New CDF Results for Lepton-Photon '07

Mark Neubauer

University of Illinois, Urbana-Champaign

*for the **CDF Collaboration***

FNAL Wine & Cheese Seminar, 08/10/2007

Overview

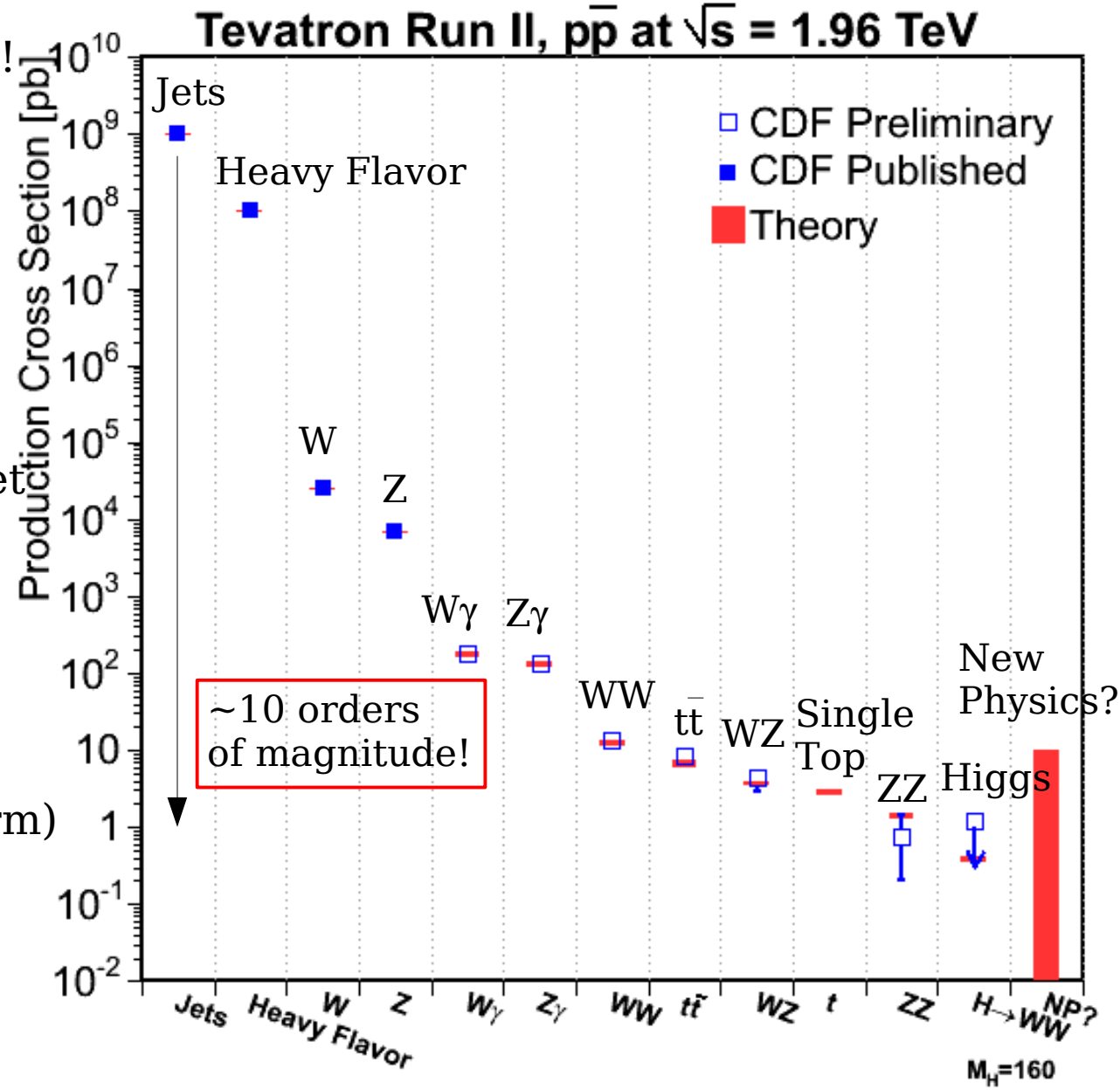
45 Publications in calendar 2006!
30 (and counting) in 2007!
(54 in last 12 months)

This talk will only show the new results since the Winter 2007 conferences

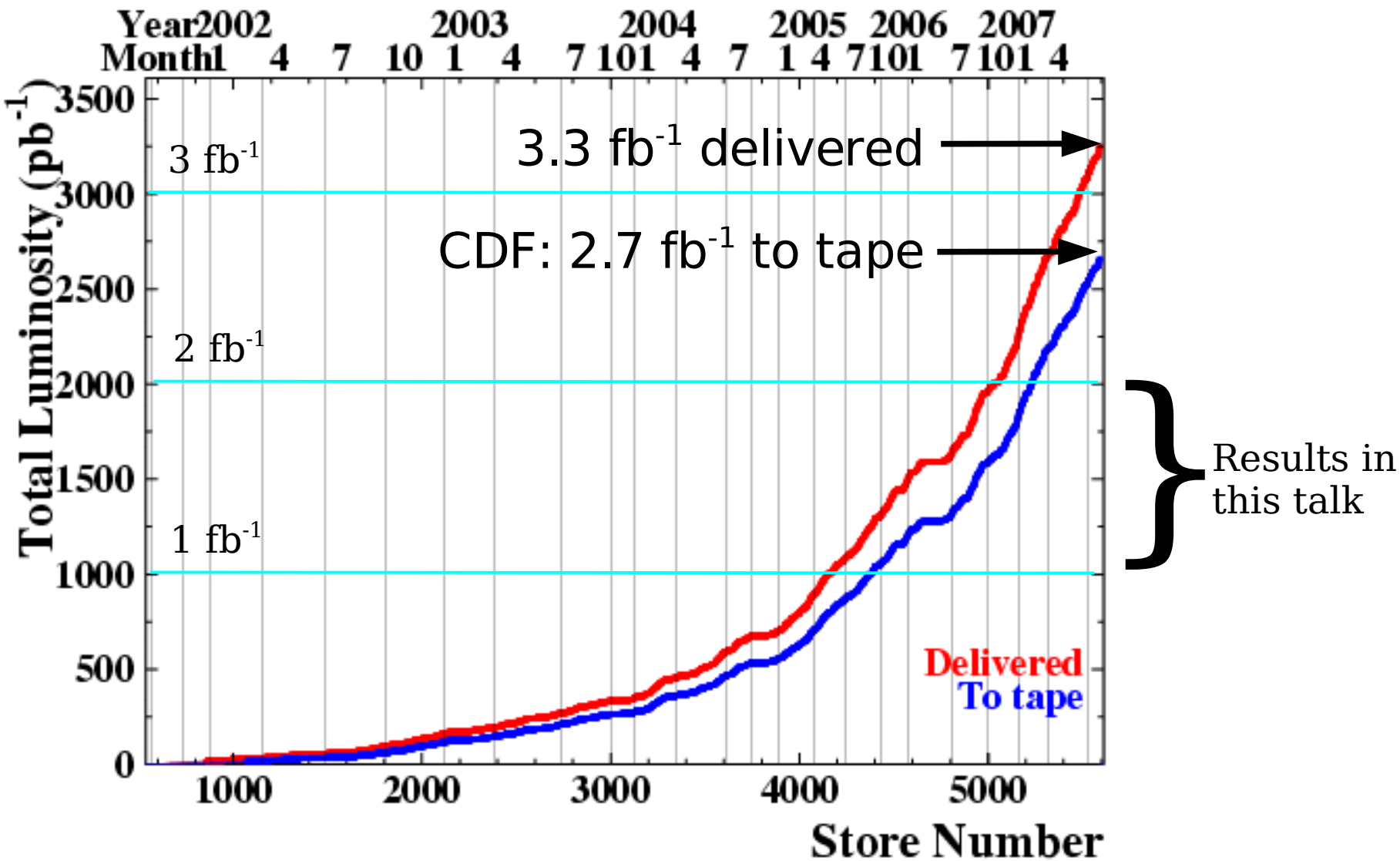
~ 50 new results since April '07
~ 30 use the full available dataset

These results cover the full spectrum of CDF physics capabilities:

- QCD / Jets
- Heavy Flavor (bottom & charm)
- Electroweak
- Top
- Higgs
- New physics searches



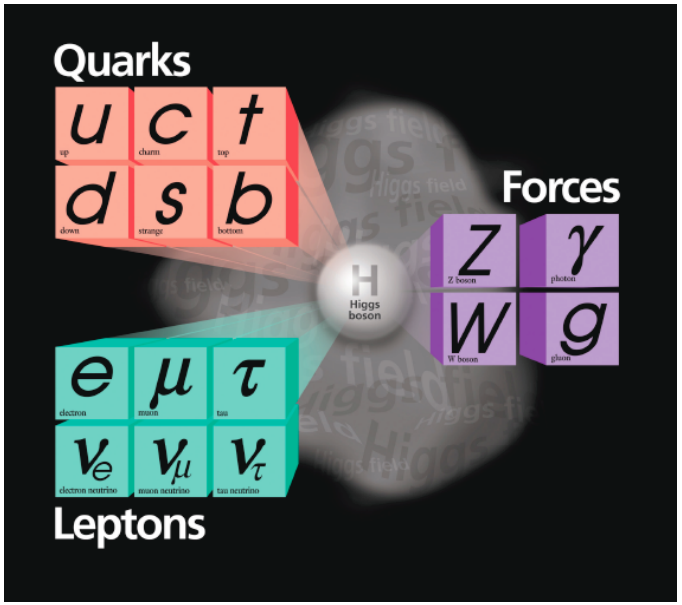
Integrated Luminosity



Thanks to the accelerator division for such wonderful Tevatron performance!

Some Open Questions in the SM

The Standard Model (SM) has been very successful at describing the known particles and their interactions under extraordinary experimental scrutiny



At the cornerstone is electroweak symmetry breaking

- $SU(2)_L \otimes U(1)_Y$ is a spontaneously broken symmetry
- Generates masses of the weak gauge bosons ($W^{\pm}$, Z^0) and the fermions
- Predicts existence of a scalar particle: Higgs boson

However, the SM is an effective theory describing physics at the electroweak scale and is incomplete:

- Neutrino mass and mixing
- Gauge coupling unification
- Dark Matter / Dark Energy
- Higgs mass (m_H) unstable against radiative corrections (hierarchy problem)

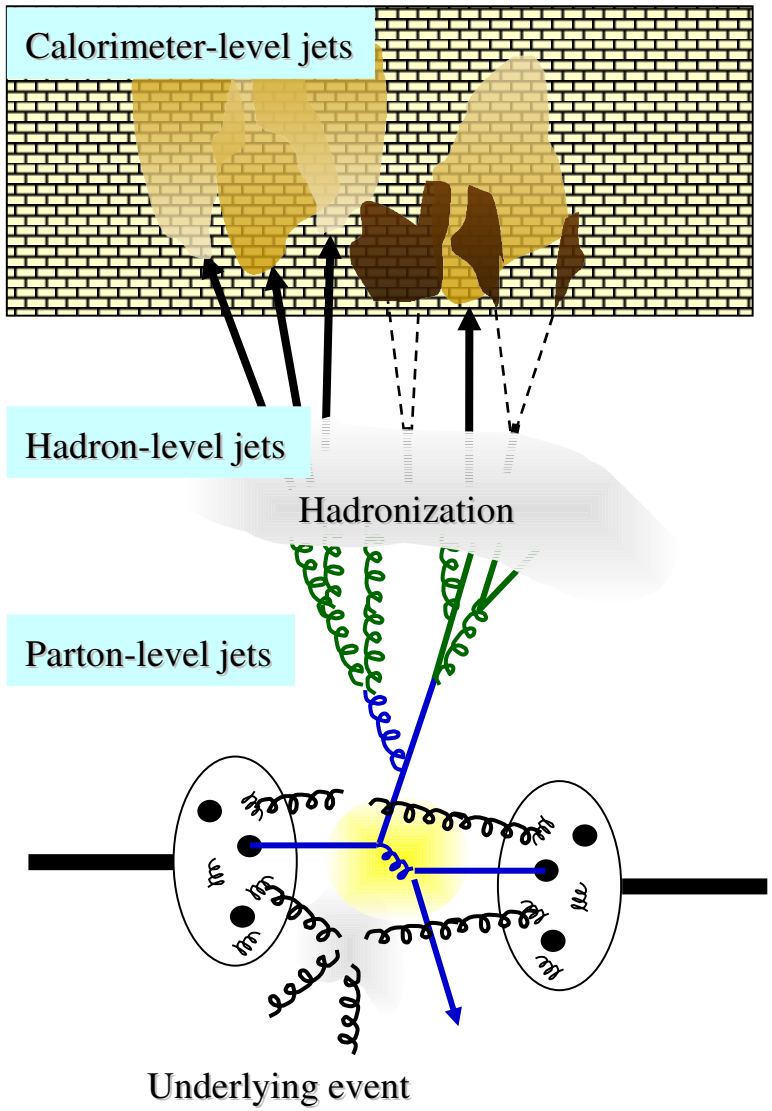
Expect new physics at the TeV scale!

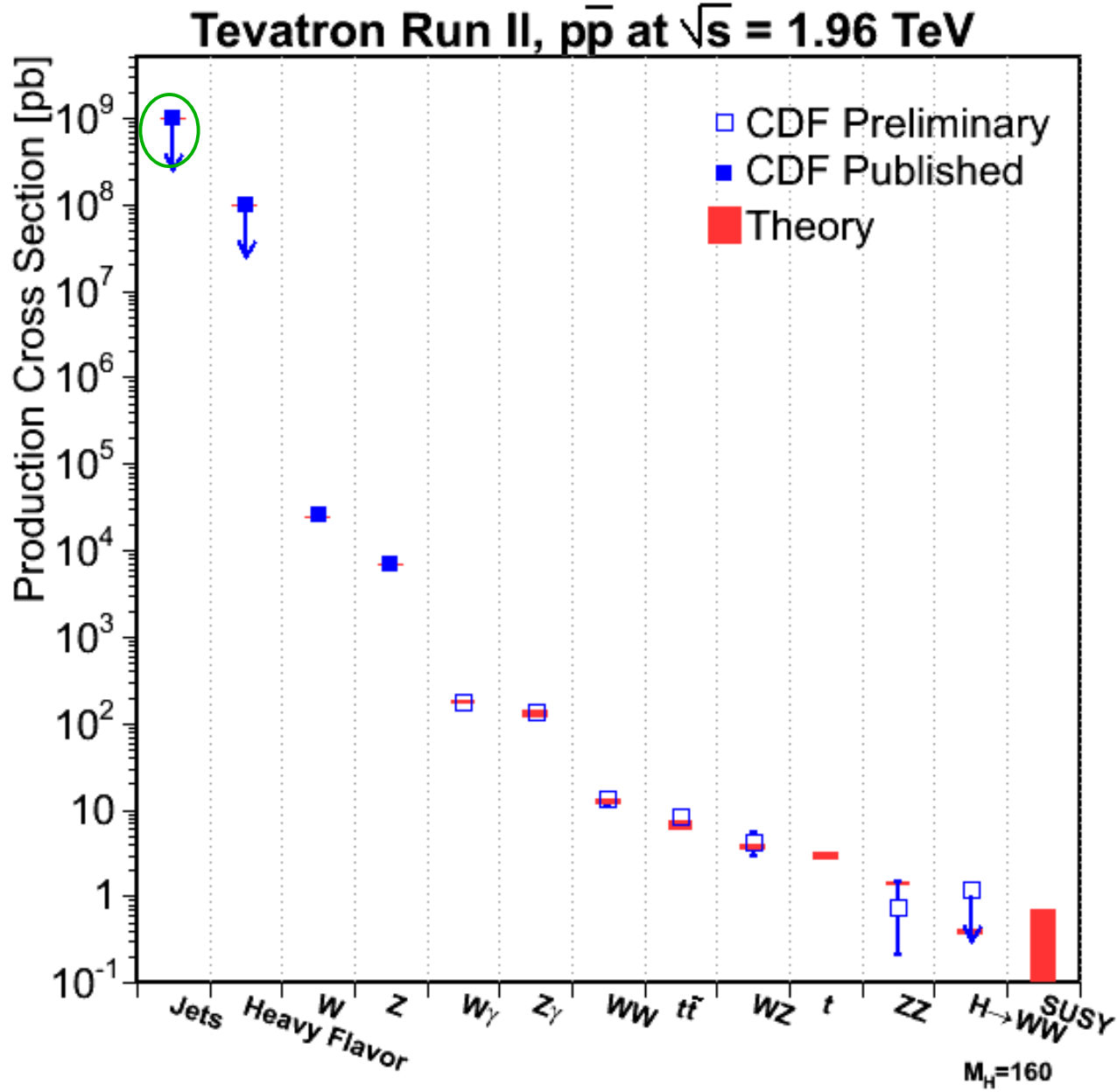
Q: Are neutrinos Dirac or Majorana?
Q: What is Dark Matter/Energy?
Q: What is the origin of EWSB?
Q: Is nature supersymmetric?
Q: Are there new dimensions of space?
Q: Does Nature realize NP we haven't thought of?
Q: Does Nature realize NP we've thought of but missed?

Strategy

- Test the SM where you can
- Search as broadly as possible (e.g. signature/model-independent)
- Work to get as much out of the data as possible (e.g. increased acceptance, advanced techniques)

QCD (Jet) Physics



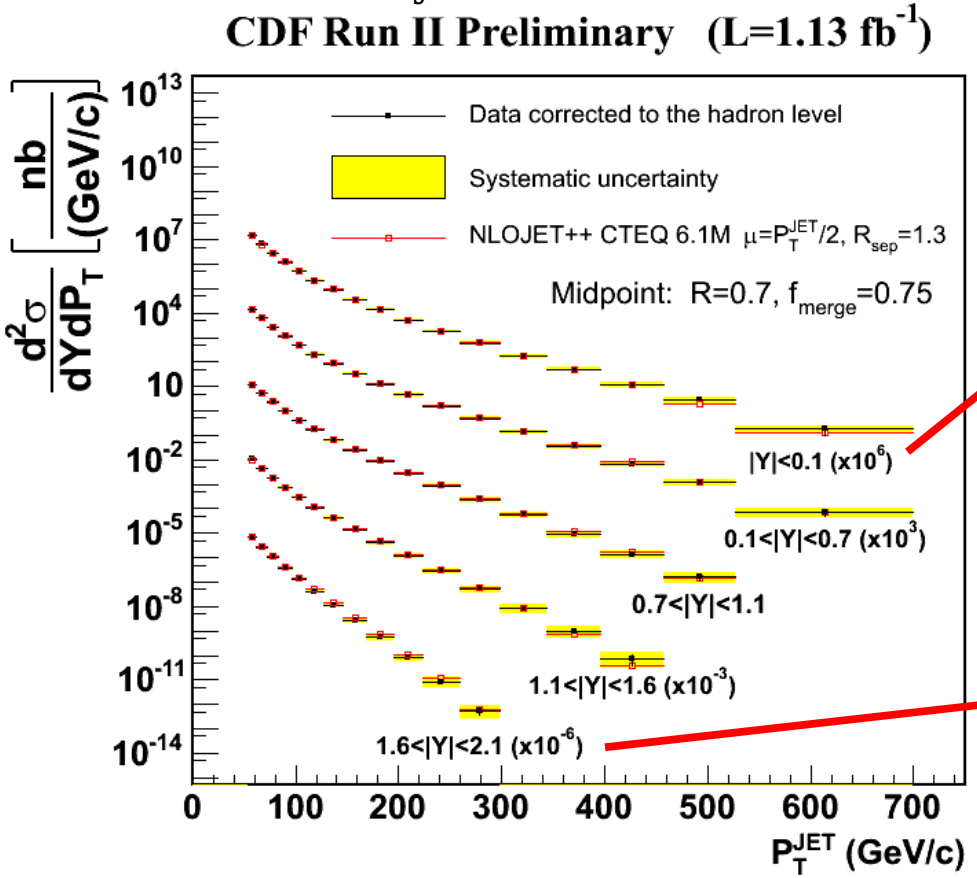


1.1 fb^{-1}

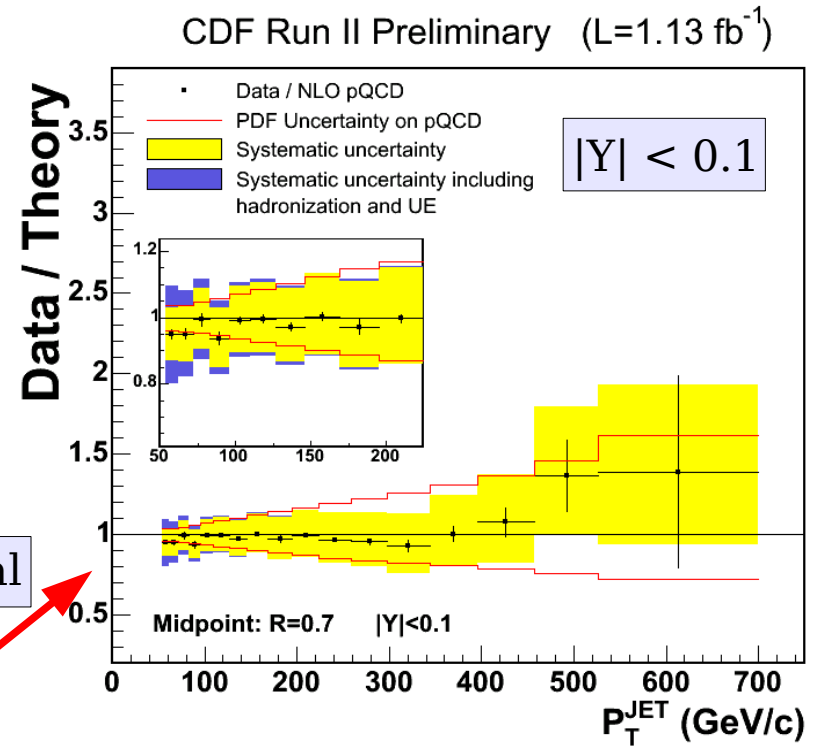
Inclusive Jet Production

Measure jet production over a large range of p_T and rapidity (Y) using Midpoint algoritm

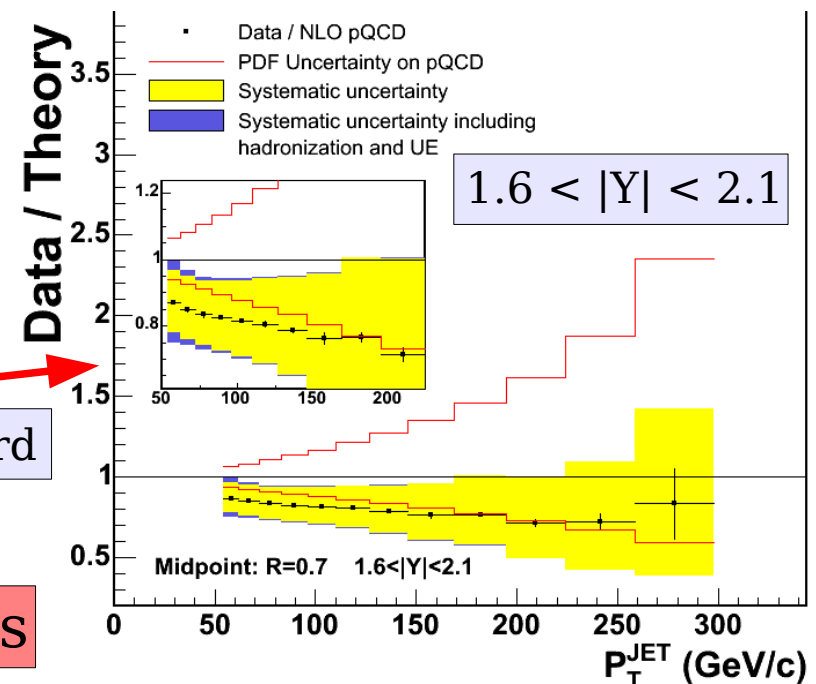
- Central jets sensitive to new physics (NP) at high Q^2
- Forward jets probe higher x at lower Q^2
  - Distinguish PDFs from possible NP at higher Q^2
  - Extend sensitivity to lower x



Central



Forward



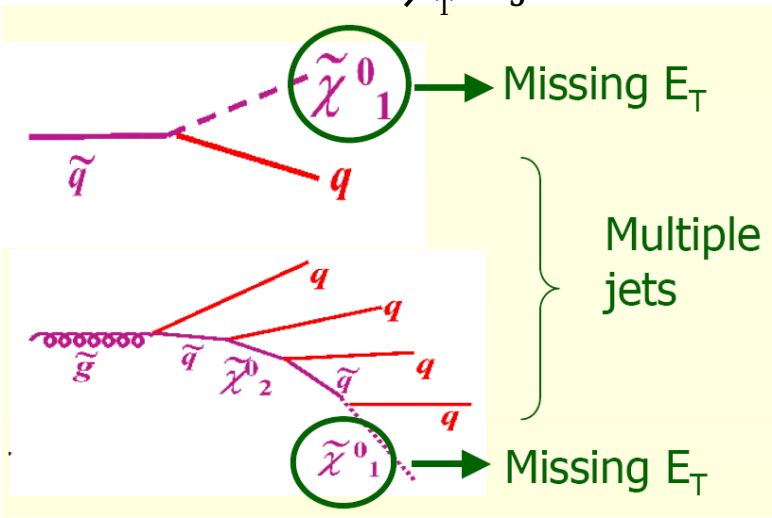
Good agreement w/ NLO pQCD predictions

1.7 fb^{-1}

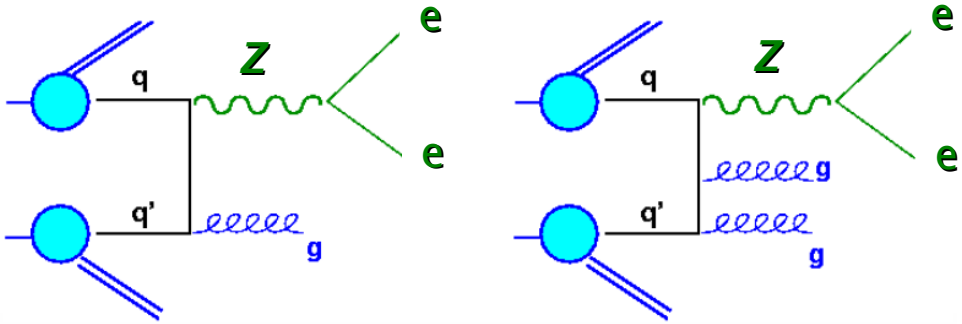
Z+jet(s) Production

- Boson + jets production is important
- Test of pQCD at high Q^2
- Background to many new physics searches

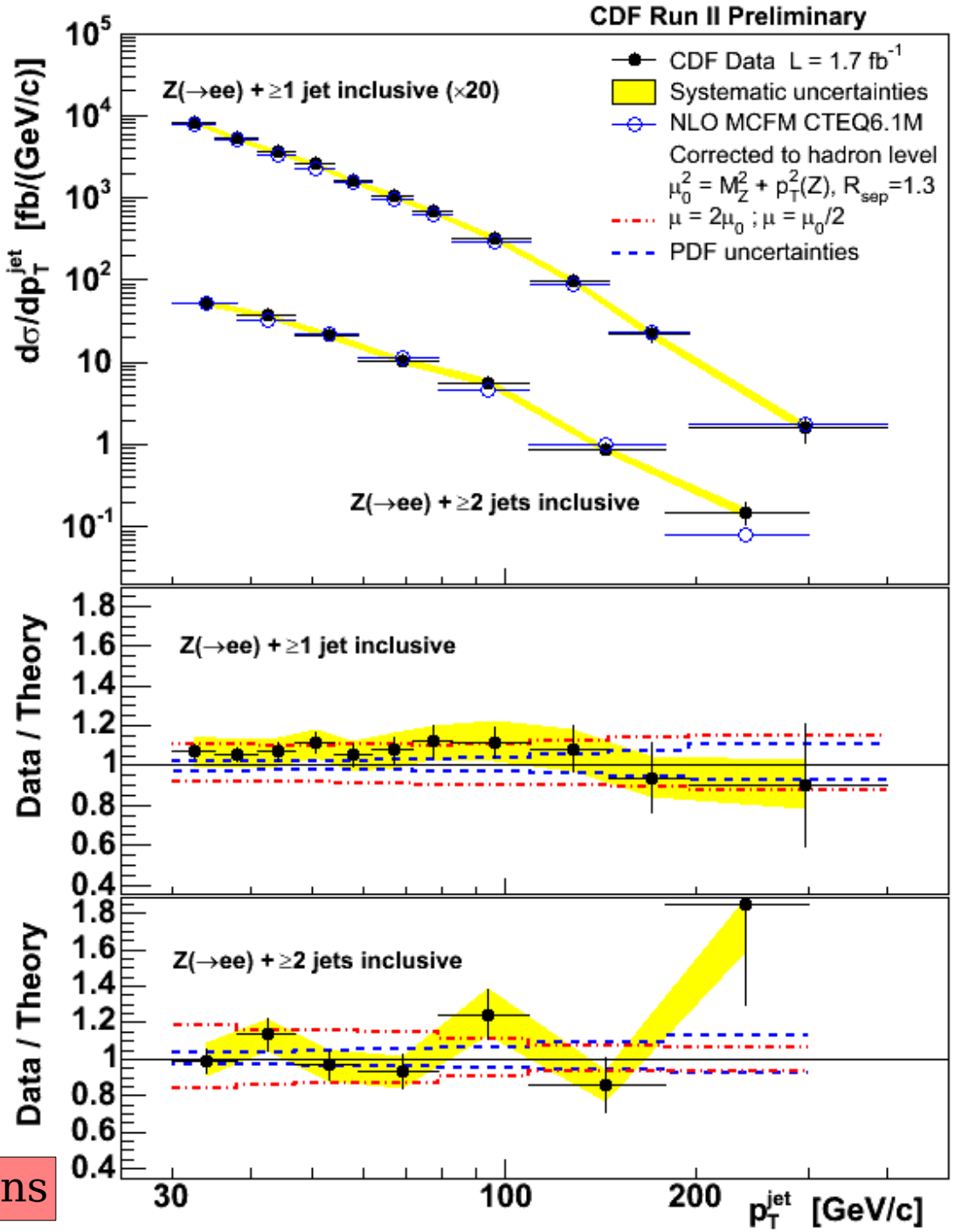
E.g. Z(νν)+jets, W(ℓν)+jets backgrounds to SUSY search in $\not{E}_T$ + jets channel



Study Z+jets production in e^+e^- channel



Use Midpoint Algorithm, pT>30 GeV, |y|<2.1

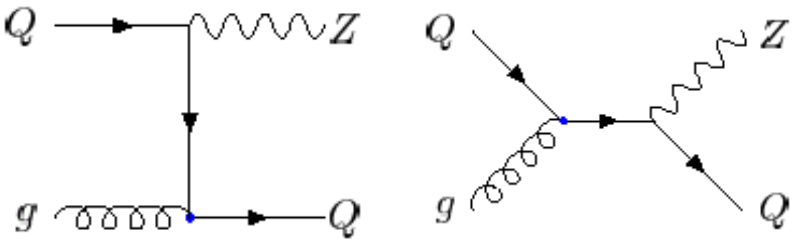


Good agreement w/ NLO pQCD predictions

1.5 fb^{-1}

Z+b Jet(s) Production

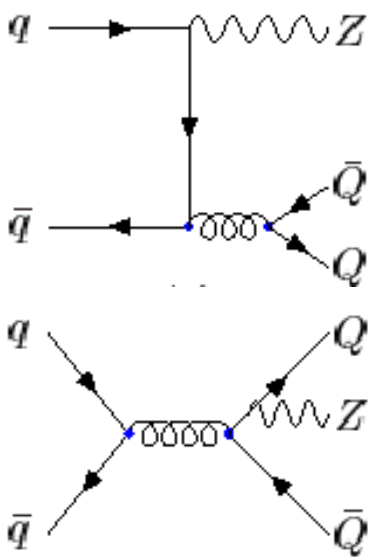
Probe the less well known heavy flavor content of the proton



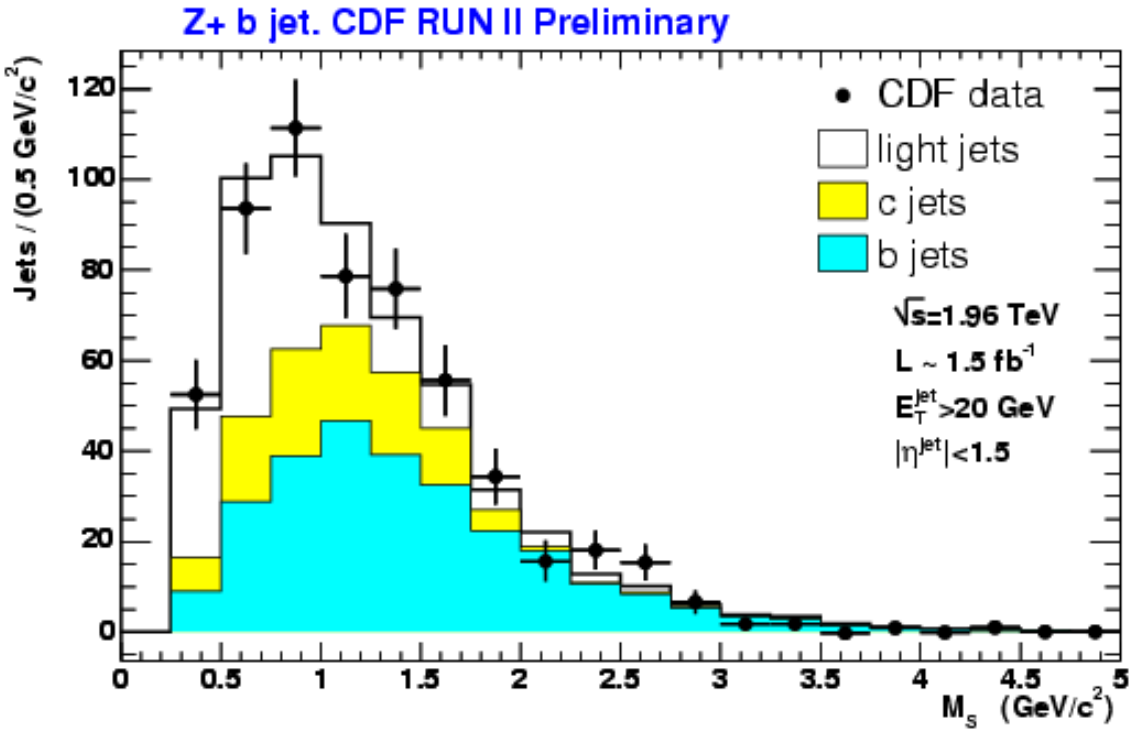
Important for understanding:

- Single Top: $qb \rightarrow q't$, $gb \rightarrow Wt$
- SUSY Higgs: $gb \rightarrow Hb$, $b\bar{b} \rightarrow H$

Major background for SM Higgs searches (e.g. ZH, $H \rightarrow b\bar{b}$)



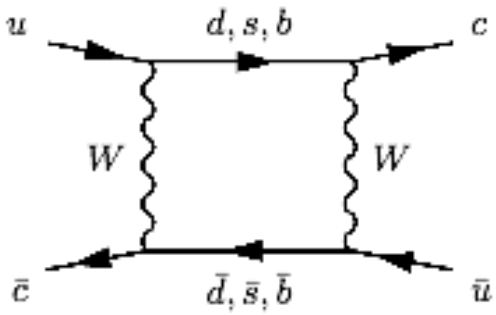
Fit to invariant mass of charged tracks associated with the secondary vertex

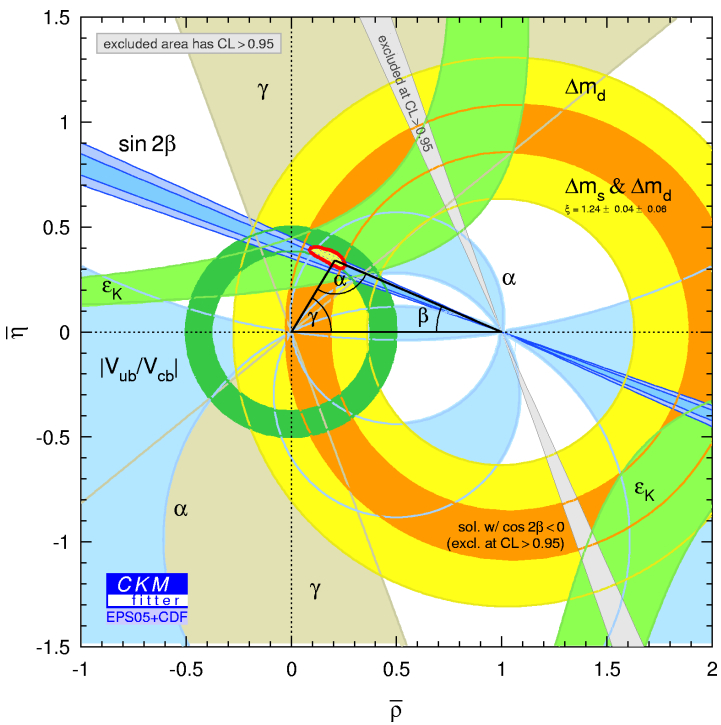


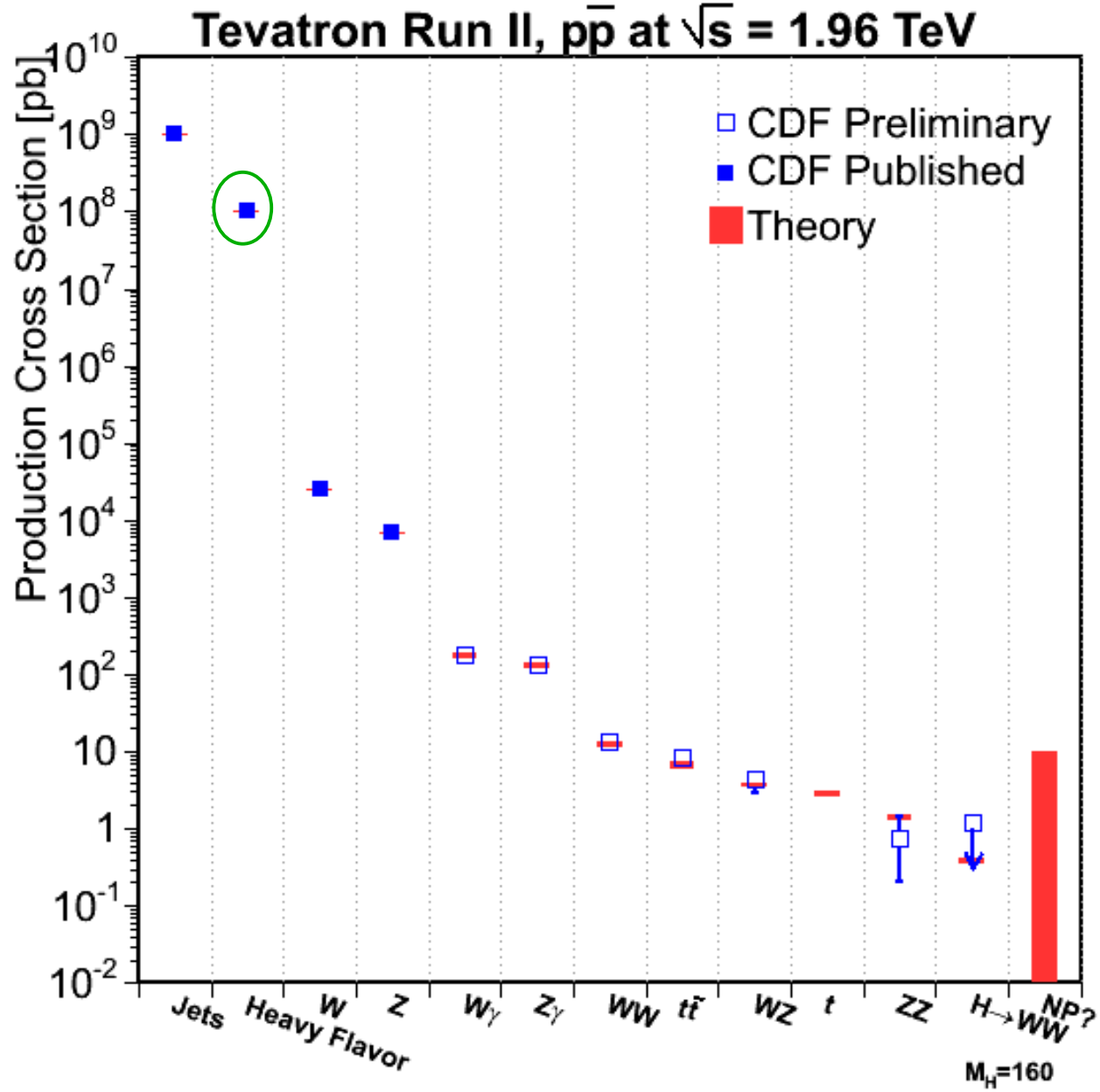
E_T^{jet}>20 GeV, η^{jet}<1.5 R_{jet}=0.7	CDF Run II Preliminary measurement	PYTHIA	MCFM NLO + UE + hadr.
σ(Z+*b*-jet)	0.94 ± 0.15 ± 0.15 (pb)		0.56(pb)
σ(Z+*b*-jet) / σ(Z)	0. 369 ± 0.057 ± 0.055 %	0.35 %	0.23 %
σ(Z+*b*-jet) / σ(Z+jet)	2.35 ± 0.36 ± 0.45 %	2.18 %	1.77 %

Data somewhat higher than NLO prediction
Following up with theorists on this...

Heavy Flavor (Bottom and Charm) Physics





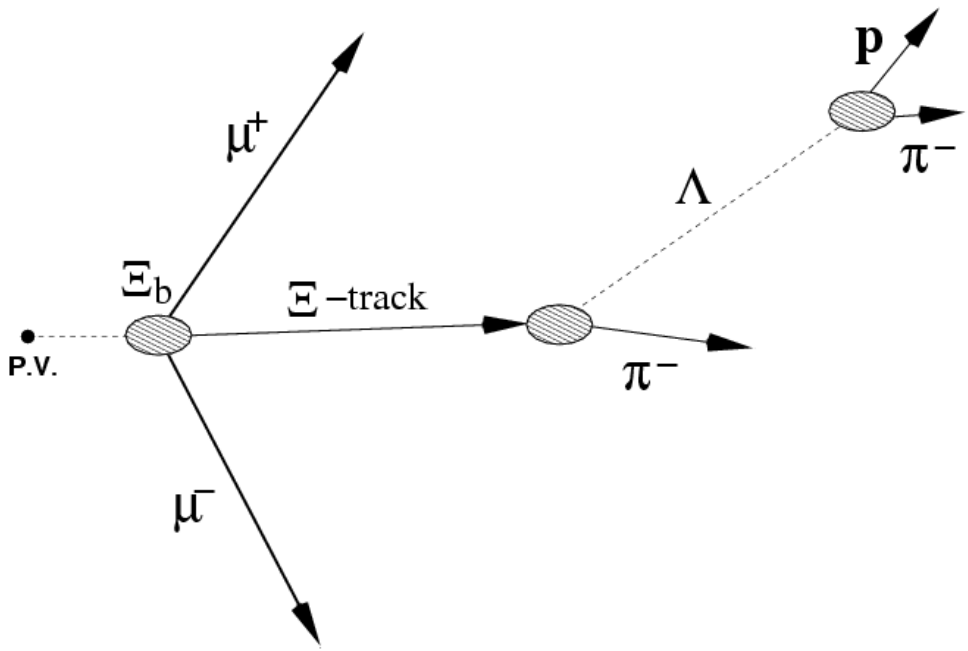


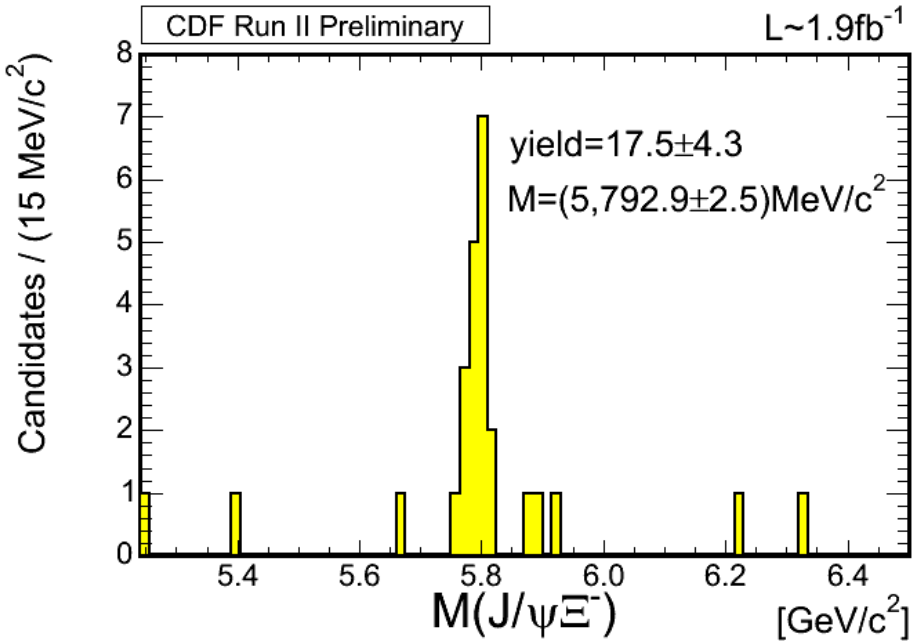
1.9 fb^{-1}

Observation of the Ξ_b

Lastest observation in a string of newly discovered bottom baryons in Run II!

$\Xi_b^- \to J/\psi \Xi^-$; $J/\psi \to \mu^+\mu^-$; $\Xi^- \to \Lambda^0\pi^-$; $\Lambda^0 \to p\pi^-$

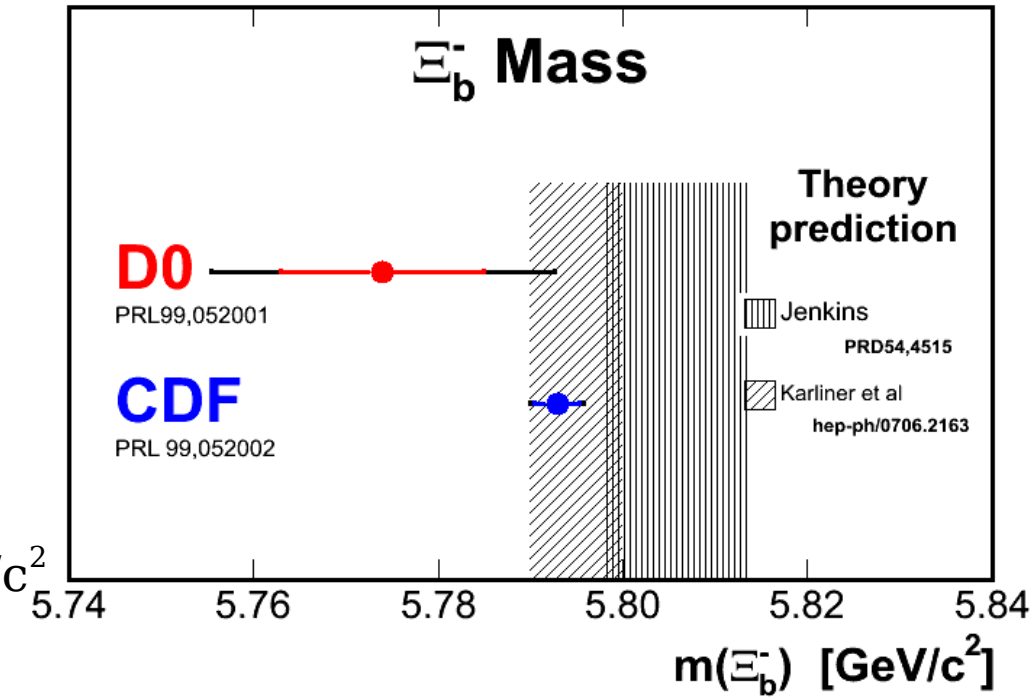




Makes use of silicon-based Ξ tracking developed at CDF (1st in a hadron collider experiment

Statistical significance of Ξ_b^- signal > 7 σ

$M(\Xi_b^-) = 5792.9 \pm 2.5(\text{stat.}) \pm 1.7(\text{syst.})$ MeV/c^2



B_s Lifetime Difference

Flavor eigenstates ≠ mass eigenstates

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H$$

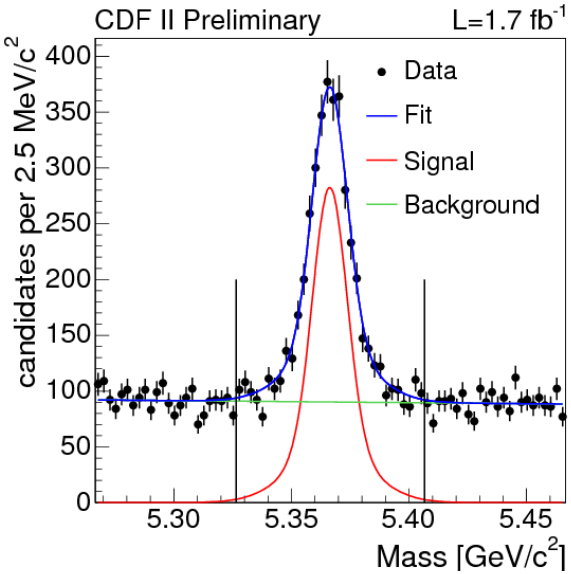
$\Delta\Gamma_s$ large ⇒ sensitivity to mixing induced CP-violating phase ϕ_s without tagging

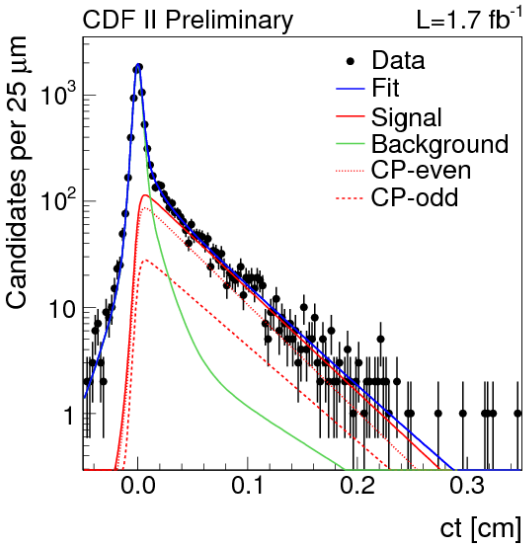
Standard model: $\Delta\Gamma_s \approx 0.1\ ps^{-1}$, $\phi_s \approx 0$

⇒ *large* $|\phi_s|$ *would indicate new physics!*

Separation of B_{sL}(CP even) and B_{sH}(CP odd) by angular analysis of $B_s \to J/\psi\phi$

Mass, lifetime and angle fit





B_s Lifetime Difference

Assuming no CP violation:

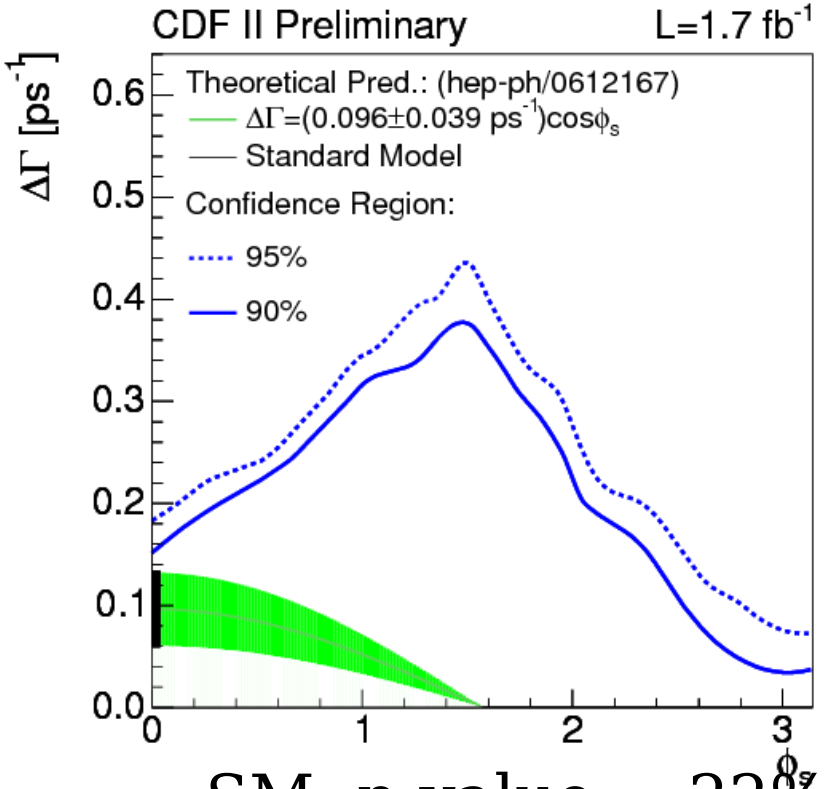
- $\Delta\Gamma_s = 0.076\ ^{+0.059}_{-0.063}$ (stat) ± 0.006 (syst) ps^{-1}
- $c\tau_s = 456 \pm 13$ (stat) ± 7 (syst) μm
- $|A_0|^2 = 0.530 \pm 0.021$(stat) ± 0.007 (syst)
- $|A_{||}|^2 = 0.230 \pm 0.027$(stat) ± 0.009 (syst)

$\Delta\Gamma_s$ measurement agrees well with standard model (0.096 ps) and D0 result

Allowing for CP violation:

→ Bias for low $\Delta\Gamma$ and ϕ_s observed in toy MC

→ Quote p-value and confidence region instead of point estimate

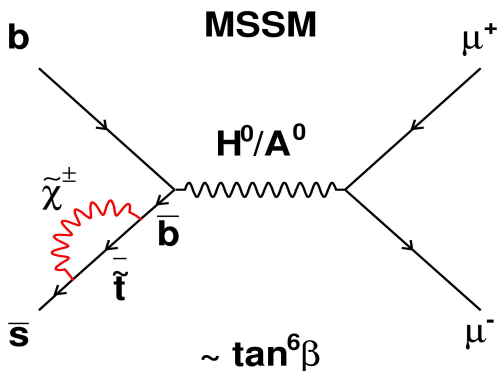


SM: p-value = 22%

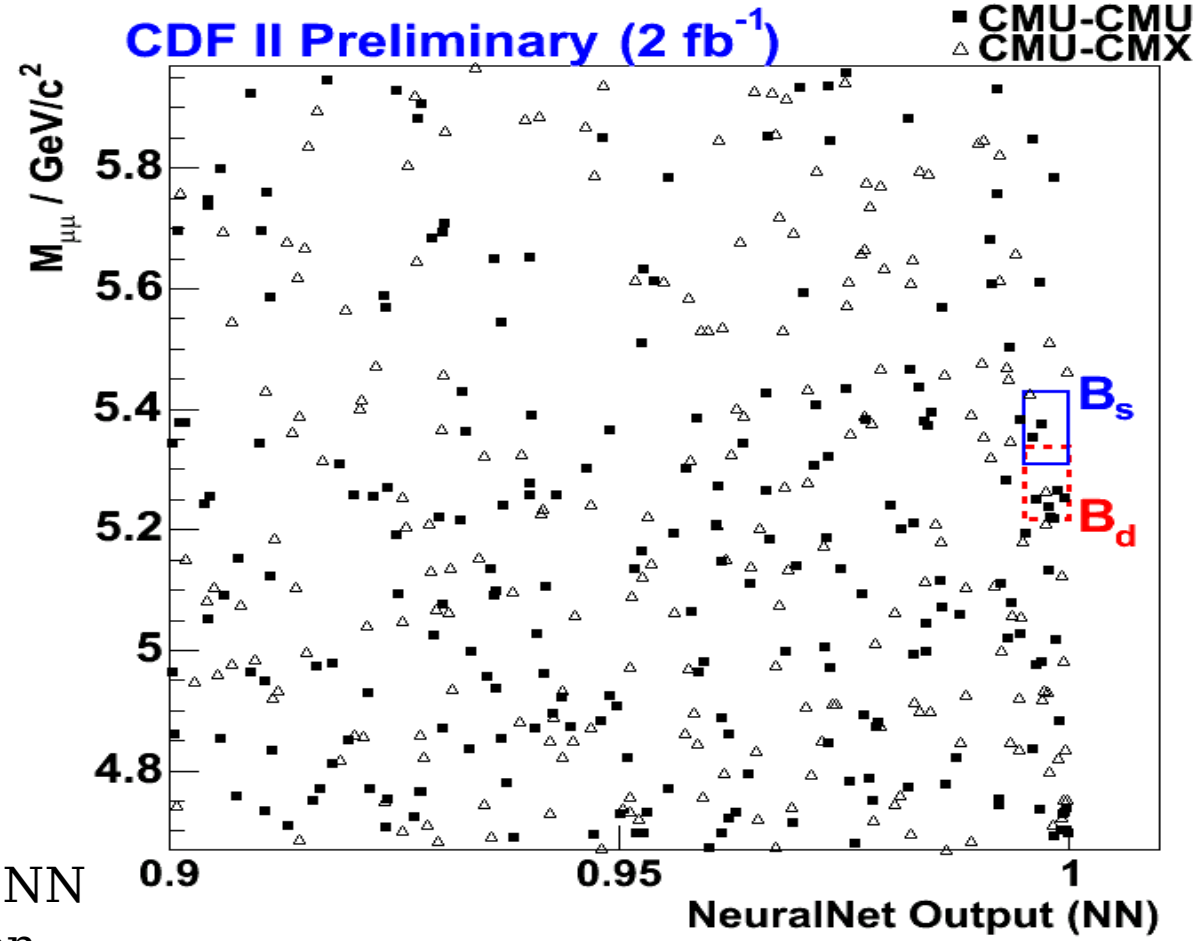
2 fb^{-1}

Search for $B_s(d) \to \mu^+\mu^-$ Decays

- S.M. BR ~3.5×10^{-9}
- Many new physics models (e.g. SUSY) can enhance BR by x100



- Good mass resolution
  → can distinguish B_s from $B_d \to \mu\mu$
- Use neural net to extract signal
- Improve sensitivity by including NN output and $M_{\mu\mu}$ in limit calculation



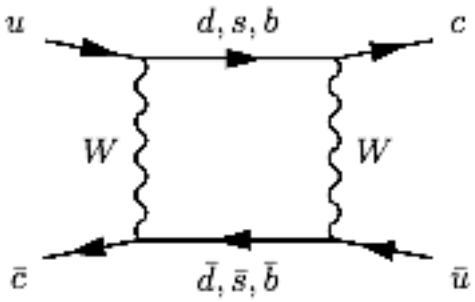
- For NN > 0.995 (most sensitive bin):
  B_s window 3 events
  B_d window 6 events

  → No significant excess

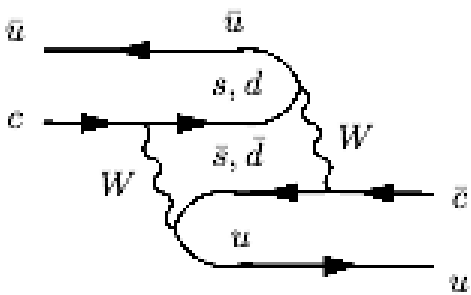
$Br(B_s \to \mu\mu) < 5.8 \times 10^{-8}$ @ 95% CL
$Br(B_d \to \mu\mu) < 1.8 \times 10^{-8}$ @ 95% CL

Both limits are world best!!!

Charm Mixing

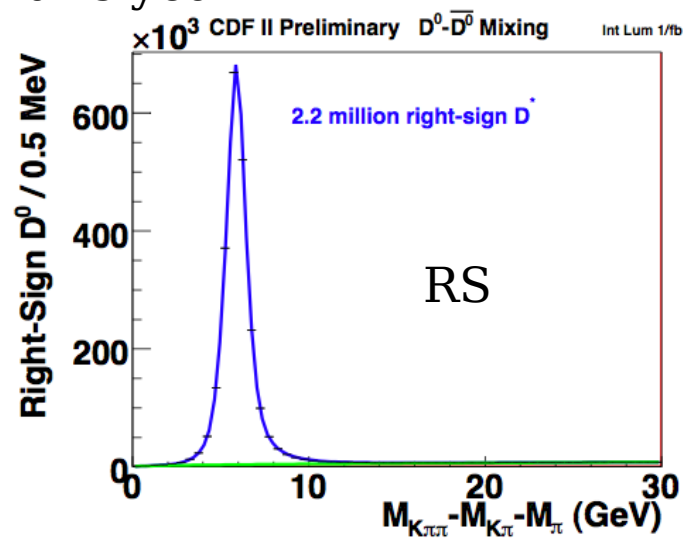


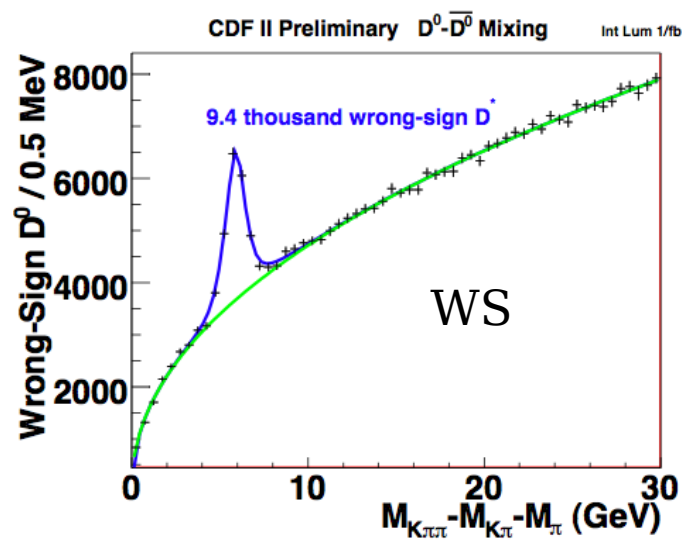
Mixing box diagram



Mixing long distance diagram

- Charm mixing is small in the Standard Model
  Beauty and kaon mixing is larger due to M_{top} in box diagram
- Mixing beyond SM predictions would be sign of new physics
- Experiments now have enough charm to see charm mixing evidence, as present at Moriond this year
- Belle: Lifetime differences for $D^0 \to K\pi/KK/\pi\pi$
- Babar: 3.9σ significance for $D^0 \to K\pi$ decays

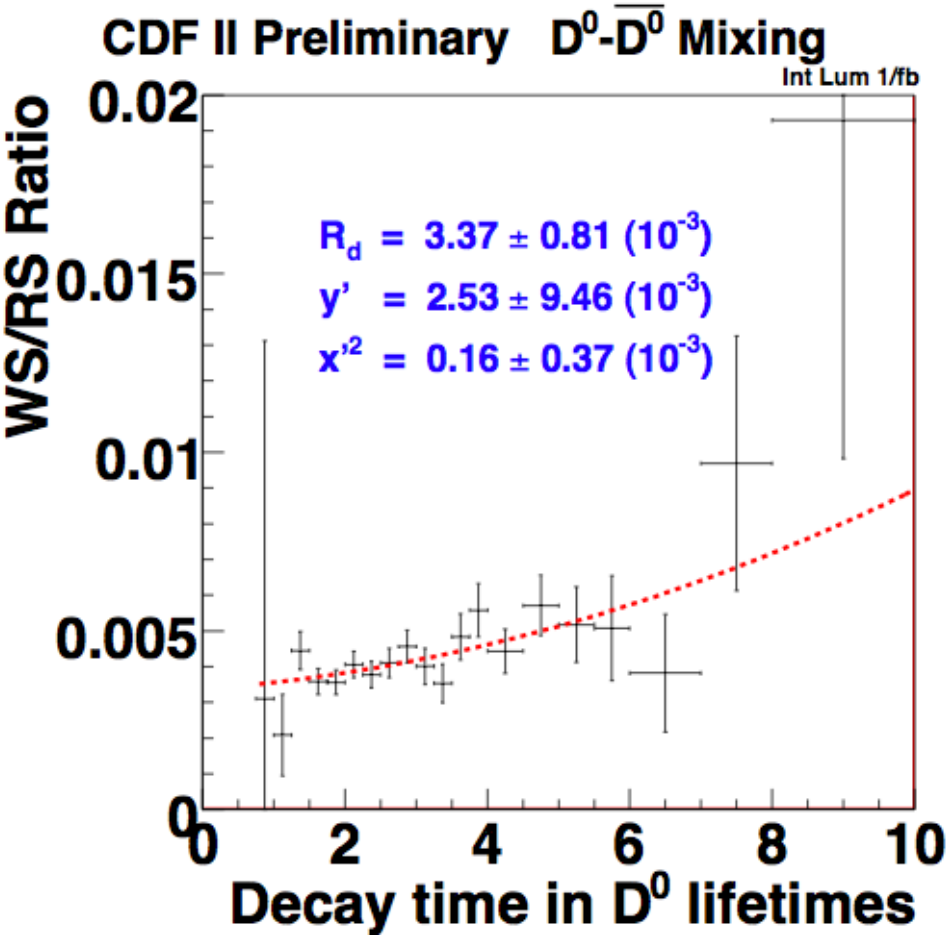




- Data from CDF in $D^* \to \pi D^0$, $D^0 \to K\pi$ mode complements the B factory results
- For $D^0 \to K\pi$ mode, the Belle result did not reach 3σ, and the best fit from Babar was in an unphysical region ($x'^2<0$)
- D^0 mesons recorded as longer decay times
- Good decay time resolution
- Different analysis method with different systematics and minimal use of Monte Carlo

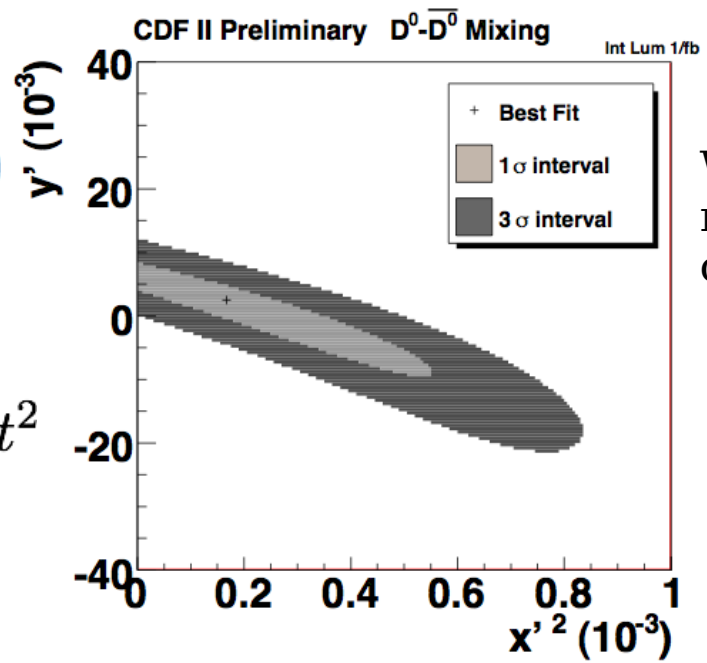
1 fb^{-1}

Evidence for D^0-$\bar{D}^0$ Mixing



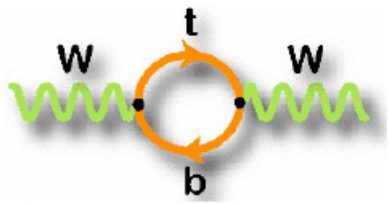
- Binned fits to D^* ratio
- Charge of the p from D* decay determines whether the charm meson was produced as D0 or D0bar
  - Right-sign: Cabibbo-favored decay
  - Wrong-sign: Doubly-Cabibbo-supressed decay or mixing
- No mixing probability of 0.13%
- Equivalent to 3.2 standard deviations

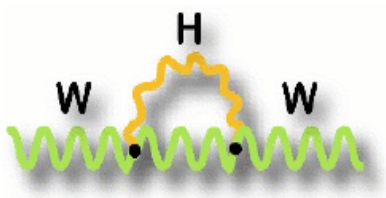
$$R(t) = R_D + y'\sqrt{R_D}\,t + \frac{x'^2 + y'^2}{4}\,t^2$$

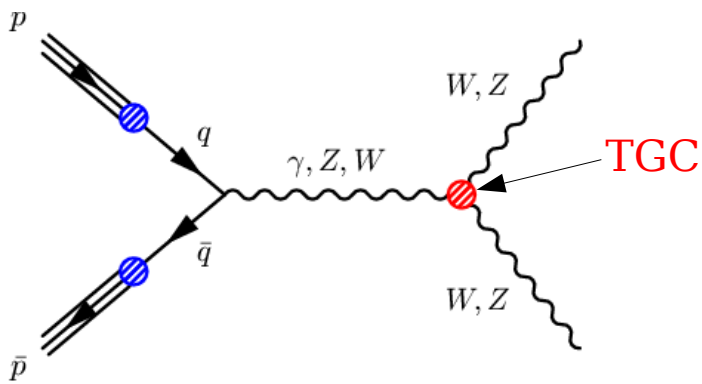


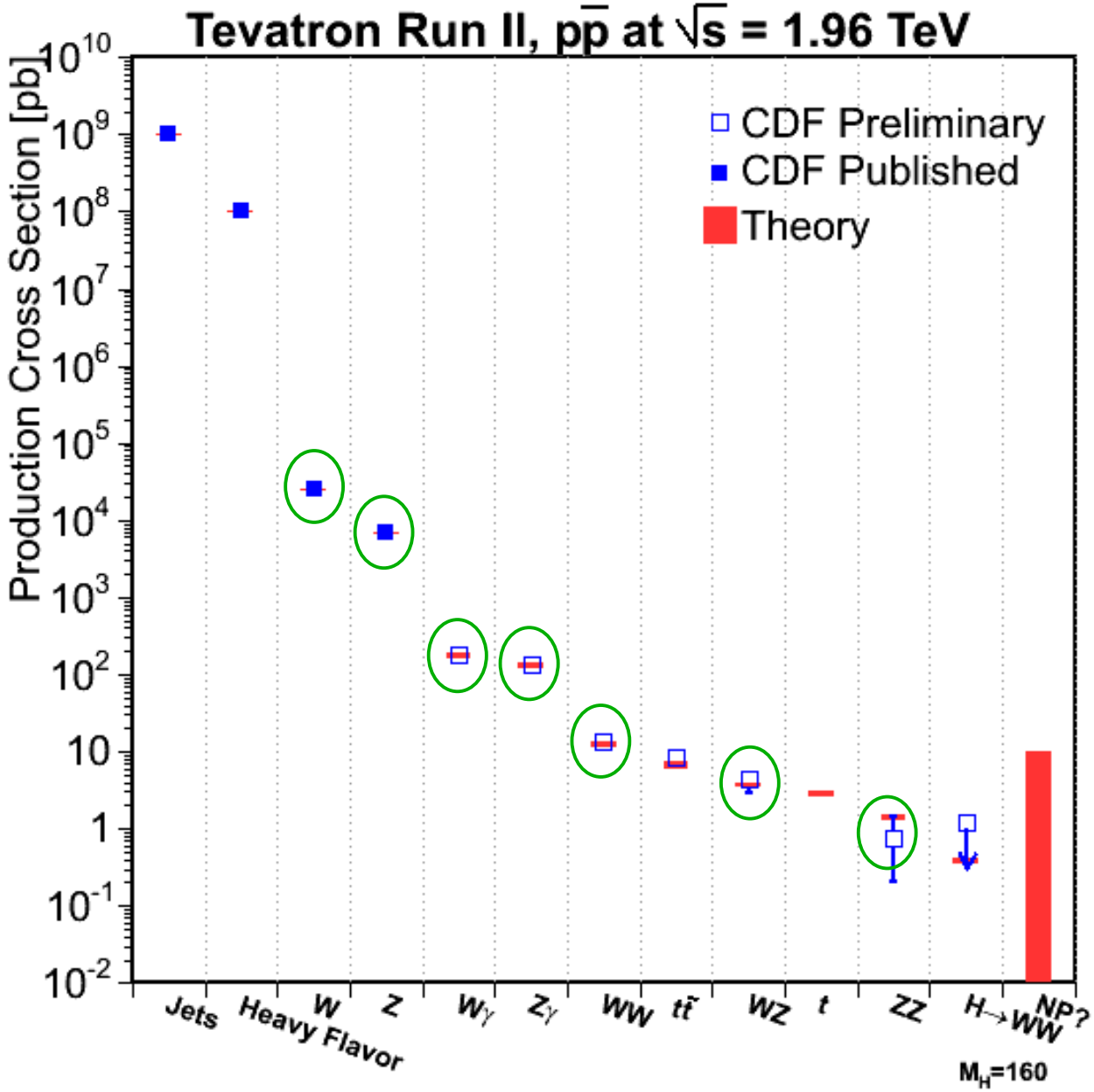
Working to include more data (already on tape)

Electroweak Gauge Boson Physics









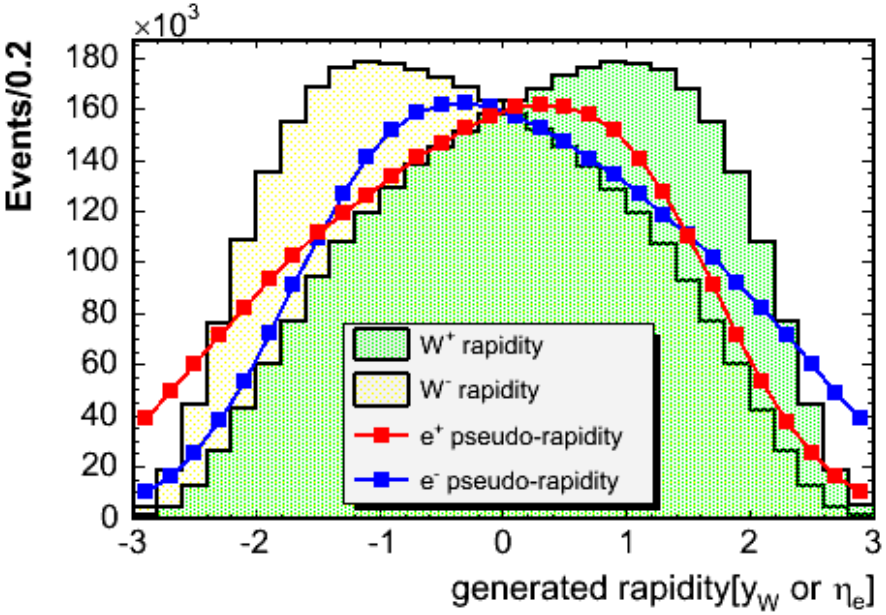
1.1 fb^{-1}

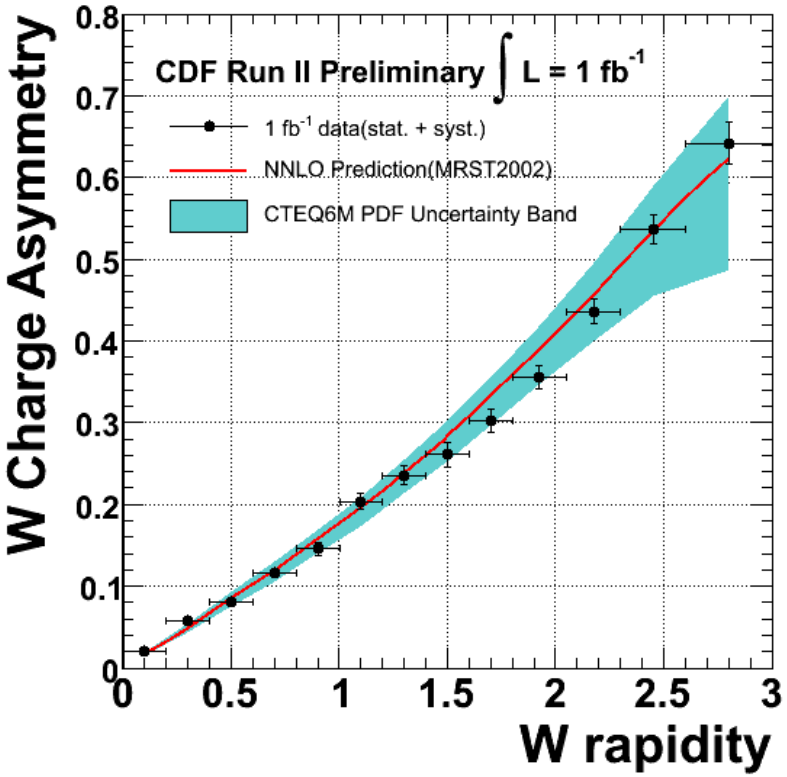
W Boson Charge Asymmetry

- Asymmetric u,d quark momentum distributions within the proton lead to asymmetric W^+, W^- rapidity distributions

- New CDF measurement significantly increases sensitivity to PDF

- Direct reconstruction of charge asymmetry (two kinematic solutions using mass constraint). Weigh solutions using production and decay characteristics





Extended Lepton Acceptance

In states which can lead to multileptons (e.g. WW,WZ,ZZ), lepton acceptance is key

⇒ Try to exploit every reconstructed track and electromagnetic shower available

Electrons

- Central calorimeter fiducial
- Forward calorimeter fiducial
  - With or w/o Si-based track

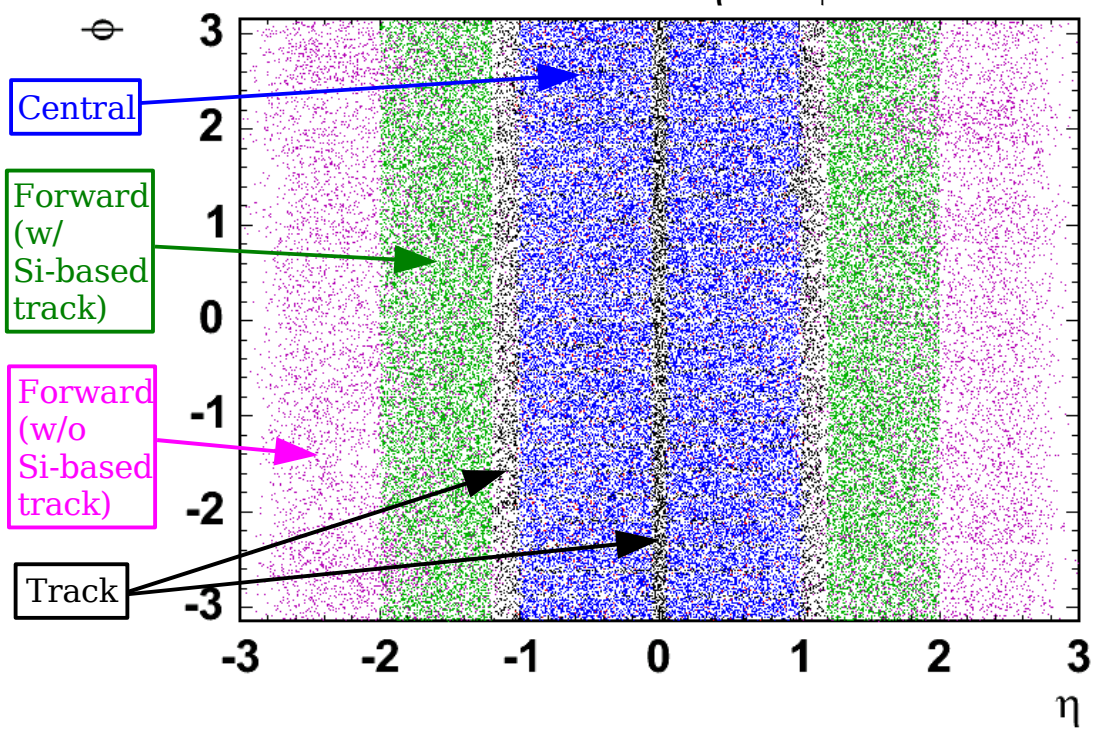
Muons

- Central stubbed muons
- Minimum Ionizing Particle (MIP)
  - central and forward region

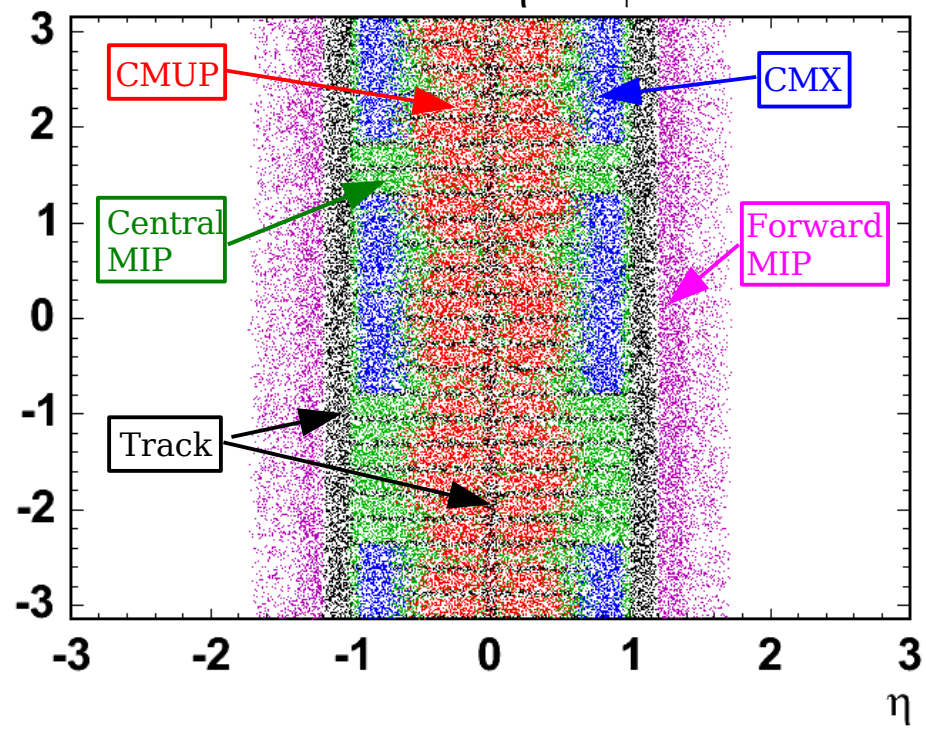
Track-only leptons

- Fill in regions not fiducial to a calorimeter (shower max)
- Considered flavor neutral (e or μ)

Electrons η vs. ϕ



Muons η vs. ϕ



Strategy used extensively in heavy diboson analyses (and Higgs)

- working on incorporating hadronic taus into general strategy
- improved tracking for more forward tracking acceptance on the horizon

1.9 fb^{-1}

WZ Diboson Production

WZ Production is a rare process in the SM
$WZ \to \ell^{\pm}\nu\ell^{+}\ell^{-}$ final state:

- small $\sigma \times$ Br, but very clean signature
- sensitive to new physics contributions

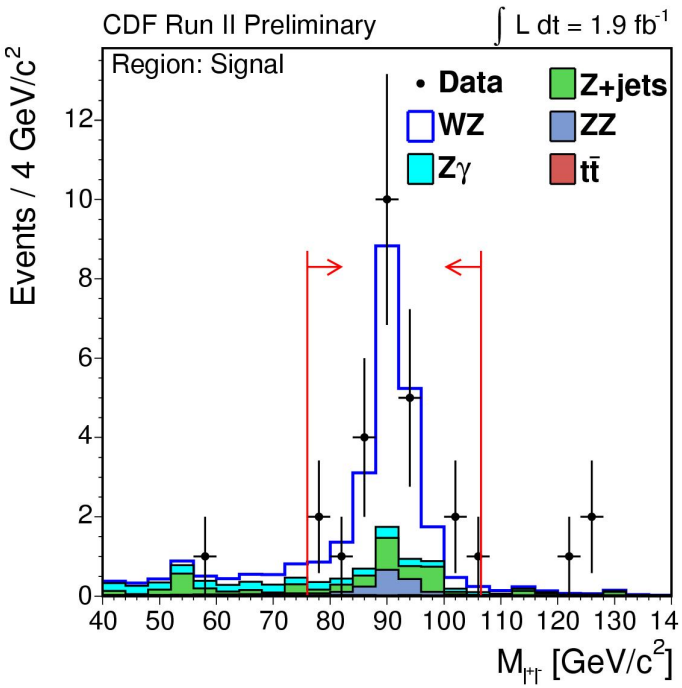
October 2006: WZ Discovery from CDF:
1st Observation of WZ Production (6σ)
in $WZ \to \ell^{\pm}\ell^{+}\ell^{-} + \not{E}_T$ using 1.1 fb^{-1}

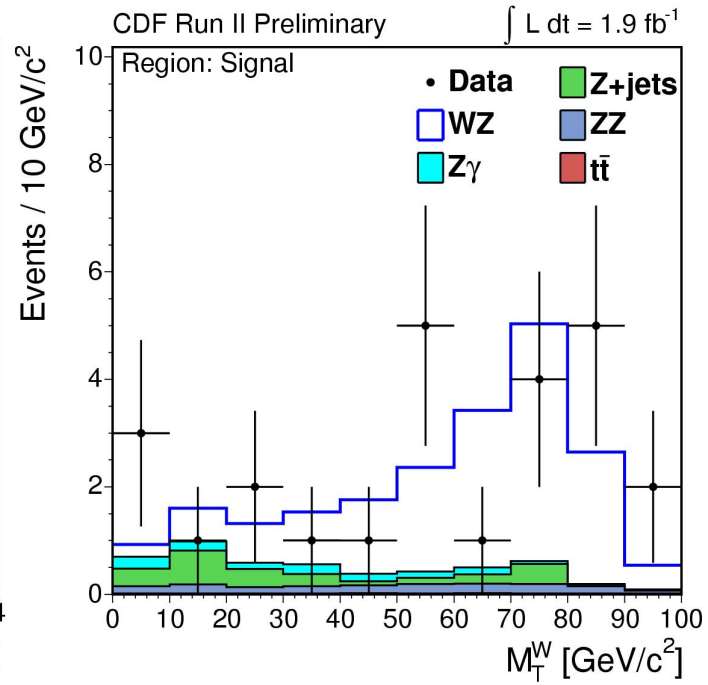
PRL98, 161801 (2007)

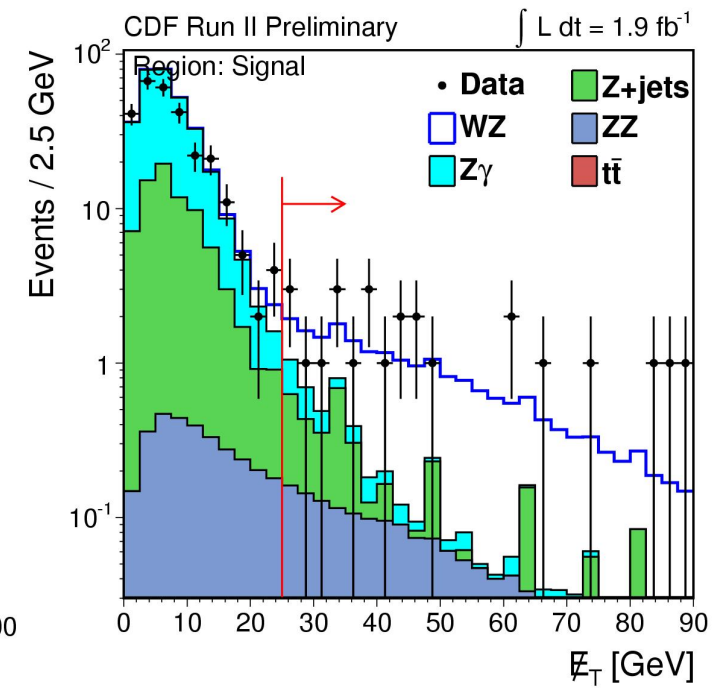
New lepton strategy crucial for this result!

Update this analysis using 1.9 fb^{-1}:

Source	Expected ± Stat ± Syst ± Lumi
Z+jets	2.45 ± 0.48 ± 0.48 ± 0.00
ZZ	1.53 ± 0.01 ± 0.16 ± 0.09
$Z\gamma$	1.03 ± 0.06 ± 0.35 ± 0.06
$t\bar{t}$	0.17 ± 0.01 ± 0.03 ± 0.01
WZ	16.45 ± 0.03 ± 1.74 ± 0.99
Total	21.63 ± 0.48 ± 2.25 ± 1.15
Observed	**25**







$$\sigma(WZ) = 4.3^{+1.3}_{-1.0}\ (\text{stat.}) \pm 0.2\ (\text{syst.}) \pm 0.3\ (\text{lumi.})\ \text{pb}$$

(world's best)

consistent with NLO
σ(WZ) = 3.7 ± 0.3 pb

WWZ Gauge Boson Couplings

Boson pair production probes gauge boson self-interactions

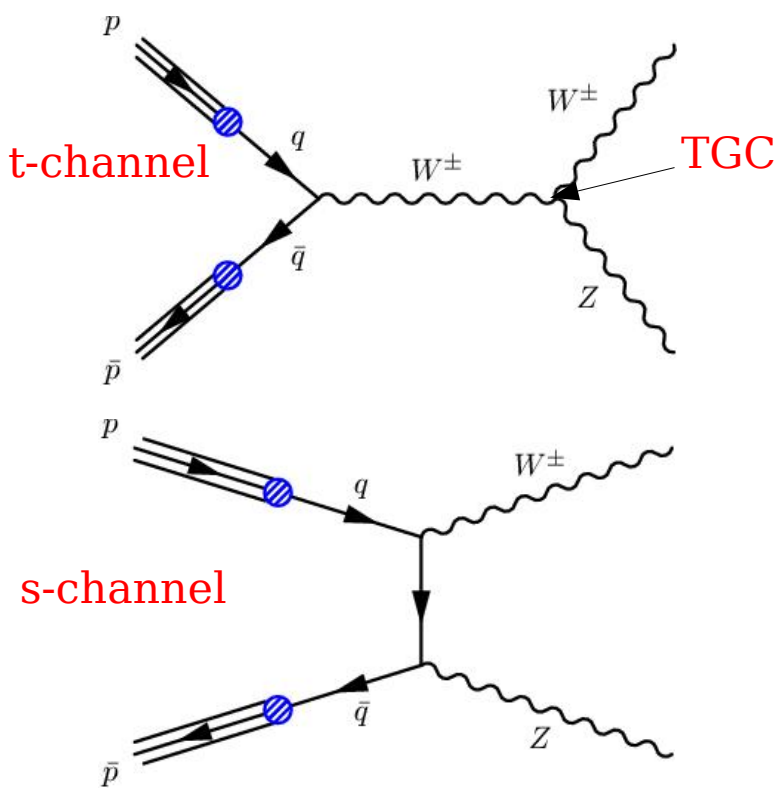
→ consequence of non-Albelian nature of $SU(2)_L \otimes U(1)_Y$

→ sensitive to new physics in trilinear gauge couplings (TGC)

Tevatron probes highest $\hat{s}$ currently available

WZ production probes the WWZ coupling directly

→ production characteristics sensitive to new physics in anomalous WWZ couplings



Use effective Lagrangian approach to set model-independent limits of coupling parameters

$$L_{WWZ}/g_{WWZ} = i\boxed{g_1^Z}(W^\dagger_{\mu\nu}W^\mu Z^\nu - W^\dagger_\mu Z_\nu W^{\mu\nu}) + i\boxed{\kappa_Z}W^\dagger_\mu W_\nu Z^{\mu\nu} + \frac{i\boxed{\lambda_Z}}{M_W^2}W^\dagger_{\lambda\mu}W^\mu_\nu Z^{\nu\lambda}$$

SM at tree level: $g_1^Z = k_Z = 1, \quad \lambda_Z = 0$

$\Delta\kappa_Z = 0 \;\; (\Delta\kappa \equiv \kappa - 1) \qquad \Delta g_1^Z = 0 \;\; (\Delta g_1^Z \equiv g_1^Z - 1)$

Form factor anzatz to avoid unitarity violation at large $\hat{s}$:

$$\alpha \;\Rightarrow\; \alpha(\hat{s}) = \frac{\alpha_0}{(1+\hat{s}/\Lambda^2)^2}$$

$\Lambda \sim$ 1-2 TeV

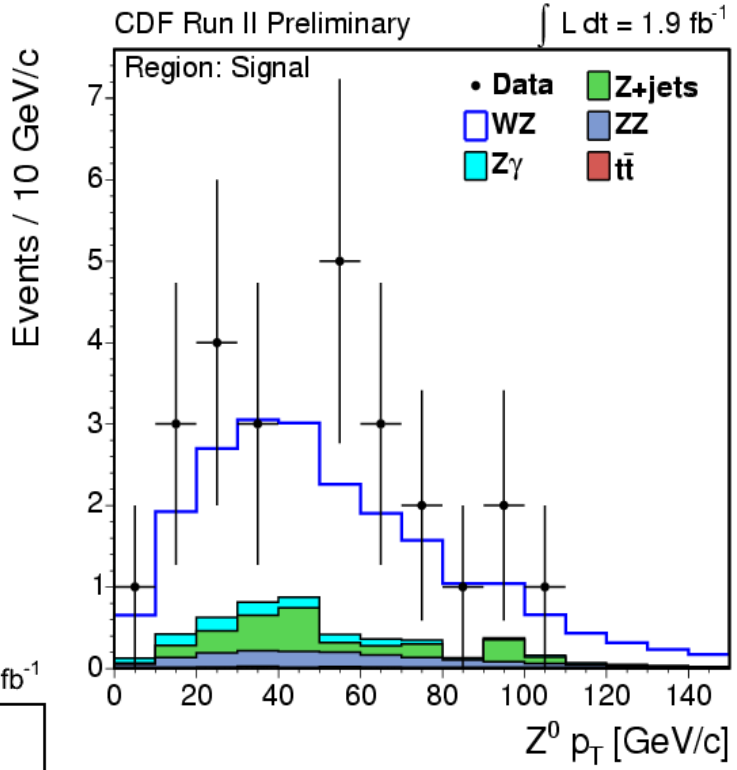
1.9 fb^{-1}

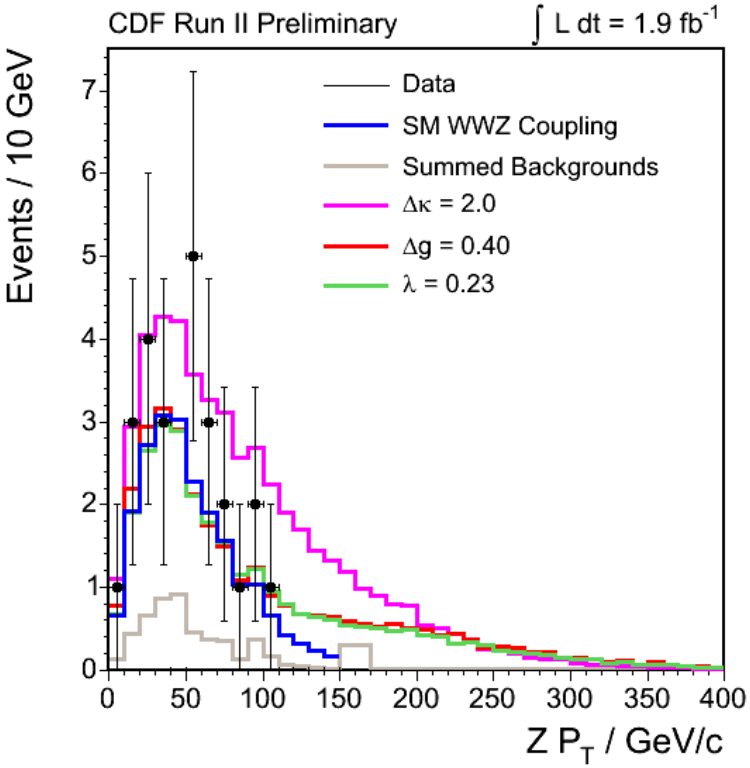
Limits on Anomalous WWZ Couplings

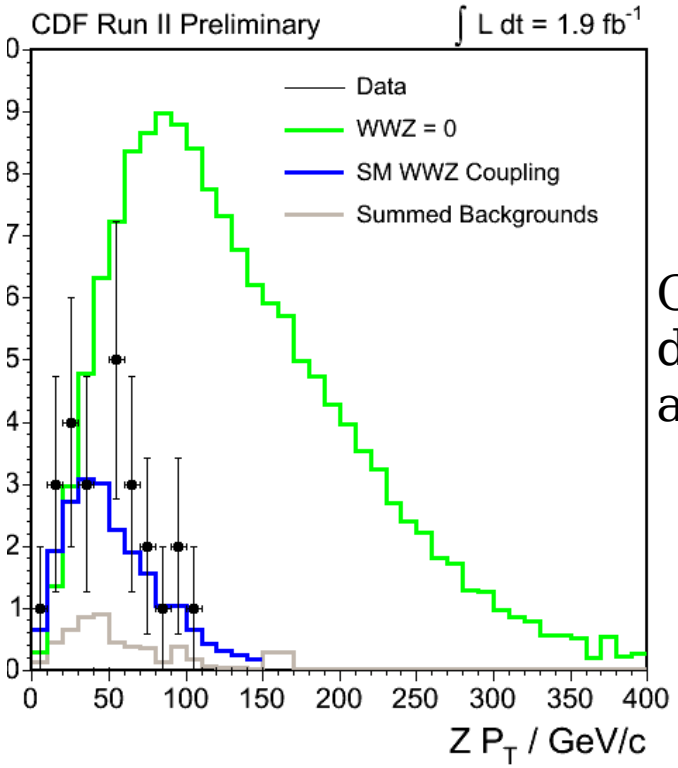
Use Z Boson p_T as variable sensitive to aTGC

Λ = 1.5 TeV	Λ = 2.0 TeV
$-0.14 < \lambda < 0.16$	$-0.13 < \lambda < 0.14$
$-0.17 < \Delta g < 0.27$	$-0.15 < \Delta g < 0.24$
$-0.86 < \Delta\kappa < 1.36$	$-0.82 < \Delta\kappa < 1.27$

Most stringent model-independent WWZ coupling limits available

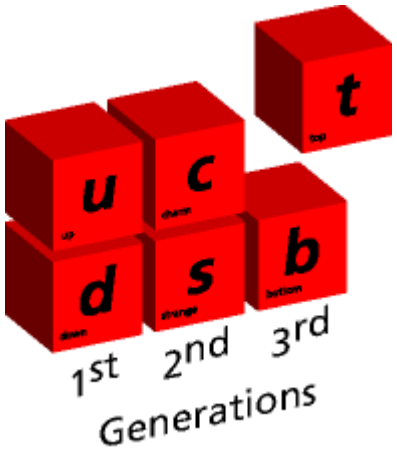


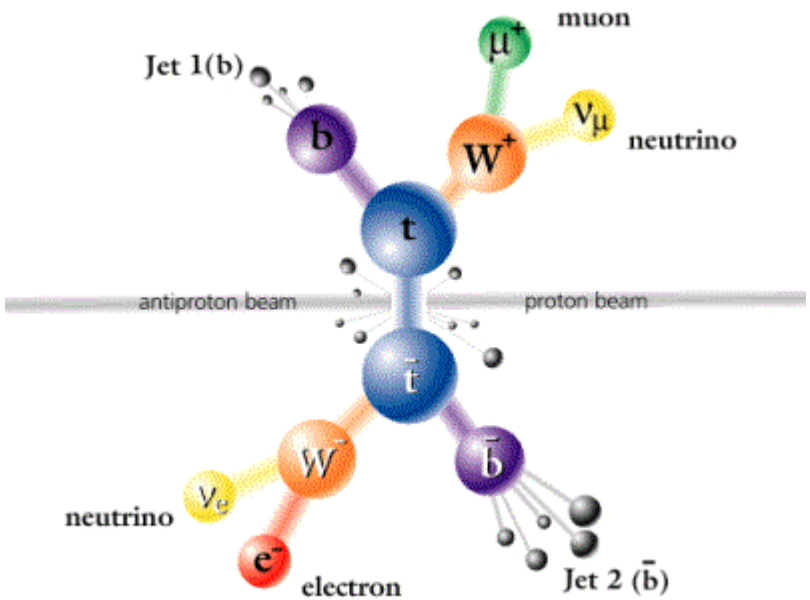


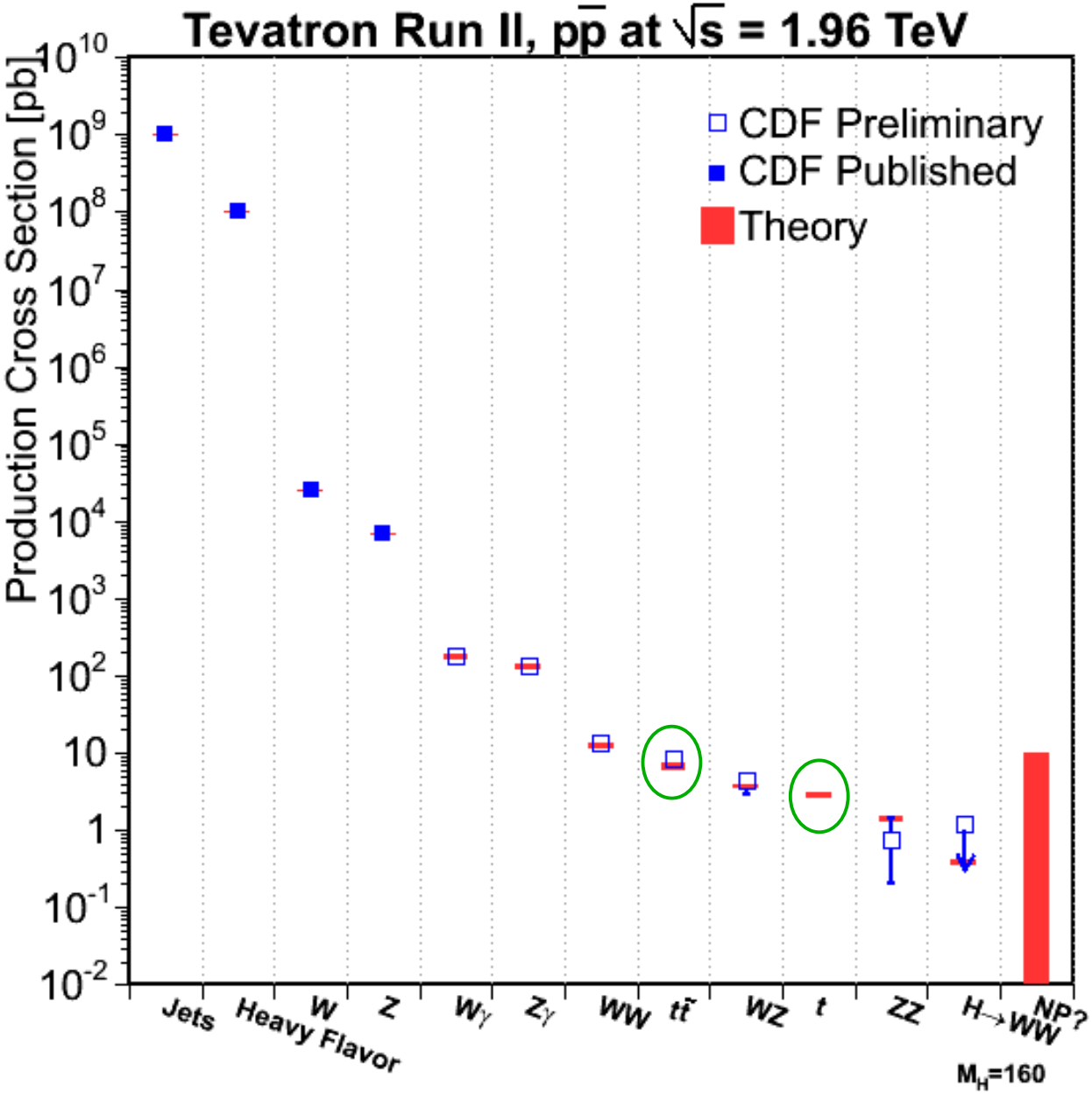


Conservative systematics due to limited MC statistics are currently being updated

Top Quark Physics

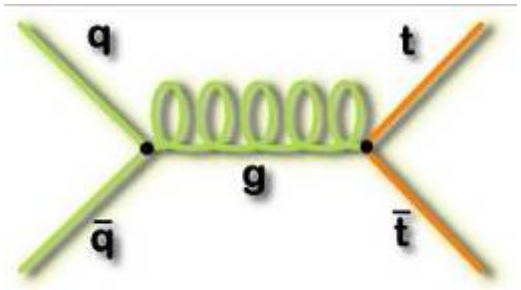






Top Quark Production @ Tevatron

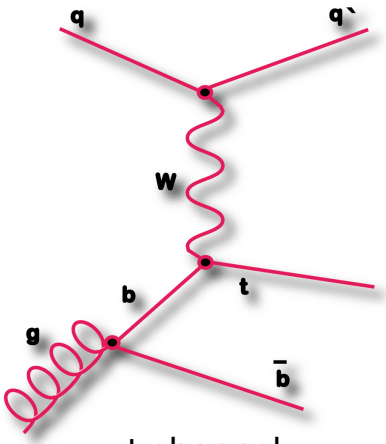
At the Tevatron, top quarks are primarily produced in pairs via the strong interaction:



$\sigma_{NLO} = 6.7 \pm 0.8$ pb

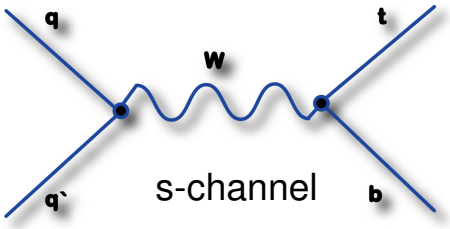
$M_{top} = 175$ GeV/c^2

The Standard Model also predicts a single top quark production via the electroweak interaction ($\sigma_{st} \sim 1/2\sigma_{tt}$)



t-channel

$\sigma_{NLO} = 1.98 \pm 0.21$ pb



s-channel

$\sigma_{NLO} = 0.88 \pm 0.07$ pb

Since top production has not been observed, although our D0 colleagues have recently reported the first evidence.

1.0-1.2 fb^{-1}

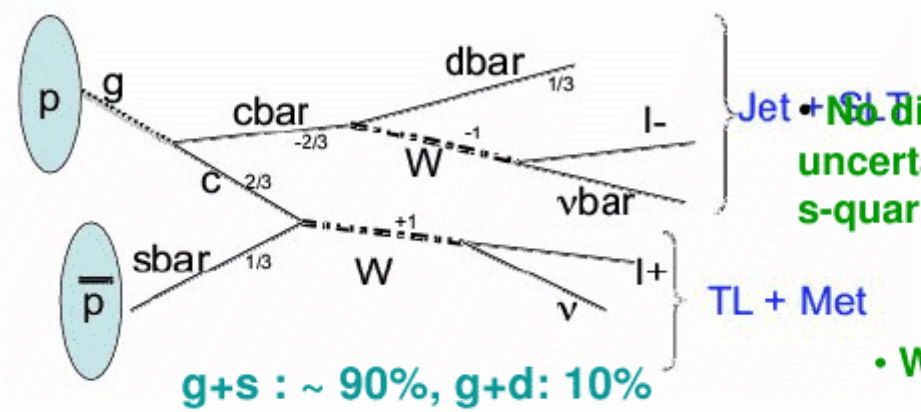
$t\bar{t}$ Production Cross Section

New CDF Cross Section Results For $p\bar{p} \rightarrow t\bar{t}$

Measurement	Description	Value
Lepton + Jets *Tight Tag* *1.12 fb^{-1}*	• One well-defined Lepton • At least 4 Jets • ≥ one jet tagged as bottom	$8.2 \pm 0.5_{stat} \pm 0.8_{syst} \pm 0.5_{lumi}$ pb
Dilepton *Two Leptons* *1.2 fb^{-1}*	• Two well-defined leptons • At least 2 jets • Significant MET	$6.2 \pm 1.1_{stat} \pm 0.7_{syst} \pm 0.4_{lumi}$ pb
Dilepton *Lepton + Track* *1.07 fb^{-1}*	• One well-defined lepton • One isolated track • At least 2 jets • Significant MET	$8.3 \pm 1.3_{stat} \pm 0.7_{syst} \pm 0.5_{lumi}$ pb
Dilepton *Lepton + Track + Tag* *1.0 fb^{-1}*	• Same as Lepton + Track • ≥ one jet tagged as bottom	$10.1 \pm 1.8_{stat} \pm 1.1_{syst} \pm 0.6_{lumi}$ pb

First measurement of W+c cross section

The first measurement of the ppbar->W+c production cross section with Soft Muon Tagging (SLT)



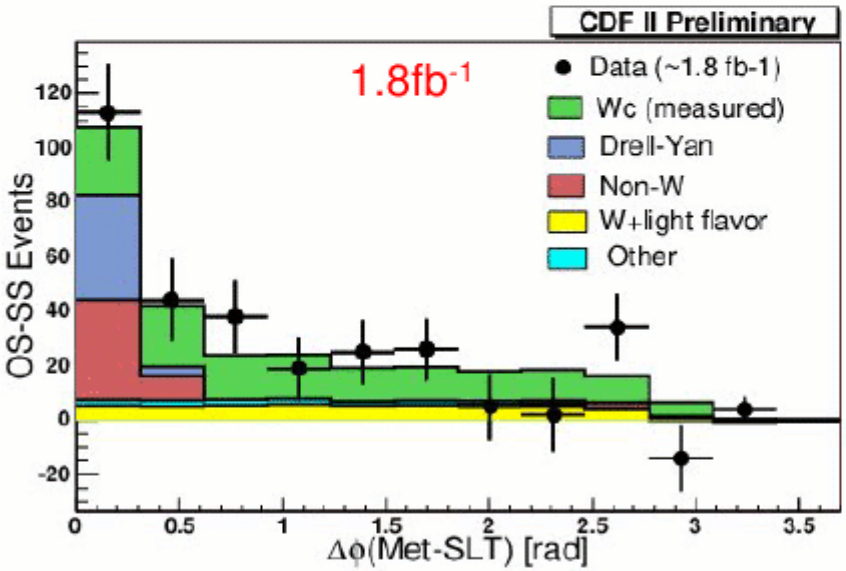
Motivation

- No direct measurement before, reduce systematic uncertainties on many other measurements, probe s-quark PDF and determine Vsc

Algorithm

- Wc: TL, SLT charges are fully anti-correlated,
  - ✓ large charge asymmetry A
- Backgrounds: W+l.f., nonW QCD, DY, etc
  - ✓ mostly charge symmetric except DY
- Observable: same sign subtracted events
  - ✓ N(OS) – N(SS)

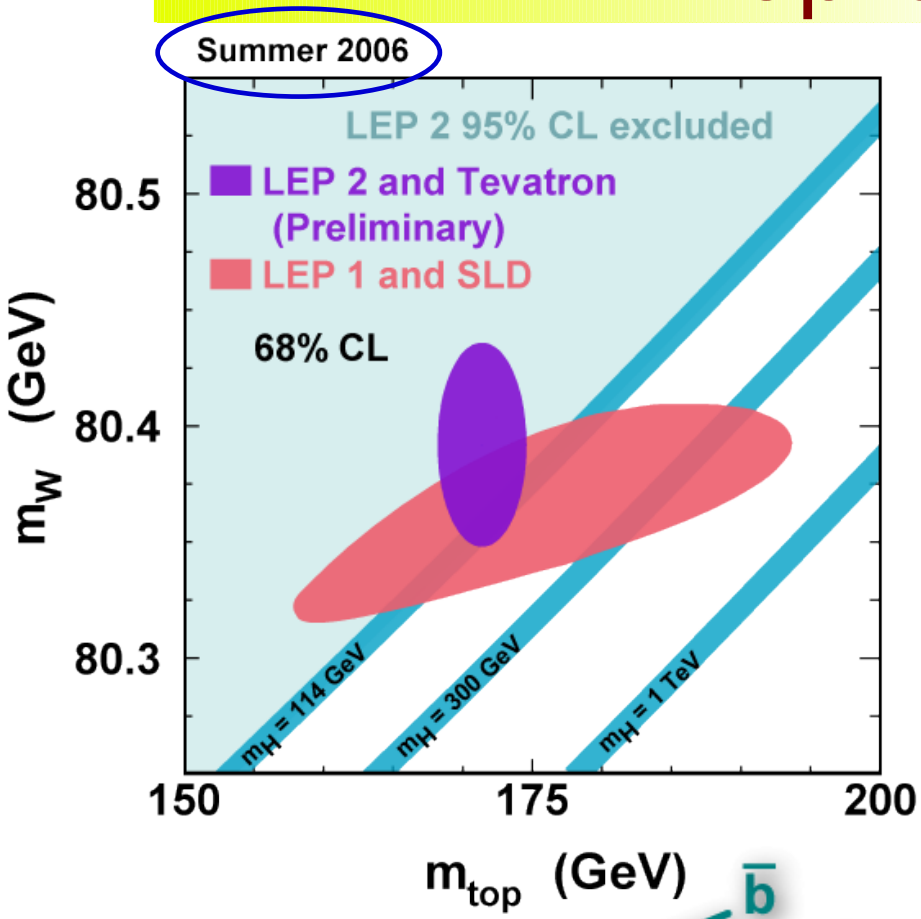
$$A = \frac{N_{OS} - N_{SS}}{N_{OS} + N_{SS}}$$



CDF II Preliminary

$$\sigma_{Wc}(pt_c > 8, |\eta_c| < 3) \times BR(W \to \ell\nu)$$
$$= 28.5 \pm 8.2(\text{stat})^{+4.0}_{-4.3}(\text{syst}) \pm 1.7(\text{lum})\ \text{pb}$$

Top Quark Mass

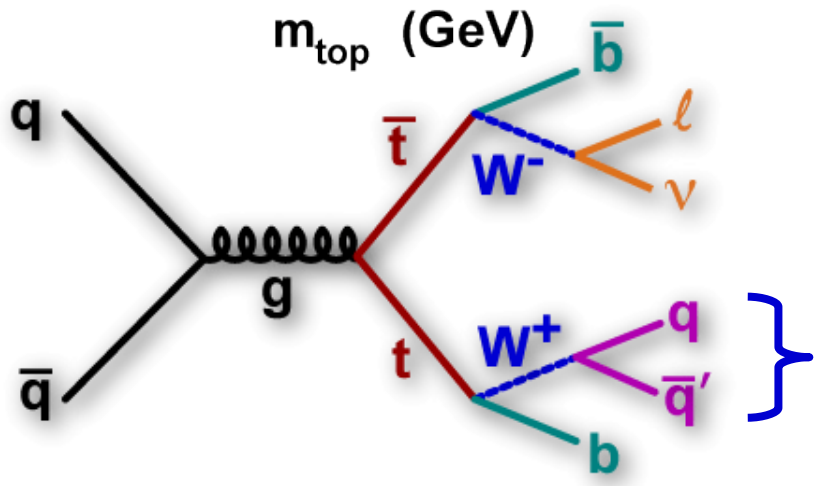


Top Quark Mass

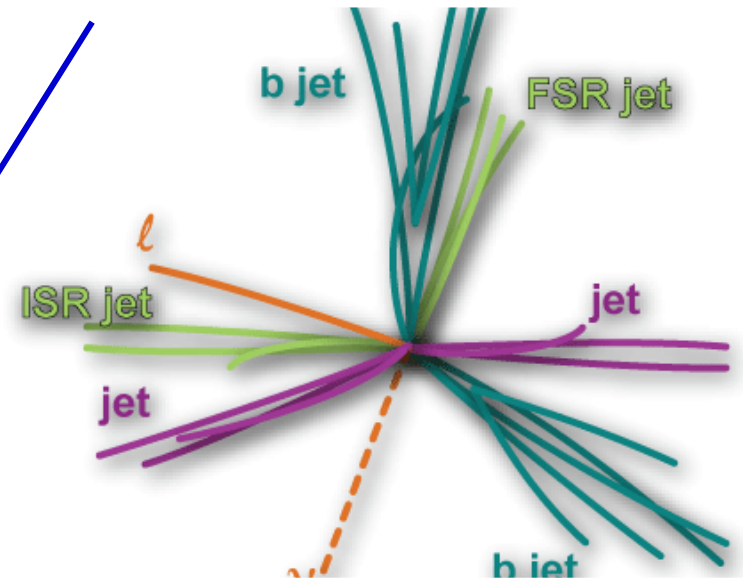
- Important EWK parameter
- Key role in BSM physics models
- Constrains the Higgs mass
- Heavy: Unexpected role in EWSB?

Challenges: combinatorics, b-tagging efficiencies, jet energy scale.

Solutions: sophisticated analyses, in-situ W→jj calibration

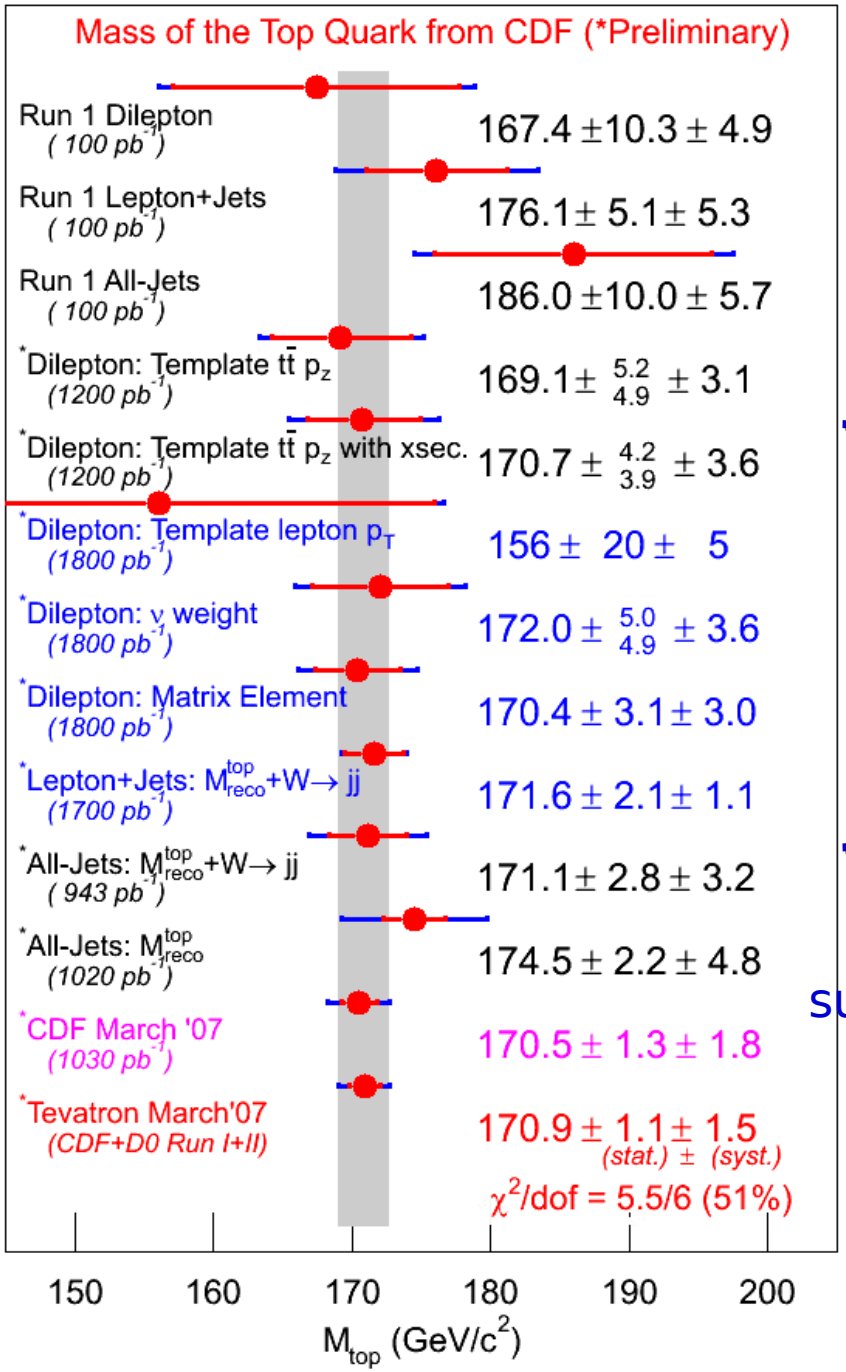


What a theorist sees…



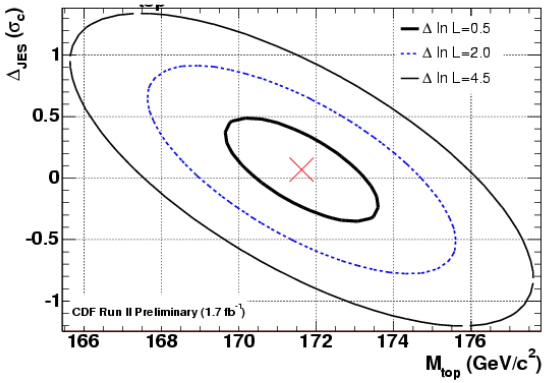
What an experimentalist sees

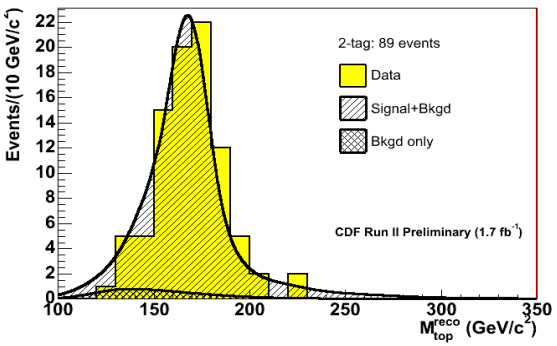
Top Quark Mass



New for summer 2007!

most precise lepton + jets channel:

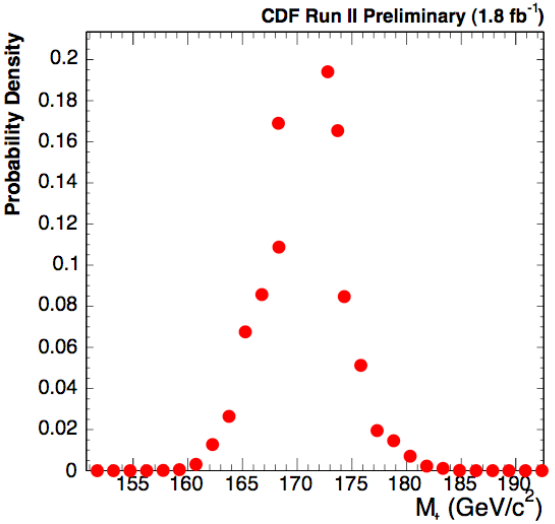




M_{top}=171.6 ± 2.4 (stat+syst) GeV/c^2

most precise dilepton channel:

ME analysis



M_t=170.4 ± 3.1(stat) ± 3.0(sys)GeV/c^2

1.1 fb^{-1}

Search for FCNC t→Zq

- FCNC are rare in the Standard Model
- Within the SM:

  BR(t → Wb) > 99%

  BR(t → Zq) = $O(10^{-14})$

  ⇒ Top FCNC extremely rare

- Beyond SM:

  Some models predict larger branching ratios, up to $O(10^{-2})$

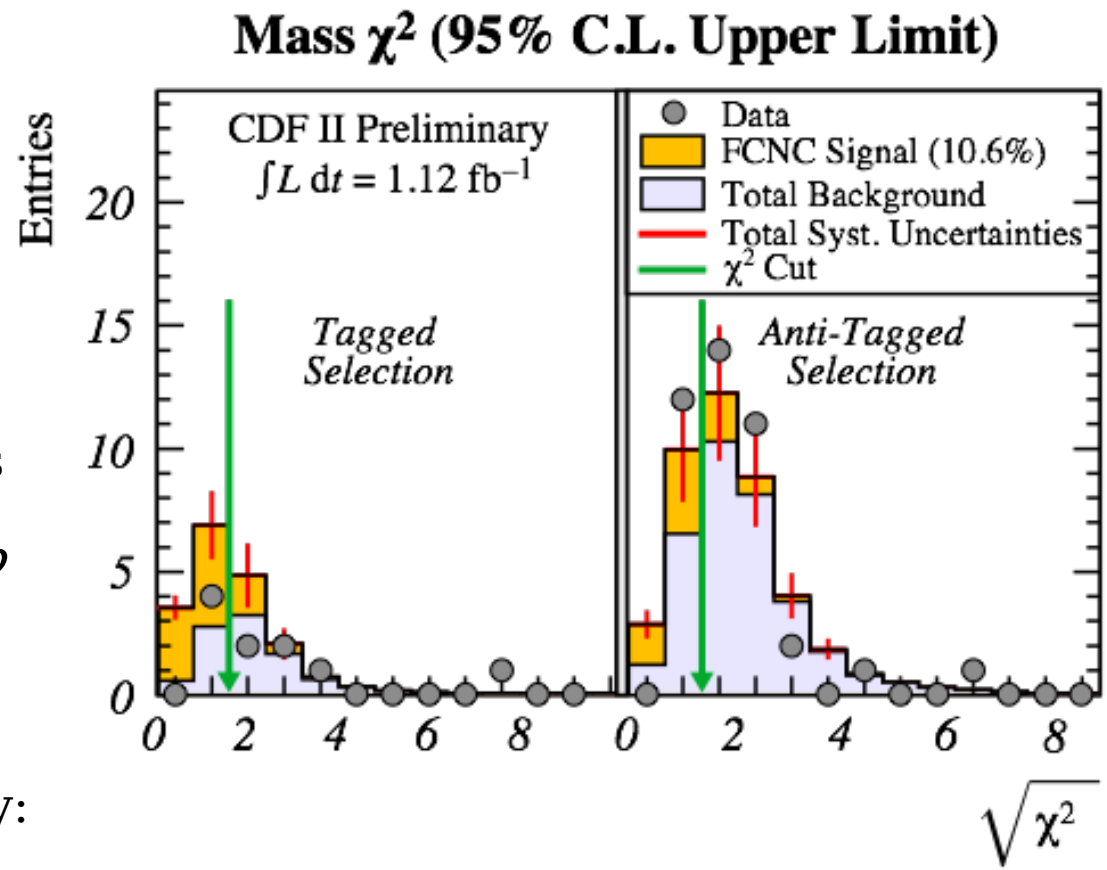
  ⇒ Signal @ Tevatron → new physics

Signature: $t\bar{t} \rightarrow ZqWb \rightarrow l^+ l^- qq' \bar{q}'' b$

- Dominant background: Z + jets

Blind search in Z + ≥4 jets channel

- 2 signal regions to increase sensitivity: loose SECVTX tagged & anti-tagged
- Mass χ^2 from W, SM top, FCNC top



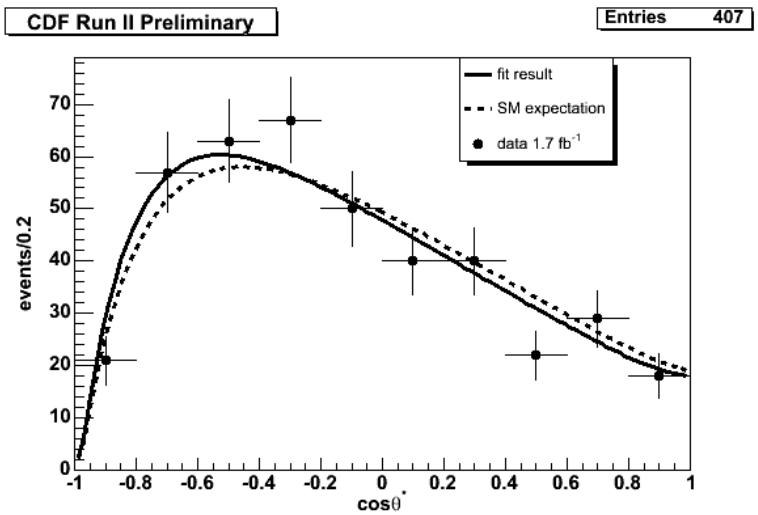
World's best limit:
BR(t→Zq) < 10.6% @ 95% C.L.

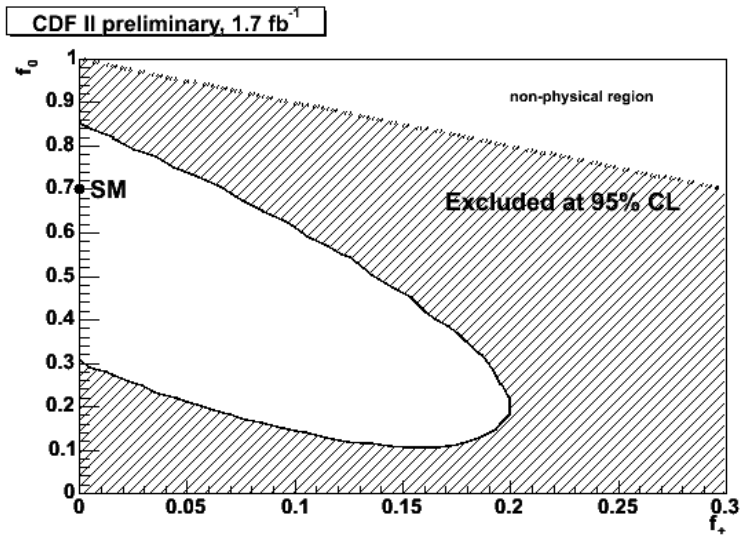
Previous best limit (L3): 13.7%

1.7 fb^{-1}

W Helicity in Top Quark Decays

- W helicity in top decays is fixed by M_{top}, M_W and V-A structure of tWb vertex
- SM prediction:
  - f_- ~30% -left-handed; f_0 ~ 70% - longitudinal; f_+ ~ 0.036% - right-handed
- Select and fully reconstruct lepton+jets events
- Measure angular distribution of charged lepton wrt top in W rest frame: $\cos\theta^*$
- Fit helicity fractions with unbinned likelihood





1D: (fixed f_0 or f_+)

f_0 = 0.57 ± 0.11(stat) ± 0.04(syst)

f_+ < 0.07 @ 95%CL

2D:

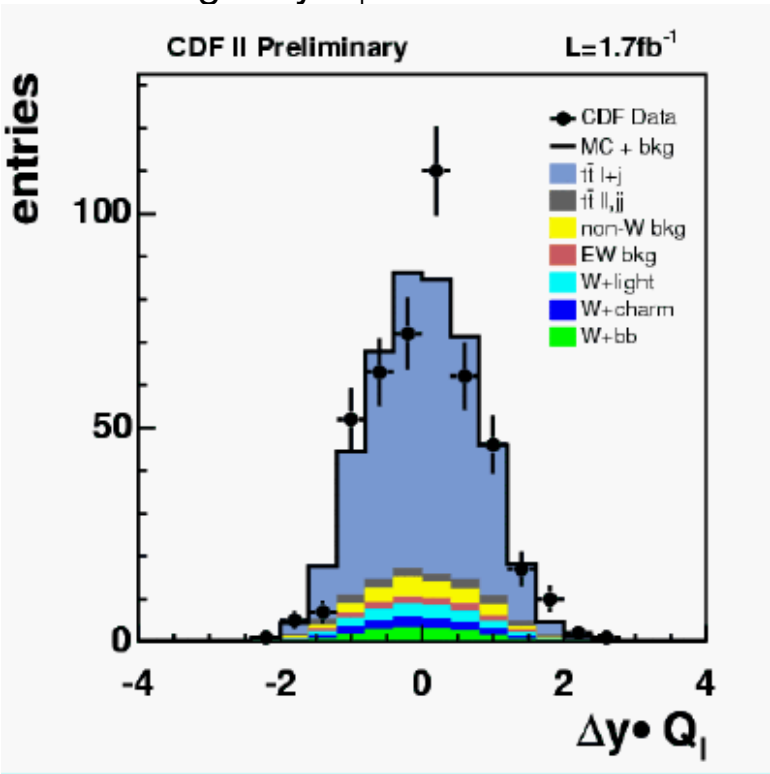
f_0 = 0.61 ± 0.20(stat) ± 0.03(syst)

f_+ = -0.02 ± 0.08(stat) ± 0.03(sy

1.7 fb^{-1}

Top Production A_{fb}

- NLO calculations predict forward-backward asymmetry of 4-6%
  - (J.Kühn et al. Phys. Rev. Lett. 81, 49 (1998), Phys. Rev.D 59, 054017 (1999))
- Asymmetry arises from interference between contributions symmetric and antisymmetric under the exchange: top -> anti-top
- Top pairs in lepton + ≥ 4 jets channel are fully reconstructed
- Make use of Lorentz-invariant rapidity difference of top and anti-top times the lepton charge: $\Delta y \cdot Q_l$ variable



- Numbers of events measured in two bins: positive and negative values of $\Delta y \cdot Q_l$

The asymmetry value is background subtracted and corrected for smearing effects of ttbar pair reconstruction with the inversion of 2x2 matrix

$$A_{fb} = 28 \pm 13(\text{stat.}) \pm 5(\text{syst.})\ \%$$

1.5 fb^{-1}

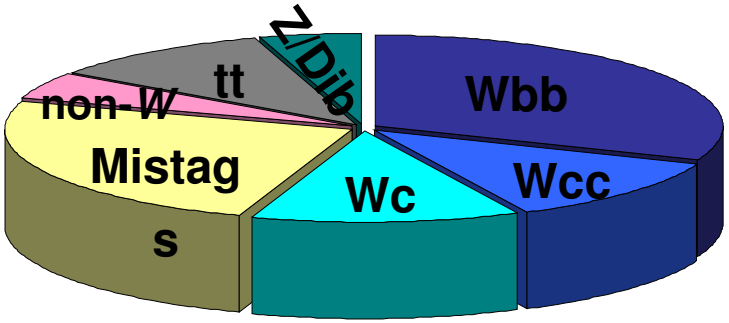
Single Top Production

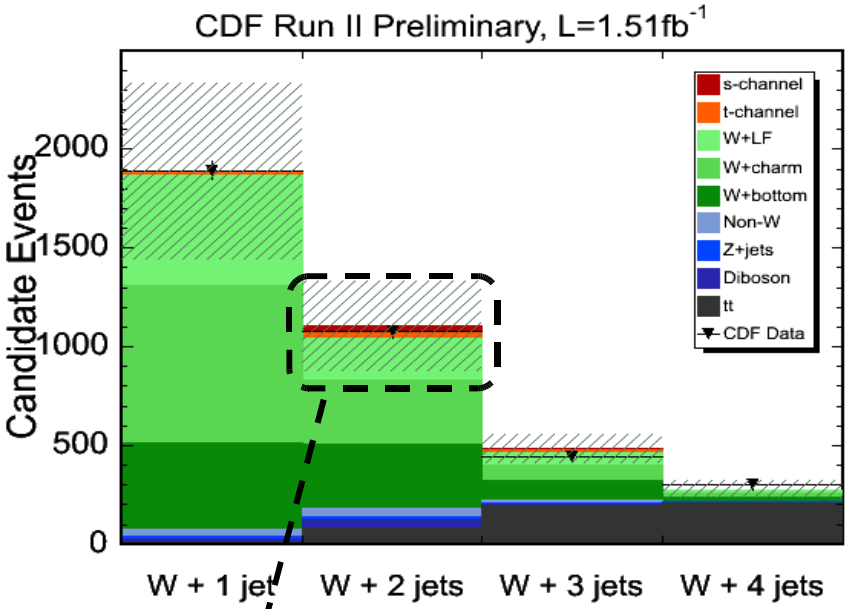
CDF Run II Preliminary

Predicted event yield with 1.51 fb^{-1}

s-channel	23.9 ± 6.1
t-channel	37.0 ± 5.4
Single top	60.9 ± 11.5
$t\bar{t}$	85.3 ± 17.8
Diboson	40.7 ± 4.0
Z + jets	13.8 ± 2.0
W + bottom	319.6 ± 112.3
W + charm	324.2 ± 115.8
W + light	214.6 ± 32.2
Non-W	44.5 ± 17.8
Total background	1042.8 ± 218.2
Total prediction	1103.7 ± 230.9
Observed	1078

New Improvement: HF calibration using W+1 jet data!





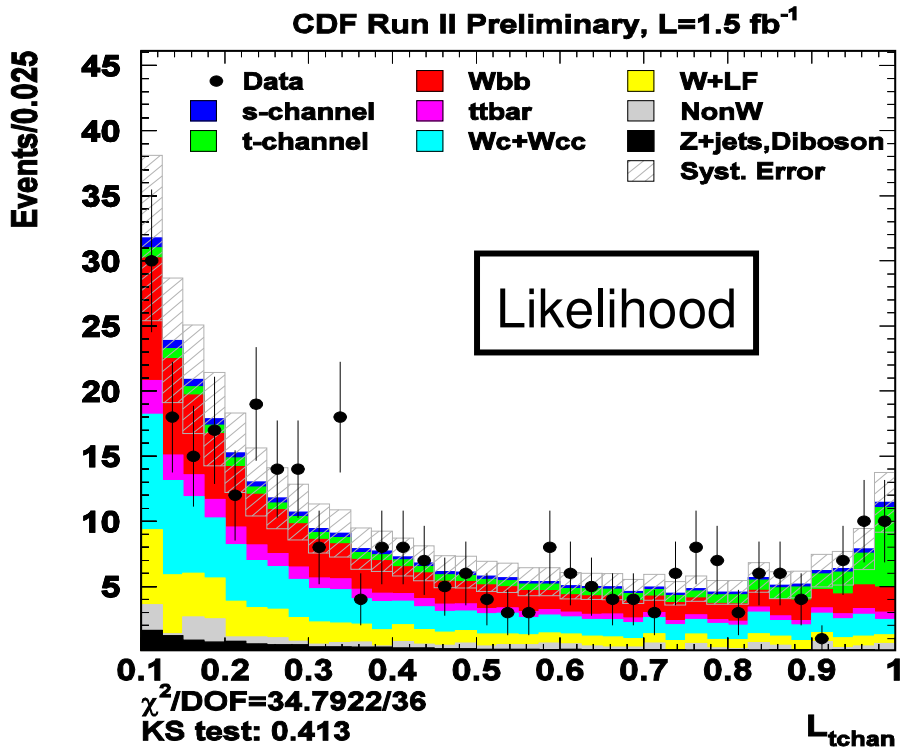
Single top hidden behind background uncertainty!

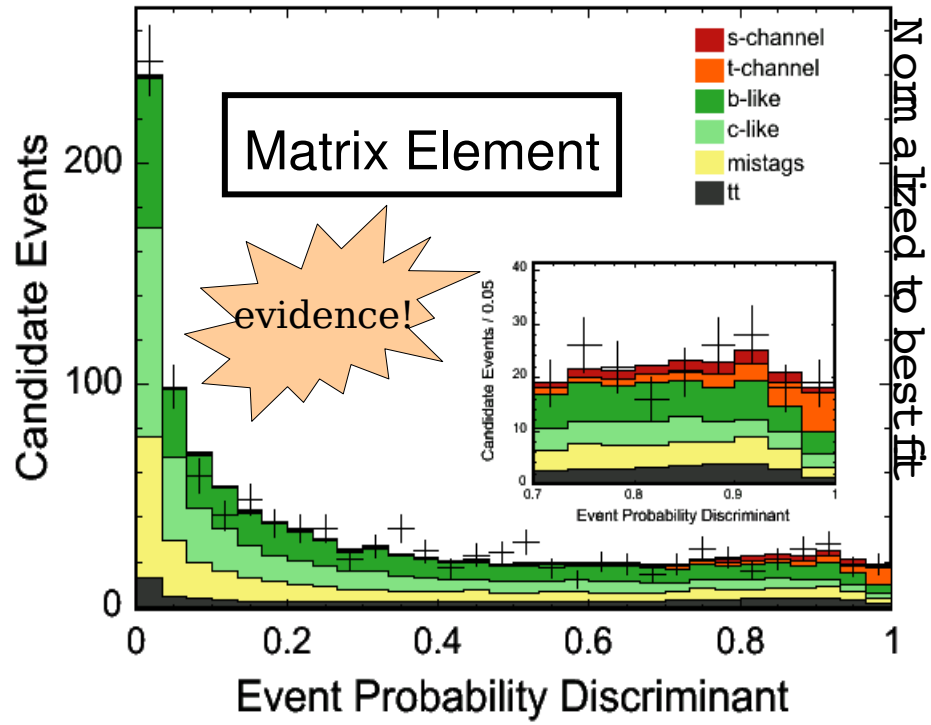
→Makes counting experiment impossible!

→Multivariate Techniques necessary

1.5 fb^{-1}

Single Top Production



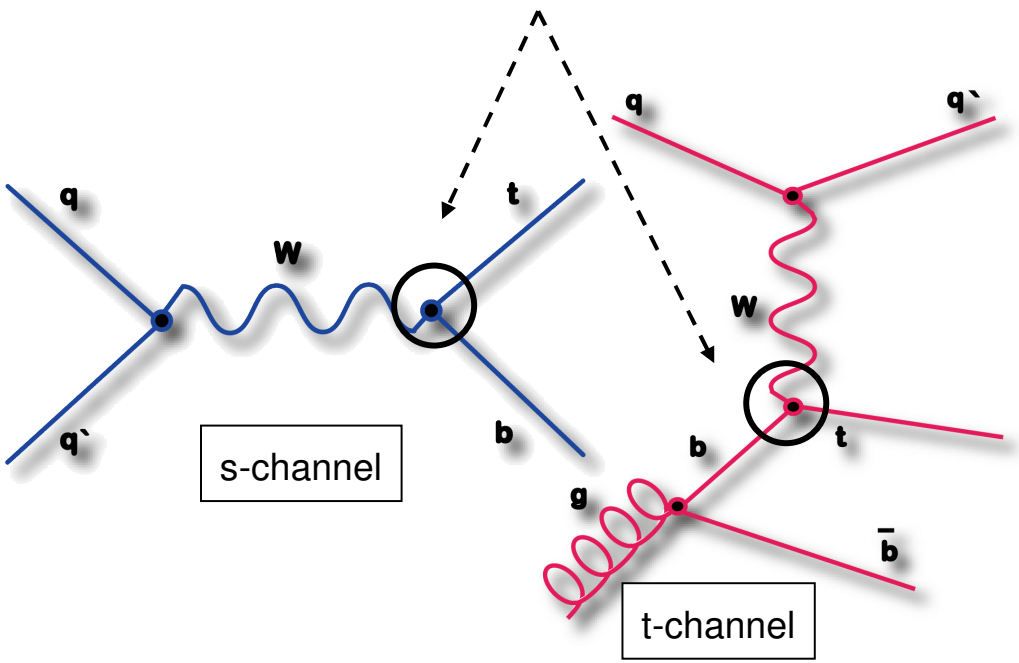


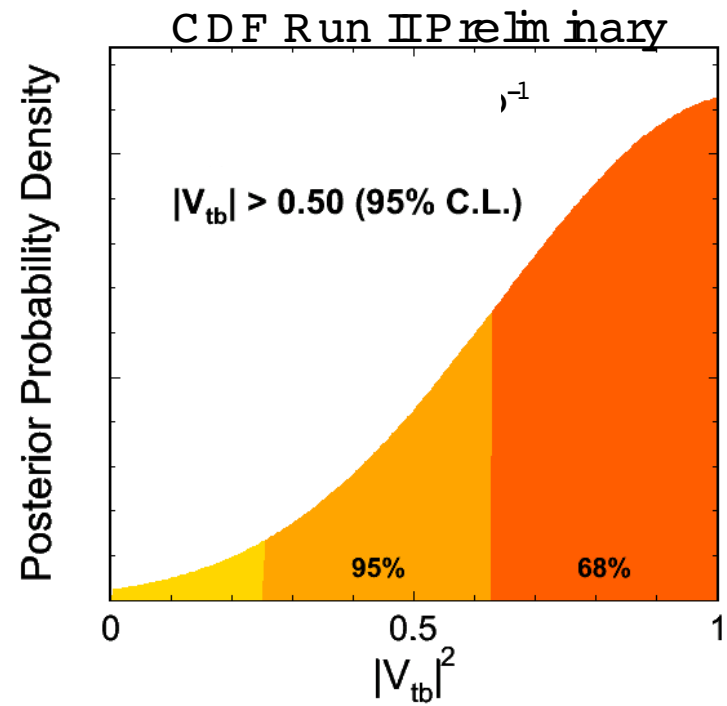
Observed p-value = 0.31% / 2.7σ	Observed p-value = 0.09% / 3.1σ
Expected p-value = 0.20% / 2.9σ	Expected p-value = 0.13% / 3.0σ
$\sigma_{s+t} = 2.7^{+1.3}_{-1.1}$ pb	$\sigma_{s+t} = 3.0^{+1.2}_{-1.1}$ pb
$\sigma_{s} = 1.1^{+1.4}_{-1.1}$ pb	$\sigma_{s} = 1.1^{+1.0}_{-0.8}$ pb
$\sigma_{t} = 1.3^{+1.2}_{-1.0}$ pb	$\sigma_{t} = 1.9^{+1.0}_{-0.9}$ pb

1.5 fb^{-1}

$|V_{tb}|$ Measurement

- Using the Matrix Element cross section measurement, we determine $|V_{tb}|$ assuming $|V_{tb}| >> |V_{td}|, |V_{ts}|$



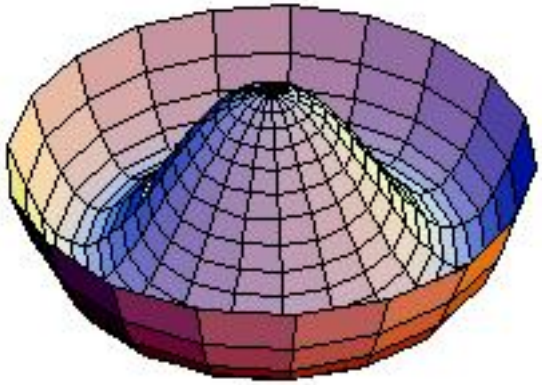


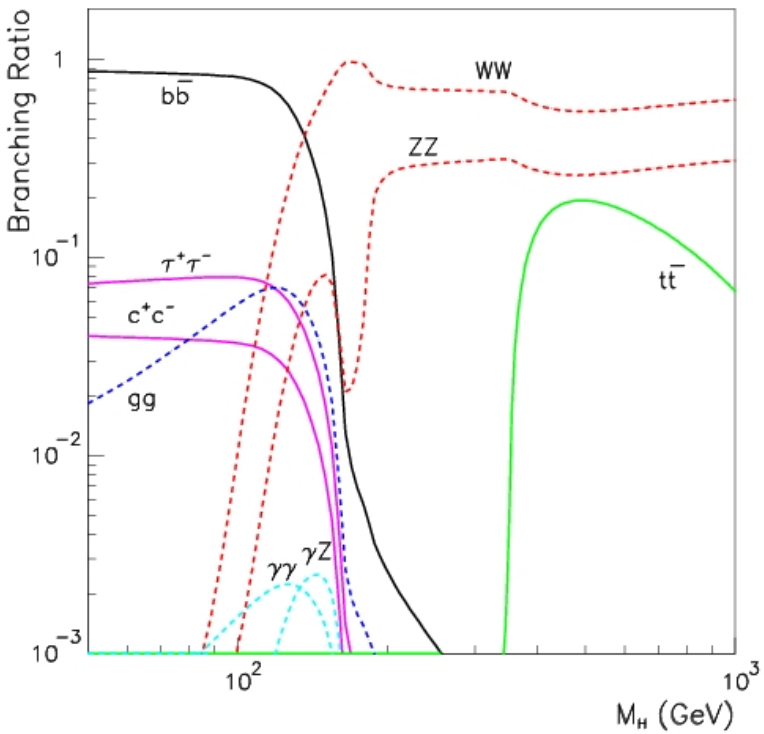
Flat prior in $|V_{tb}|^2$

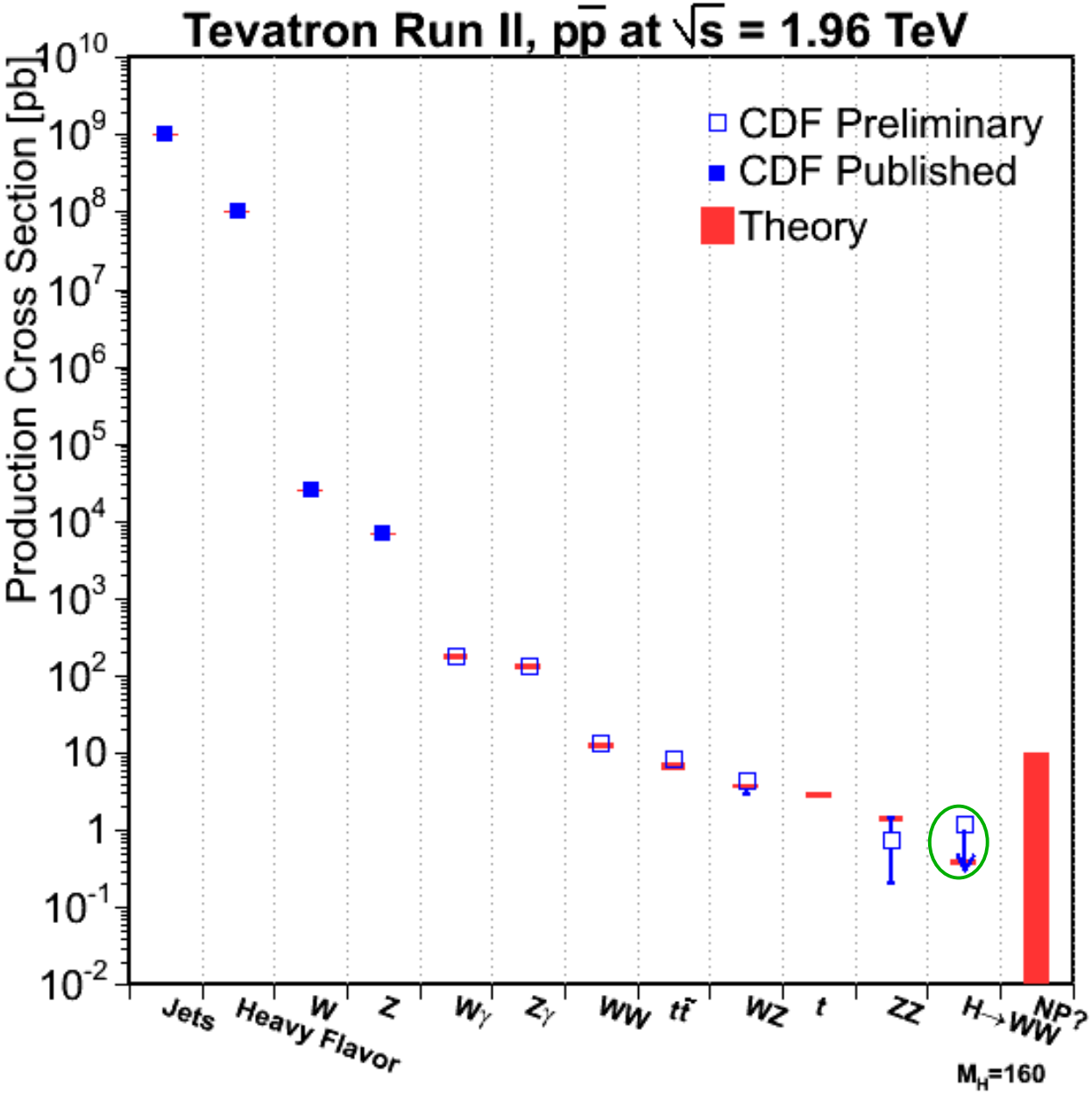
$$|V_{tb}| = 1.02 \pm 0.18\ (\text{experiment}) \pm 0.07\ (\text{theory})$$

Z. Sullivan, Phys.Rev. D70 (2004) 114012

Searches for the Standard Model Higgs





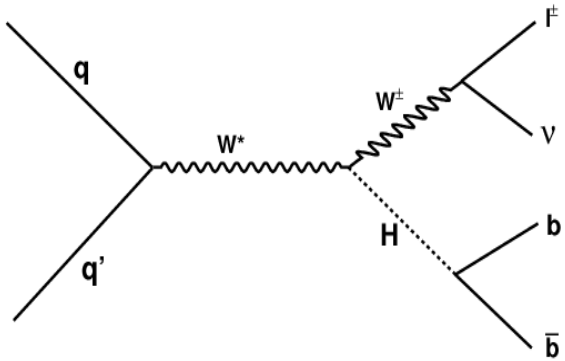


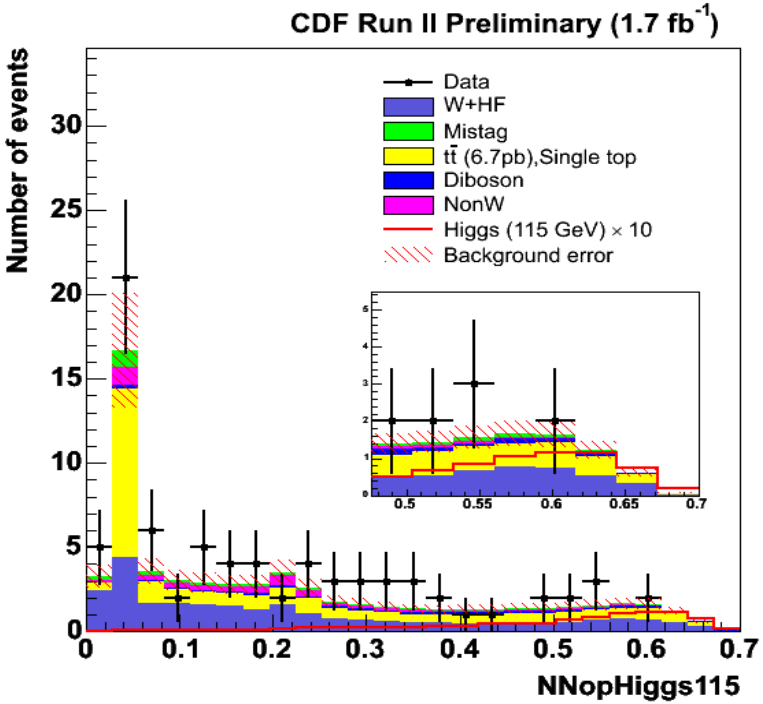
1.7 fb^{-1}

Search for WH→$\ell\nu b\bar{b}$

Search for SM Higgs in double b-tag events

Sensitive to low mass Higgs (110-150 GeV/c^2)



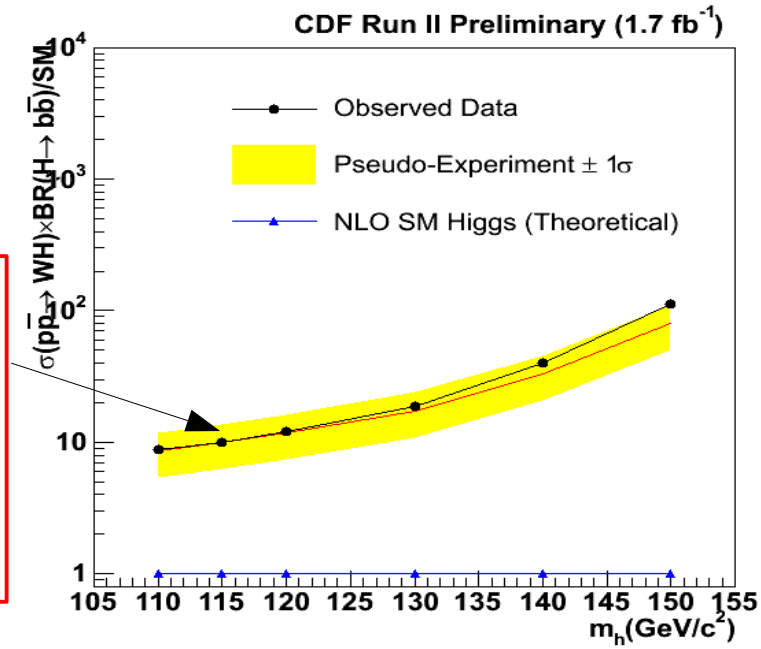


- Main backgrounds include W+2 jets, tt, diboson, and QCD multijet production
- Significant improvements since prior analysis using 955 pb^{-1}
- new double tag category (secondard vertex + jet probability tagger)

  ~25% improvement
- artificial neural network to improve signal discrimination

  ~10% improvement

- At m_H = 115 GeV/c^2:
- Expected limit: 9.9 x SM (=1.3 pb)
- Observed limit: 10.1 x SM (=1.33 pb)



1.7 fb^{-1}

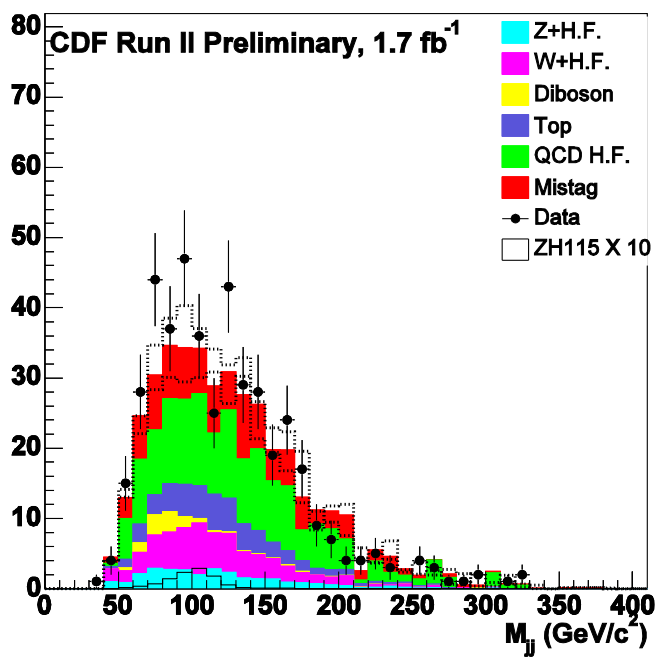
Search for $ZH \rightarrow \nu\nu b\bar{b}$

- Search for SM Higgs boson produced in MET plus b-jets signature.
  - ZH->ννbb
  - WH->(l)νbb (lepton escapes detection)
  - Large MET + bb signal (MET > 70 GeV)

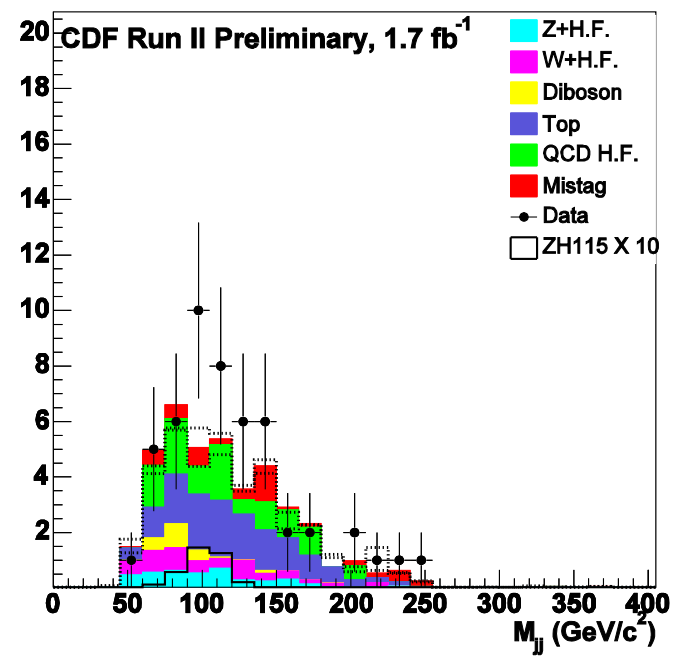
- 1 Jet b-tagged by tight SecVTX algorithm or
- 2 jets b-tagged by loose SecVTX algorithm.

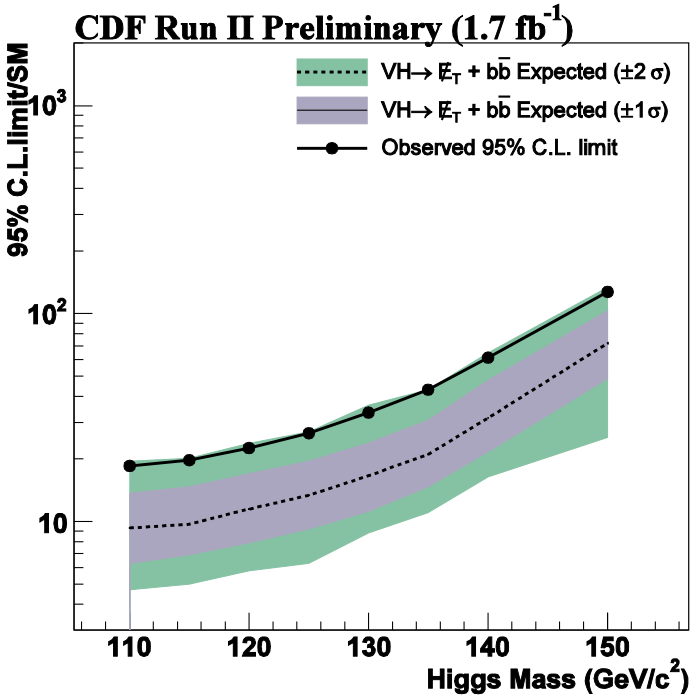
Process	Single Tag	Double Tags
QCD h.f.	$157.4 \pm 9.0 \pm 44.0$	$10.6 \pm 2.4 \pm 3.9$
Top	$48.2 \pm 1.0 \pm 6.9$	$14.0 \pm 0.5 \pm 2.1$
Di-boson	$11.5 \pm 0.6 \pm 2.5$	$1.9 \pm 0.2 \pm 0.4$
W + h.f.	$59.9 \pm 4.1 \pm 27.0$	$4.6 \pm 1.1 \pm 2.0$
Z + h.f.	$28.3 \pm 1.9 \pm 12.7$	$4.1 \pm 0.7 \pm 1.9$
Mistag	$98.2 \pm 7.3 \pm 31.7$	$4.7 \pm 1.0 \pm 1.1$
Total bck	403.5 ± 60.1	39.9 ± 6.1
Observed	443	51
$(VH\ m_H = 115\,\mathrm{GeV}/c^2)$	(1.9)	(1.2)

Dijet Mass, SR, Single Tight



Dijet Mass, SR, L+L





1.9 fb^{-1}

Search for H→WW$^{(*)}$

Why search for gg→H→WW$^{(*)}$→ℓνℓν?

- Most sensitive channel for $m_H \geq 130$ GeV/c^2

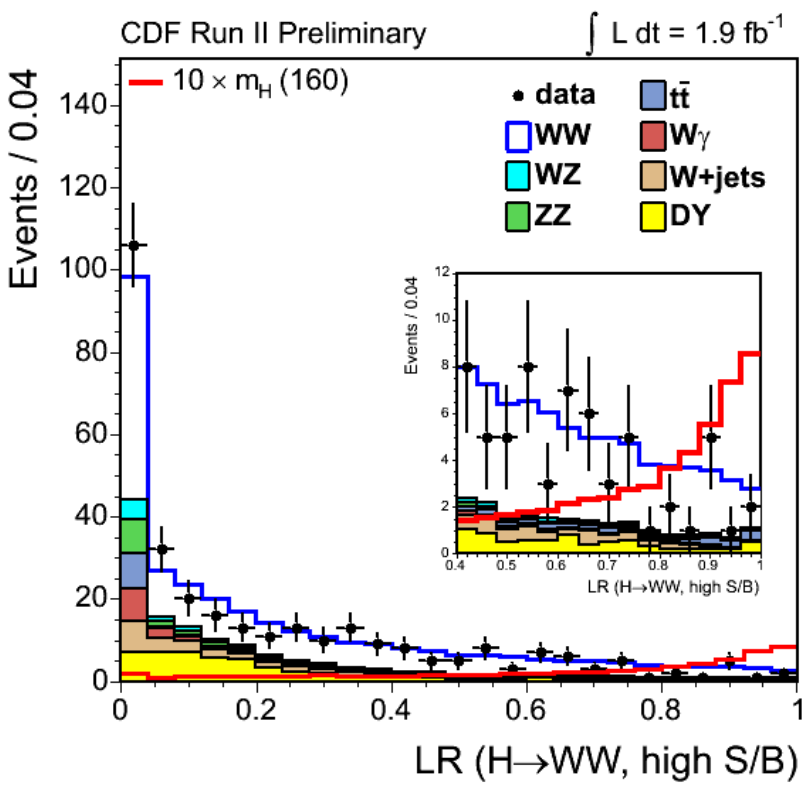
Use Matrix Element Techniques

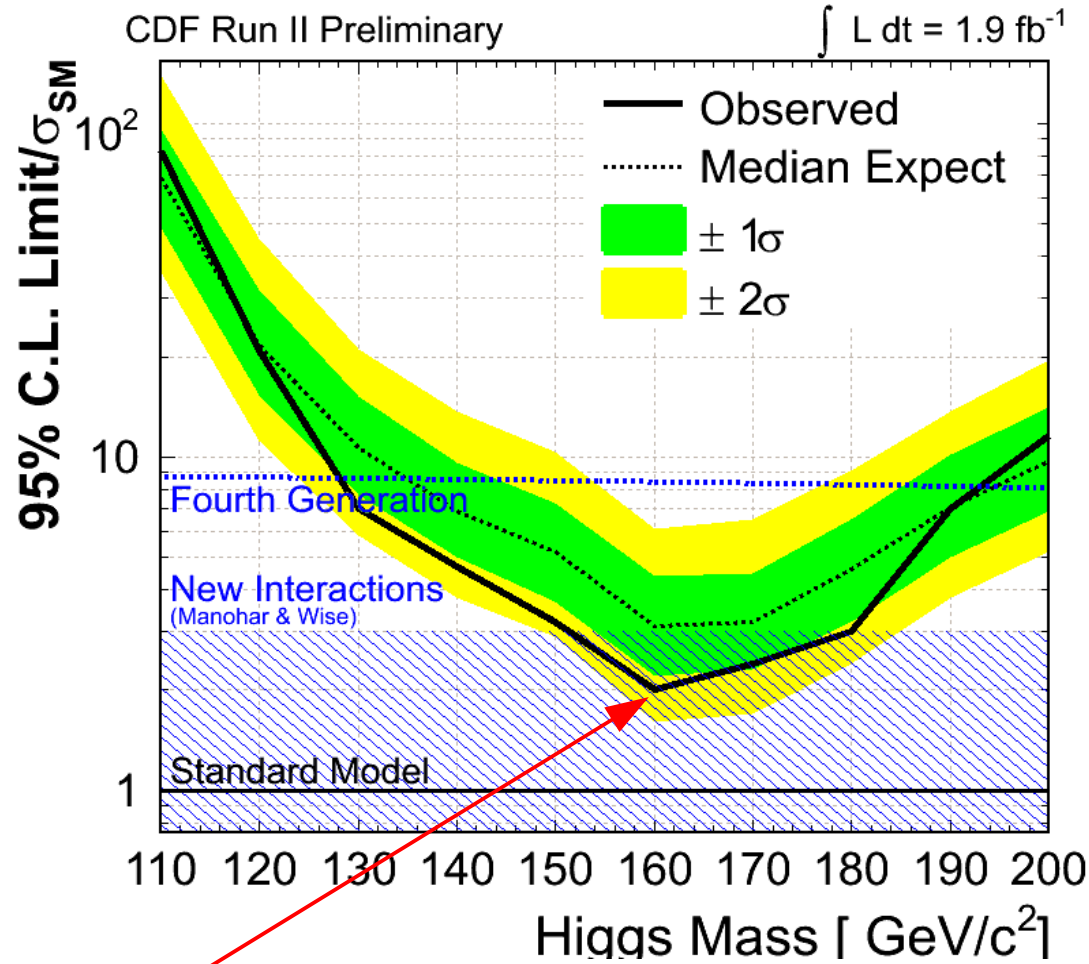
- Calculate LO probability density using full kinematic information

$$P(x_{obs}) = \frac{1}{<\sigma>} \int \frac{d\sigma(y)}{dy} \epsilon(y) G(x_{obs}, y)\, dy$$

- Construct LR discriminant and do 1-D fit

$$LR = \frac{P_{H\to WW}(m_H)}{P_{H\to WW}(m_H) + \sum_i f_{bkg,i} P_{bkg,i}}$$



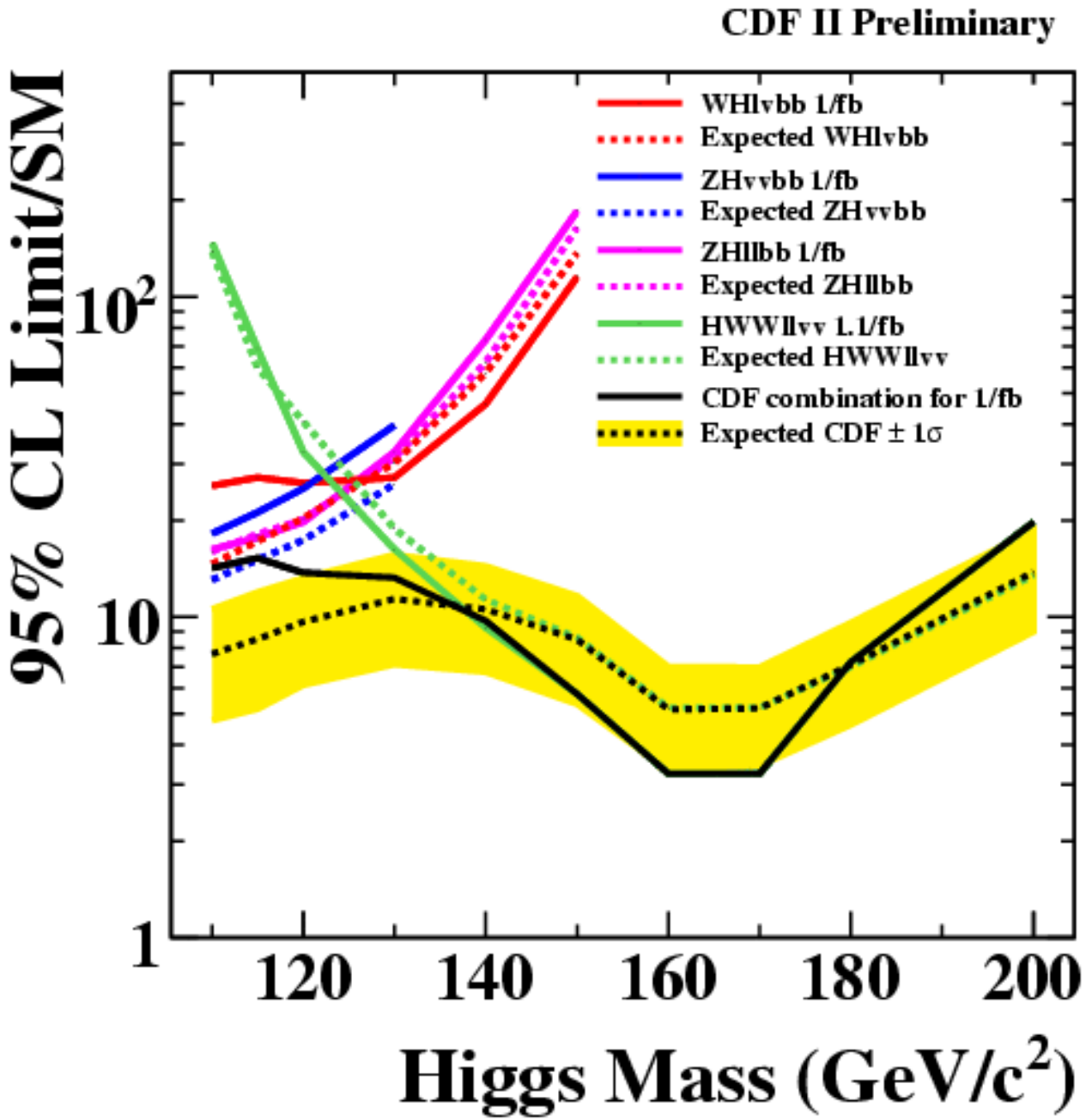


- At m_H = 160 GeV/c^2:
- Expected limit:
  3.1 x SM (=1.2 pb)
- Observed limit:
  2.0 x SM (=0.8 pb)

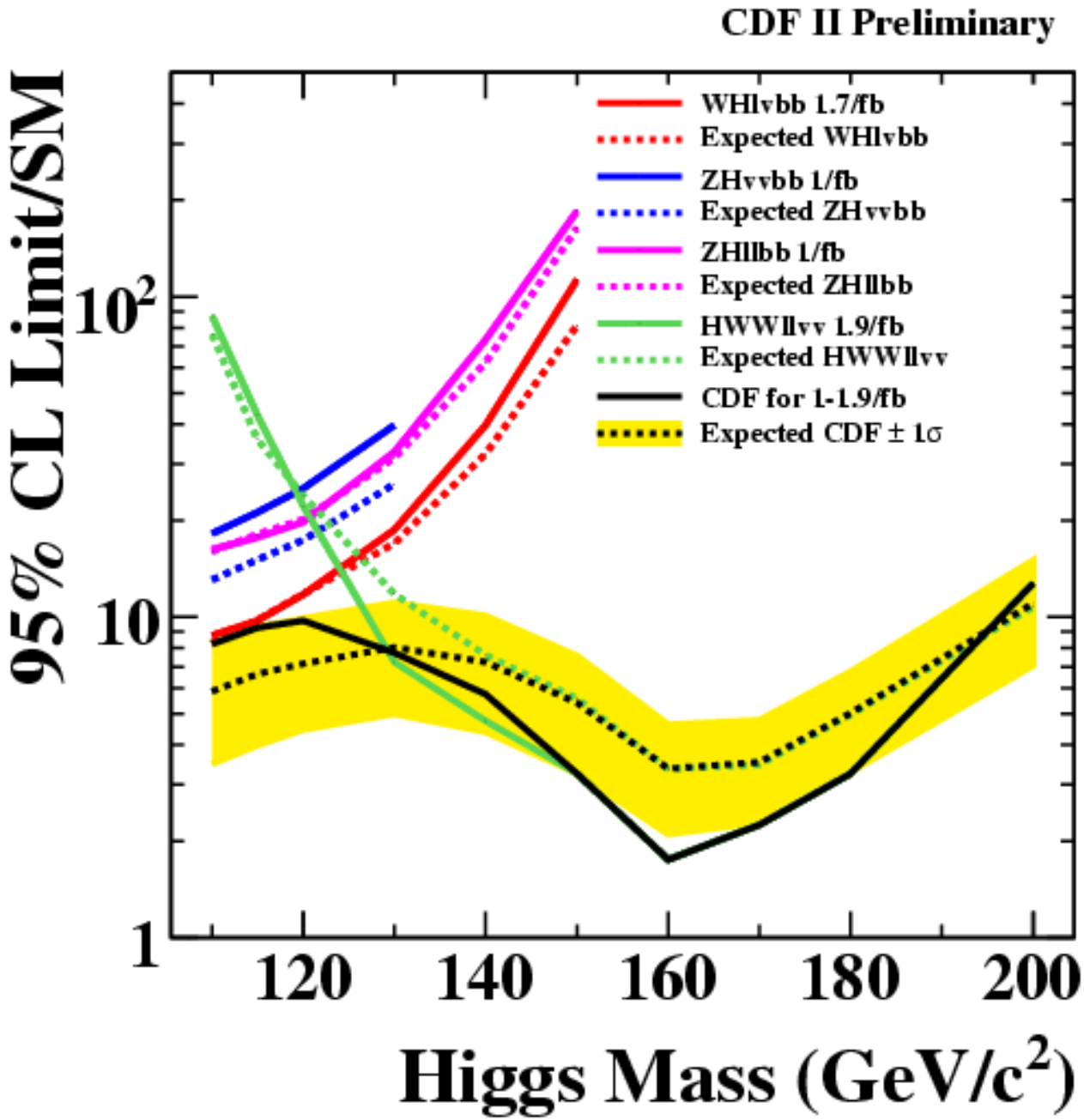
These methods can be applied to other model dependent searches

- E.g. ZZ→ℓℓνν

CDF Combined Higgs Boson Limits (before new Lepton-Photon Results)



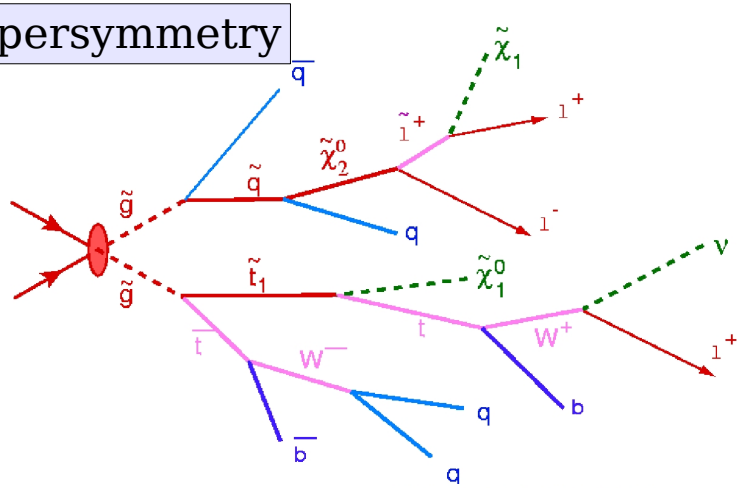
CDF Combined Higgs Boson Limits (after new Lepton-Photon Results)



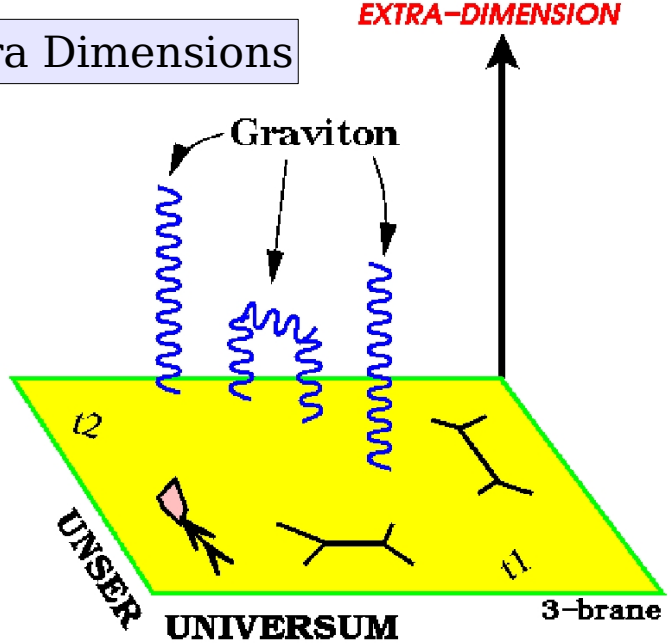
new $ZH \rightarrow \nu\nu b\bar{b}$ result not yet included in this combination

Beyond the Standard Model...

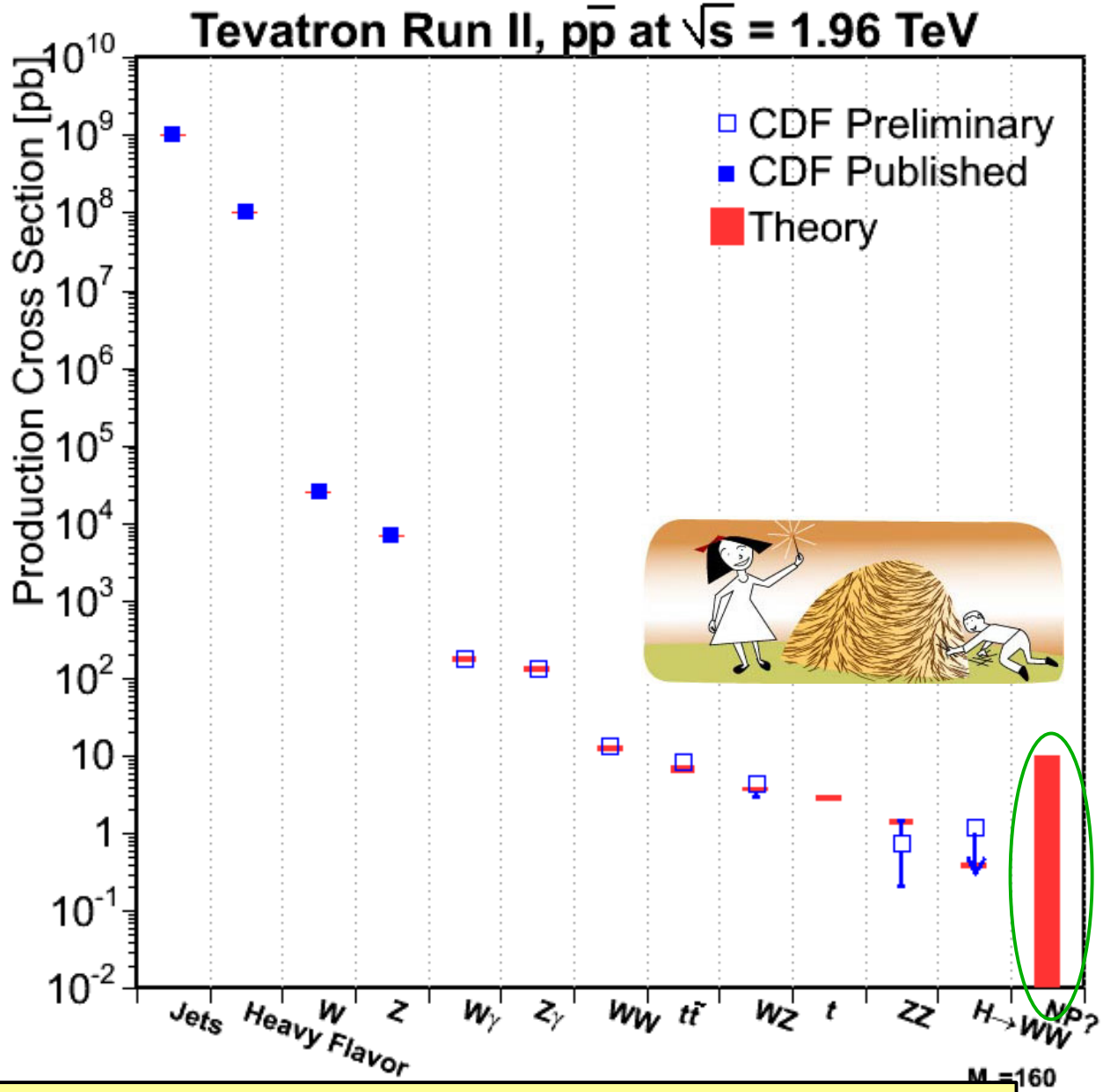
Supersymmetry



Extra Dimensions



Something else , ..., ?



More experimental input is needed to show us the way!

1.0 fb^{-1}

MSSM Higgs in 3 b-quark Channel

- MSSM neutral scalars h/H/A
- "Down"-type fermion couplings enhanced by $\tan^2\beta$
- Radiated from b's, decay to b or τ

This search: $\phi + b \rightarrow b\bar{b} + b$

- Trigger: 2 jets $E_T > 15$ GeV, matched to displaced tracks, 3rd jet $E_T > 10$ GeV
- Offline: 3 b-tagged jets, $E_T > 20$ GeV

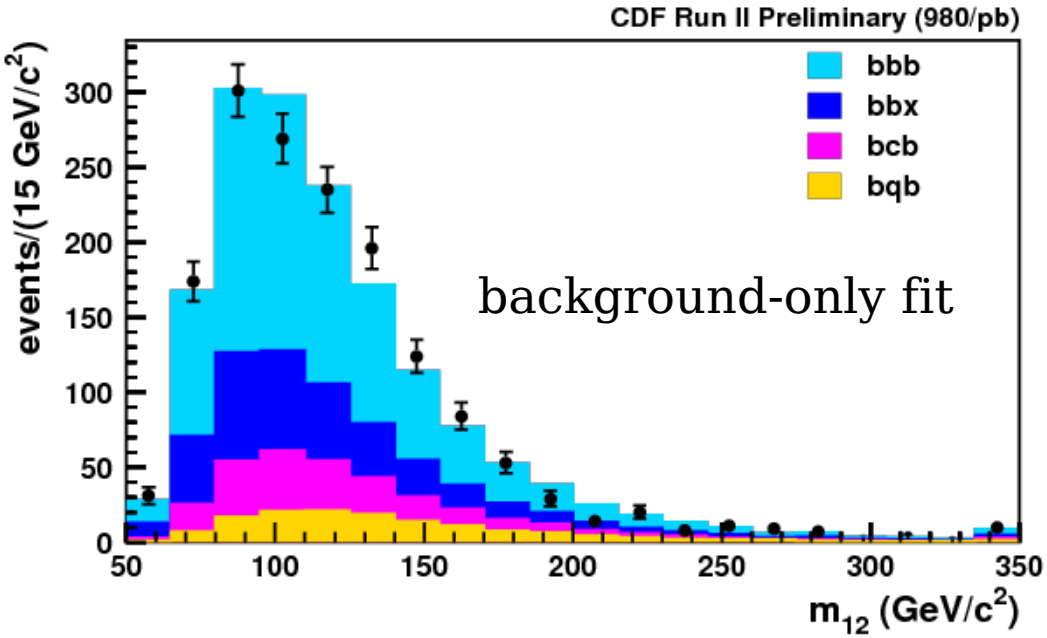
Backgrounds: heavy flavor multijets

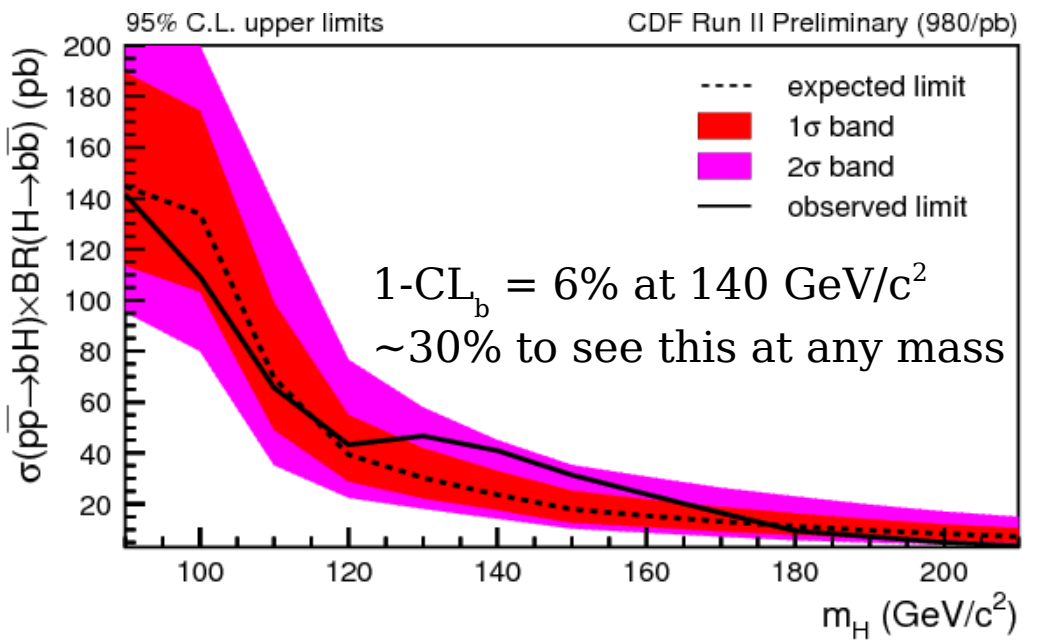
- Mostly bbb, bbq, bcb, bqb
- Modeled using double tagged events
  - Small corrections for each process determined from simulation (Pythia)

Signal: Pythia $gb \rightarrow Hb$, 90-210 GeV/c^2

Fit data to 4 component bkg + signal in

- m_{12} = mass of two leading E_T jets
- Also use b-tag properties in discrimination





Exclude large $\tan\beta$ ($\gtrsim 100$) in most benchmark models

2.0 fb^{-1}

Search for Anomalous Production of $\tau\gamma\gamma$

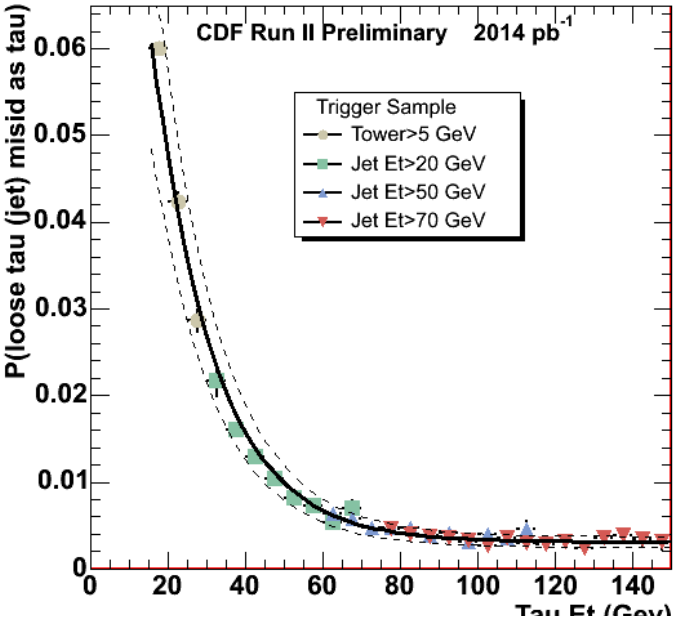
Signature-based search for anomalous $\tau\gamma\gamma$ production
Search broadly, w/o reference to specific models

Selection:

Two central ($|\eta|<1$) photons, $E_T > 13$ GeV

One central 1-prong or 3-prong τ, $E_T > 15$ GeV

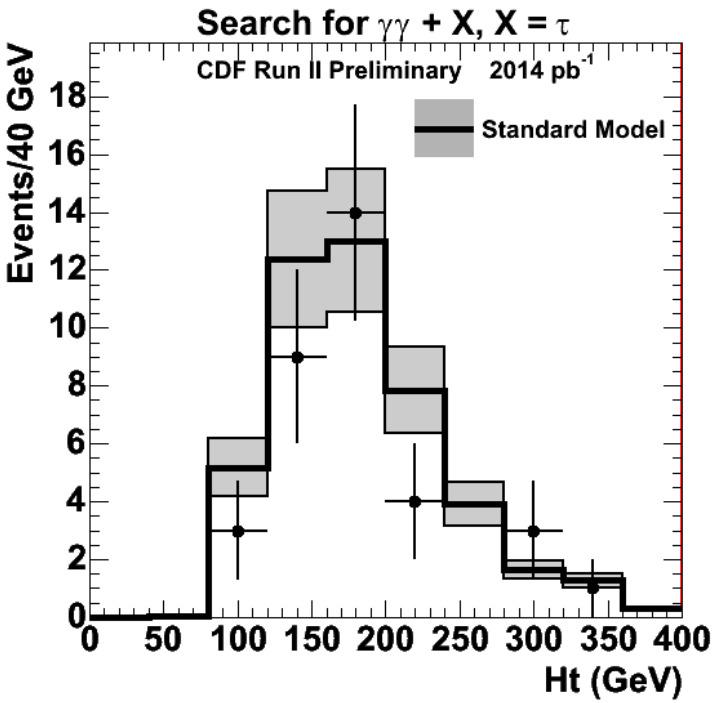
Measure jet$\rightarrow \tau$ fake probability

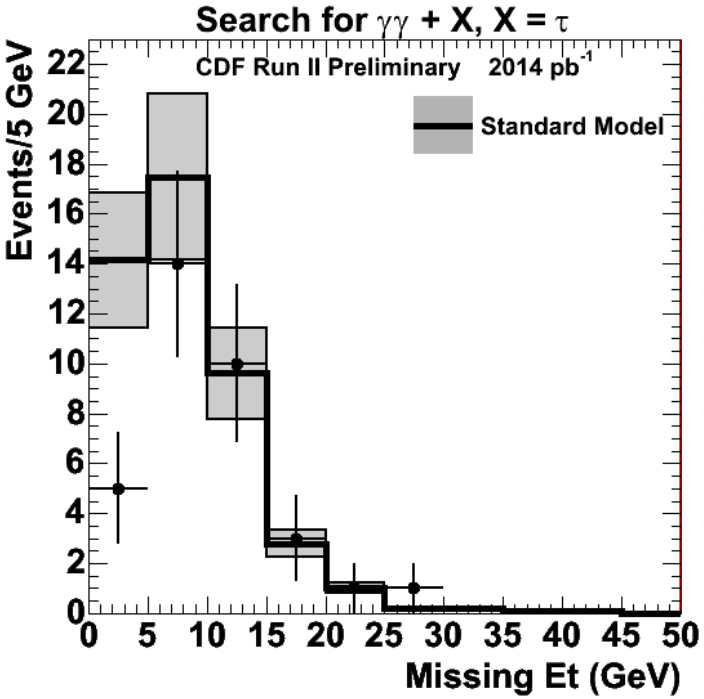


SM expectations:

fake τ's: 44 +/- 10
ewk: 2 +/- 1

Total: 46 +/- 10
Observe 34





1 fb^{-1}

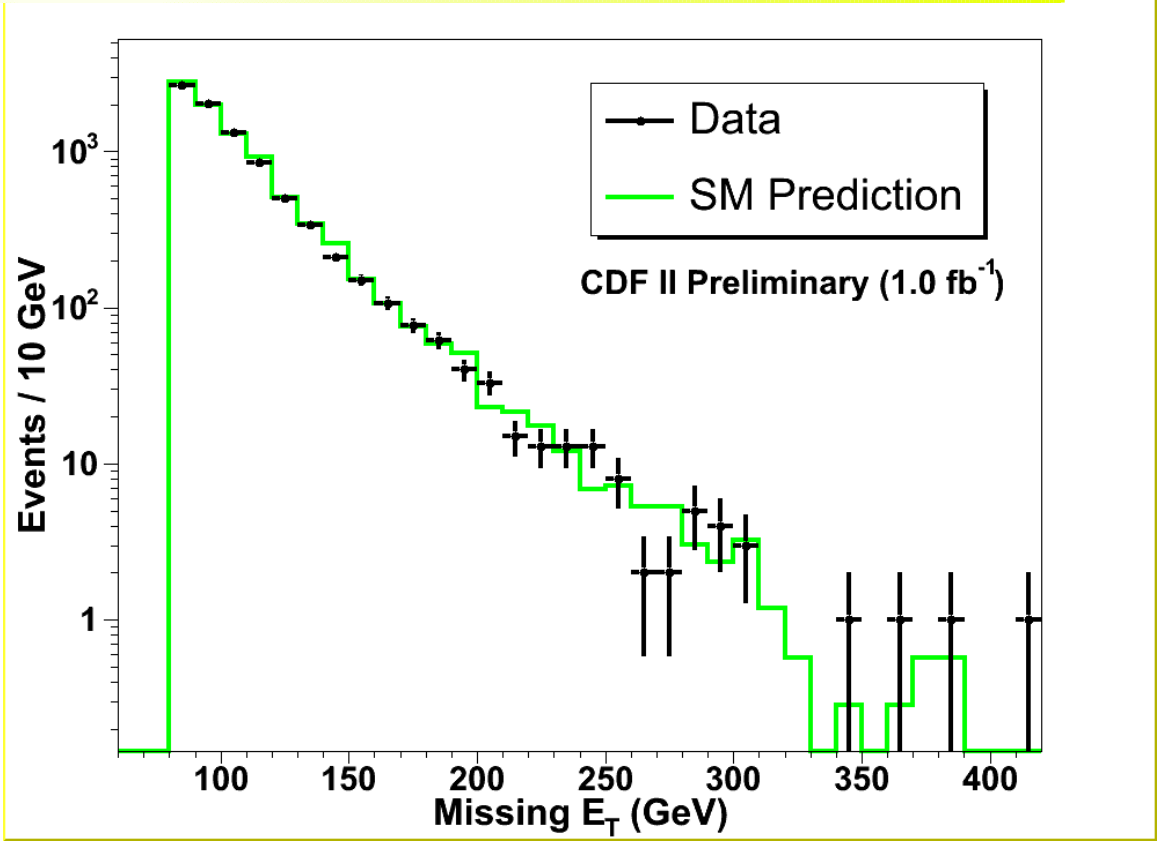
Monojet Searches in Jet+$\not{E}_T$

The high E_T jet + missing E_T channel is sensitive to new physics

Perform model-independent search based on data-driven background estimates

Generic search covering very wide kinematic range:

Jet E_T > 80 GeV, $\not{E}_T$ > 80 GeV



Direct measurement of Γ_Z(inv):

$$\Gamma_Z(\text{inv}) = \frac{\sigma(Z + 1\text{-jet}) \times Br(Z\to\nu\nu)}{\sigma(Z + 1\text{-jet}) \times Br(Z\to ll)} \times \Gamma_Z(ll)$$

LEP

Our measurement:

Γ_Z(inv) = 466 ± 42 MeV (CDF II)

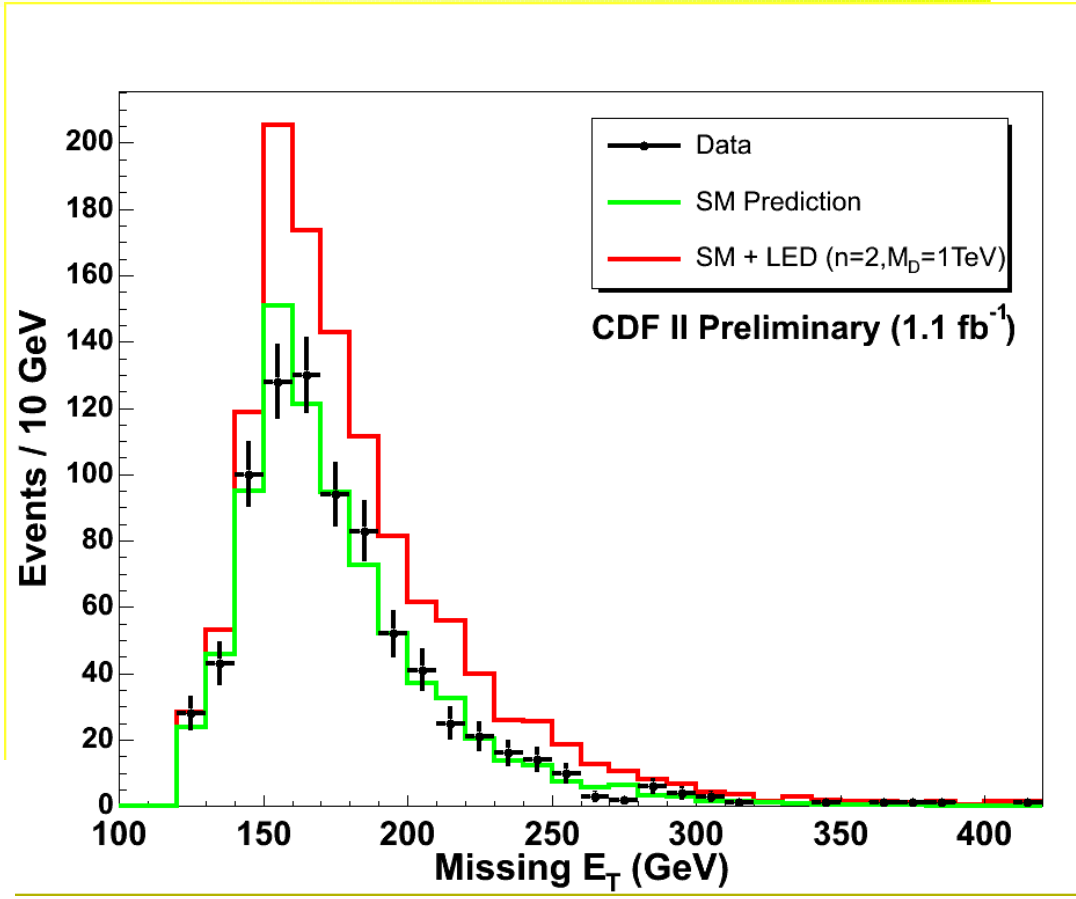
Direct measurements from LEP:

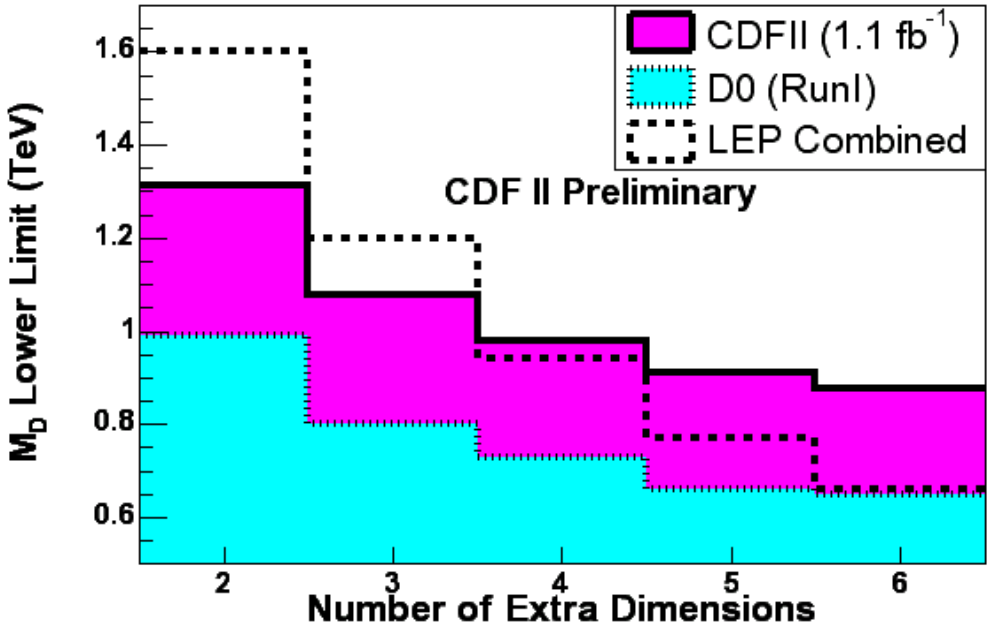
Γ_Z(inv) = 493 ± 17 MeV (L3)
539 ± 31 MeV (OPAL)
450 ± 48 MeV (ALEPH)

1 fb^{-1}

Monojet Searches in Jet+$\not{E}_T$

- One potential signal is direct graviton production in Large Extra Dimensions (LED) models
-
- Optimized search:
-
- Jet E_T > 150 GeV
- $\not{E}_T$ > 120 GeV





Total Predicted = 808 ± 62

Data Observed = 809

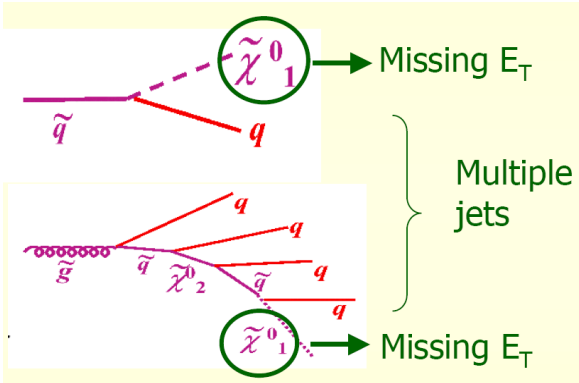
World's best lower limits on M_D for n > 3!

1.4 fb^{-1}

Search for Squark/Gluino Production

Squark/gluino search performed within mSUGRA framework

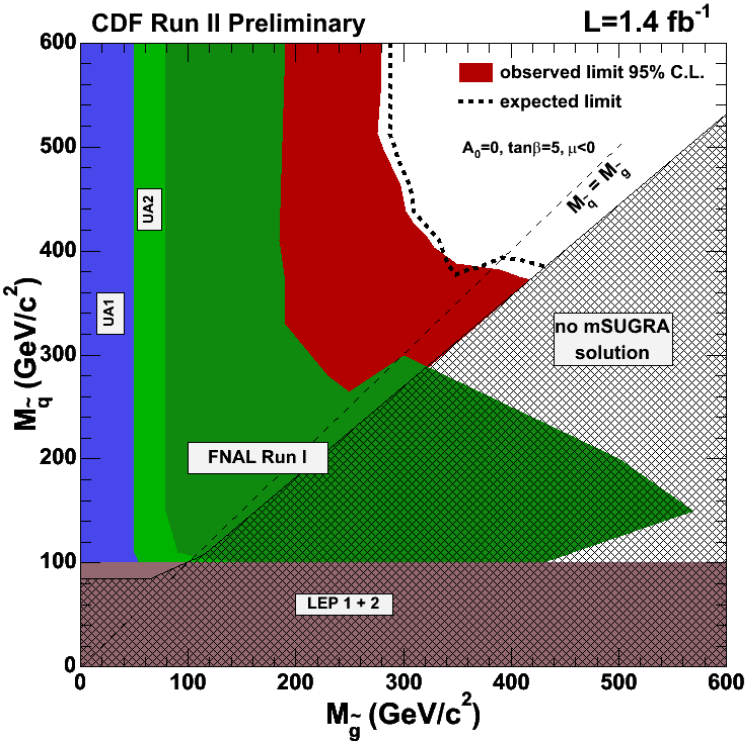
Signature: multjets + $\not{E}_T$



Five different sets of cuts optimized

events in 1.4 fb^{-1}	DATA	SM Expected
≥ 4 jets	29	27 ± 2 ± 9
≥ 3 jets (type A)	616	607 ± 16 ± 146
≥ 3 jets (type B)	166	154 ± 7 ± 44
≥ 3 jets (type C)	22	25 ± 2 ± 8
≥ 2 jets	13	11 ± 2 ± 3

No evidence of SUSY → set limits

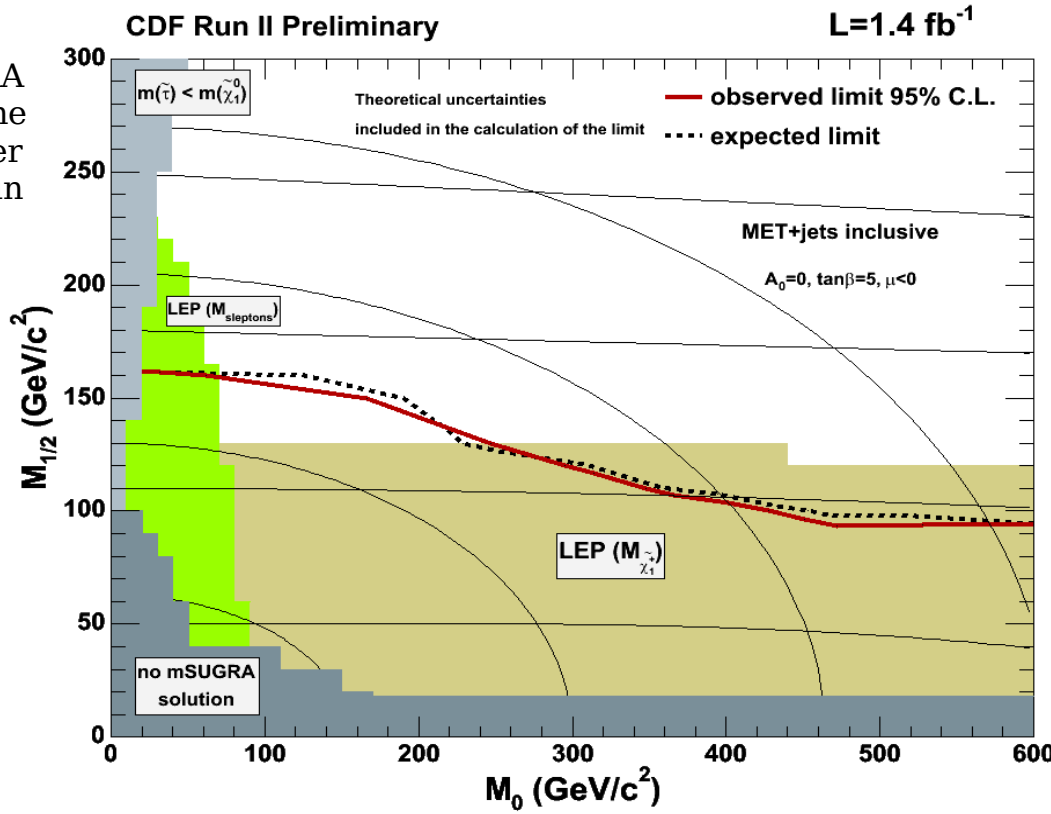


M_g < 380 GeV/c^2 excluded when $M_g \sim M_q$

M_g < 280 GeV/c^2 excluded in any case

Limit in mSUGRA parameters at the GUT scale: better limit w.r.t. LEP in region:

$75<M_0<250$ and $130<M_{1/2}<165$ GeV/c^2



Conclusions

- 25 new results presenting in this talk spanning a diverse set of physics topics
- Most use the full luminosity currently available for analysis
- Even more being presented in talks at Lepton-Photon!
- Stay tuned for more hard-hitting action!

CDF keeps attacking the Standard Model vigorously!

See you in Daegu!

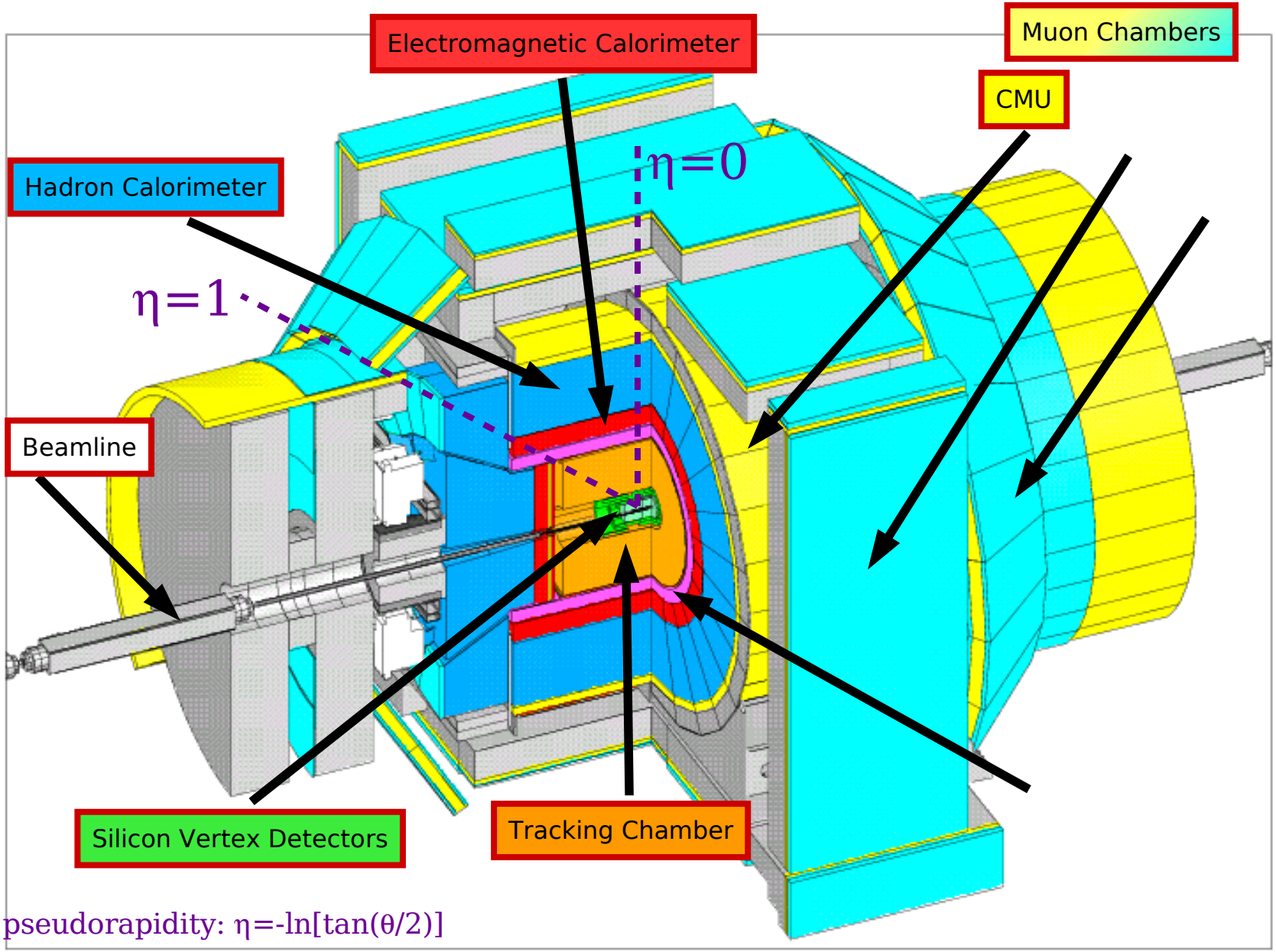
Lepton-Photon 2007

XXIII International Symposium on Lepton-Photon Interactions at High Energy

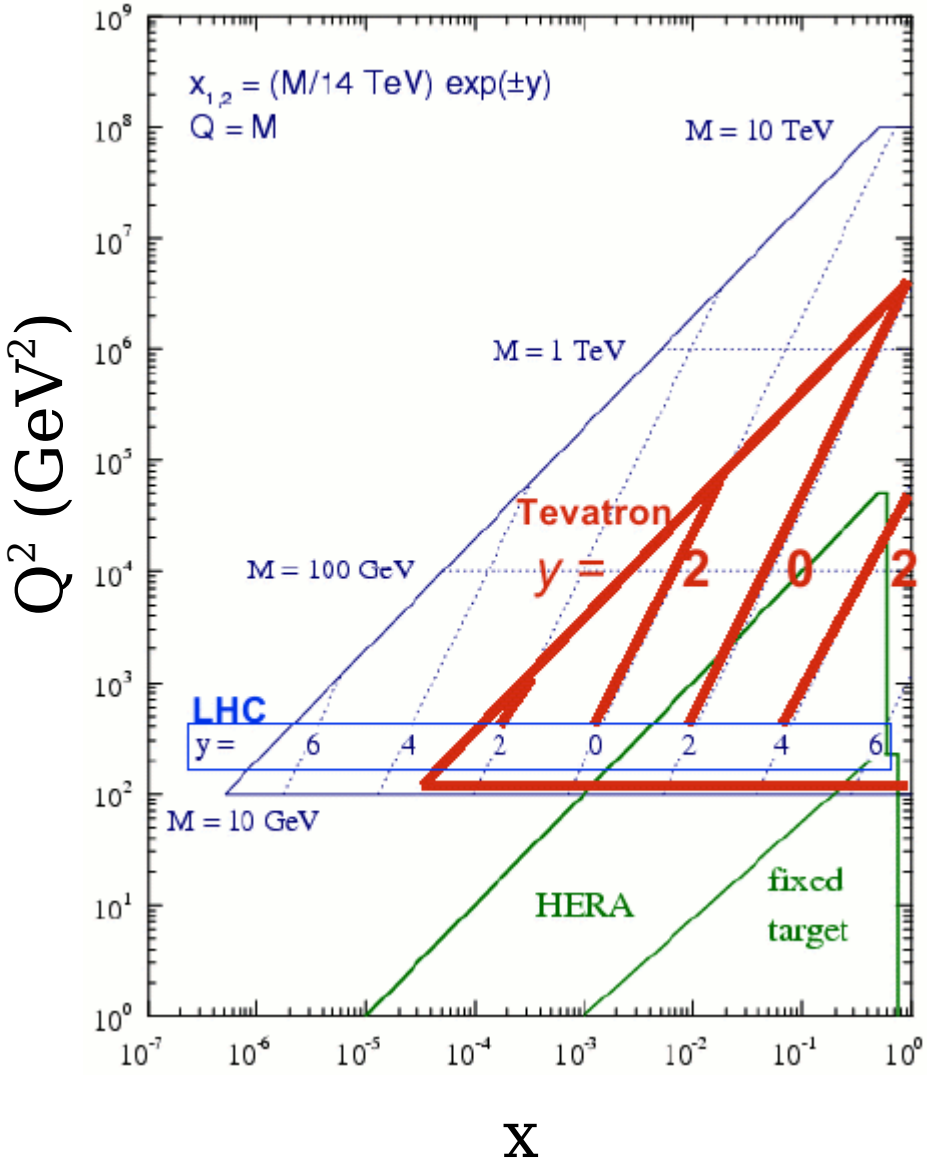
Kyungpook National University, Daugu, Korea
August 13-18, 2007

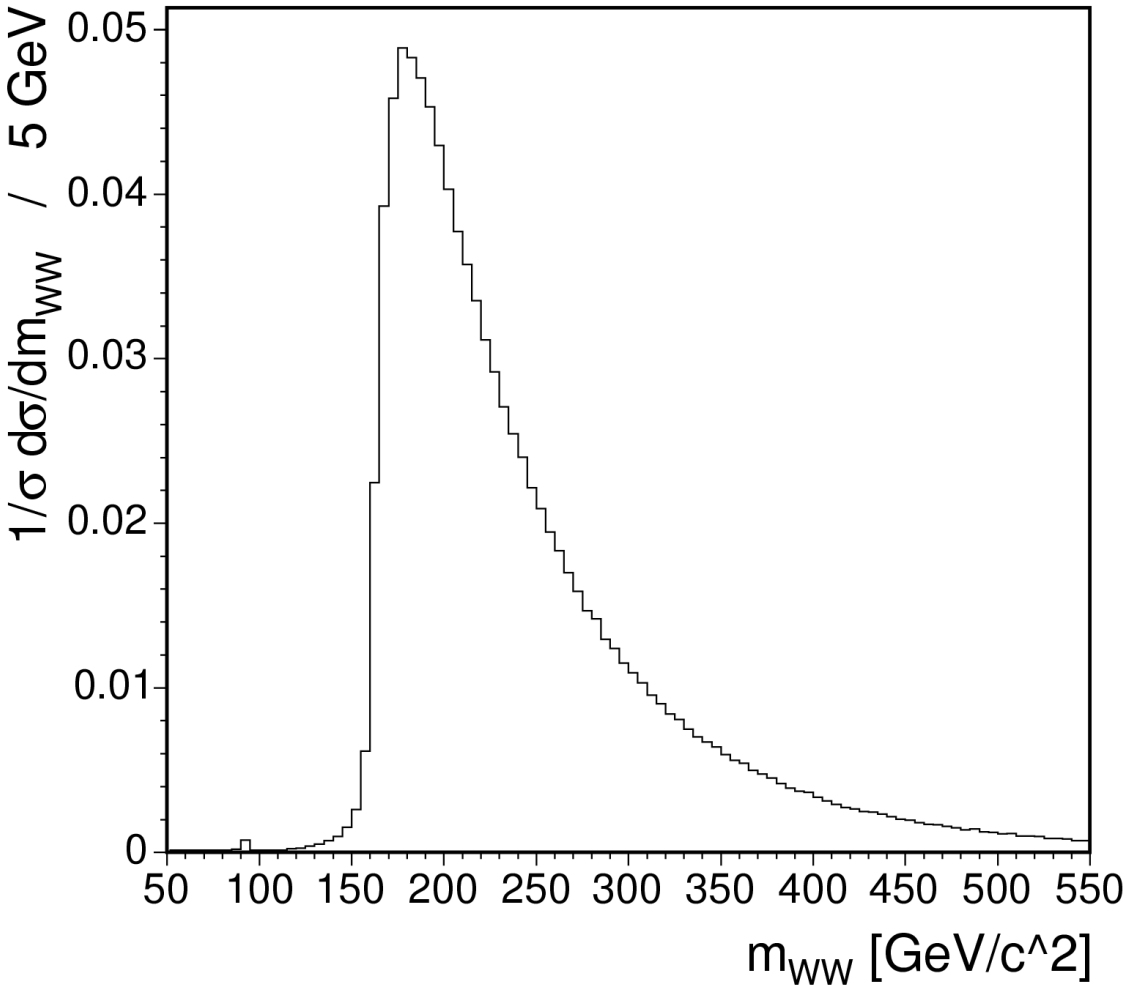
Extras

The CDF II Detector



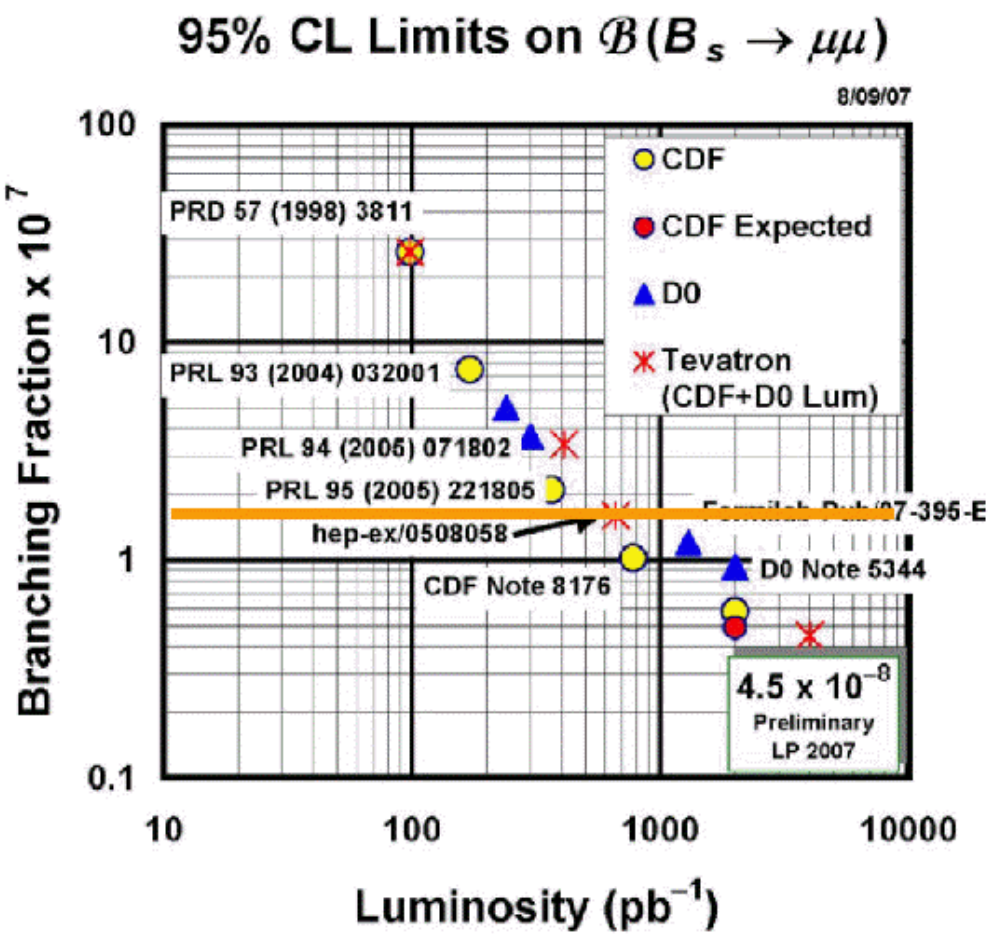
PDF and Scale

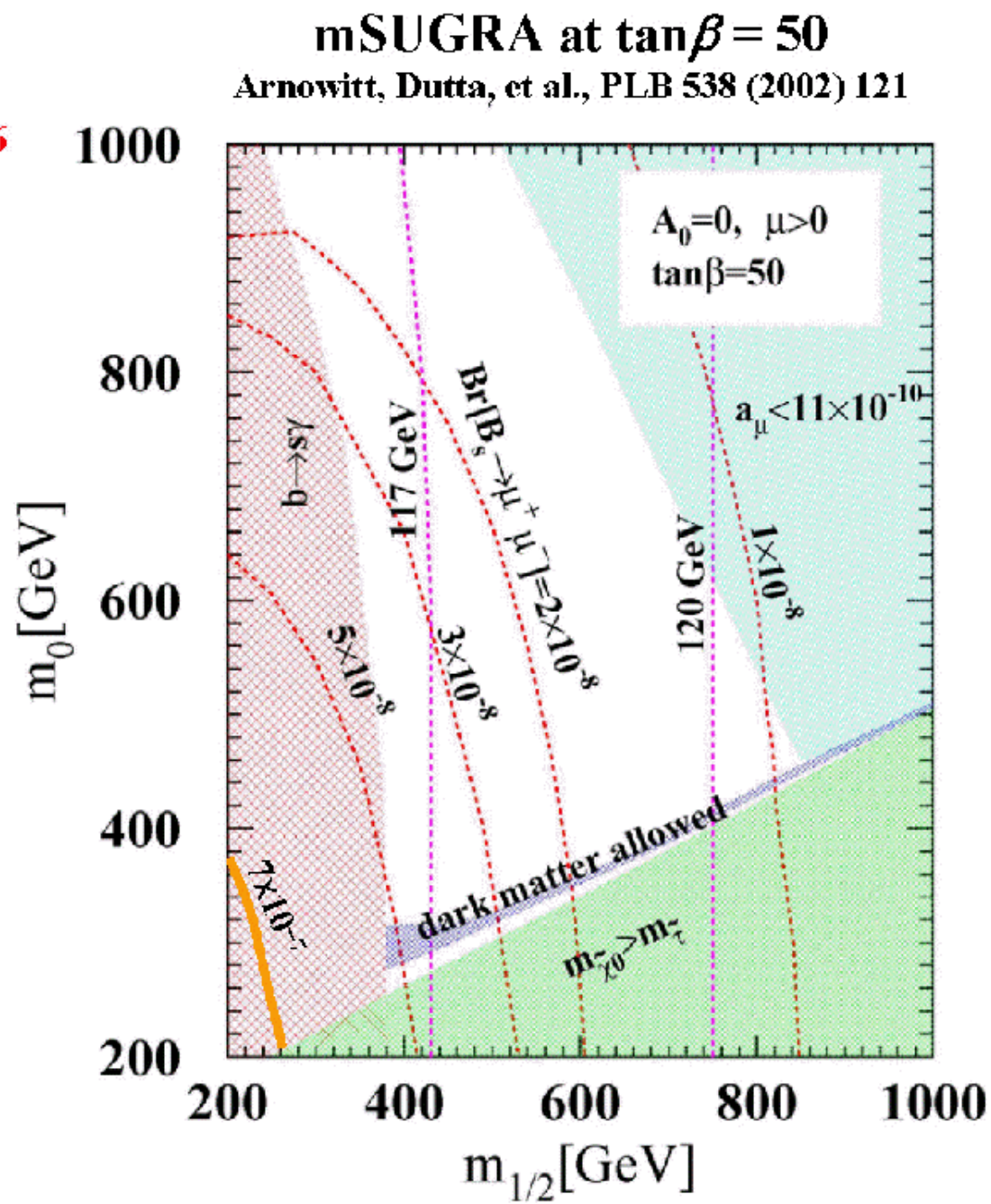




$\mathcal{B}(B_s \to \mu\mu)$ and Cosmological Connection

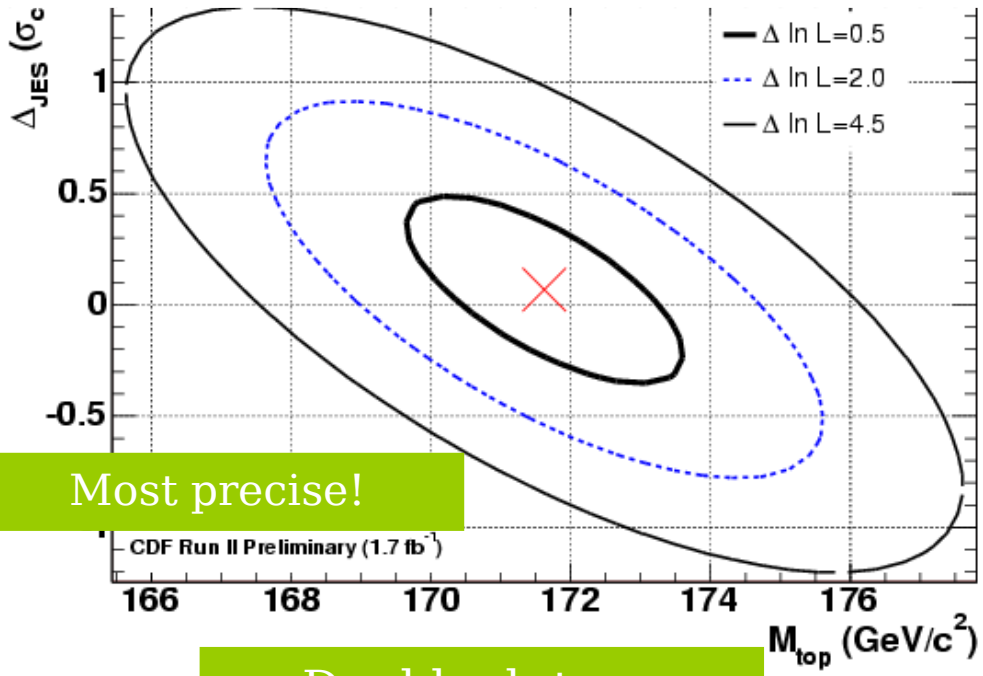
$$\mathcal{B}_{SM} = 3.4 \times 10^{-9} \quad \mathcal{B}_{SUSY} \propto (\tan\beta)^6$$





New for Lepton-Photon: Most precise l+jets channel

M_{top}=171.6 ± 2.4 (stat+syst) GeV/c²

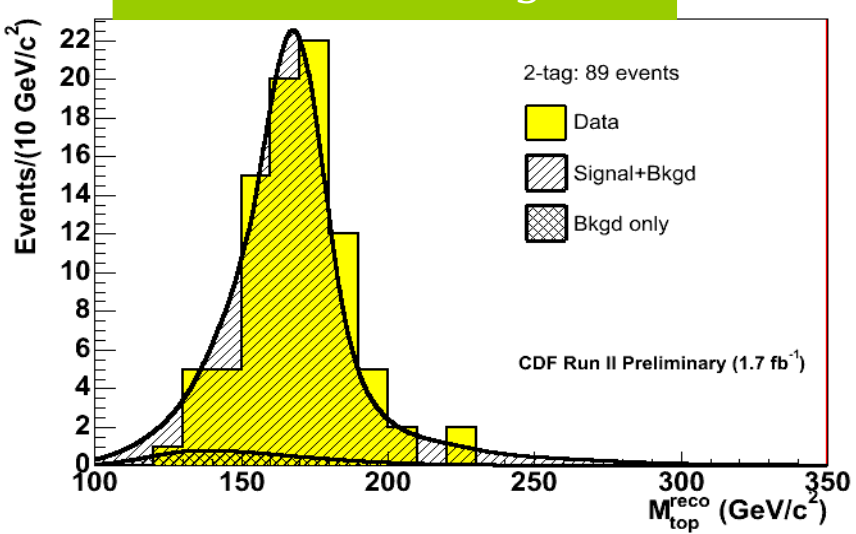


Most precise!

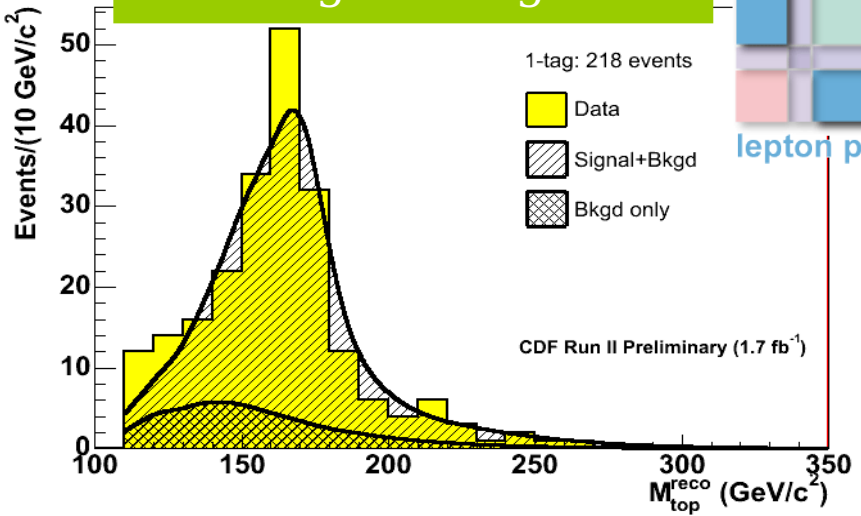
Systematic table

ISR	0.4
FSR	0.2
Generator	0.3
Residual JES	0.6
Background JES	0.4
PDFs	0.2
QCD modeling	0.1
Background composition	0.2
Background shape	0.2
B-JES	0.6
MC statistics	0.1
TOTAL	**1.1**

Double b-tag

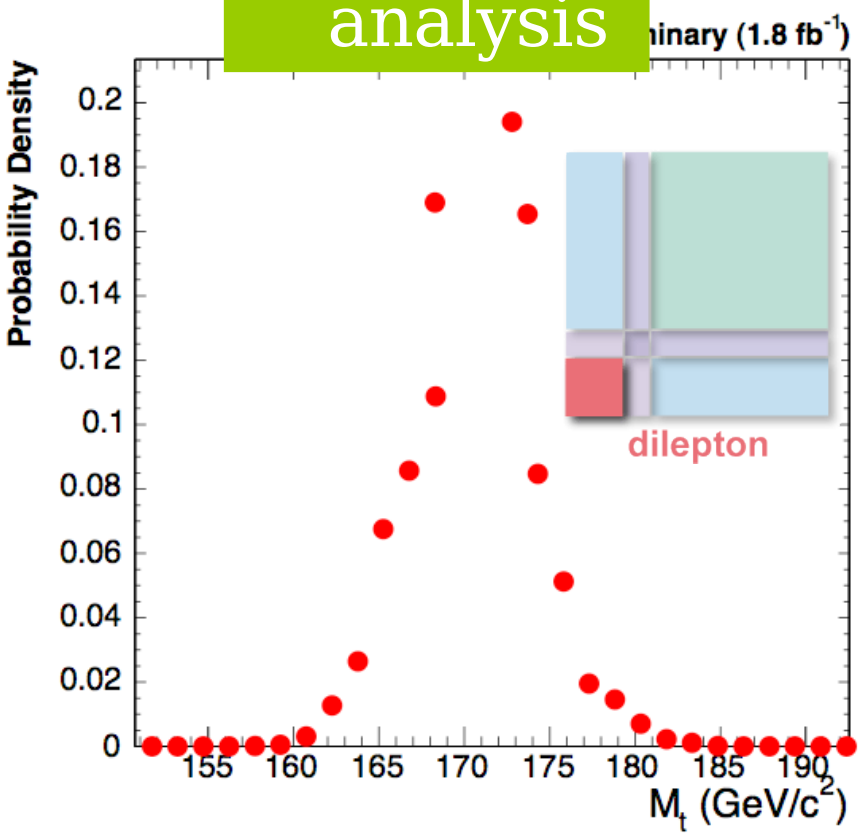


Single b-tag



New for Lepton-Photon:
Most precise dilepton channel

ME analysis



M_t=170.4 ± 3.1(stat) ± 3.0(sys)GeV/c²

Systematic table

Source	Size (GeV/c^2)
Jet Energy Scale	2.6
B-jet energy scale	0.2
Generator	0.6
Response uncertainty	0.7
Sample composition uncertainty	0.3
Tagged sample composition uncertainty	0.2
Background statistics	0.7
Background modeling	0.3
ISR modeling	0.3
FSR modeling	0.3
PDFs	0.5
α_s	0.2
Lepton Energy Scale	0.1
Total	3.0

all-hadronic from winter 2007:

M_t=170.4 ± 3.7(stat+JES) ± 2.1(sys)GeV/c²

CDF Single Top: What Changed ?

Likelihood

- improved treatment of kinematic ambiguities
- Bug fix in matrix element
- More MC statistic allows refined training

Overall expected sensitivity gain:

(as measured on 955 pb^{-1} analysis) :35%

Matrix Element

- Separate treatment of single and double tag events
- More refined transfer functions
- Overall expected sensitivity gain:

(as measured on 955 pb^{-1} analysis) :~10%

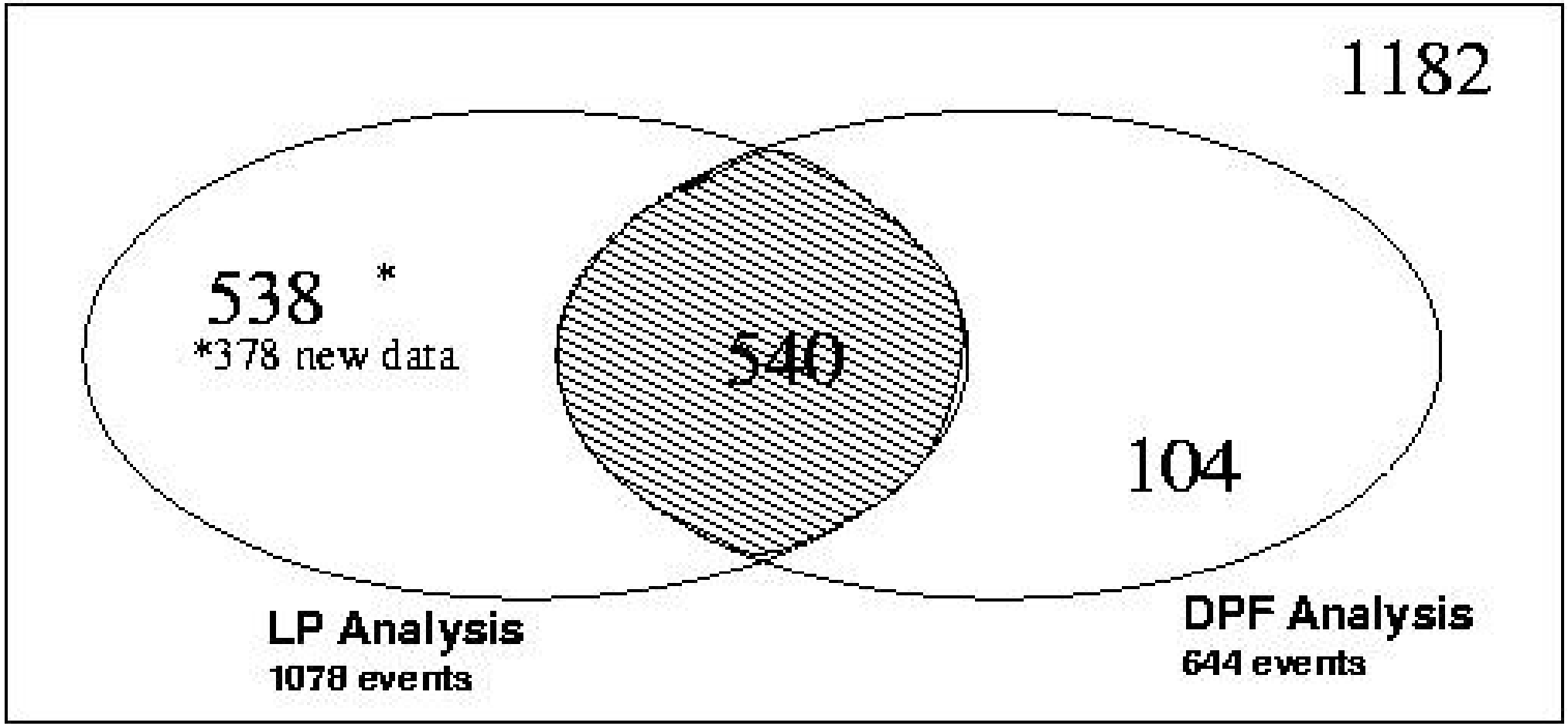
Common Improvements

- new ALPGEN Monte Carlo
- W + Heavy Flavor normalization from W + 1 jet eve nts
- Define event selection on **hadron leveljets:**
  - -CDF Top group wide change
  - -More meaningful to theorists
  - -Better understood (MET resolution, nonW model..)

Causes event migrations:

- LF loses 1 gains 7
- ME loses 5 gains 4 for highest discriminant region

Event Yield of DPF and LP Analyses



W + Heavy Flavor Estimate

- Method inherited from CDF Run I (G. Unal et. al.)
- Measure fraction of W+jets events with heavy flavor (b,c) in Monte Carlo
- Normalize fractions to W+jets events found in data
- New improvement: get normalization from W + 1 jet bin (instead of generic dijet sample)

Note: Similar for W+charm background

$$N_{Wbb}^{data} = \left(\frac{N_{Wbb}}{N_{W+jets}}\right)^{MC} \cdot K \cdot N_{W+jets}^{data}$$

Heavy flavor fractions
and b-tagging efficiencies
from LO ALPGEN Monte Carlo

Calibrate ALPGEN heavy flavor
Fractions from W + 1 jet bin

Correct data for non W+jets events

$$N_{W+jets}^{data} = N_{candidates}^{data} - N_{non\,W} - N_{Mi}$$

Large uncertainties from Monte Carlo estimate and heavy flavor calibration (~25-30%)

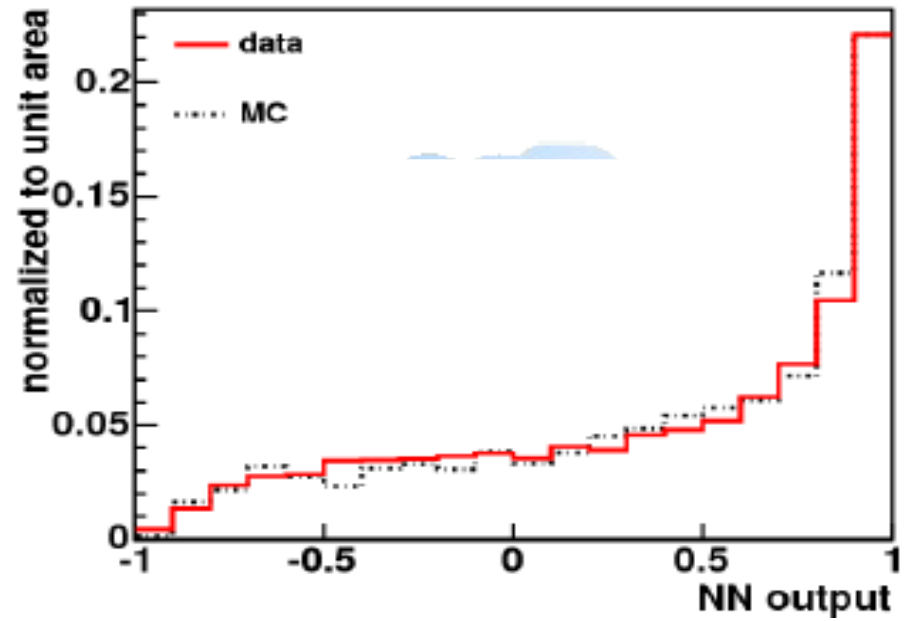
CDF Run II Reference for standard method:
PhysRevD.71,052003

Heavy Flavor Normalization

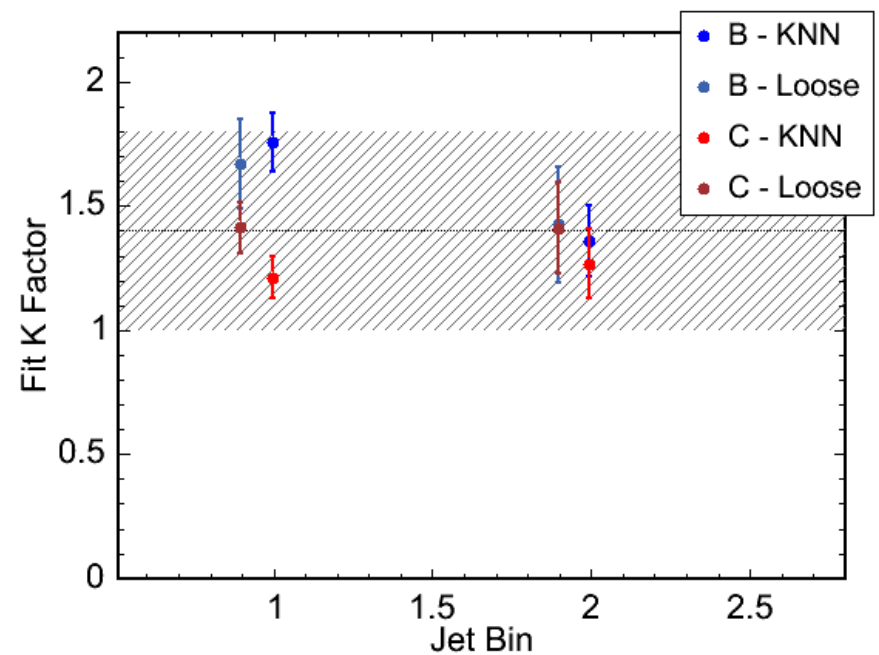
- Improve heavy flavor estimate by calibrating it in W+1 jet side band
- Take advantage of NN based flavor separator
- Compare Loose Secondary Vertex mass and NN flavor separator output:
  - consistent results within errors
- K-factor for heavy flavor:

  1.4 ± 0.4

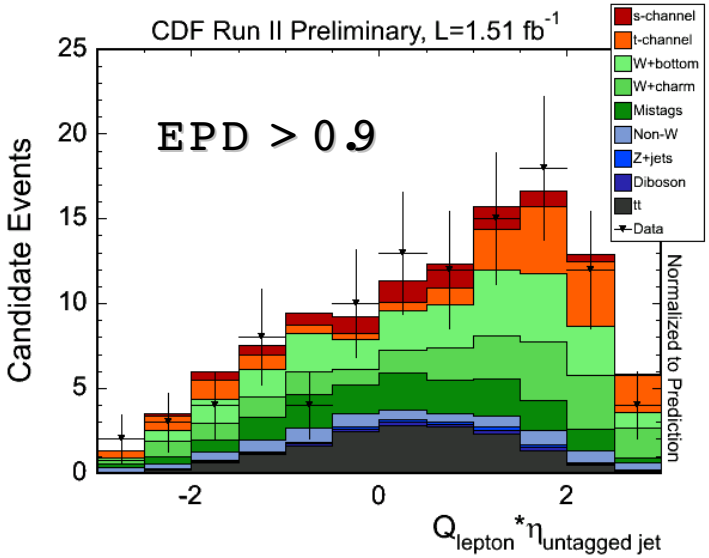
- Applied to predict W + Heavy Flavor content of W + 2 jets bin

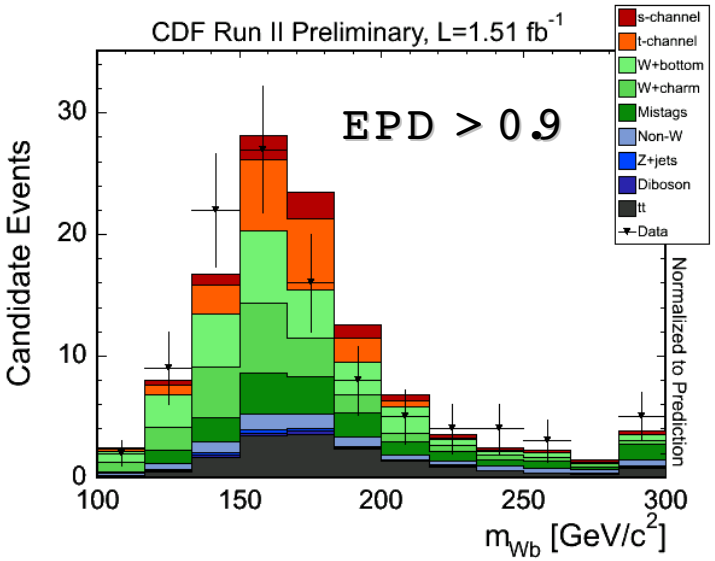


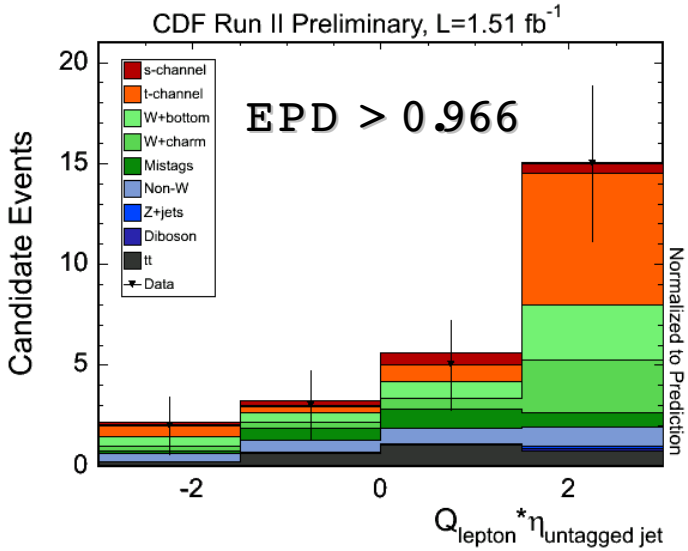
mistags / **charm** ..... **beauty**

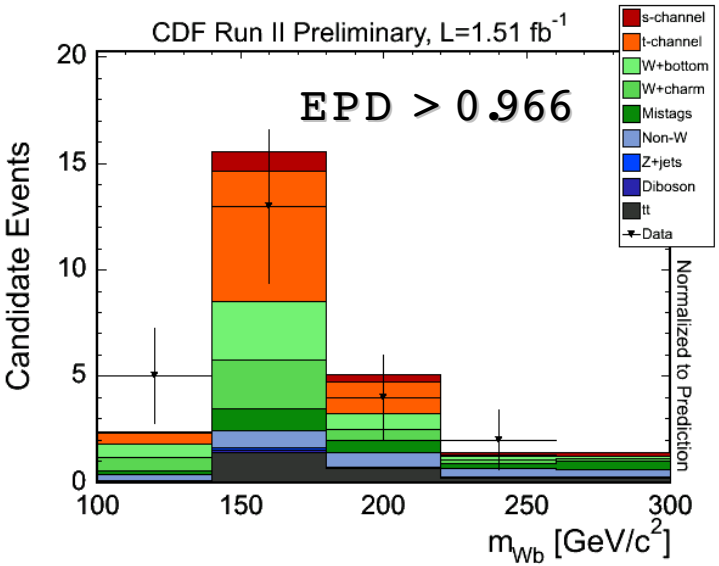


$Q^*\eta$ and $M_{l\nu b}$ cross-checks



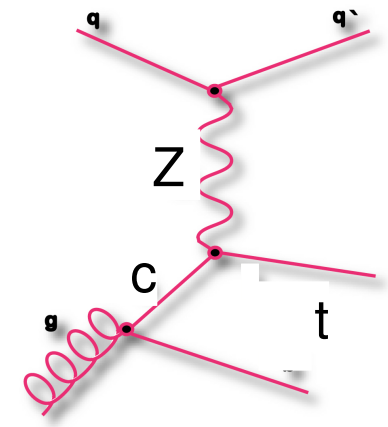




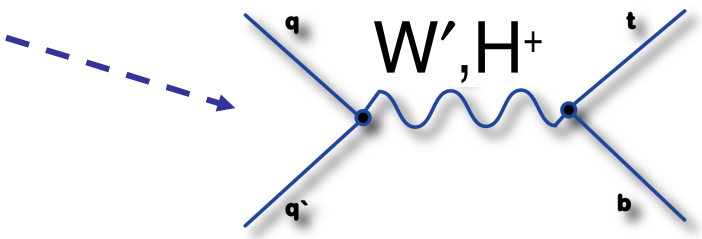


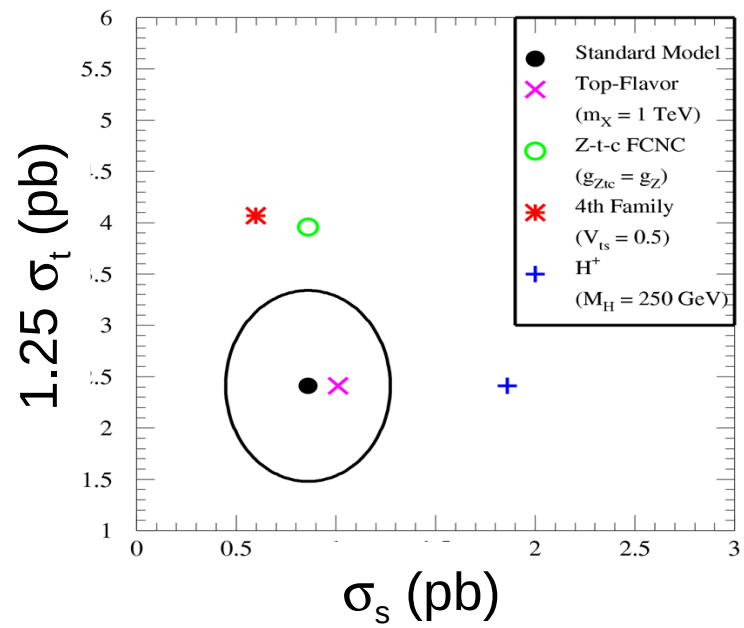
Sensitivity to New Physics and WH

- Single top rate can be altered due to the presence of New Physics:
  - t-channel signature: Flavor changing neutral currents (t-Z / g-c couplings)



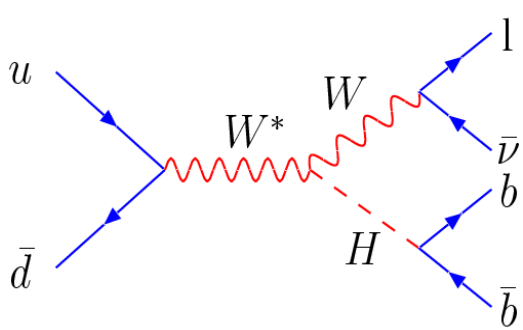
  - s-channel signature: Heavy W' boson, charged Higgs H^+, Kaluza Klein excited W_{KK}





Tait, Yuan PRD63, 014018(2001)

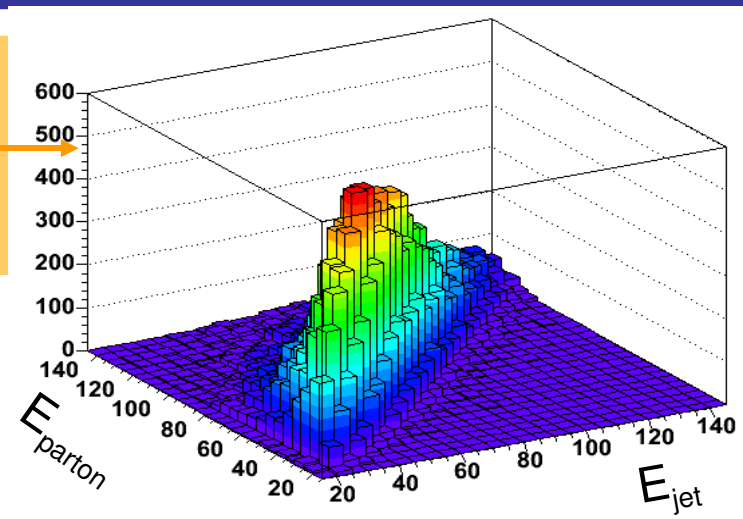
- s-channel single top has the same final state as WH→lνbb
=> benchmark for WH search!



Matrix Element Method

- Pioneered by top quark mass analyses
- Now applied to a search!
- Calculate event probability density for signal and background

W(E$_{jet}$,E$_{part}$) gives the probability of measuring a jet energy E_{jet} when E_{part} was produced



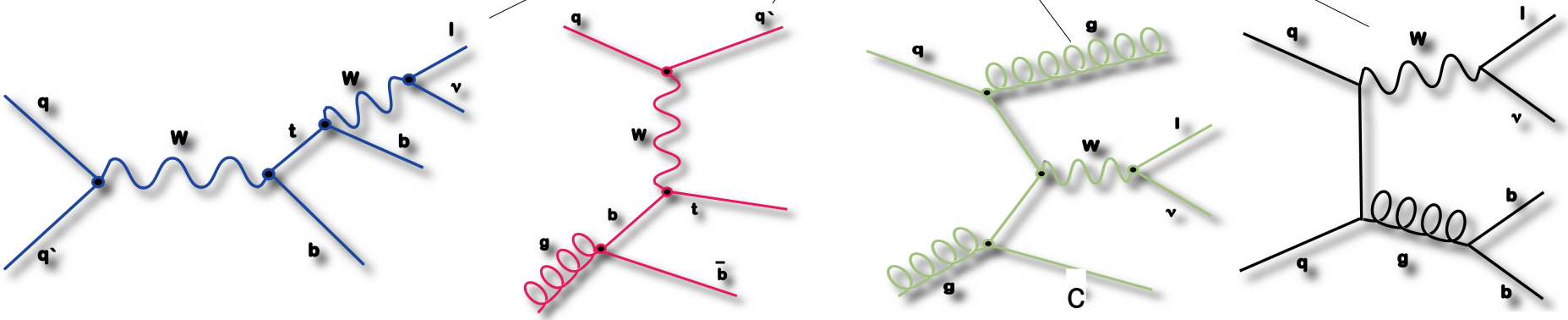
Integration over part of the phase space

Leading Order matrix element (MadEvent)

$$P(p_l^\mu, p_{j1}^\mu, p_{j2}^\mu) = \frac{1}{\sigma}\int d\phi_{j1}\, d\phi_{j2}\, d^3\nu \sum_{comb} |M(p_l^\mu)|^2 \frac{f(q_1)f(q_2)}{|q_1||q_2|}\, \phi_4\, W_{jet}(E_{jet}, E_{part})$$

Inputs only lepton and 2 jets 4-vectors!

Parton distribution functions

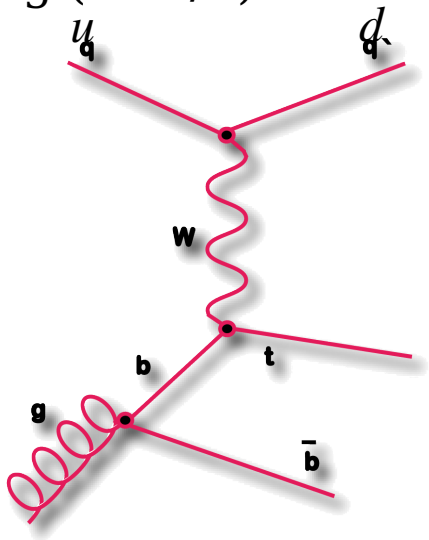


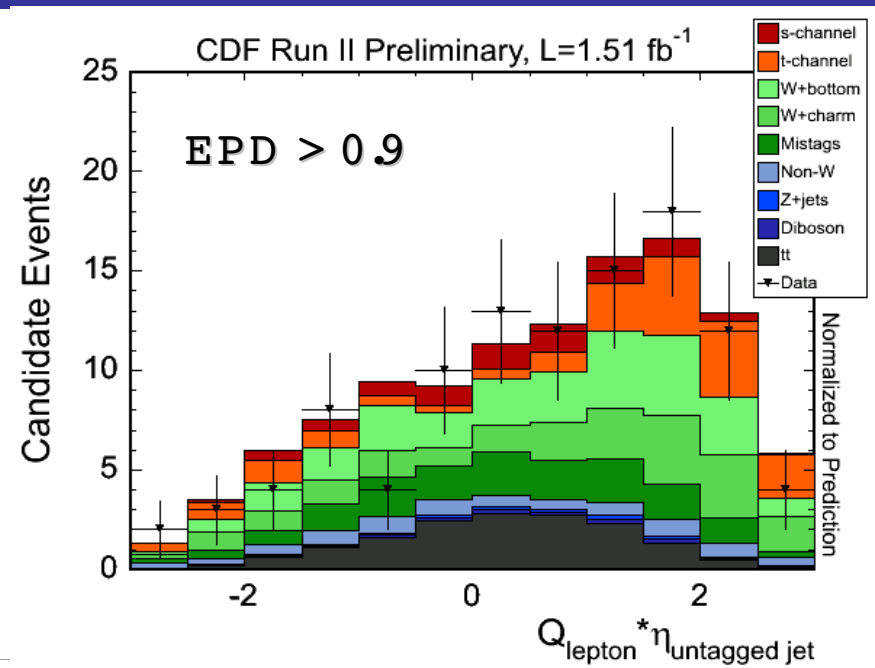
Single Top Candidate Event

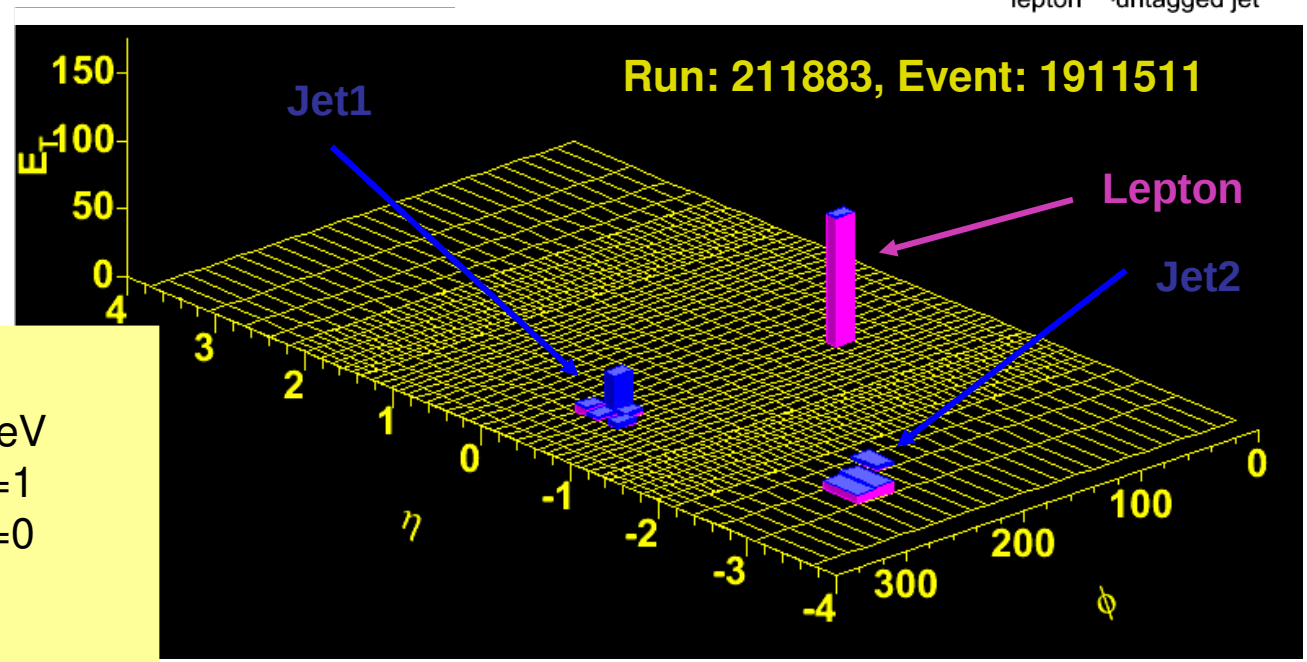
t-channel single top production has a kinematic peculiarity:

- Distinct asymmetry in Q x η distribution:

  lepton charge (Q) x pseudo-rapidity η=-log (tanθ/2) of untagged jet

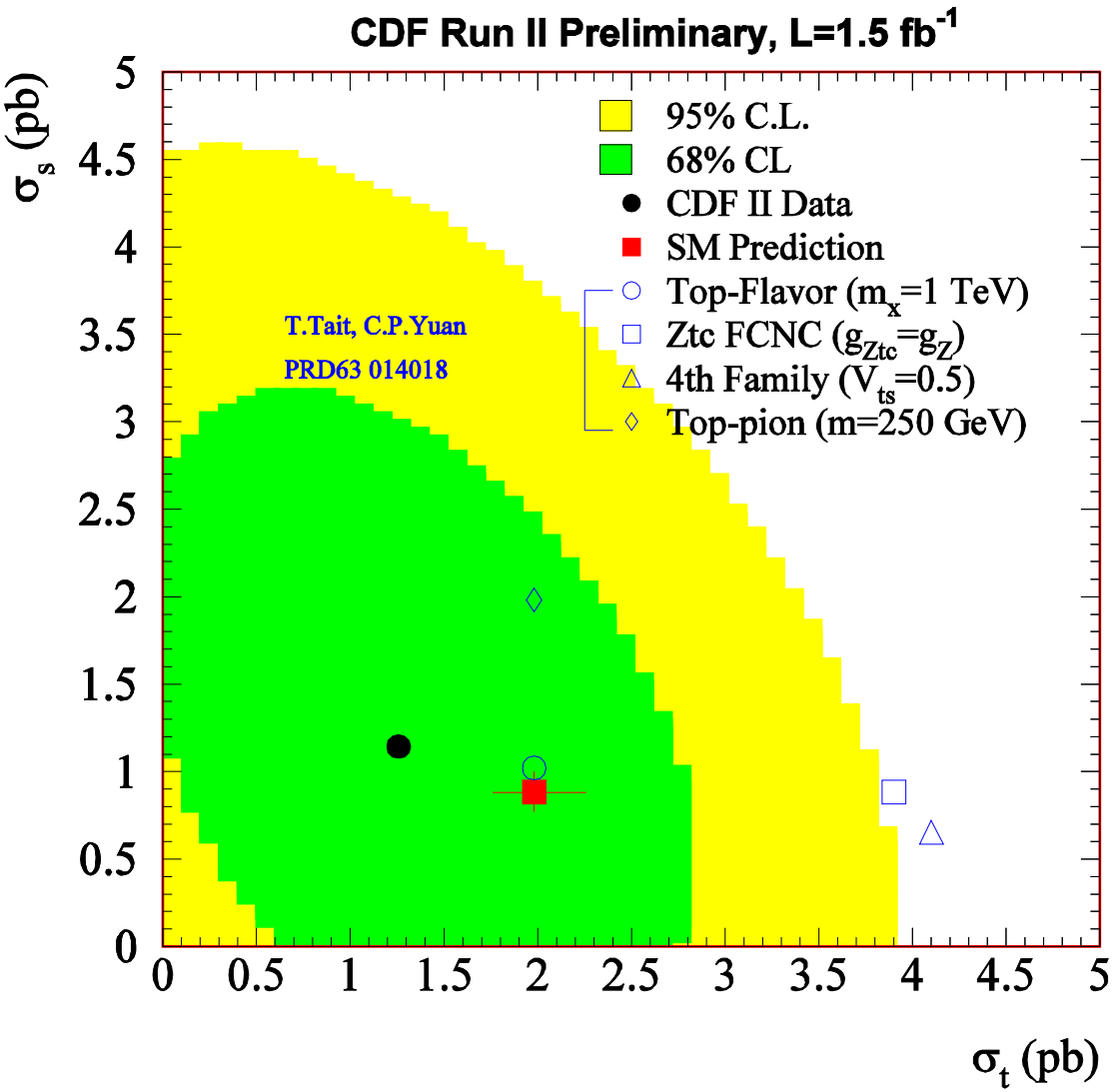






Central Electron Candidate
Charge: -1, Eta=-0.72 MET=41.6 GeV
Jet1: Et=46.7 GeV Eta=-0.6 b-tag=1
Jet2: Et=16.6 GeV Eta=-2.9 b-tag=0
Q x Eta = 2.9 (t-channel signature)
EPD=0.95

The Likelihood 2D Fit



Best-Fit Point:

$$\sigma_s = 1.1^{+1.4}_{-1.1}$$

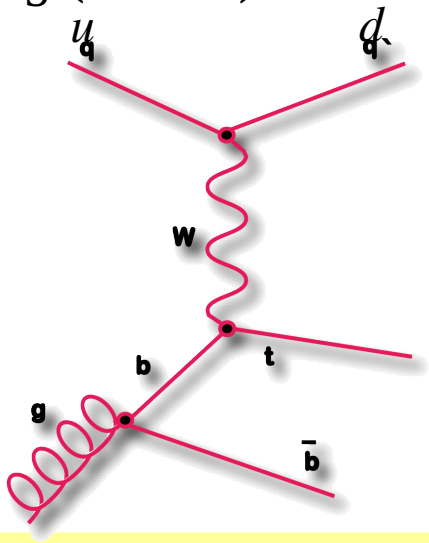
$$\sigma_t = 1.3^{+1.2}_{-1.0}$$

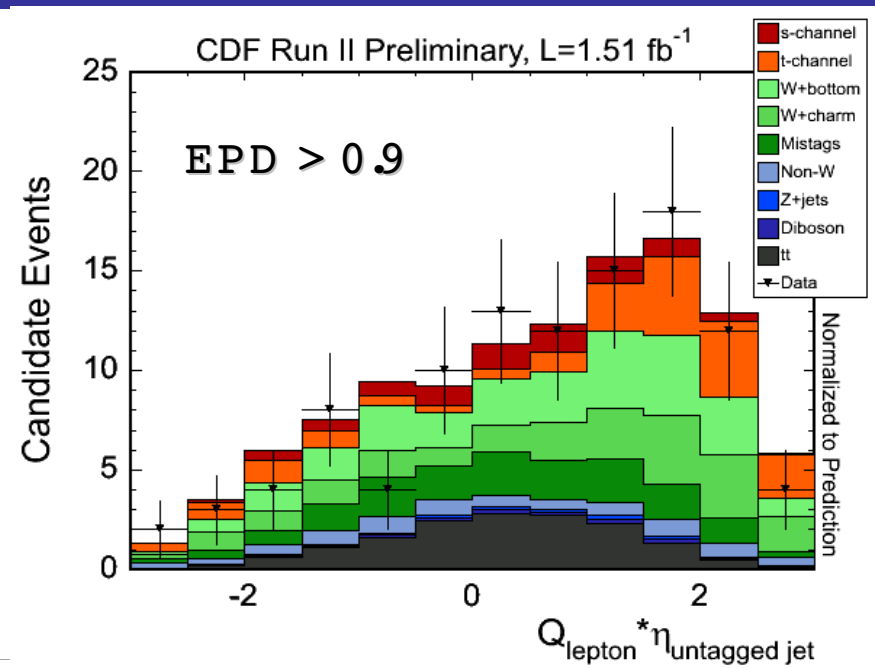
Each nuisance parameter fit for at each test value of the cross section.

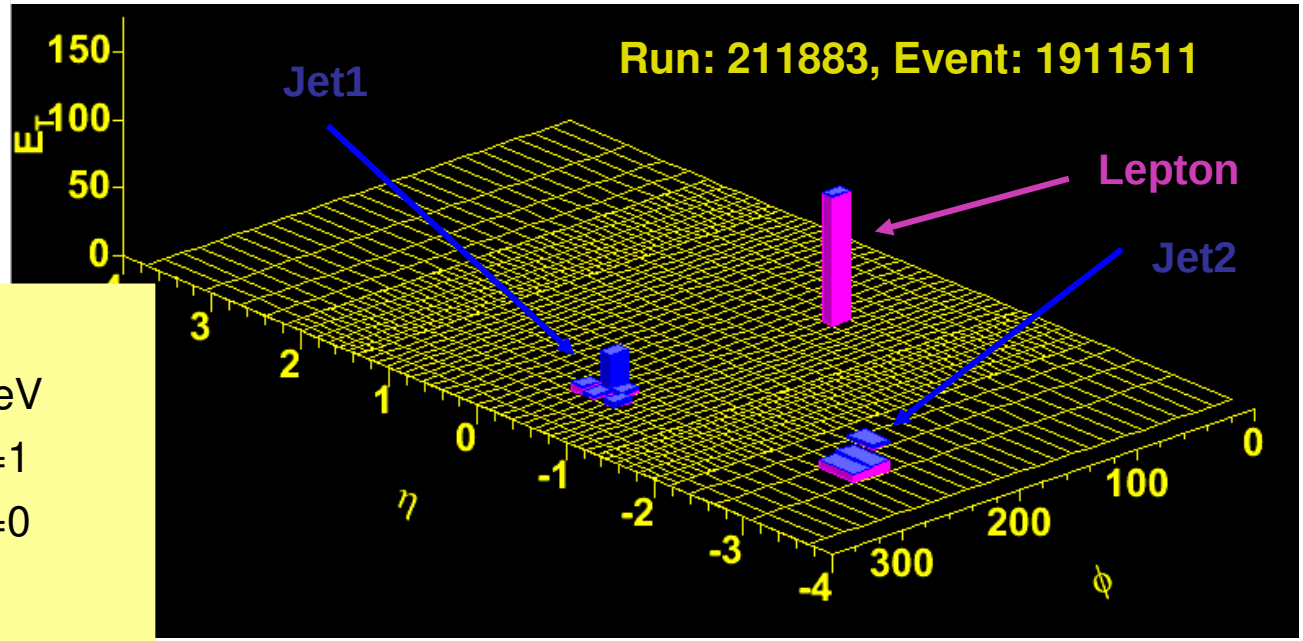
Single Top Candidate Event

t-channel single top production has a kinematic peculiarity:

- Distinct asymmetry in Q x η distribution:
  lepton charge (Q) x pseudo-rapidity
  η=-log (tanθ/2) of untagged jet







Central Electron Candidate

Charge: -1, Eta=-0.72 MET=41.6 GeV

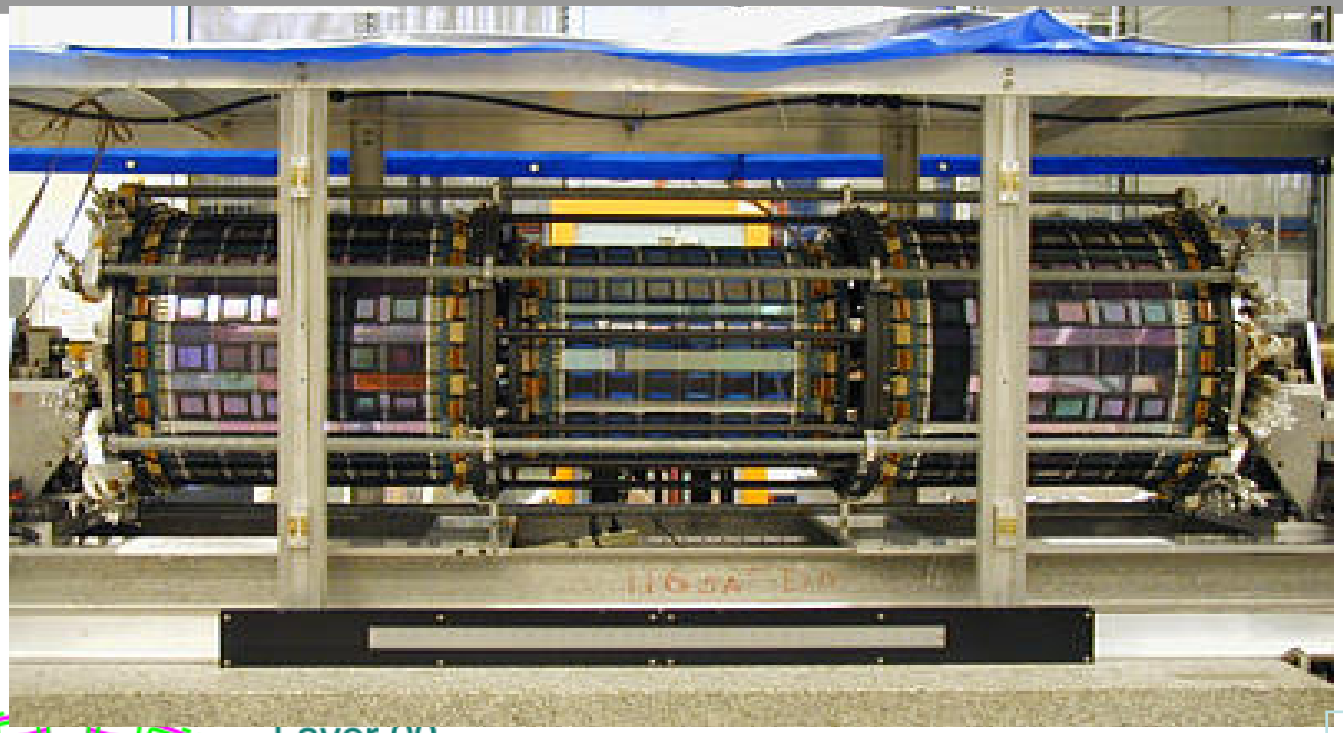
Jet1: Et=46.7 GeV Eta=-0.6 b-tag=1

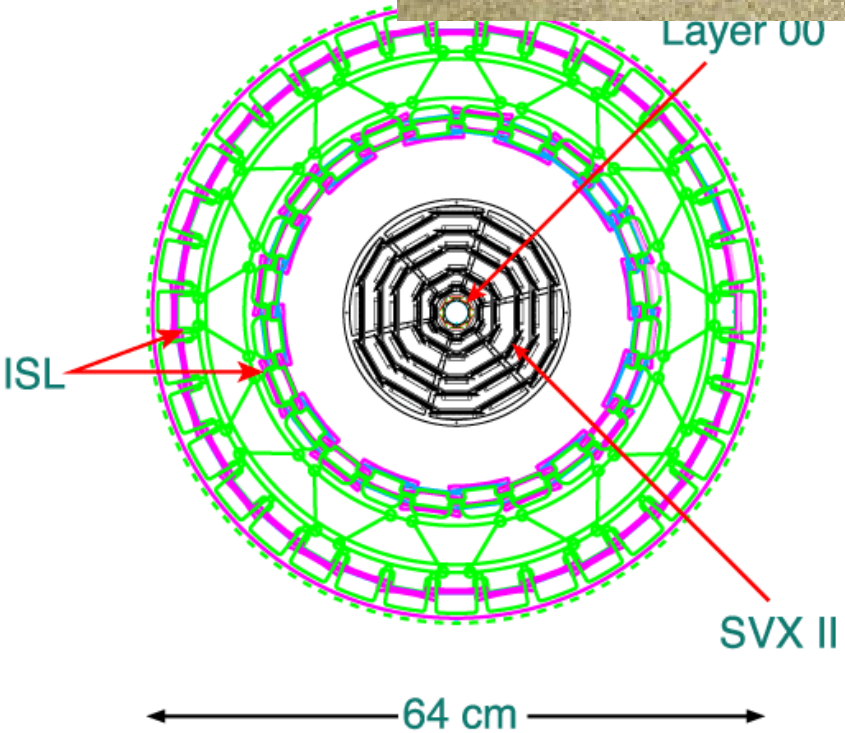
Jet2: Et=16.6 GeV Eta=-2.9 b-tag=0

Q x Eta = 2.9 (t-channel signature)

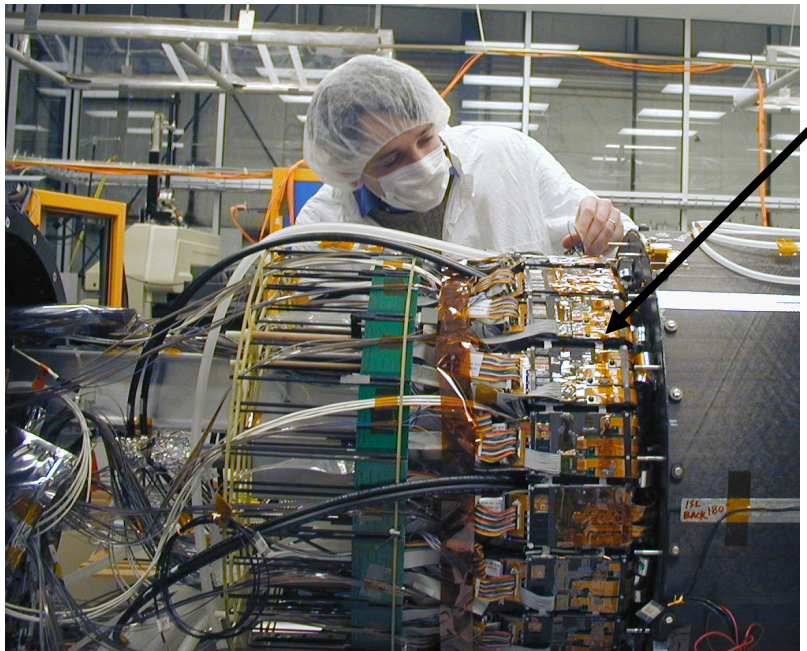
EPD=0.95

CDF Silicon Detectors

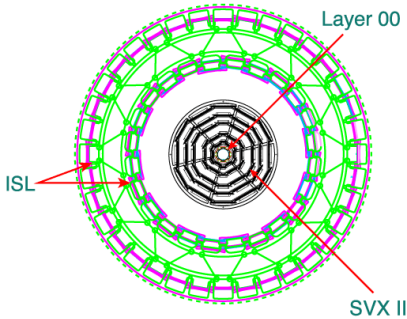




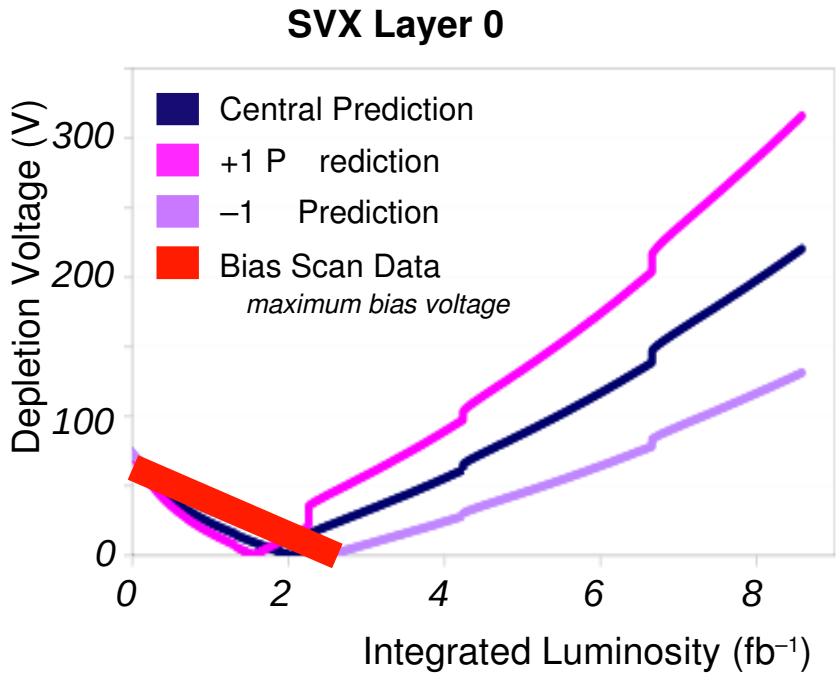
ISL/L00 Portcards



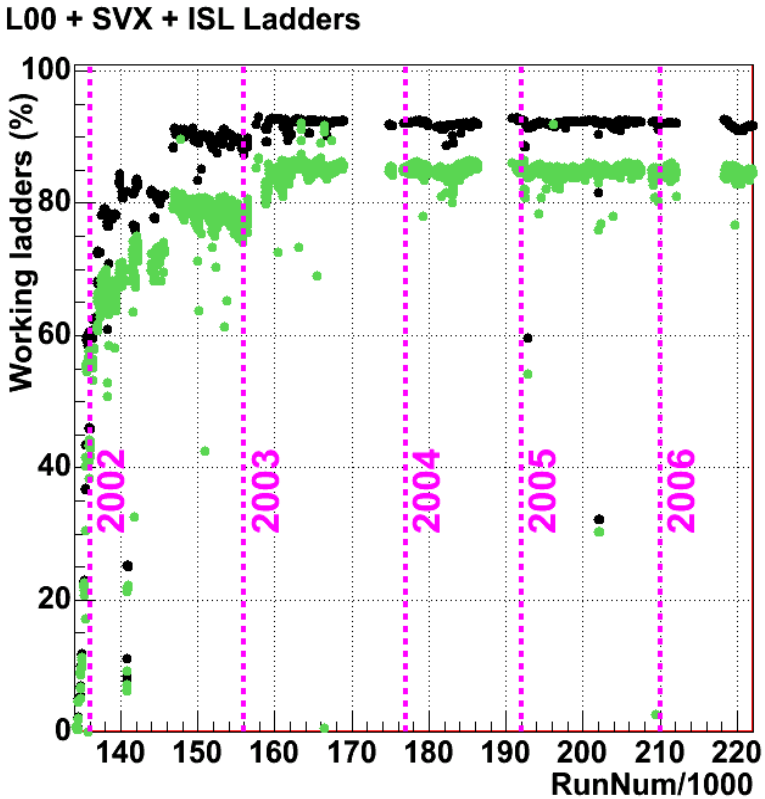
Silicon Longevity - details



- Bias voltage required to fully deplete Silicon sensors changes with irradiation: decrease – type inversion – increase
- If depletion voltage larger than maximum safe bias voltage:
  - cannot fully deplete sensors → efficiency loss
- Recent bias scans show innermost SVX layer (most vulnerable) is nearing inversion



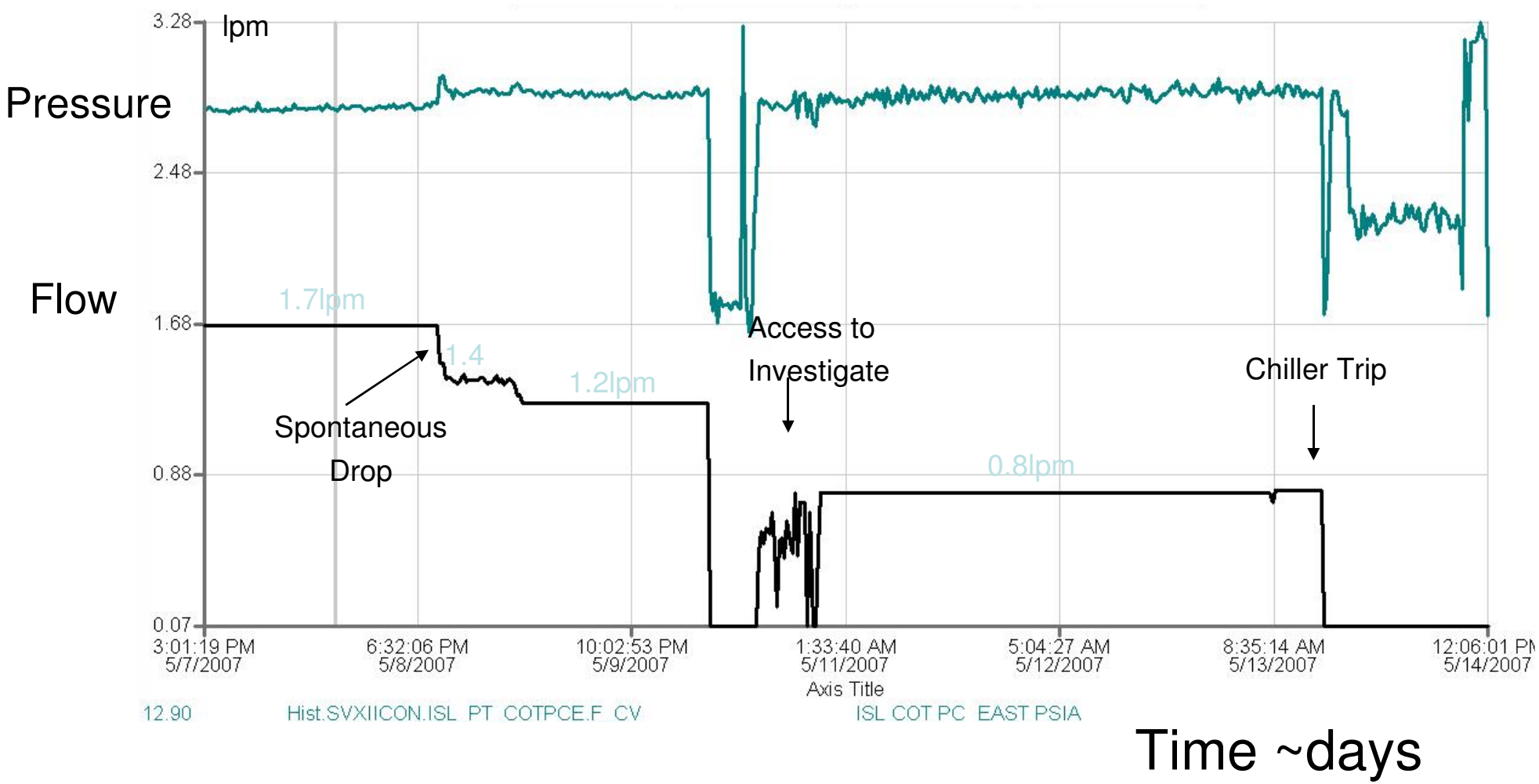
Model: S. Worm, *Lifetime of the CDF Run II Silicon*, VERTEX 2003



Silicon stable and expected to outlast 8f b^{-1}

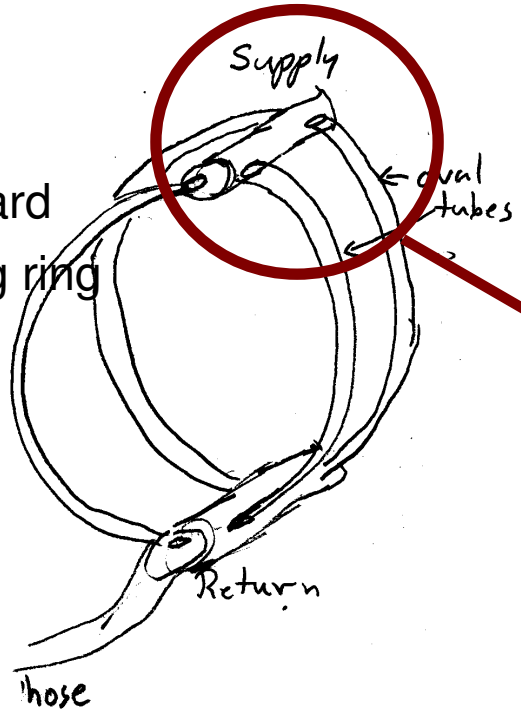
The Leak

Recently, flow in East ISL/L00 portcard circuit dropped from 1.7 lpm (nominal) to 0.0 lpm:

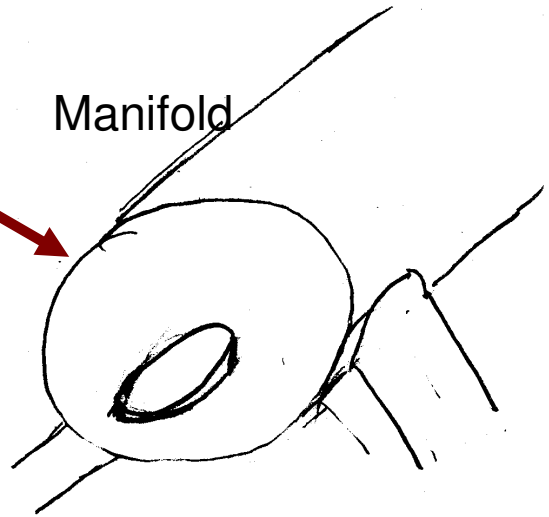


Boroscope pictures

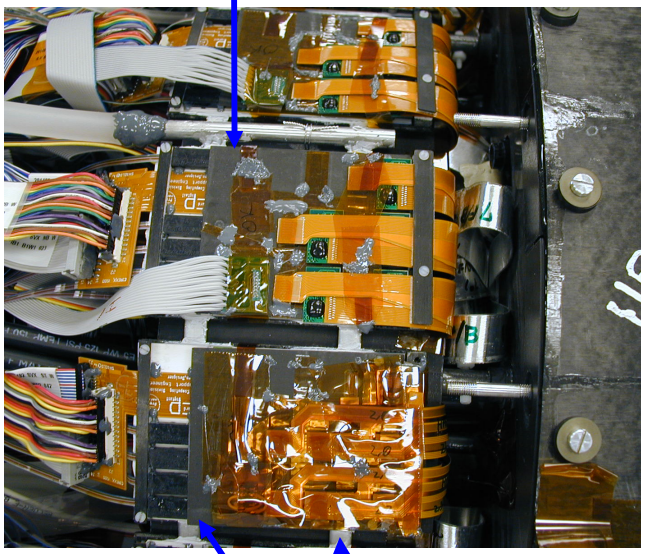
Port card
cooling ring



Manifold



Manifold



Cooling Pipes

Established Task Force

- Objectives:
  - Determine a safe short term operating configuration
  - Determine probable cause of leak and repair it
  - Studying other potential vulnerabilities in system

- Plan:
  - Expect repair to be completed during summer shutdown
    - 9-week shutdown starting on August 6th

CONFIDENT WE WILL FIX IT

Physics Impact

- Established task force to assess impact on physics while off
- Preliminary conclusions:
  - Efficiency for adding silicon hits to COT tracks and impact parameter resolution both only moderately affected
  - Forward electron ID down by ~5%
  - B-tagging
    - Efficiency down by 10-15% per jet
    - Mis-tag rate also down by ~15%
    - Re-optimization would mitigate efficiency loss somewhat
  - Higgs
    - Total lepton acceptance falls by <5%
    - Events with ==1 Btag falls by ~7%
    - Events with ==2 Btags falls by ~20%