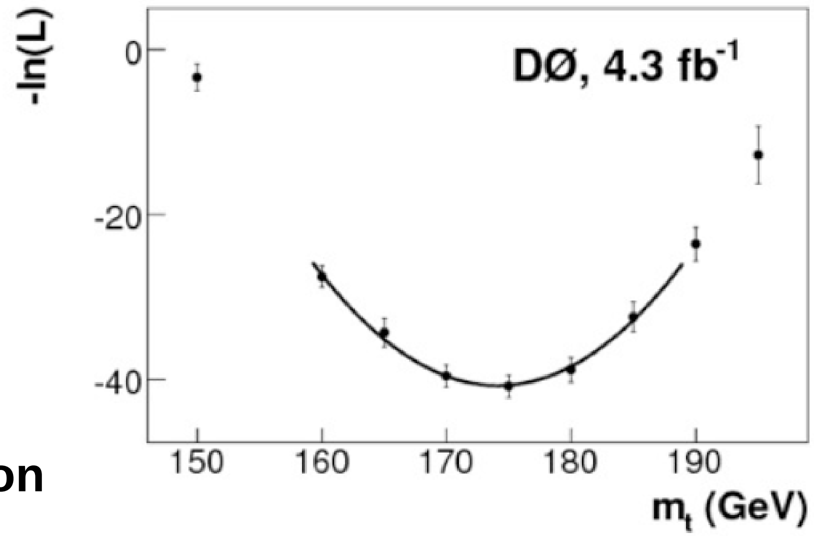
PRD 84, 032004 (2011)



- Dileptonic channel
  - Kinematically underconstrained
  - New D0 measurement transfers JES uncertainty from fit in l+jets channel
  - Integrate over unknown neutrino momenta
  - Use templates to extract fit mass
  - *Template:* form templates as function of mt and JES from fully simulated events

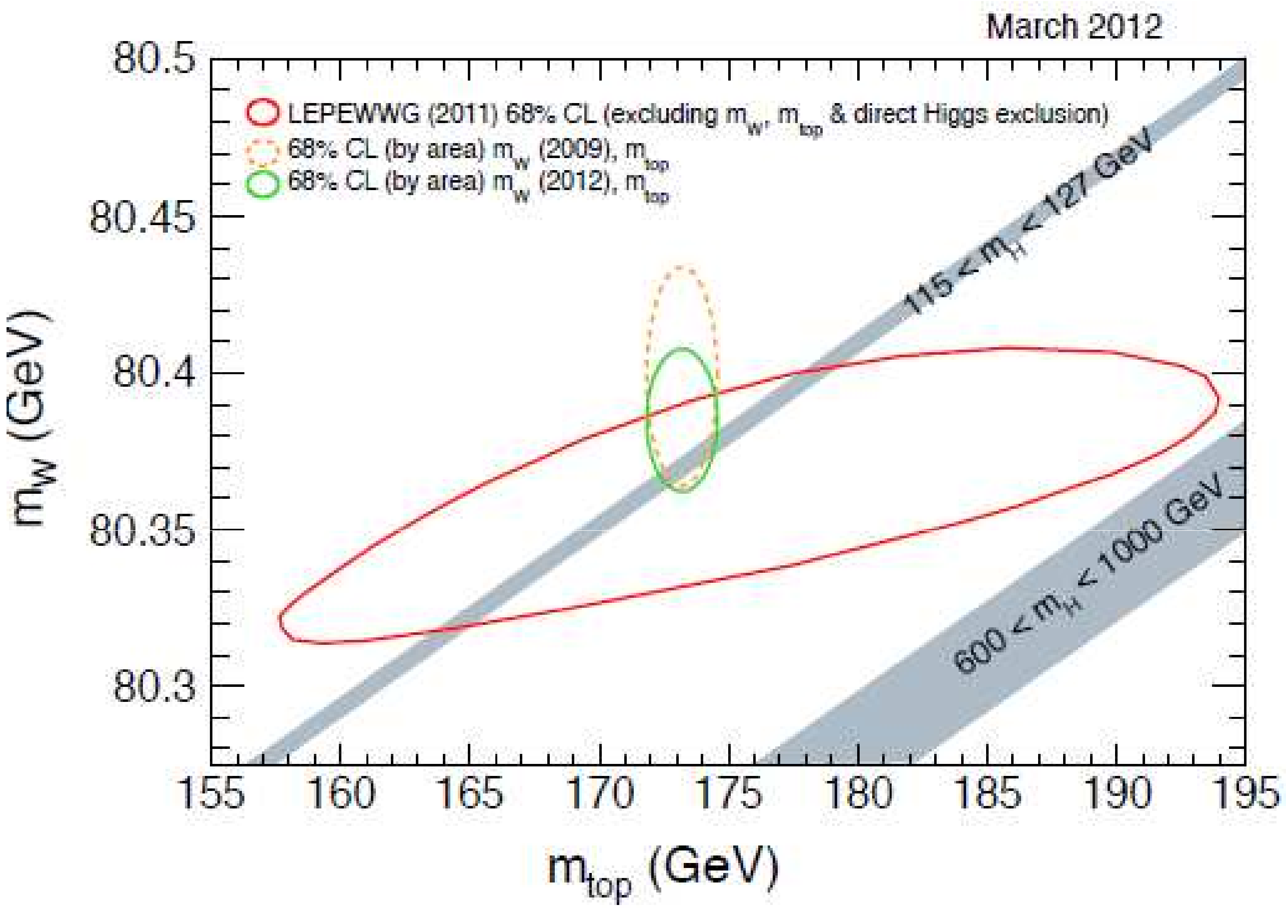
m_t=174.0±2.4 (stat)±1.4 (syst) GeV

Submitted to PRL, arXiv 1201.5172



Tevatron Combination will be updated soon

Top mass vs W mass



- As of March 2012

  $M_H = 94^{+29}_{-24}$ GeV

  $M_H < 152$ GeV @95% CL

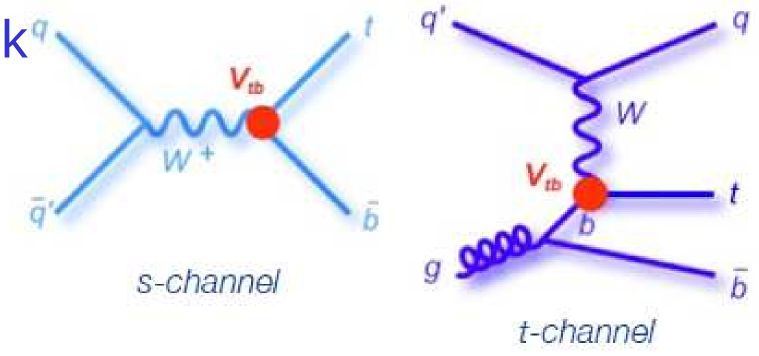
  Uses:

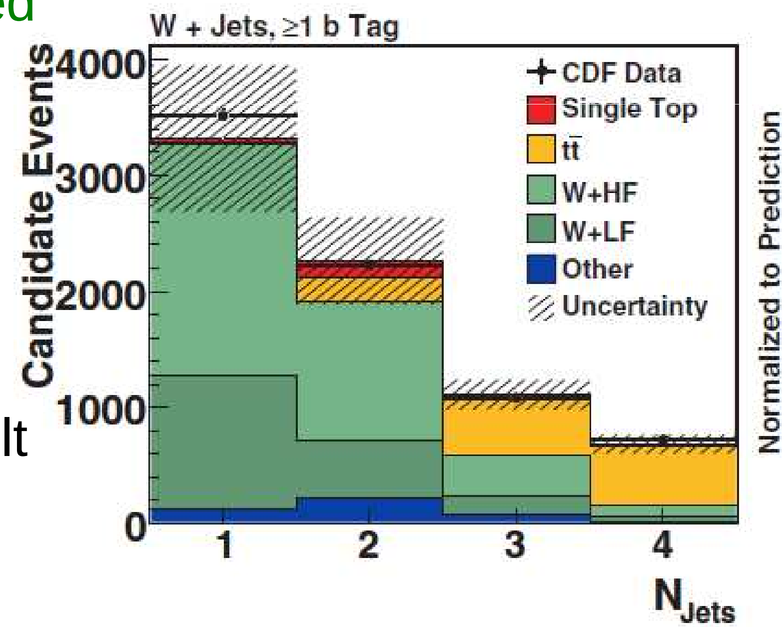
  M_W = 80385±15 MeV

  m_{top} = 173.2±0.9 GeV

Single Top Production

- Electroweak production of single top quark
  - s-channel: σ_{NLO} = 1.98 ± 0.21 pb
  - t-channel: σ_{NLO} = 0.88 ± 0.07 pb
- Allows for
  - Direct probe of W-t-b vertex
  - Several BSM phenomena (W', charged Higgs, etc)
  - Similar final state as WH→lνbb
- Not as "easy" as top pair measurement
  - Large backgrounds with large systematics
    - o Makes counting experiment difficult
- Process first observed at both CDF and D0 in 2009





Single top: cross section and $|V_{tb}|$

- Use 7.5 fb^{-1} of data
- Utilize NN discriminant
  - Signal modeling at NLO by POWHEG
- Combined t-channel, s-channel and Wt associated production

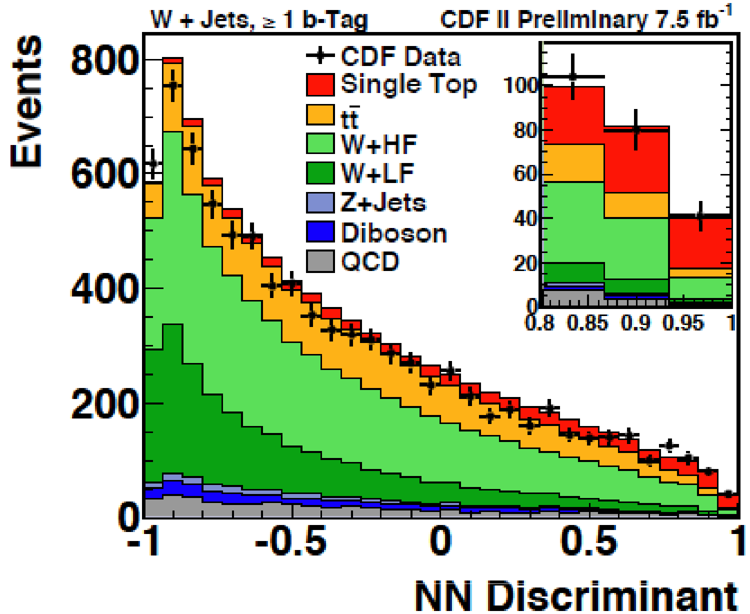
$\sigma_{s\text{-}top} = 3.04^{+0.57}_{-0.53}$ (stat+syst) pb

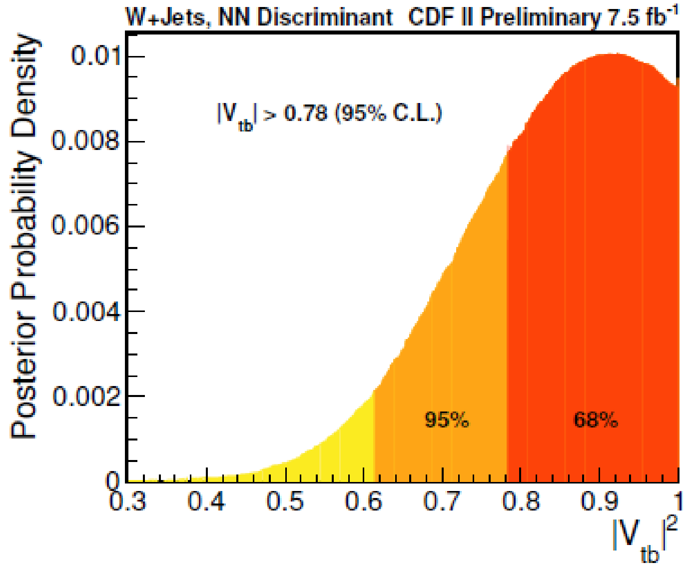
  - Assumes m_t = 172.5 GeV
  - NLO prediction 3.37 ± 0.34 pb
- Use ratio to NLO prediction ($|V_{tb}|$~1) to extract measured $|V_{tb}|$

|Vtb| = 0.96±0.09(stat+syst) ± 0.05 (theo)

|Vtb| > 0.78 @ 95% CL

$$|V_{tb,meas}|^2 = \frac{\sigma_{meas}}{\sigma_{SM}} \cdot |V_{tb,SM}|^2$$





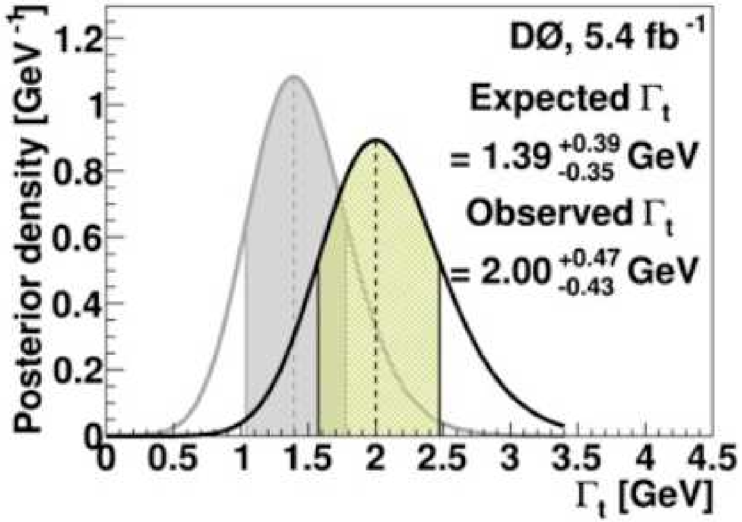
Top widh and lifetime from single top

- Use measured single top cross section and BR($t \rightarrow Wb$) to extract width

$$\Gamma_t = 2.00^{+0.47}_{-0.43}\ \text{GeV}$$

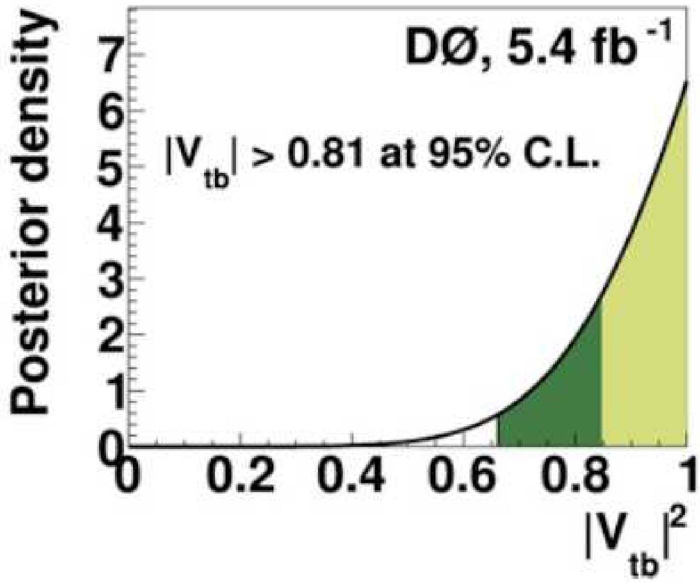
$$\tau_t = (3.29^{+0.90}_{-0.63}) \times 10^{-25}\ \text{s}$$

  - $\tau_t < 4.88 \times 10^{-25}$ s@95% CL
  - ***Most precise measurement of top width to date***



- Can utilize measurement to extract $|V_{tb}|$
  - Does not assume s- and t- channel ratios or decay BR for Wb

$$|V_{tb}| > 0.81\ @95\%\ \text{CL}$$



Forward Backward asymmetry

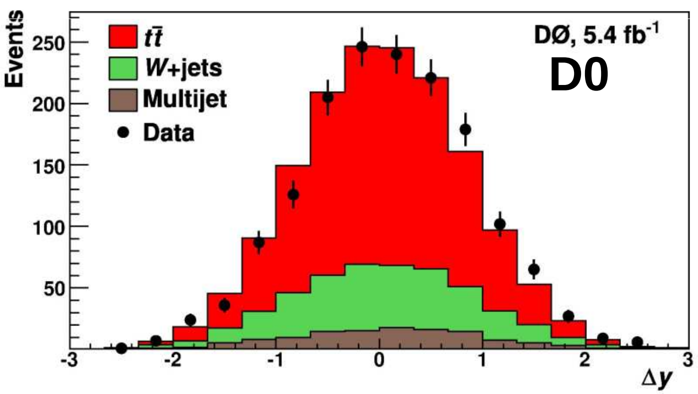
$$y = \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$$

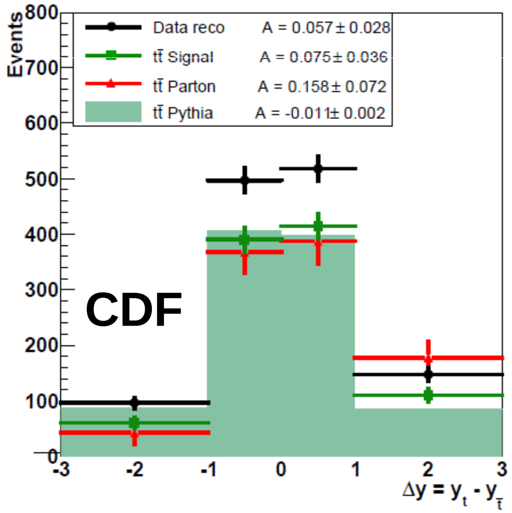
$$\Delta y = y_t - y_{\bar{t}}$$

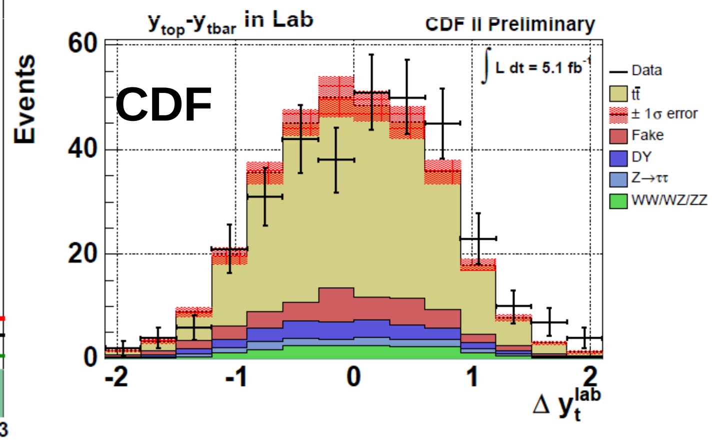
- NLO QCD predicts small (~7% asymmetry from qqbar→ttbar)
  - New physics could give rise to an asymmetry (Z', axigluons,..)
- Previous measurements (***~ 5fb^{-1}***): large forward-background asymmetry (A_{FB}) in the production angle
  - Equivalent to a ***charge asymmetry***
- A_{FB} measurement is unique to the Tevatron
  - LHC experiments can see a charge asymmetry
  - But it requires different techniques and the expected magnitud is much smaller

$$A_{FB} = \frac{N_{\Delta y>0} - N_{\Delta y<0}}{N_{\Delta y>0} + N_{\Delta y<0}}$$

PRD 84 (2011) 112005 **PRD 83 (2011) 112003** **CDF Conf. Note 10436**





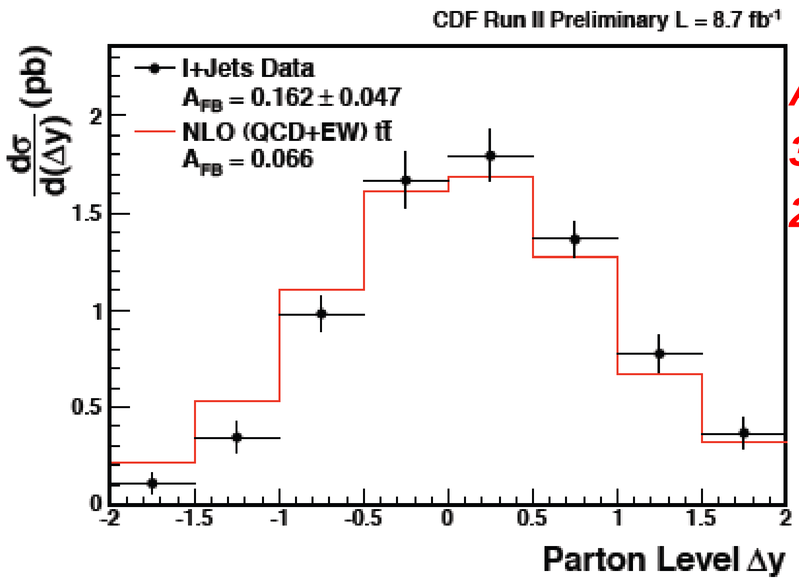


D0 Lep+Jets @5.4fb^{-1} CDF Lep+Jets @5.3fb^{-1} CDF Dilepton @5.1fb^{-1}

A_{FB}= 19.6±6.5% ***A_{FB}= 15.8±7.4%*** ***A_{FB}= 42±16%***

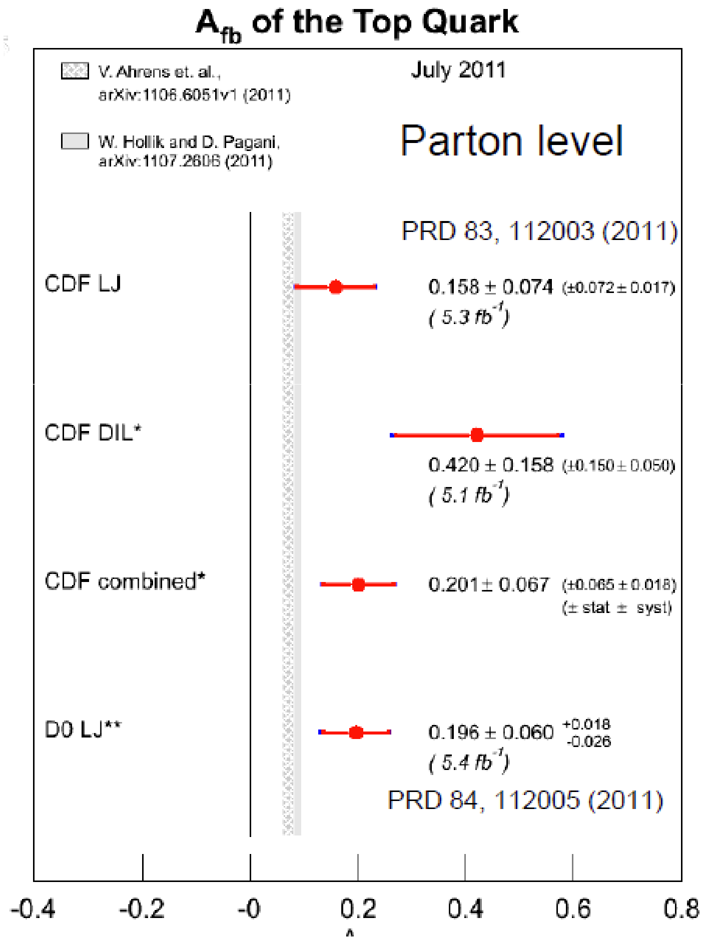
Forward Backward Asymmetry

- CDF updated the lepton + jets analysis with 8.7 fb^{-1} (full dataset)
  - Use NLO POWHEG + EW correction from SM prediction (previous analysis uses PYTHIA LO)
  - New regularized unfolding method for correction to parton level
- o 1 lepton, at least 4 jets, at least 1 btag, large MET
- o **2498** candidate events, **505** predicted background
- o Events reconstructed with χ^2–based kinematic fit



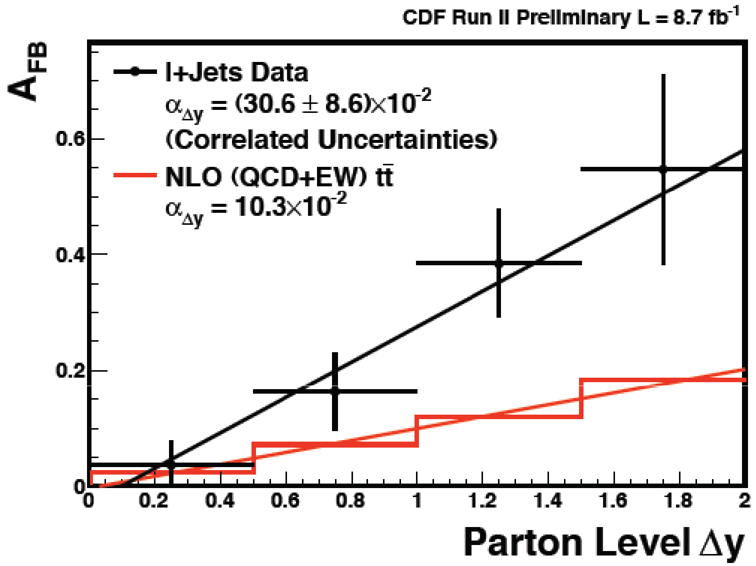
A_{FB}= 16.2±4.7%
3.4σ from no asy.
2σ from NLO POWHEG

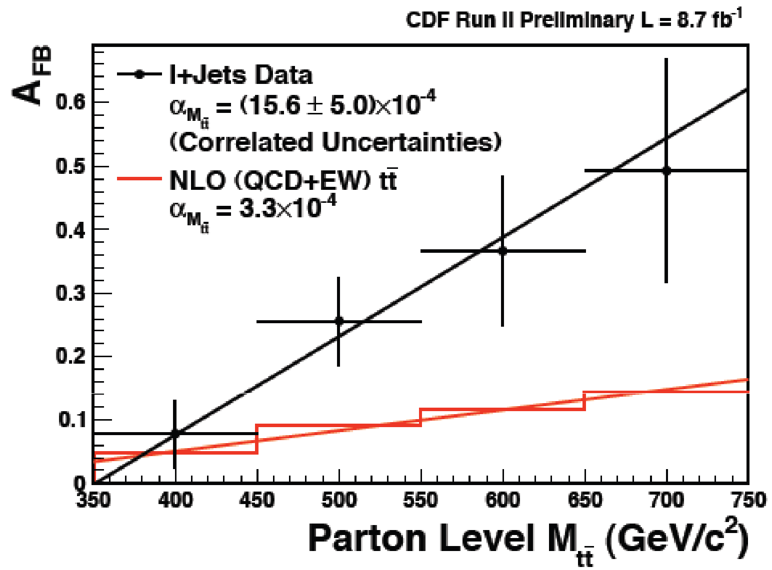
- In agreement with previous CDF and D0 results



Forward Backward Asymmetry

- Additional studies on dependcy with Δ*y* and M_{tt}
  - Previous studies only used 2 bins (somewhat ambiguous)
  - New regularized unfolding method for correction to te parton level





  - A_{FB} dependence with |Δy| and Mtt well described by a linear Ansatz both at reconstruction and parton level
  - Slope for data higher than for NLO prediction
  - Significance of discrepancy between POWHEG SM prediction and data evaluated before correction to parton level: pvalue
  - p-values: ***$6.46\text{x}10^{-3}$*** for A_{FB} vs M_{tt} and ***$8.92\text{x}10^{-3}$*** for A_{FB} vs |Δy|

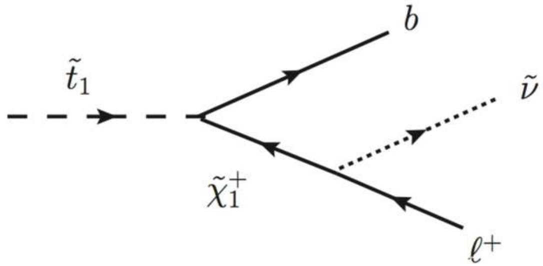
BSM

- Interesting recent results both in SUSY and no SUSY searches

D0: http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm
CDF: http://www-cdf.fnal.gov/physics/exotic/exotic.html

Stop in μ+τ final states

Submitted to Phys Lett. B arXiv:1202.1978

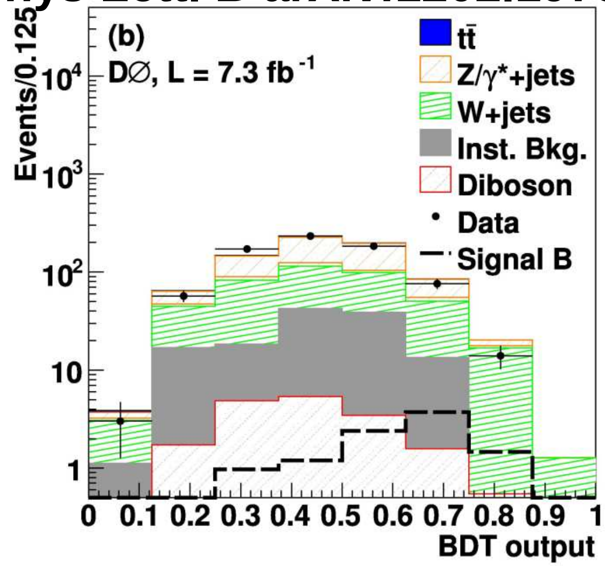


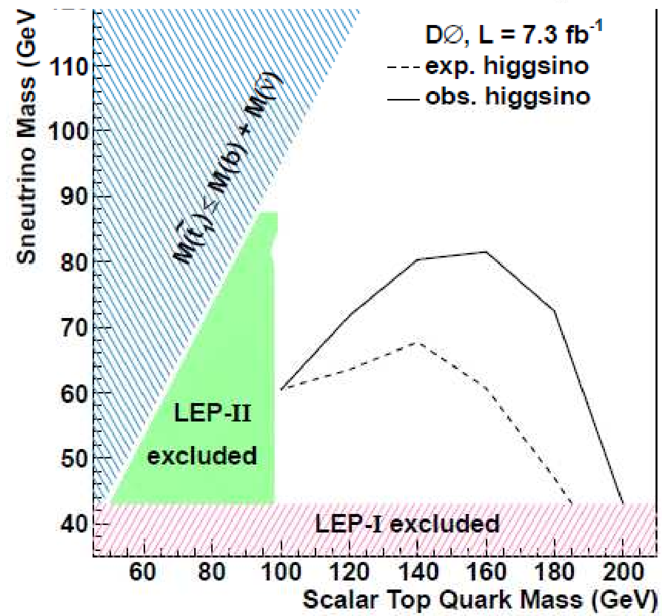
- Superpartners of the top and bottom quarks can be the lightest squarks
- D0 Search for $\tilde{t}_1\tilde{t}_1 \to bb\mu\tau\mathrm{MET}$ final state using 7.3 fb^{-1}
  - Assume $\tilde{\nu}$ is that LSP or it decays invisibly→ MET in the final state
  - Analyze 1, 2, and ≥ 2jets events separately
- Studied scenarios:

$$\text{wino scenario}: B(\tilde{t}_1 \to b\mu\tilde{\nu}) = B(\tilde{t}_1 \to b\tau\tilde{\nu}) = \frac{1}{3}$$

$$\text{higgsino scenario}: B(\tilde{t}_1 \to b\mu\tilde{\nu}) = 0.1;\ B(\tilde{t}_1 \to b\tau\tilde{\nu}) = 0.8$$

  - No significative excess of events observed
  - Limits set in the $(m_{\tilde{t}1}, m_{\tilde{\nu}})$ plane @95% CL





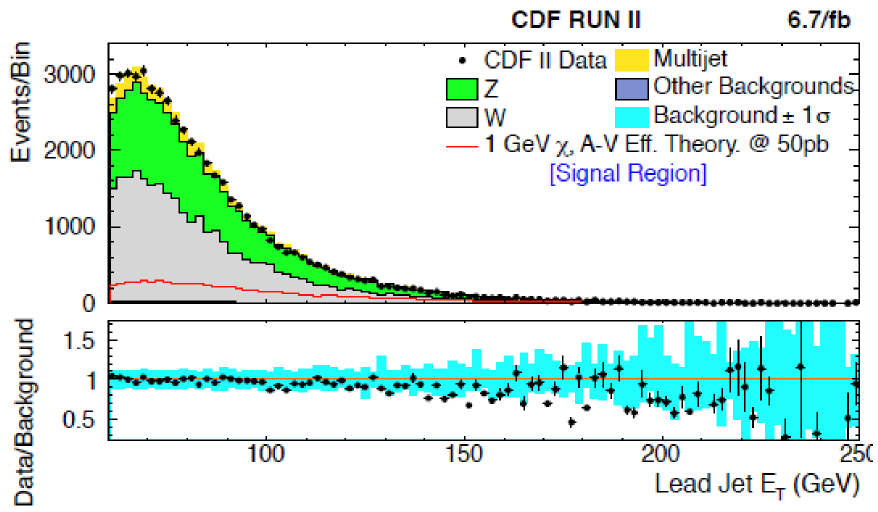
largest scalar top quark mass excluded is 200 GeV for a sneutrino mass of 45 GeV,

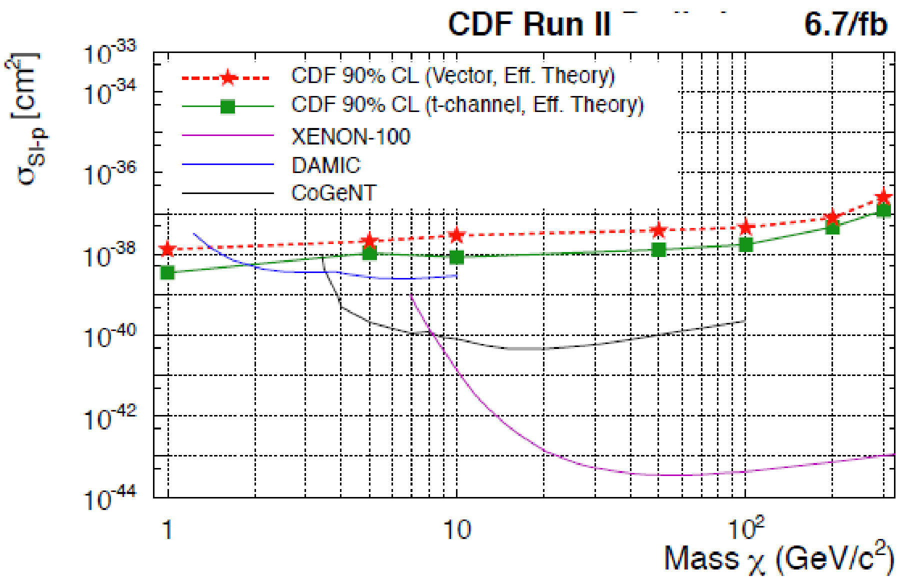
Dark matter search with monojet+missing E_T

- CDF Search for WIMP production in collider data using 6.7 fb^{-1}

  $p\bar{p} \rightarrow \chi\bar{\chi} + [=1]$ jet

  - Jet is O(100 GeV) and assumed to be ISR
- Signal region data consistent with SM
- Convert resulting limits to bounds on DM-nucleon scattering cross section
  - Y. Bai, P. Fox, R. Harnik, JHEP 1012:048 (2010)
- First search of this kind at a collider

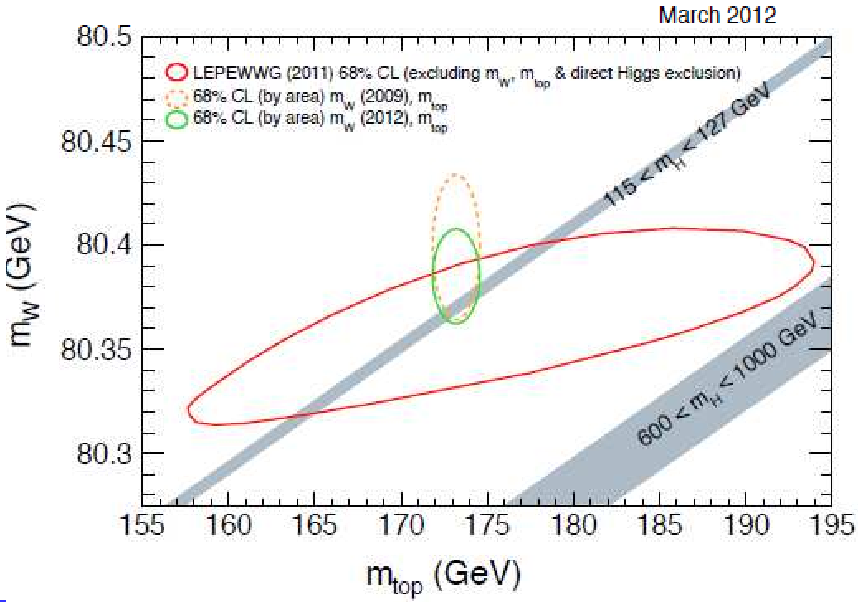




arXiv:1203.0742 accepted by PRL

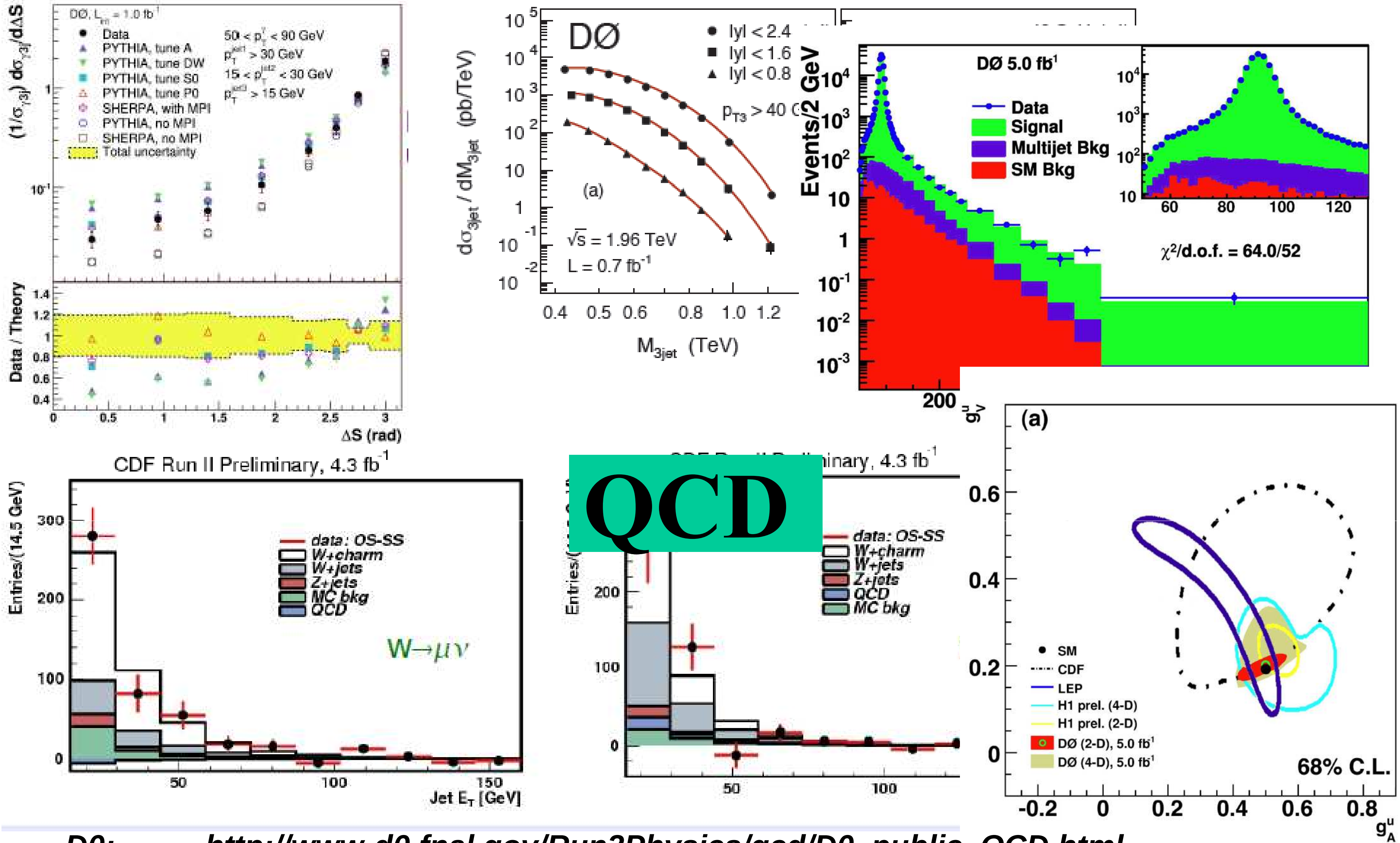
Summary

- ❑ Beginning of “final” results from the Tevatron
- ❑ 80+ new results since the Tevatron shutdown
  - ➢ Shown significative results in different physics sectors
- ❑ World best W mass measurement
- ❑ Still lead in top mass precision
- ❑ Confirmation of charm CP violation from LHCb
- ❑ Measurement of challenging signatures in the electroweak sector
  - ➢ Ultimate validation of Tevatron Higgs boson searches…



BACK-UP

QCD

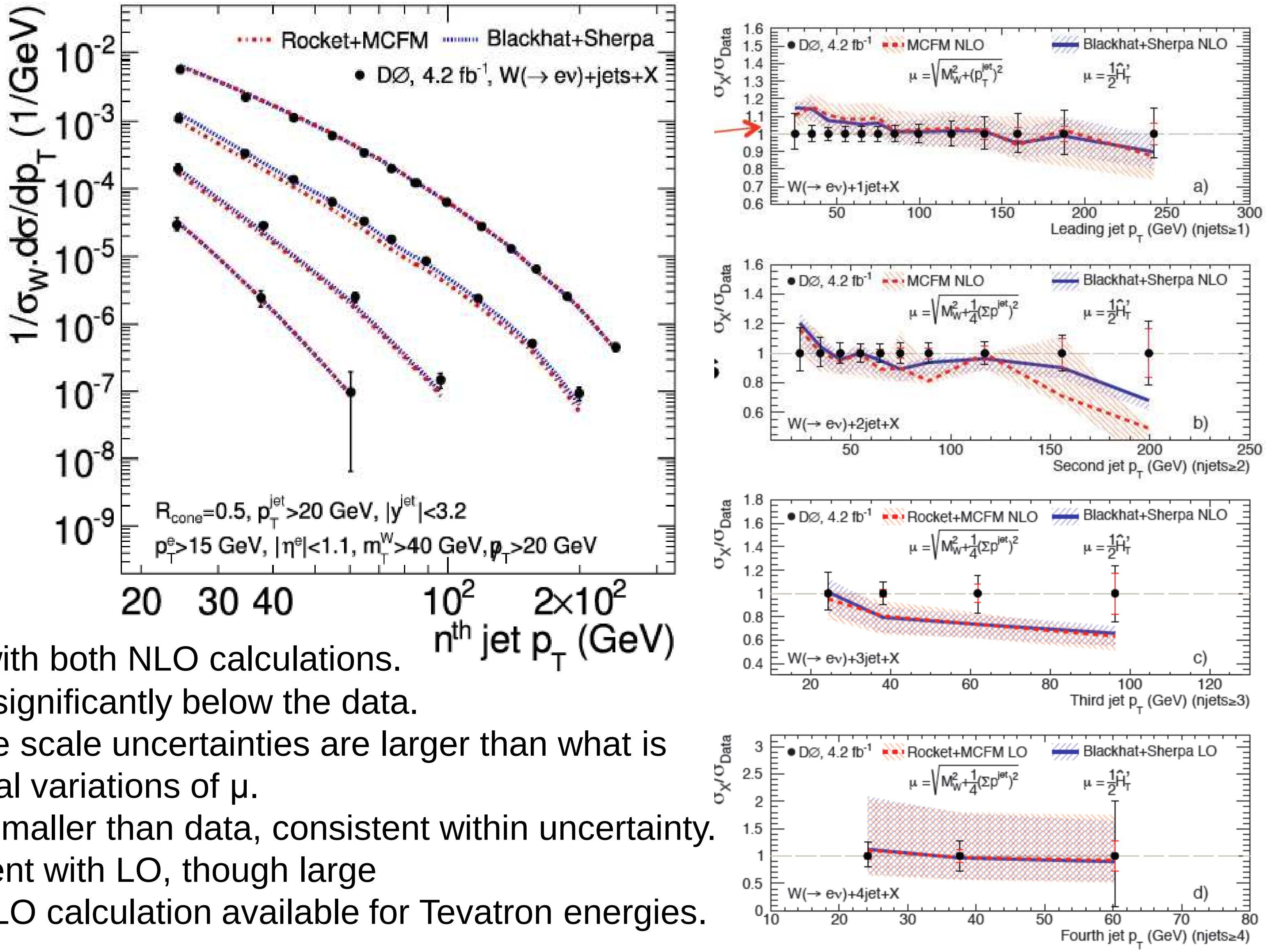


D0: ***http://www-d0.fnal.gov/Run2Physics/qcd/D0_public_QCD.html***

CDF: ***http://www-cdf.fnal.gov/physics/new/qcd/QCD.html***

QCD: W+jets production

4.2 fb^{-1} D0



o ***W+1jet***: agrees with both NLO calculations.

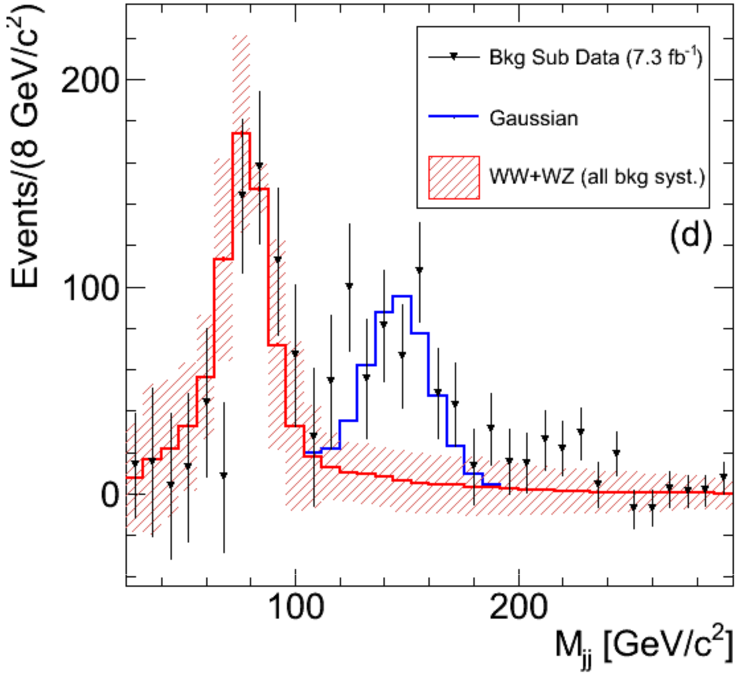
o ***W+2jets***: MCFM significantly below the data.

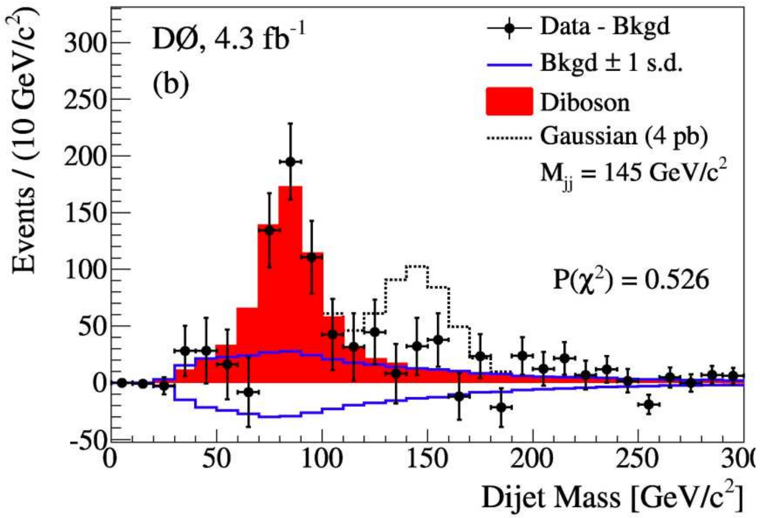
- Indicates that the scale uncertainties are larger than what is seen by conventional variations of μ.

o ***W+3jets***: theory smaller than data, consistent within uncertainty.

o ***W+4jets***: consistent with LO, though large uncertainties. No NLO calculation available for Tevatron energies.

Wjj anomaly





- **4.1 excess seen in dijet mass spectrum of W+2jet sample**
  - Binned 2 fit to Mjj distribution consistent with = 3.0±0.7 pb
  - Many cross checks performed: various bkg control regions, W+jets modelling etc

- DØ repeated CDF analysis (some minor differences)
- **No significant discrepancy w.r.t. background model**
- Results are 2.5σ apart

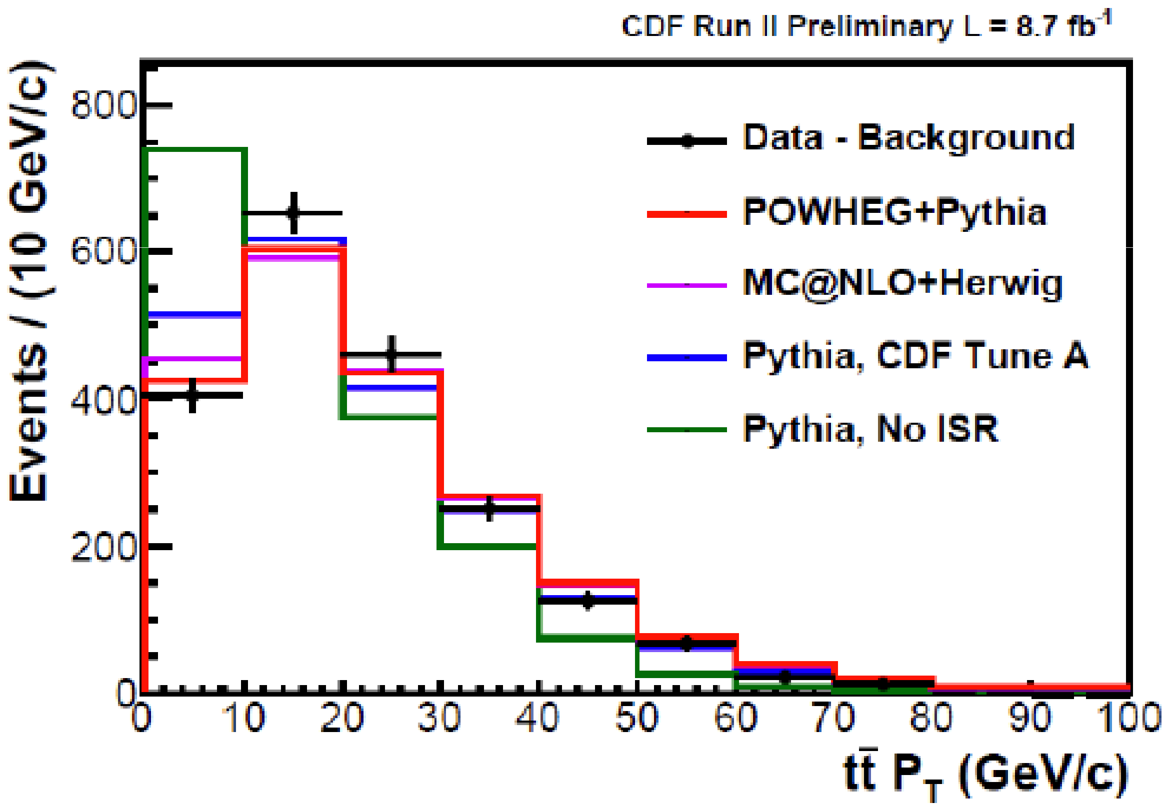
QCD: Direct γ in association with heavy quark

Data σ higher than NLO at high are higher with NLO. Possible explanations:

- Missing loop and higher order corrections in the NLO calculations
- Mismodeling of gluon splitting rate to heavy quarks
- Possible contributions from instrinsic heavy quarks
- Jets: $|y|<1.5$, $E_T>20$ GeV

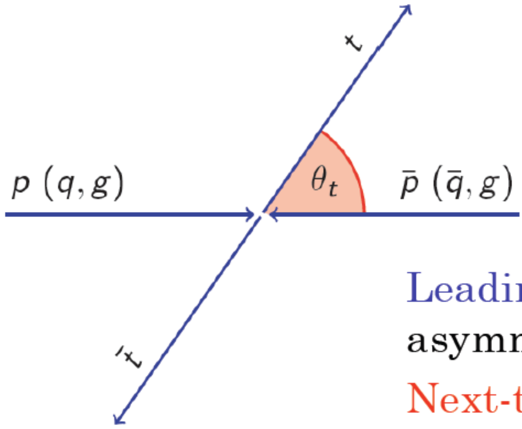
tt Forward Backward asymmetry

- Top pair P_T is a sensitive test of reconstruction and modeling (expecially at low values, due to soft jets)
- Background-subtracted data in good agreement with NLO Powheg and MC@NLO

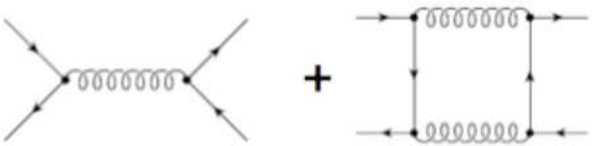


tt Forward Backward asymmetry

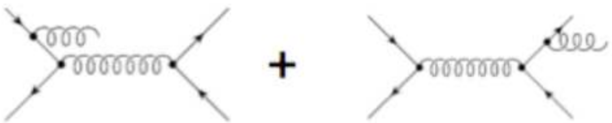
- Use Δy as a proxy for production angle
  - Invariant to boosts along the beamline
    - A_{FB} measured in top pair rest frame
  - Inclusive A_{FB} is the same in Δy and $\cos\theta$



Born + Box Interference
Positive Contribution to A_{FB}



ISR/FSR Interference
Negative Contribution to A_{FB}



Leading order: no asymmetry

Next-to-leading order: small positive asymmetry

Some uncertainty regarding theory predictions

- E.g., use LO or NLO cross-section for A_{FB} denominator?

Flat correction of 26% in Δy asymmetries for electroweak contributions

$$A_{FB}^{NLO} = 6.6\%$$

POWHEG:
Frixione, Nason, and Ridolphi, JHEP **0709**, 126 (2007)

EW Corrections:
Hollik and Pagani, Phys. Rev. D **84**, 093003 (2011)
Kuhn and Rodrigo, JHEP **1201**, 063 (2012)
Manohar and Trott, arXiv:1201.3926[hep-ph]

THE ASYMMETRY IN ~5 FB^{-1}

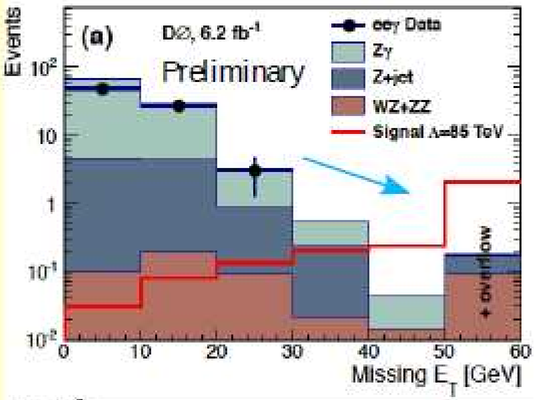
Measurement	Parton Level A_{FB} (%)
[1]CDF Lep+Jets, 5.3 fb^{-1}	15.8 ± 7.4
[2]CDF Dilepton, 5.1 fb^{-1}	42 ± 16
[3]CDF Combined	20.1 ± 6.7
[4]D0 Lep+Jets, 5.4 fb^{-1}	19.6 ± 6.5
Informal Combination*	19.8 ± 4.7
NLO (QCD+EW)	6.6

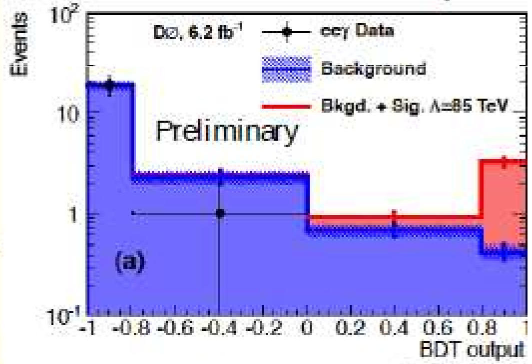
Search for Zγ+MET

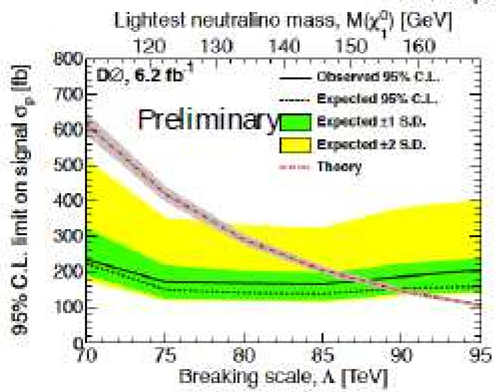
- Search for SUSY in the Z+γ+MET final state
  - Predicted by GMSB SUSY models where the lightest neutralino is NLSP produced in pairs
  - They decay to either a Z boson or a photon and to a gravitino that escapes detection.
  - parametrized by an effective SUSY breaking scale Λ
- Select a pair of oppositely charged leptons consistent with Z, photon and large MET
  $\Rightarrow$ Signal region

$\mathcal{L} = 6.2\ fb^{-1}$

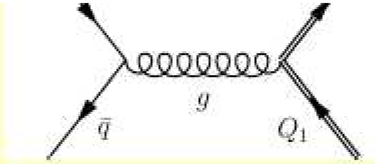
- Dominant backgrounds are Zγ which is normalized to data, and Z+jets which is obtained from control regions from data.
- Analysis is further optimized using BDT
- In the absence of an excess limits are set:
  - Model with Λ < 87 TeV is excluded
  - Lightest neutralino with m < 151 GeV is also excluded

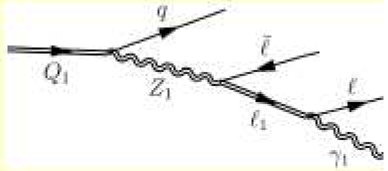






Universal Extra Dimensions with the same sign muons





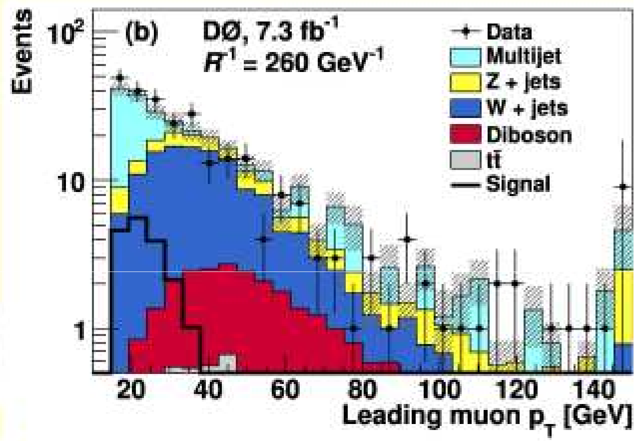
Universal extra dimensions – all particles can propagate in the extra dimensions

- Minimal UED model – only one extra dimension

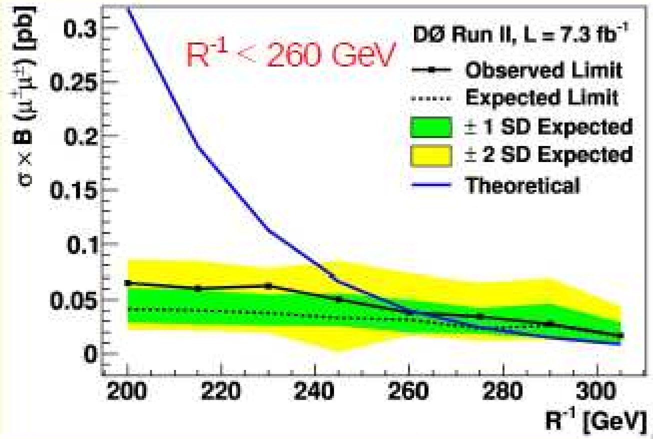
$\mathcal{L} = 7.3\ fb^{-1}$

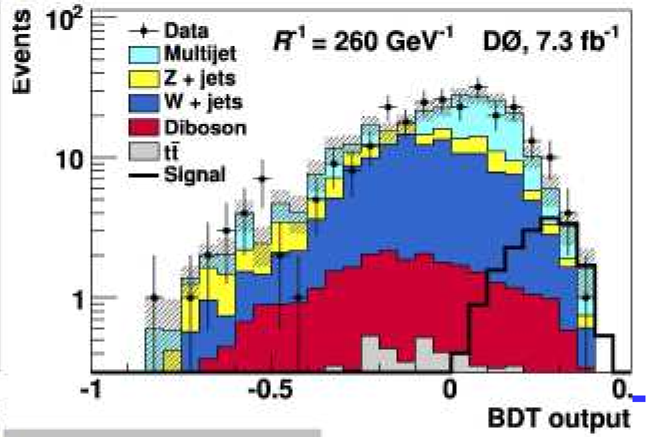
Search for the KK pair production in minimal UED

- Subsequent decays will lead to final states with up to four leptons with low p_T
- Select two same sign muons to suppress backgrounds
- To further gain sensitivity we use BDT

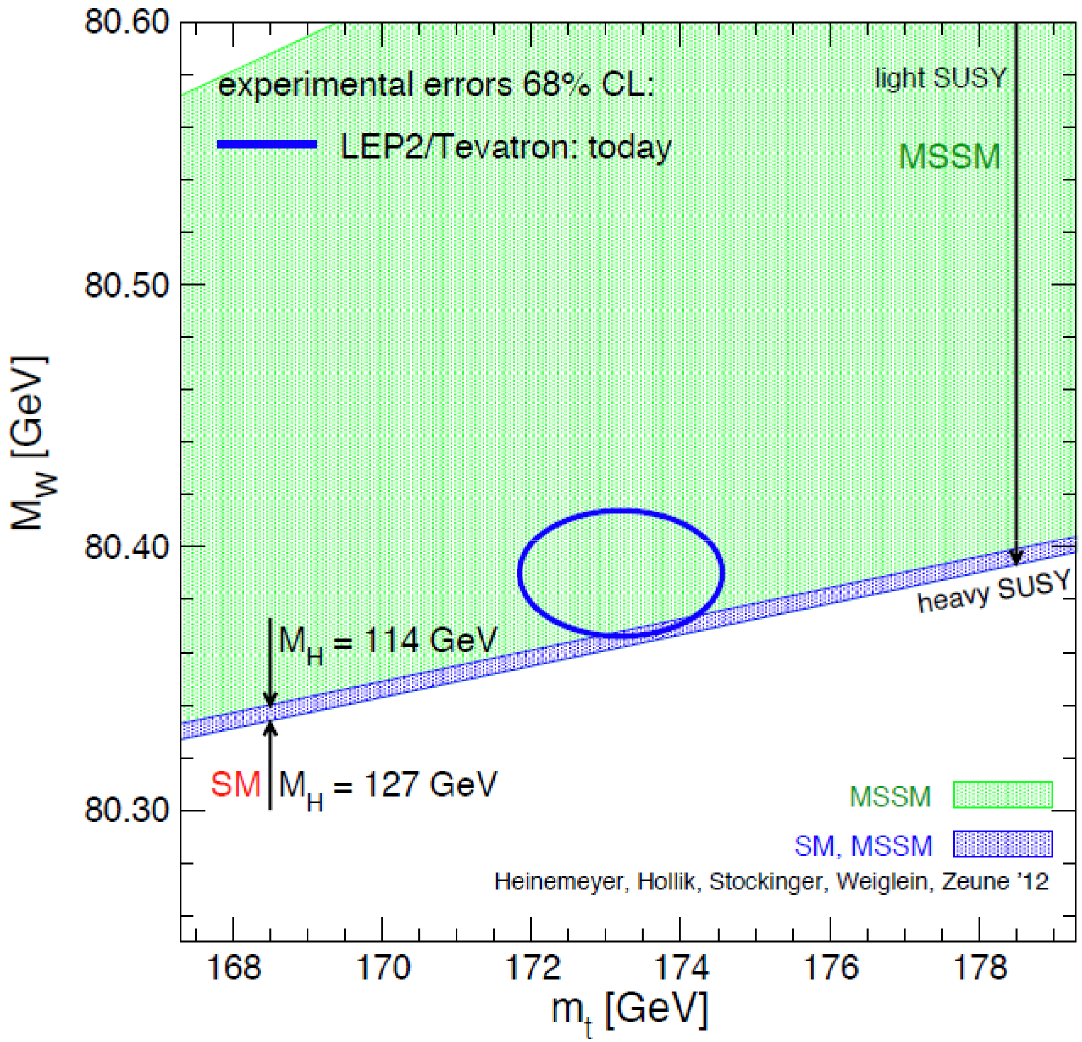


Limits set as a function of R^{-1}, which corresponds to the mass of KK state, and R is radius of compact dimension





MSSM allowed region



S. Heinemeyer, W. Hollik, D. Stockinger, G. Wiglein, L. Zeune '12