The Tevatron during the LHC era: results and prospects for the CDF experiment

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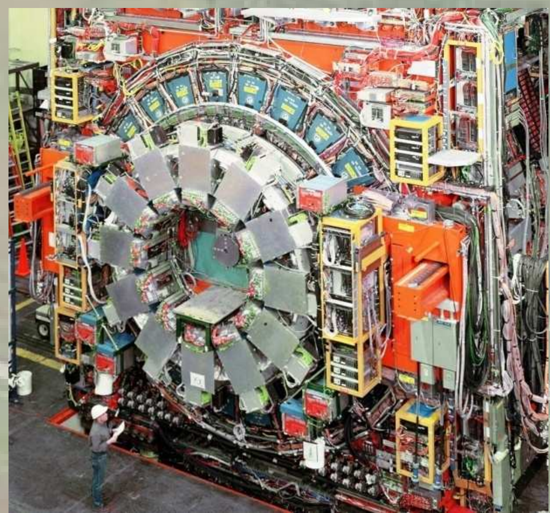


HEP Seminar, Madrid 2nd March 2010

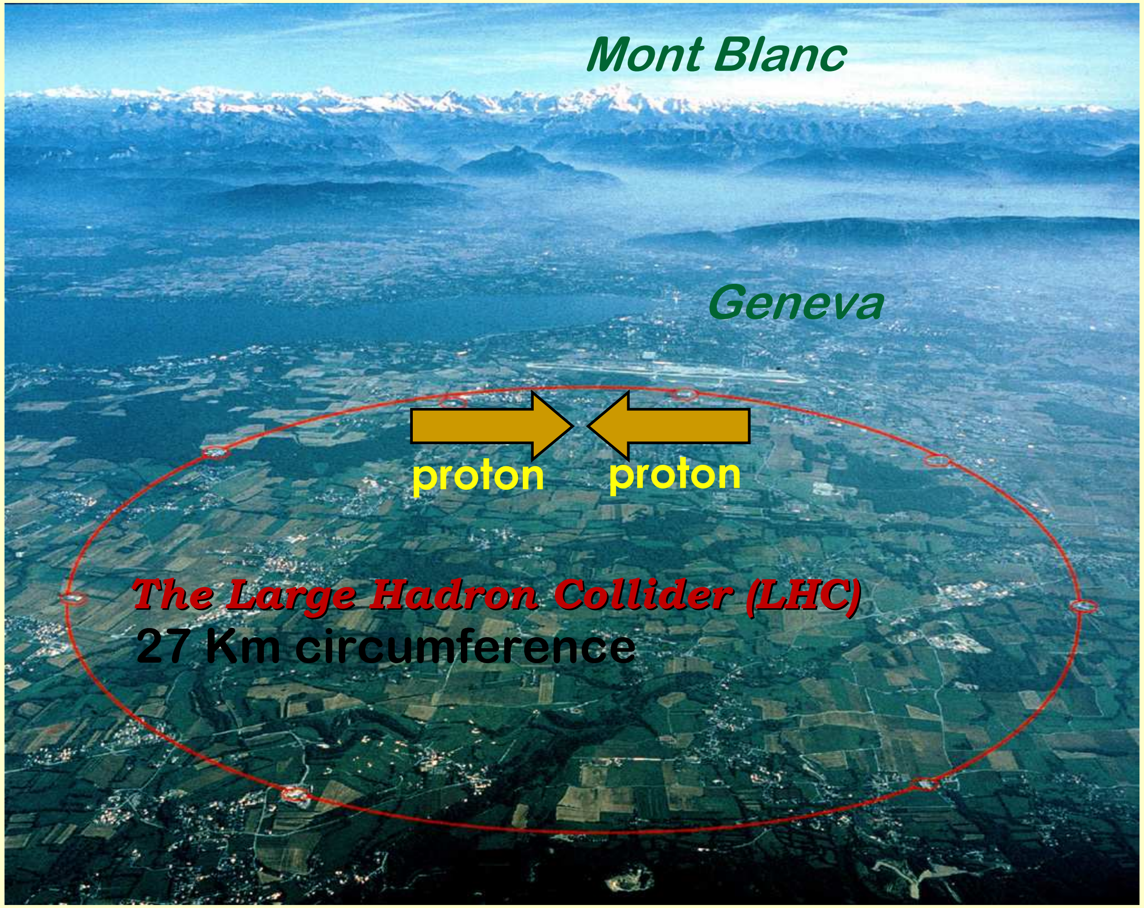
The Large Hadron Collider (LHC)

- **After 20 years of R&D, Machine and Detectors building, commissioning and preparation, the LHC is up and running!**

November 23rd 2009
- First collisions at injection energy (450GeV)

December 8th 2009
-2x2 colliding bunches accelerated at 1.18 TeV!

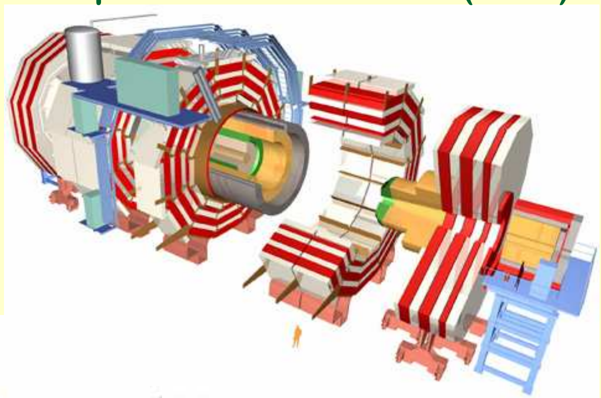
By December 16th 2009:
Recorded more than 1M events at $\sqrt{s}$=900 GeV, and 50K events at $\sqrt{s}$=2.36 TeV

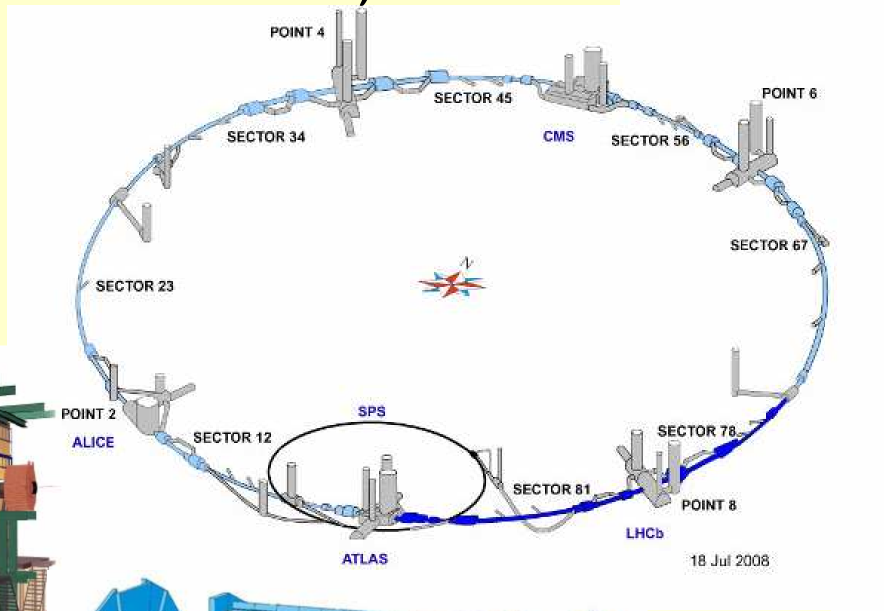


The Experiments

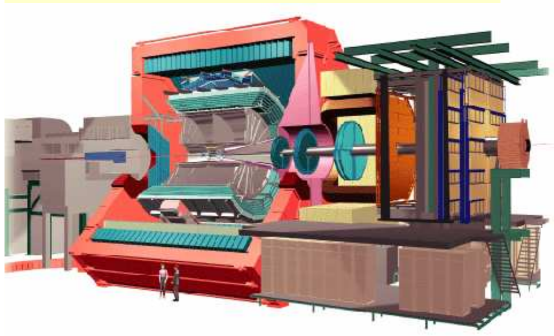
- **Two large general purpose experiments (ATLAS and CMS)**
- **Two Medium more “specialized” experiments (ALICE and LHCb)**

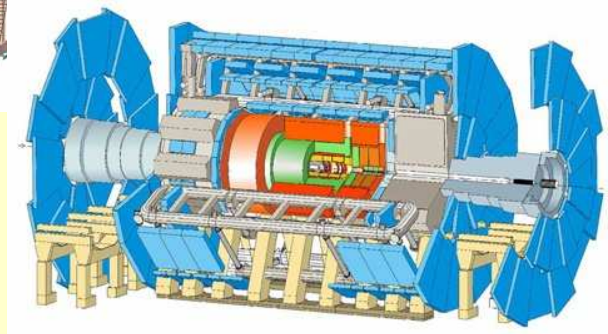
Compact Muon Solenoid (CMS)



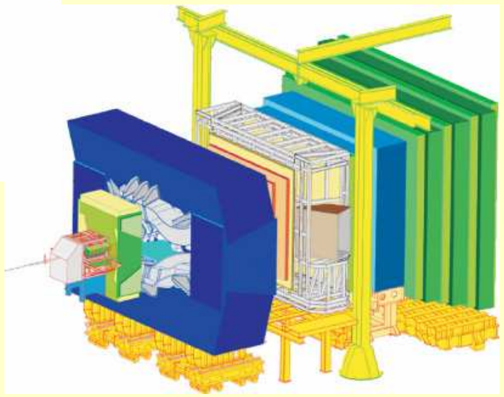


A Large Ion Collider Experiment (ALICE)



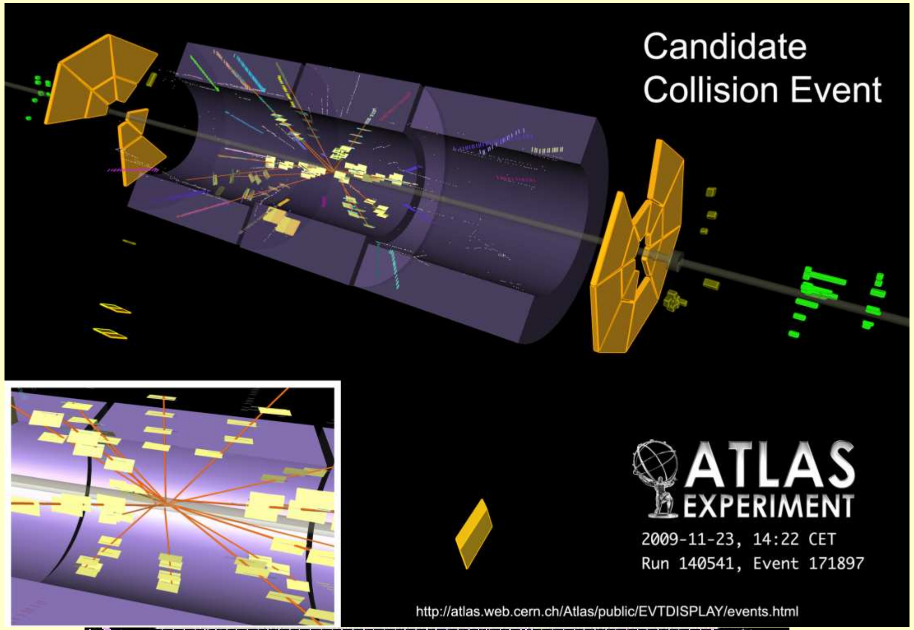


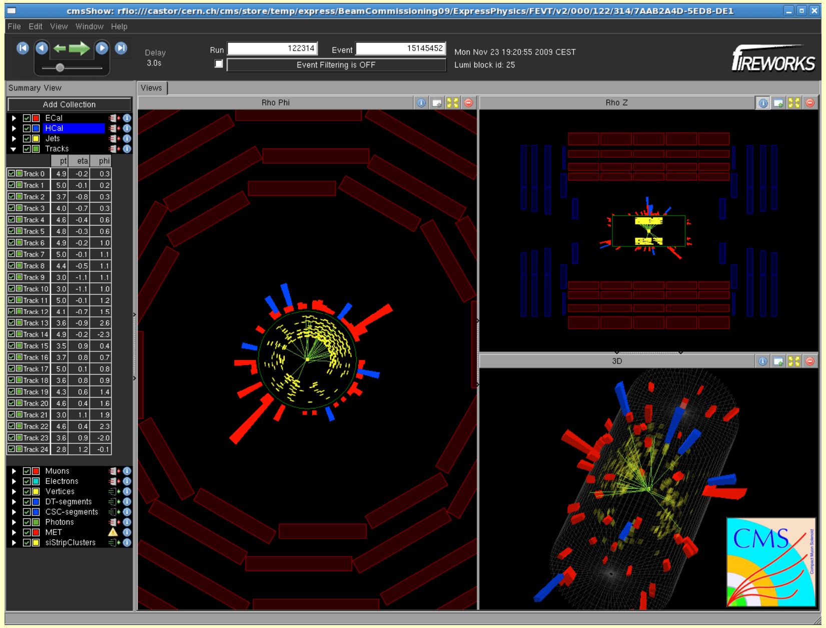
A Toroidal LHC ApparatuS (ATLAS)

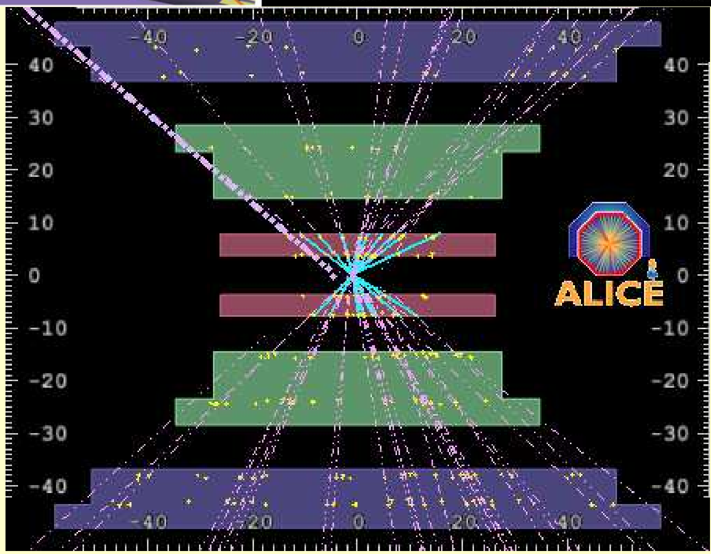


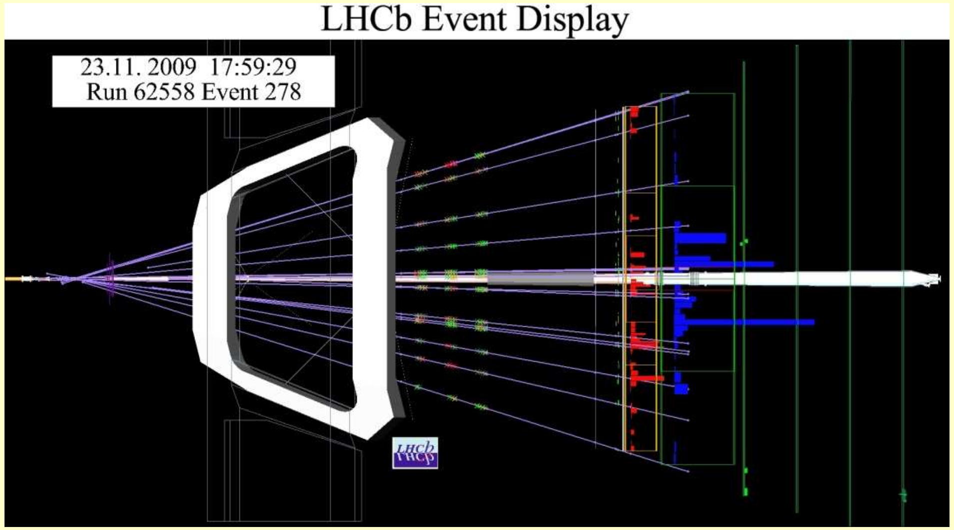
B physics at the LHC (LHCb)

November 23rd: First Collisions for All!



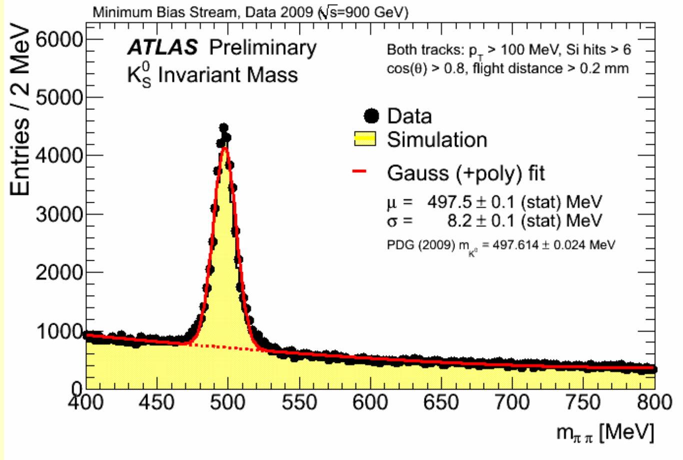




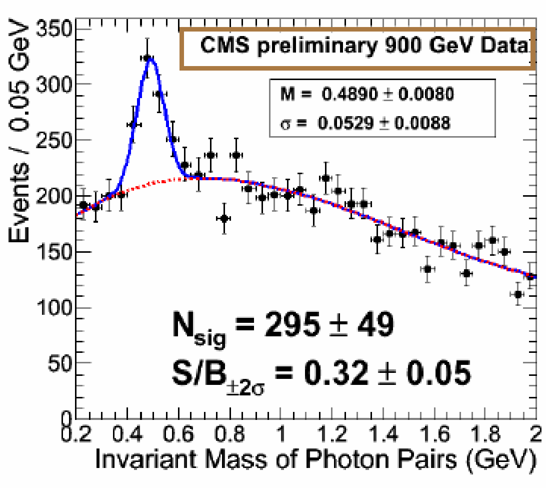


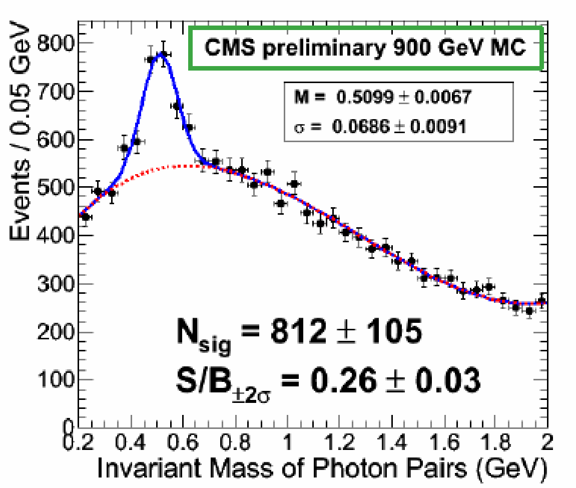
Detectors performance

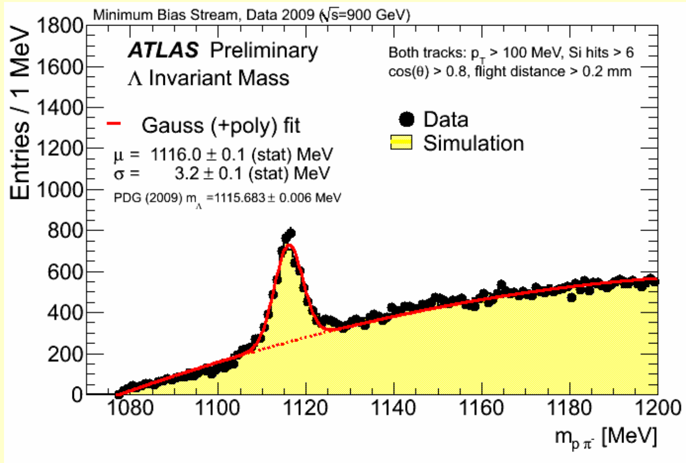
- **Amazing detector performance for all experiments**
- **First results from ATLAS and CMS (as example)**
  - **Masses of K_s and Λ agree well with PDG values, resolution agrees with expectation (tracking performance)**
  - **Good agreement between data and expectation for calorimeter objects**



$\eta \to \gamma\gamma$

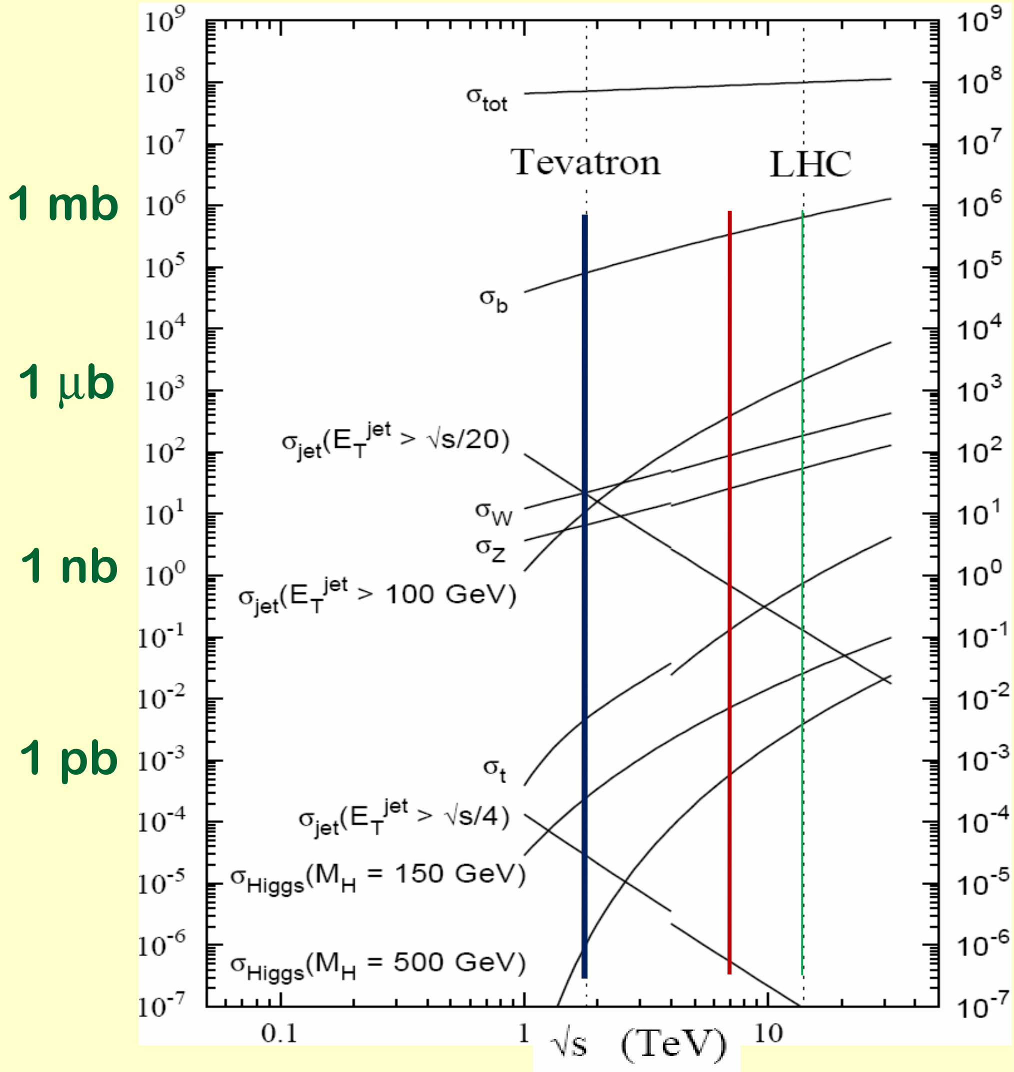






$N(\eta) / N(\pi_0) = 0.020 \pm 0.003$ DATA (left)
$N(\eta) / N(\pi_0) = 0.021 \pm 0.003$ MC (right)

Experimental reach of LHC



Nominal LHC c.o.m energy
→ 14 TeV (7 TeV+7TeV)

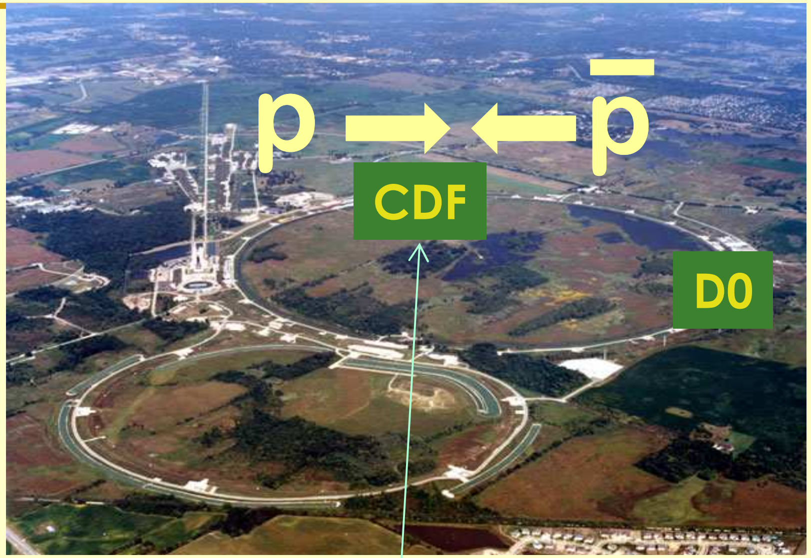
2010-2011 Running plans:
→7 TeV (3.5 TeV+3.5 TeV)
up to 1 fb^{-1} of collected luminosity
(initially foreseen @ 10 TeV)

300 pb^{-1} at 5 TeV+5 TeV
~ 1 fb^{-1} at 3.5 TeV+3.5 TeV
→ ~ 8/9 fb^{-1} at 1 TeV+ 1 TeV

Tevatron accelerator →
proton-antiproton: $\sqrt{s}$ ~ 2 TeV

Tevatron & CDF

Both still doing great after ~9 years of operations!

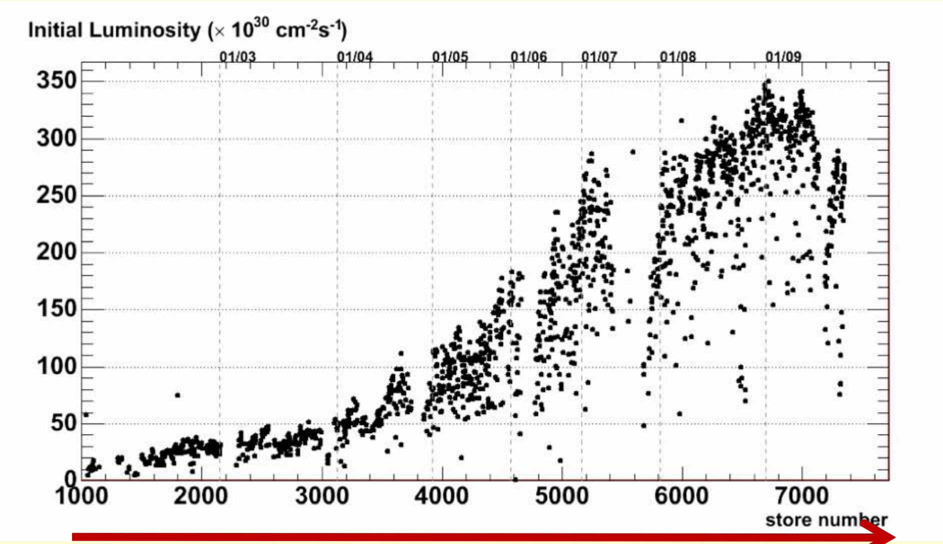


Tevatron

Proton-antiproton: $\sqrt{s}$ = 1.96 TeV

Peak luminosity → > 3.5 $\times 10^{32}$ cm^{-2} s^{-1}

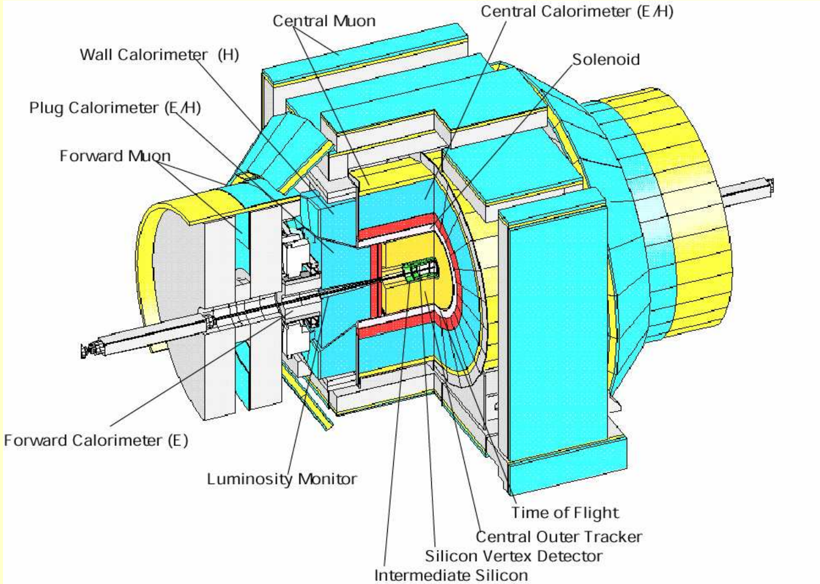
Integrated luminosity/week → ~ 70 pb^{-1}



8.5 years!

~ 8 fb^{-1} delivered

CDF

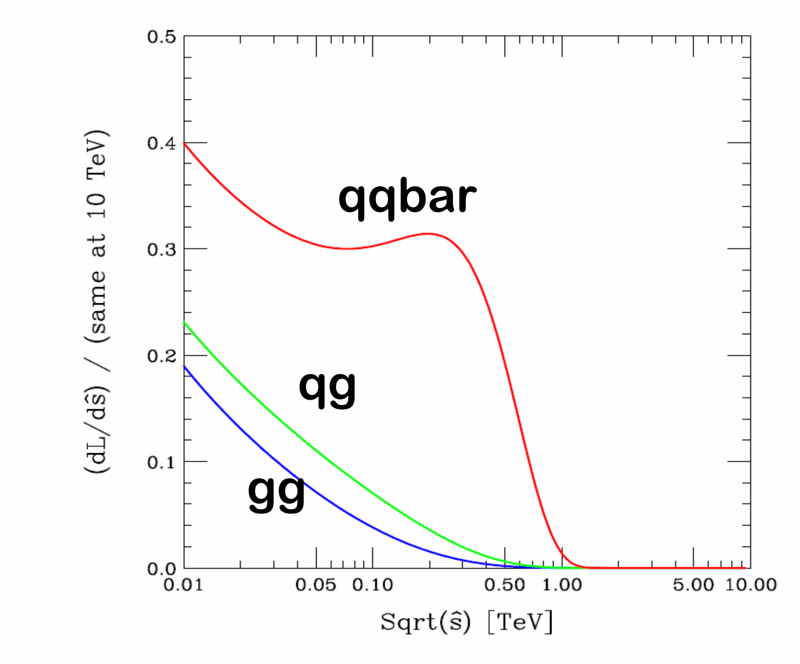


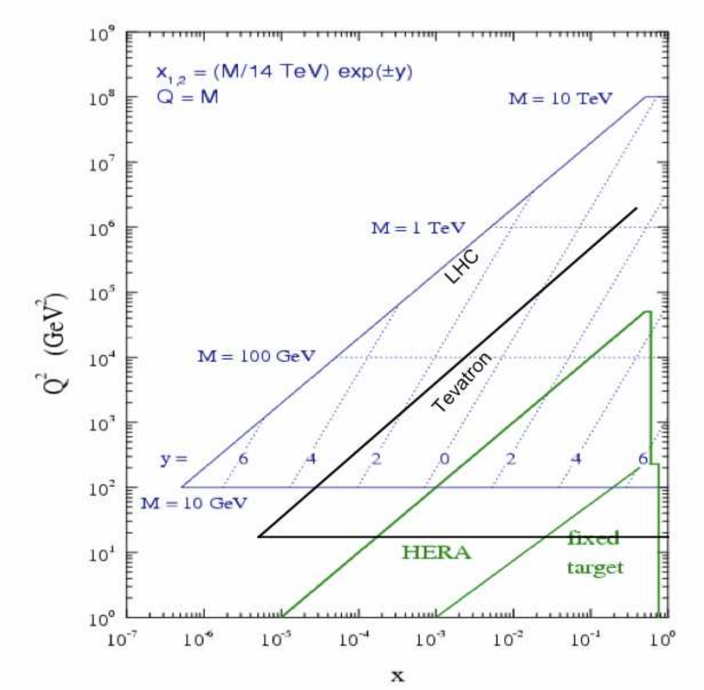
record: 85-90 % of delivered luminosity
Stable efficiency since 2002 …

Complementarities

- LHC opens a new regime for QCD and extend phase space reach

- Tevatron is a q-qbar machine
- LHC is a gluon-gluon machine
- Ratio TeV/LHC (10 TeV c.o.m.)





→ This could be an advantage for well motivated analyses:

- search for chargino/neutralino
- search for light gluinos
- asymmetry measurements

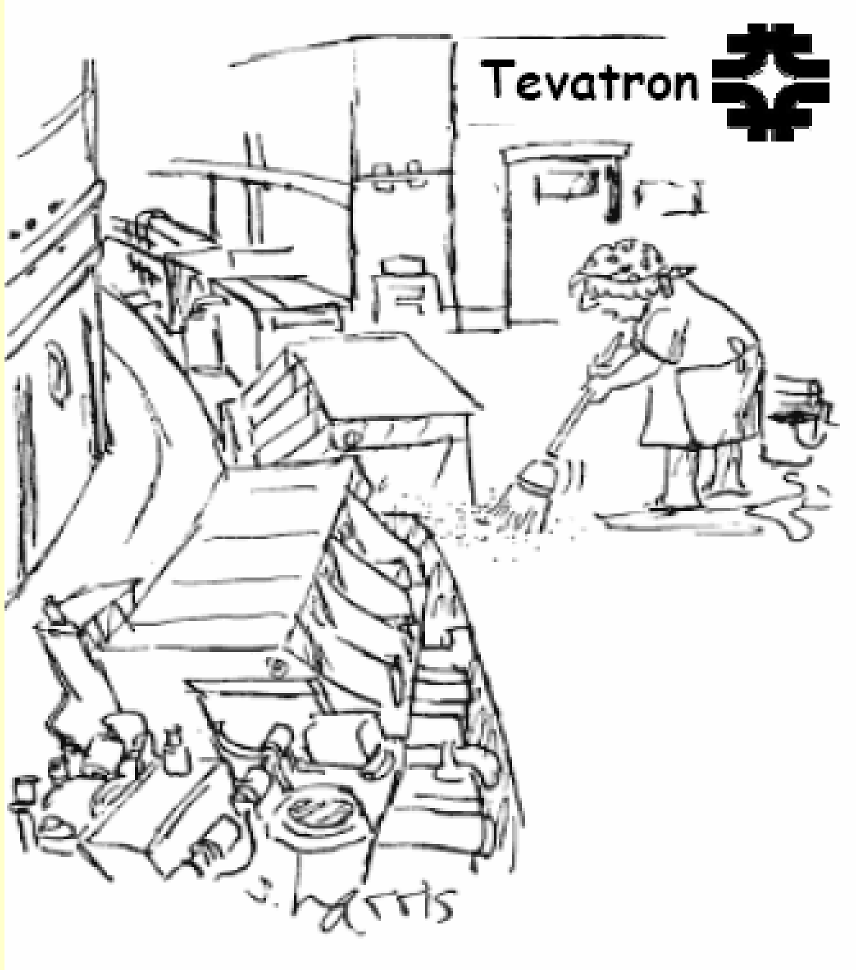
→ Similar S/B for some processes

- 3rd generation squarks, SM higgs

Common "playground" for next couple of years…

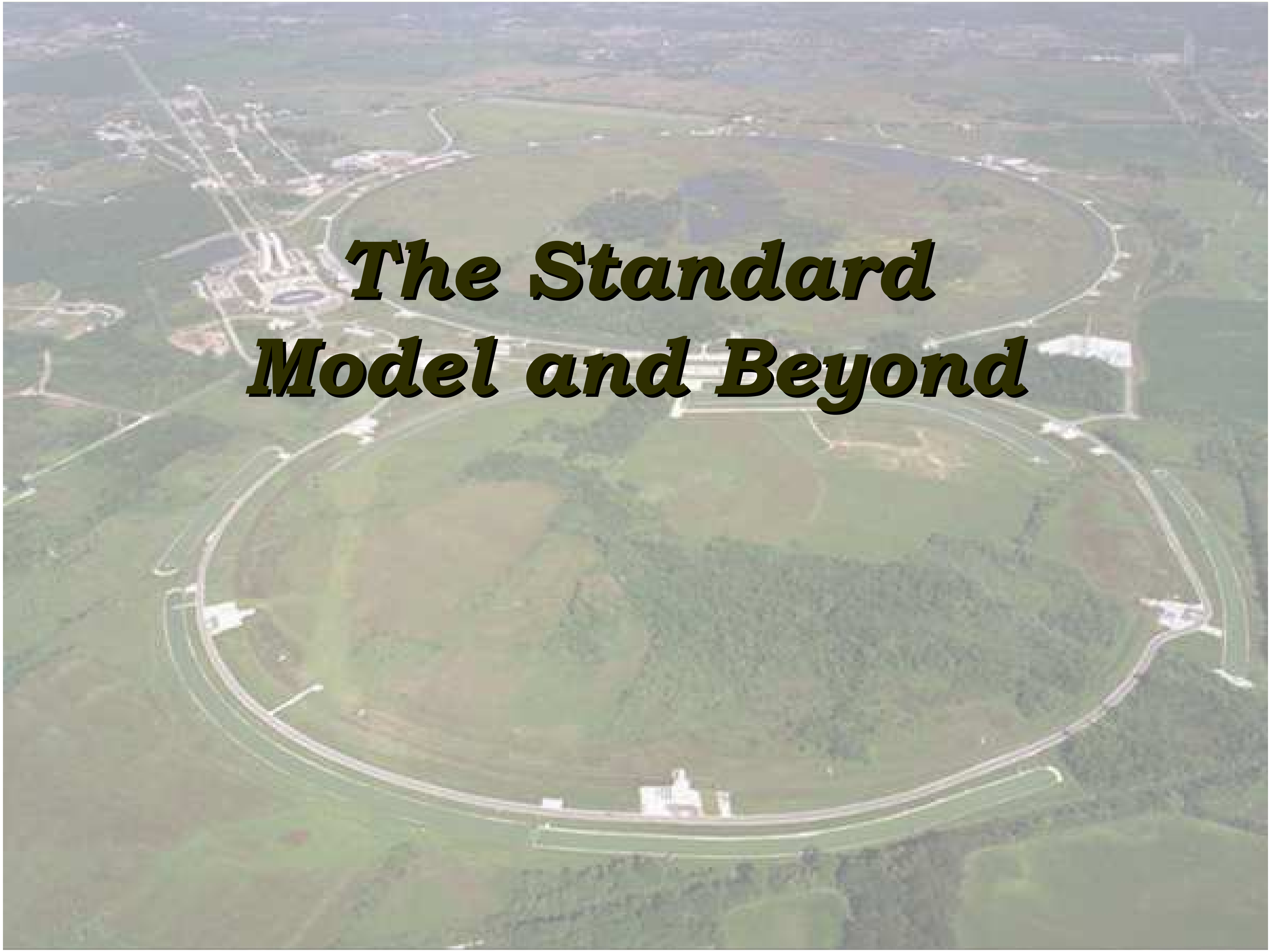
Outline

- The Standard Model and Beyond
- Precision measurements of SM processes
- Recent observations
- The SM Higgs haunt
- Searching for physics beyond SM
- Conclusions and remarks



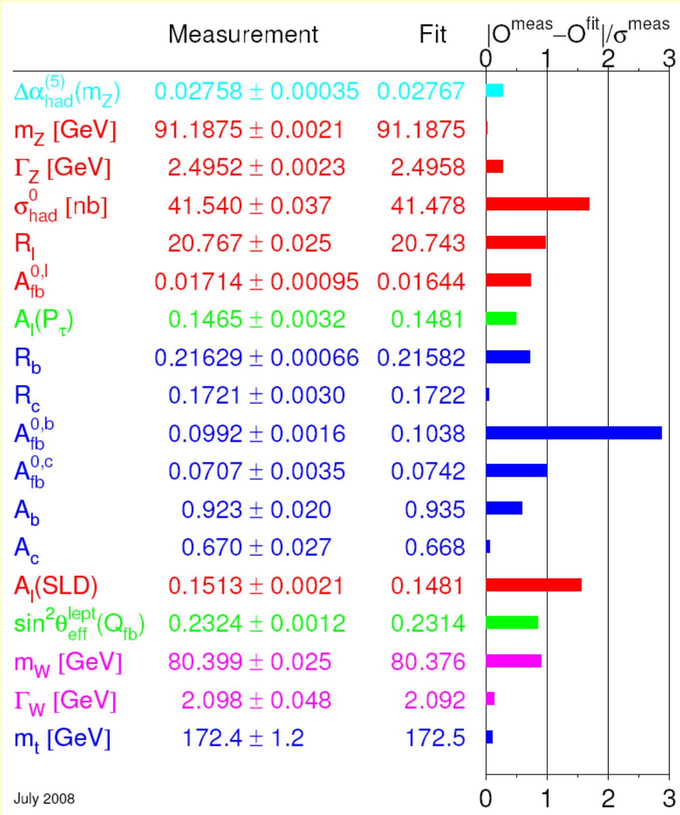
"Particles, particles, particles."

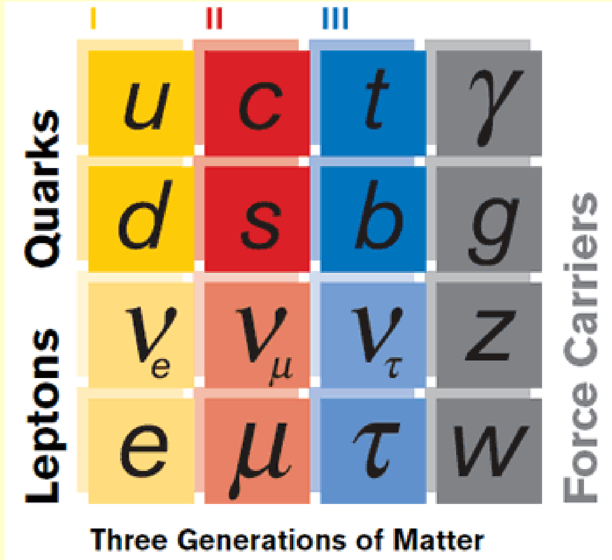
The Standard Model and Beyond



The Standard Model

- **Matter is made out of fermions:**
  - **3 generations of quarks and leptons**
- **Forces are carried by Bosons:**
  - **Electroweak: γ,W,Z**
  - **Strong: gluons**





Remarkably successful description of known phenomena:

- **predicted the existence of charm, bottom, top quarks, tau neutrino, W and Z bosons.**
- **Very good fit to the experimental data so far**

but …

The missing piece: the Higgs

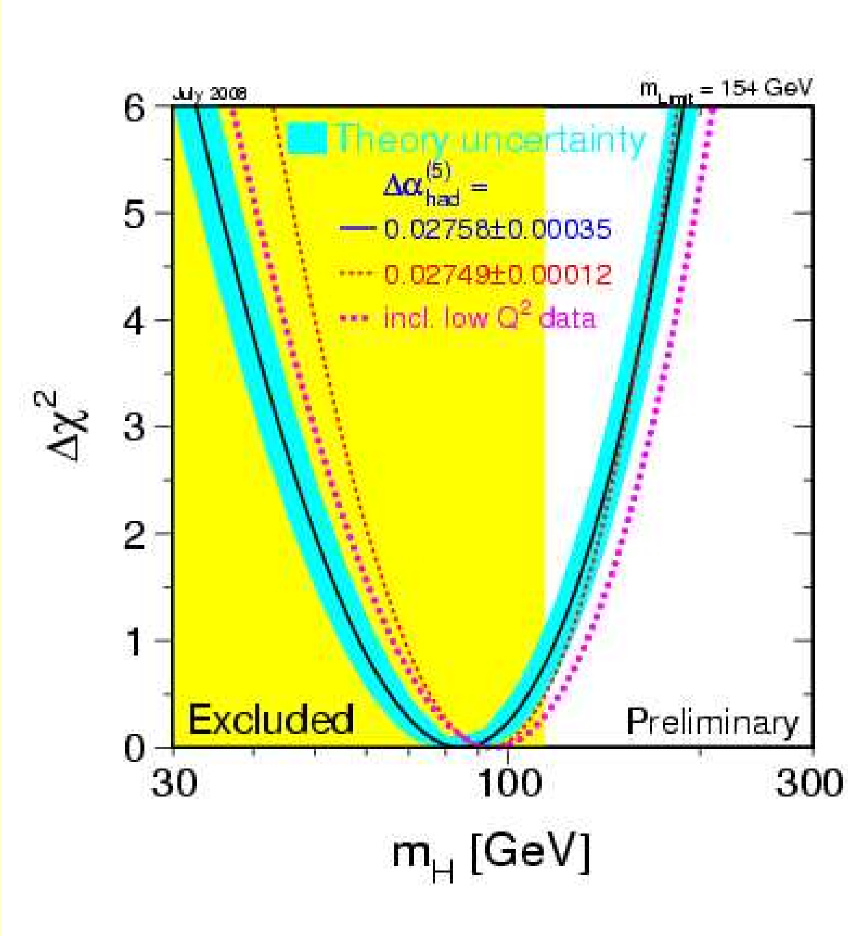
- **What is the origin of masses?**

  → Within SM, Higgs field gives mass ro Particles (EWK symmetry breaking)
- **SM predicts existence of a new massive neutral particle**

  Not found yet!
- **Theory does not predict its mass**
- **LEP limit: m_H>114 GeV @ 95% CL**
- **Indirect limit from EW data:**

  - Preferred value: $m_H = 84^{+34}_{-26}$ GeV

  - m_H < 154 GeV @ 95% CL

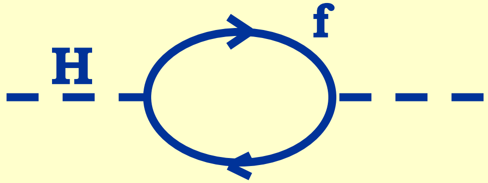


with $\alpha_S(M_Z) = 0.1185\pm0.0026$,
$\Delta\alpha_S(5)_{had}=0.02758\pm0.00035$

WOULD THE HIGGS DISCOVERY COMPLETE OUR UNDERSTANDING OF NATURE ?

Beyond SM: the Unknown

The Standard Model is theoretically incomplete



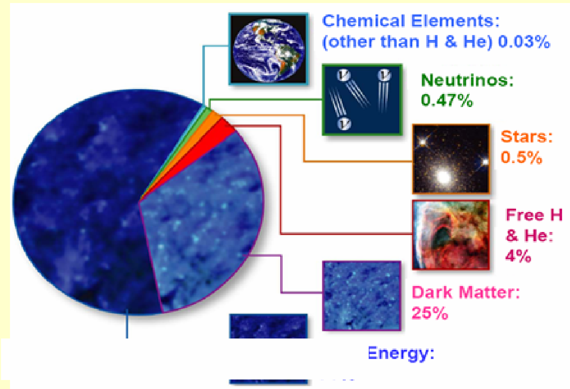
$\Delta m_H^2 \sim \Lambda^2$

$\Lambda = M_{pl}$?

- Mass hierarchy problem

→ radiative correction in Higgs sector

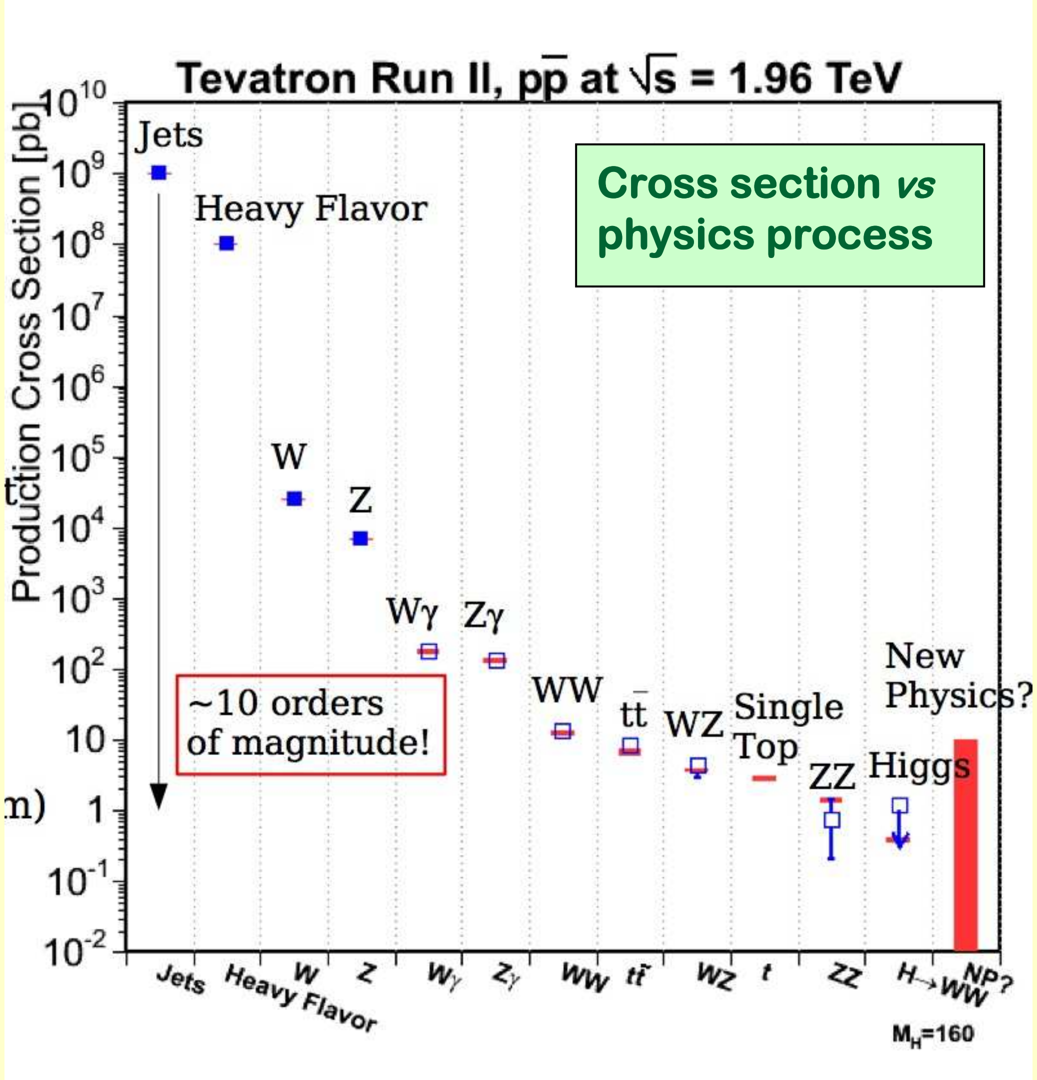
- Unification
- Dark Matter
- Matter-antimatter asymmetry



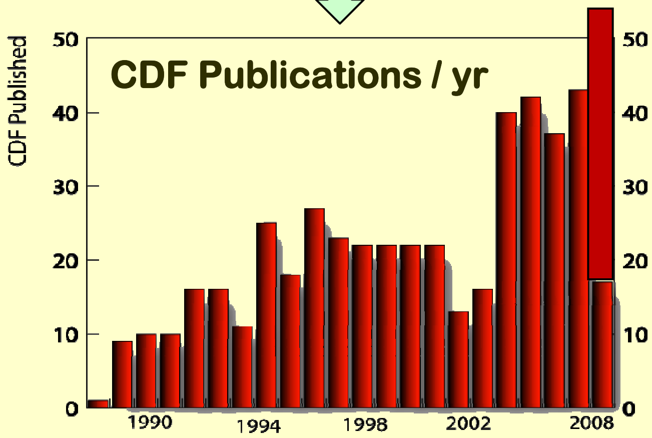
- **Many possible new particles and theories**
  - SuperSymmetry
  - Extra Dimension
  - New Gauge groups (Z', W')
  - New fermions (e*, t', b' …)
  - …

Can show up in direct searches or as subtle deviations in precision measurements

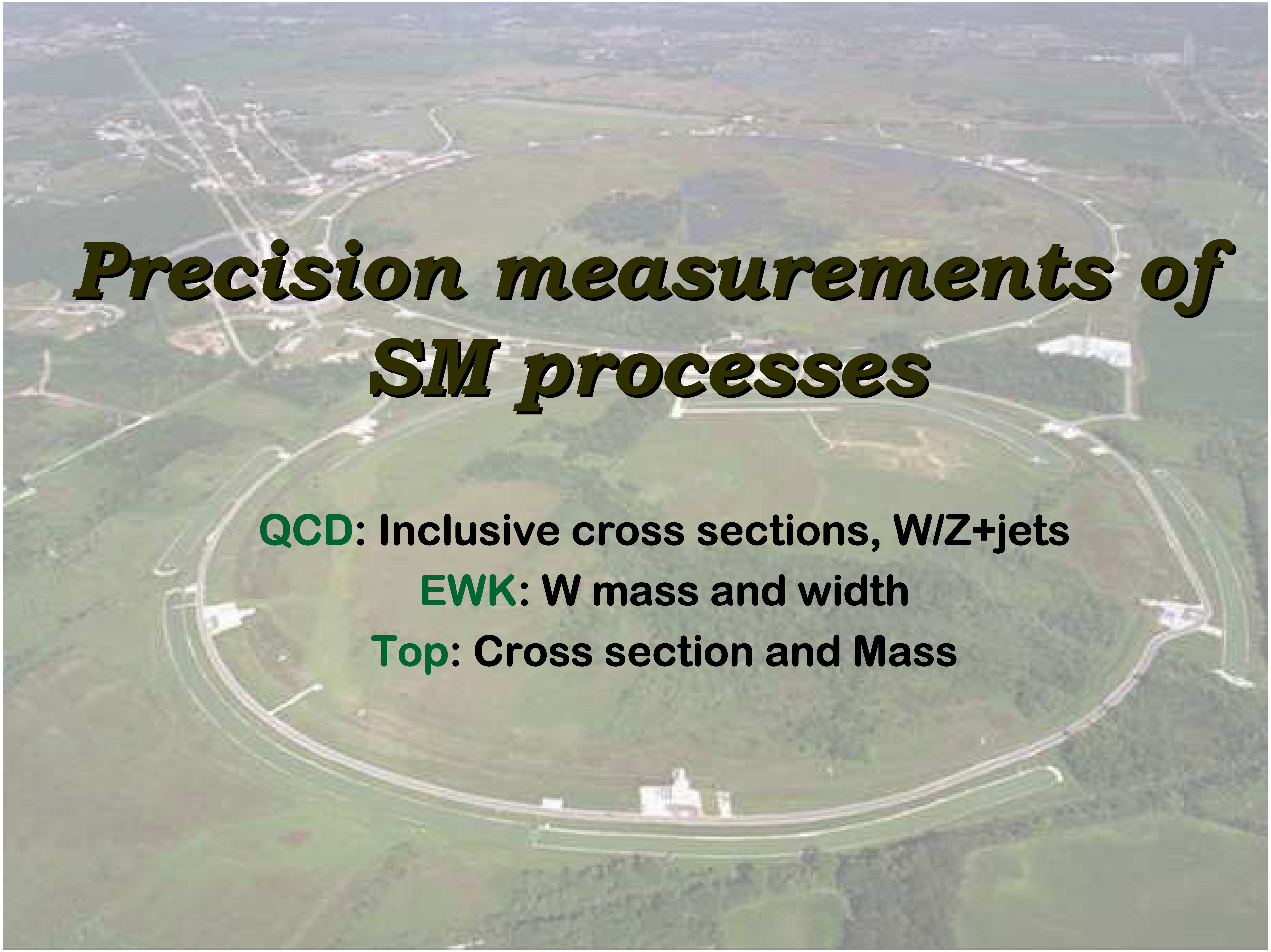
A long journey …



- Jet cross section measurements, heavy flavour physics, W/Z
- Precision measurements (Top properties, observation of rare processes…)
- Higgs and New Physics BSM, searches, looking for 'the' unexpected



More than 50 papers published only in 2009 , many to come in 2010 and beyond.



Precision measurements of SM processes

QCD: Inclusive cross sections, W/Z+jets

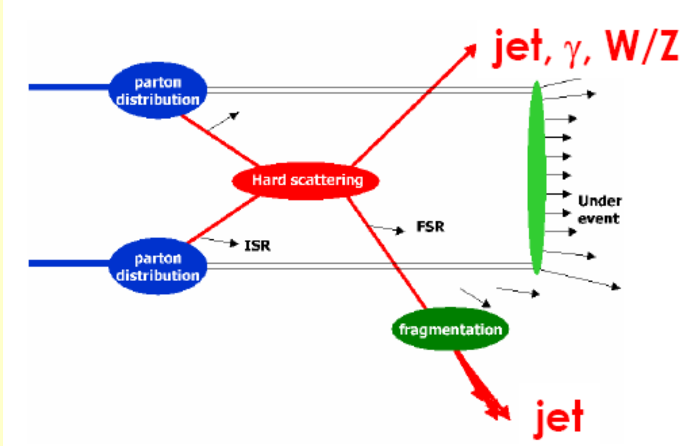
EWK: W mass and width

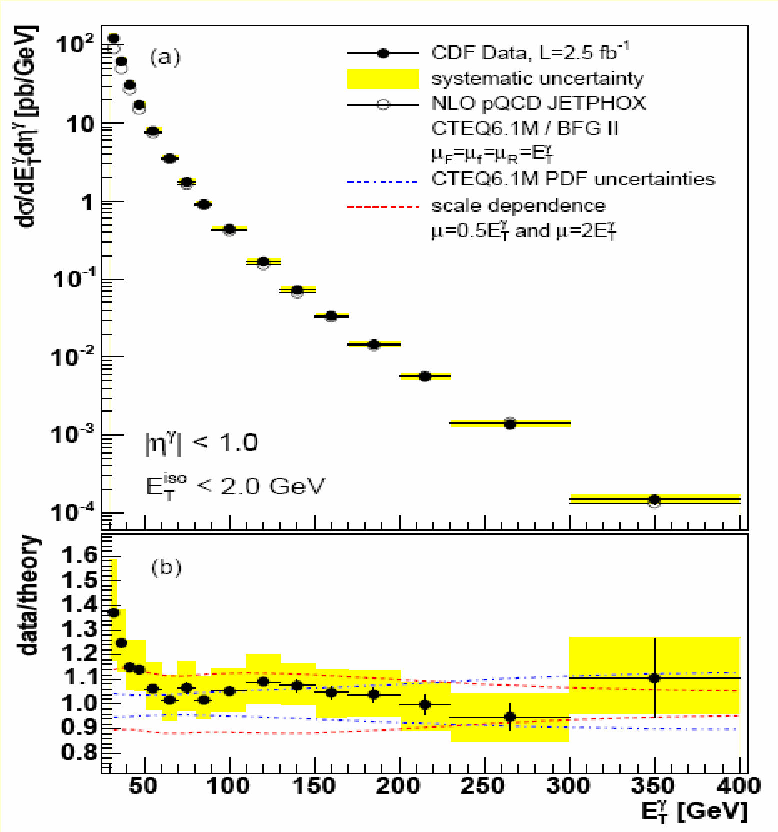
Top: Cross section and Mass

Inclusive cross sections

Test of Next-to-Leading Order (NLO) perturbative QCD

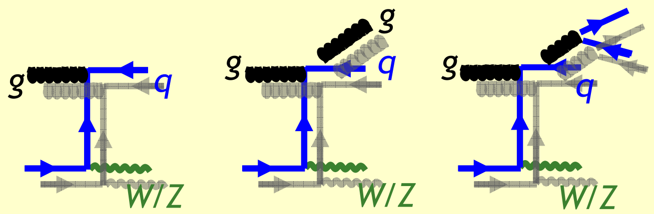
- inclusive jet / photon cross section
  - Probing distances ~10^{-19} m
  - Constrains PDF at high-x
  - Sensitive to new physics at high pT





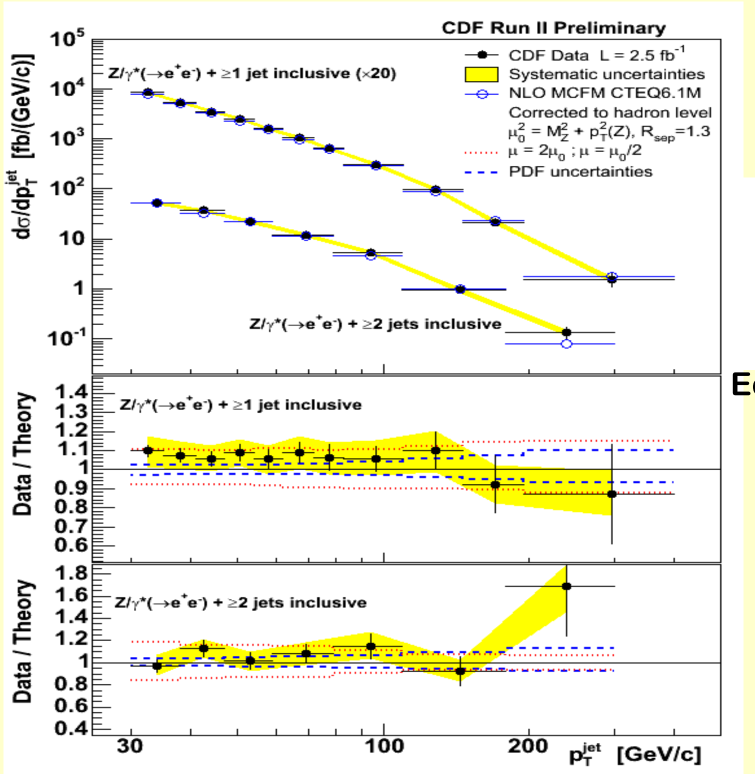
- Data/NLO pQCD in good agreement at high p_T
- Enhancement at low p_T
- D0 measurement shows similar trends (Phys. Lett. B 639, 151)
  - Similar shape also in Run 1 analyses – need to be understood

Boson+Jets Production



- W/Z+jets critical for physics at the Tevatron and LHC (i.e. Higgs, SUSY)
- NLO pQCD calculations available up to 2(3) jets
- Many Monte Carlo tools are available (LO + Parton shower) → Need "validation" by experimental measurements

Z →ee + jets



Event selection:

$66 < M_{ee} < 116$ GeV/c^2

$E_T^e > 25$ GeV, $|\eta_1^e| < 1$

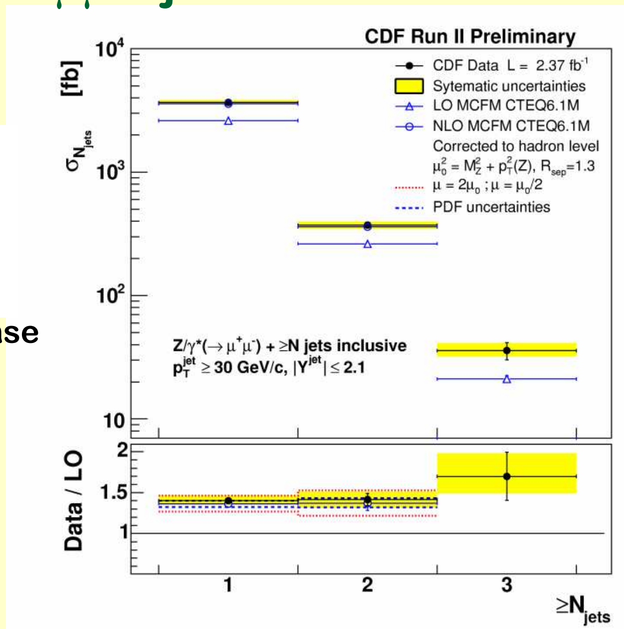
$|\eta_2^e| < 1 \;||\; 1.2 < |\eta_2^e| < 2.8$

$p_T^{jet} > 30$ GeV/c, $|y^{jet}| < 2.1$

$\Delta R(e,jet) > 0.7$

Equivalent for the μ case

Z → $\mu\mu$ + jets



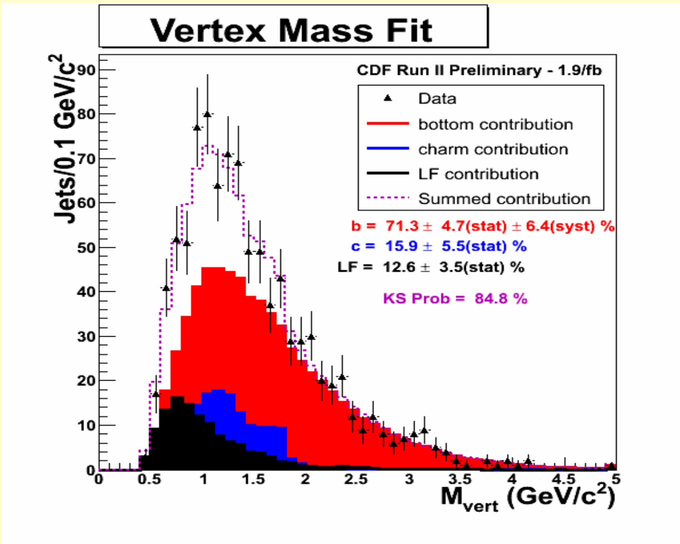
Data and NLO pQCD in agreement
Good control sample for SUSY search

Boson+b-jets

B-tagging → reconstruct secondary vertex from B-hadrons decay

W + bjets

- Event selection:
  - $p_T > 20$ GeV/c, $|\eta| < 1.1$ e/μ,
  - $p_T > 25$ GeV/c neutrino (MET),
  - 1 or 2 $E_T > 20$ GeV/c², $|\eta| < 2.0$ jets

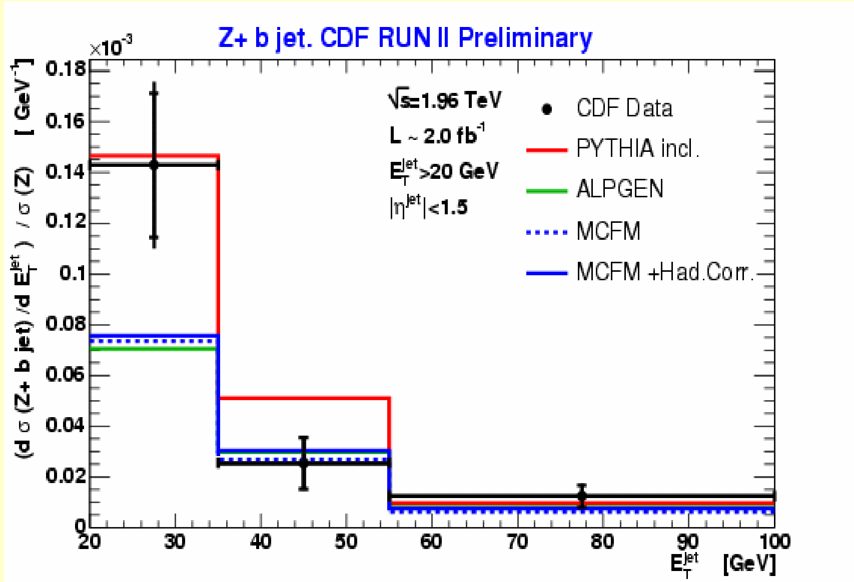


$$\sigma(W+bjet)\cdot BR(W\to l\upsilon)=2.74\pm0.27\pm0.42\,pb$$

x2.5-3.5 larger than Pythia/Alpgen/NLO

Z + bjets

- Events with:
  - $66 < M(ee/\mu\mu) < 116$ GeV/c²
  - E_T (jets) > 20 GeV/c², $|\eta| < 1.5$
  - MET<25 GeV (to remove Wjets bkg)



$$\sigma(Z+bjet)=0.86\pm0.14\pm0.12\,pb(NLO=0.53\,pb)$$

~30% larger than NLO

$$\sigma(Z+bjet)/\sigma(Z+jet)=2.11\pm0.33\pm0.34\%$$

$$(Pythia=2.18\%;Alpgen=1.45\%;NLO=1.77\%)$$

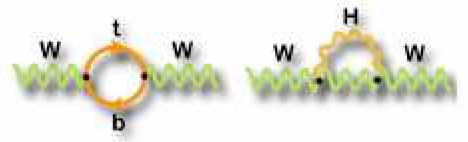
Large variations between MC models (important inputs for tuning)

W Mass and Width

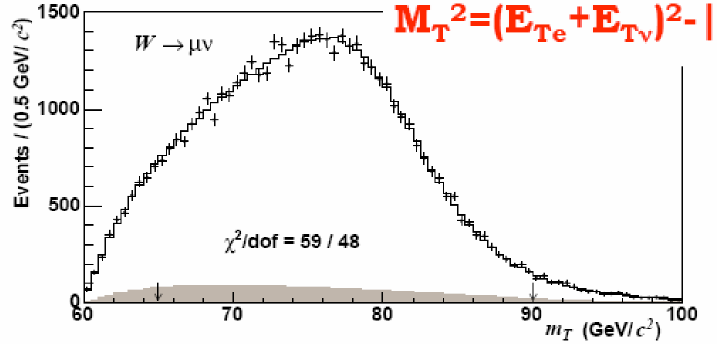
$$M_W = 4\sqrt{\frac{\pi^2\alpha^2}{2G_F^2}\frac{1}{sin\theta_W(1-\Delta R)}}$$

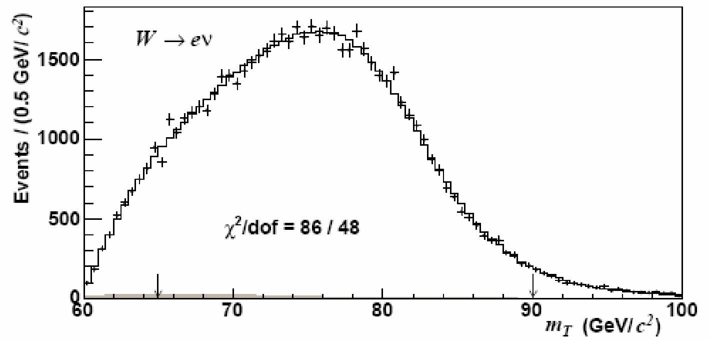
$$\Delta R \sim M_{top}^2,\ logM_H$$

Quantum loop corrections

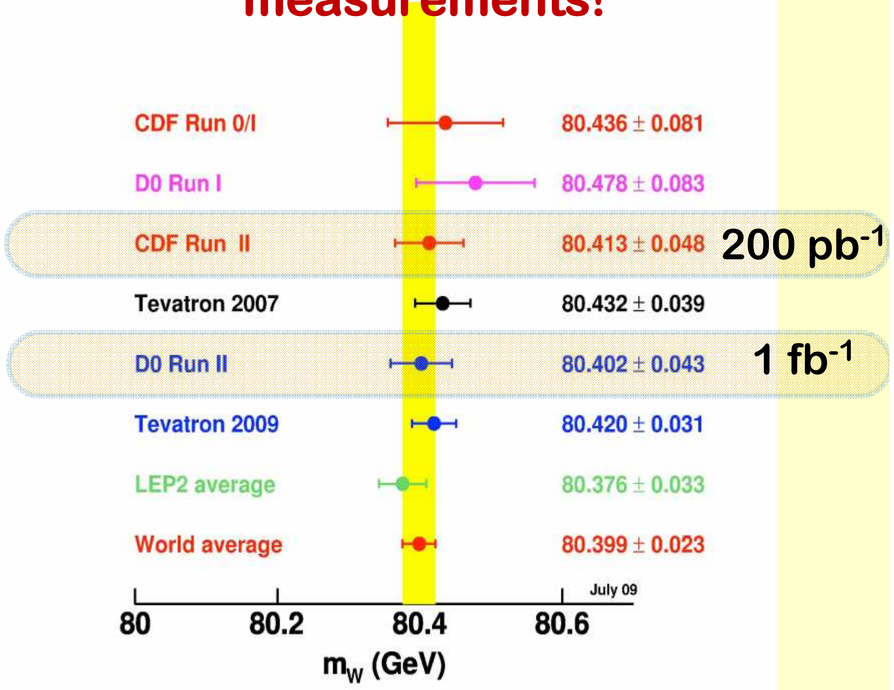


$M_T^2=(E_{Te}+E_{T\nu})^2-|\vec{p}_{Te}+\vec{p}_{T\nu}|^2$





world's most precise single measurements!



M_W = 80413±48 MeV (CDF, 0.2 fb^{-1})

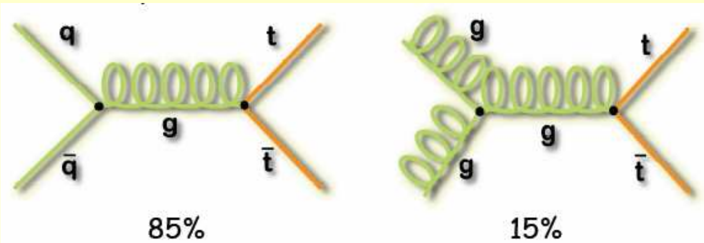
= 80401±44 MeV (DØ, 1 fb^{-1})

Γ_W = 2032±73 MeV (CDF)

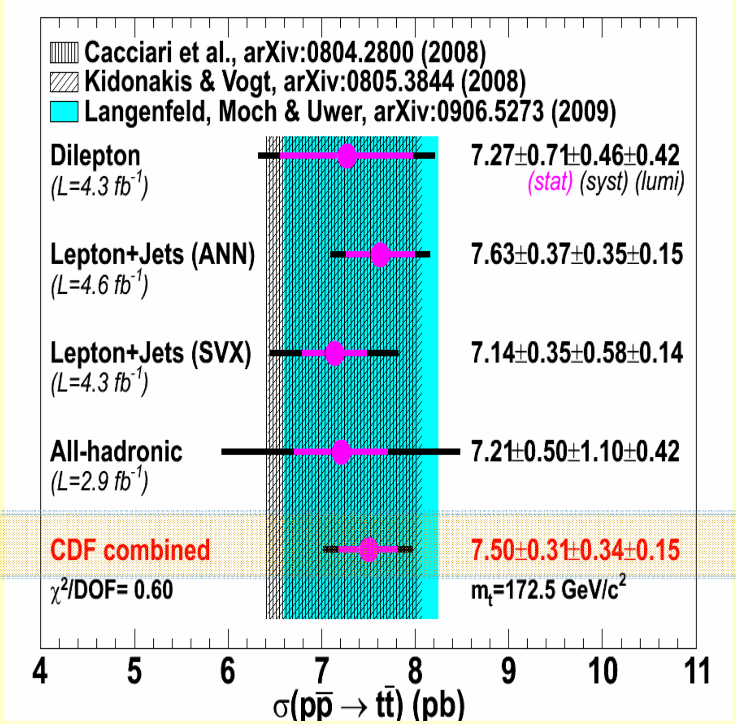
Next round CDF @ 2fb^{-1}
expect <30 MeV uncertainty !

Top Pair Production

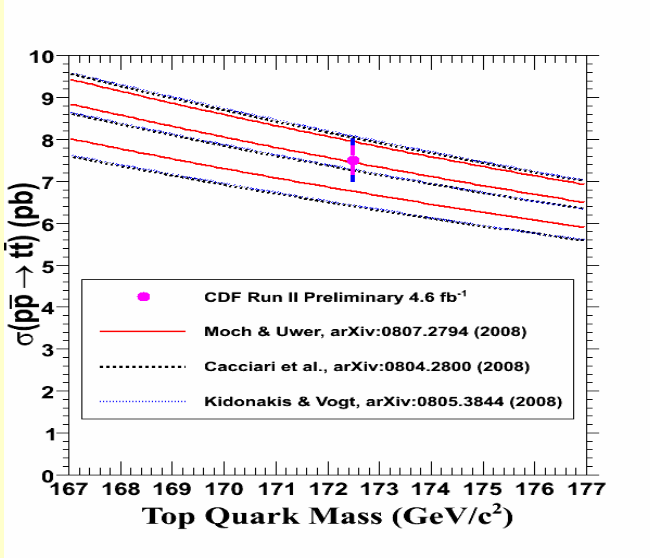
Top **discovered** at the Tevatron in 1995.



t → Wb (BR~100%), W → lν (11%) / → qq' (67%)

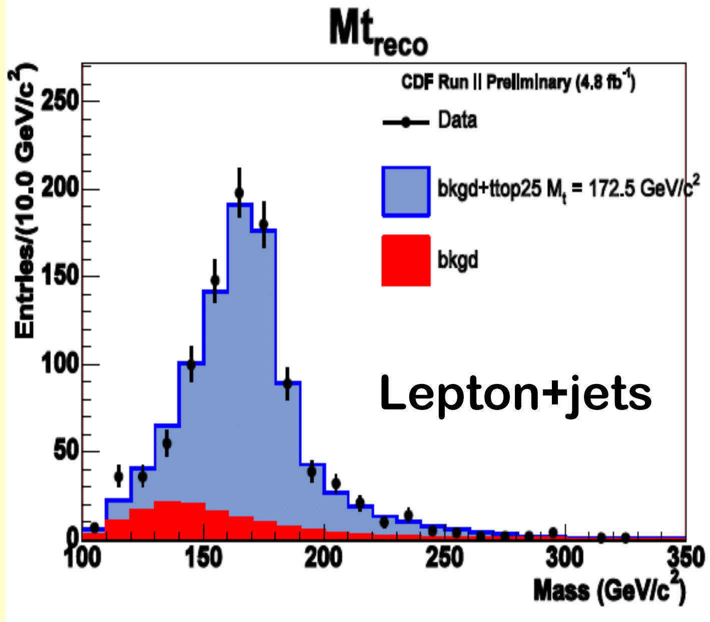


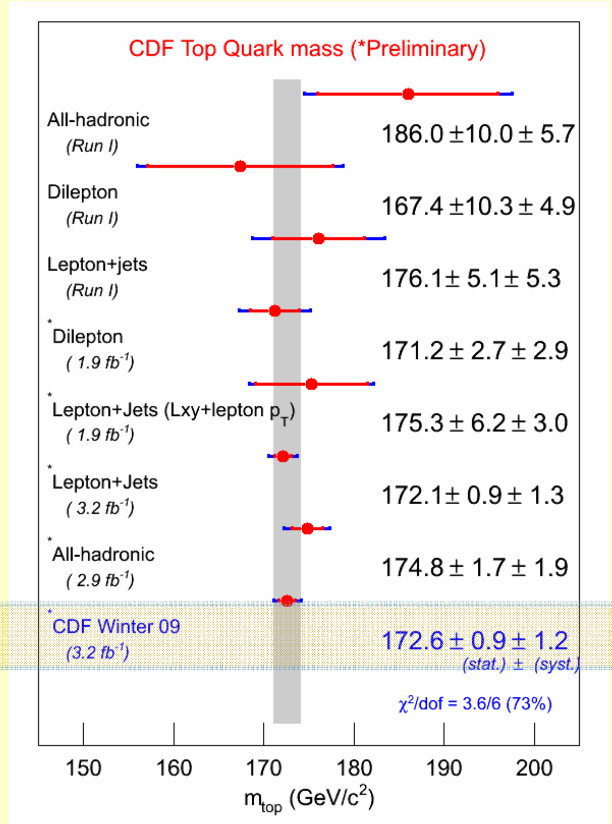
- Test QCD in very high Q^2 regime
- Measurements across all decay channels and topologies have different sensitivities to new physics:



Top Mass

- Precision in top mass measurement down to 0.75% and still improving!
- Several analysis and techniques employed
  - Matrix element, templates
  - Use in situ calibrations when possible (W→jj)

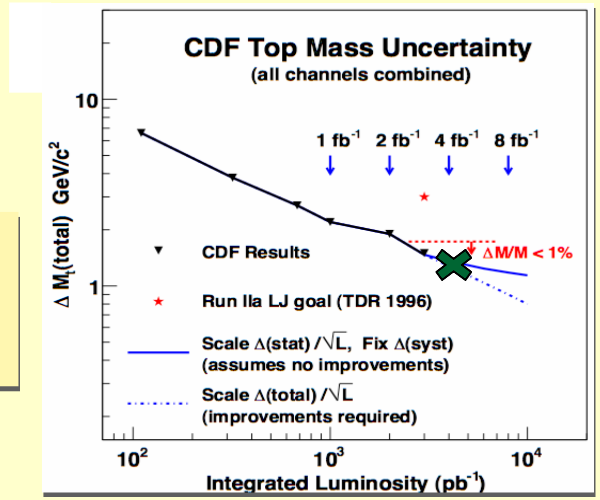


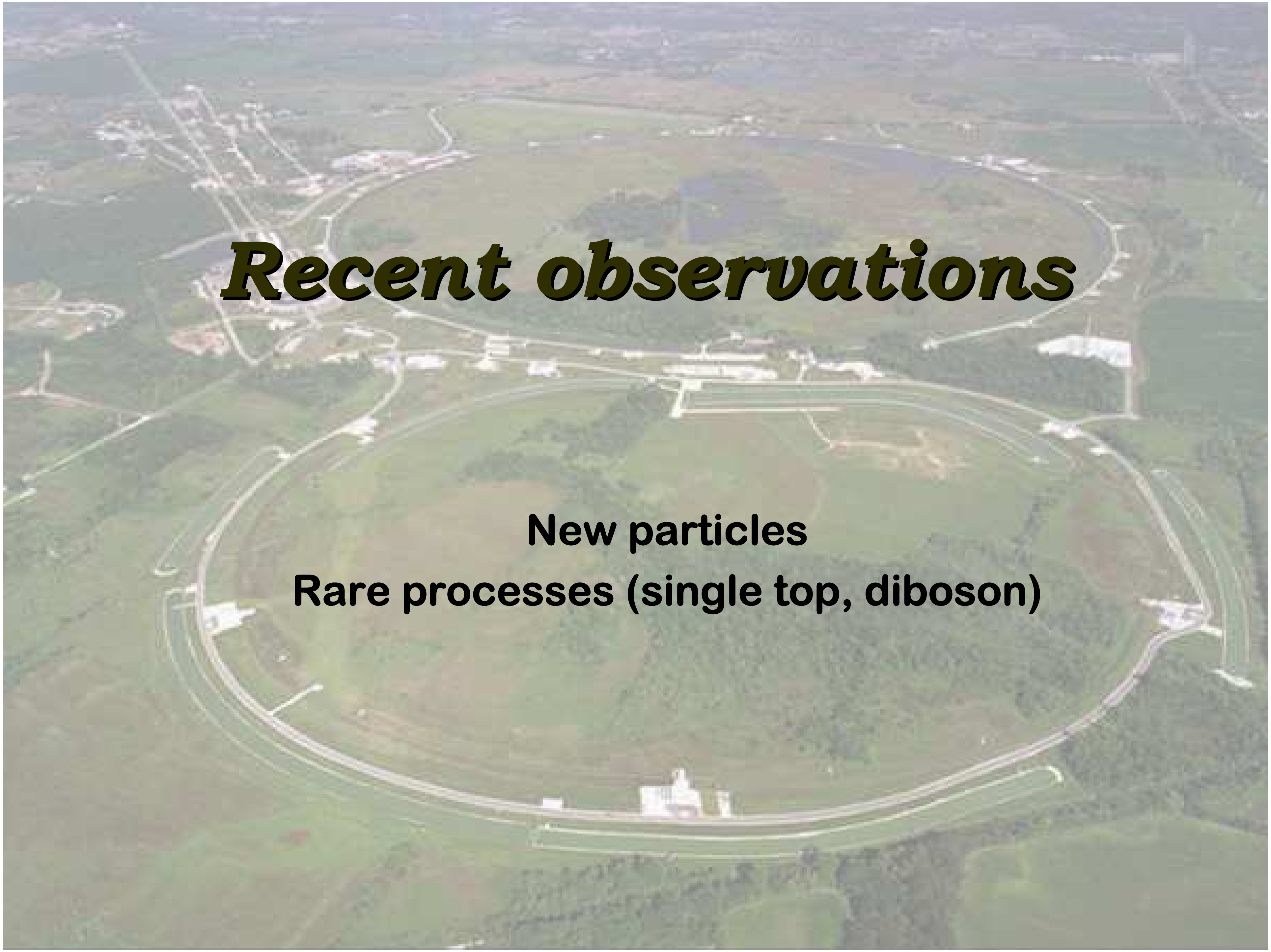


Combination with D0

Tevatron 2009:
M_{top} = 173.1 ± 1.3 GeV/c^2

At ~10 fb^{-1} top mass uncertainty expected below 1 GeV





Recent observations

New particles

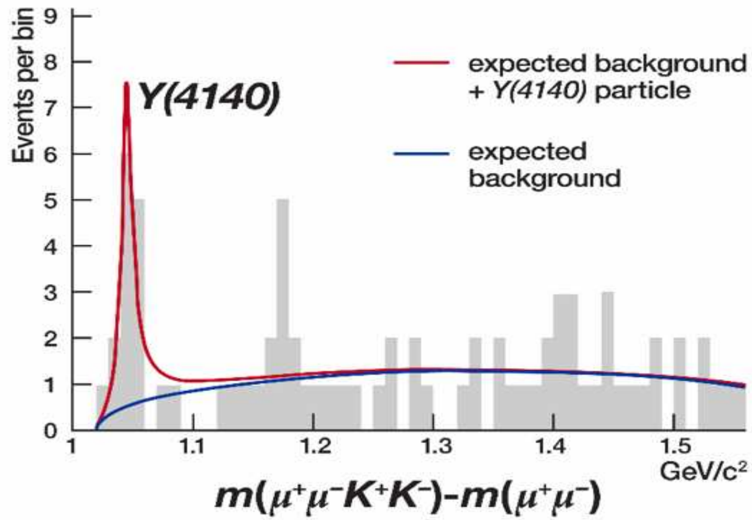
Rare processes (single top, diboson)

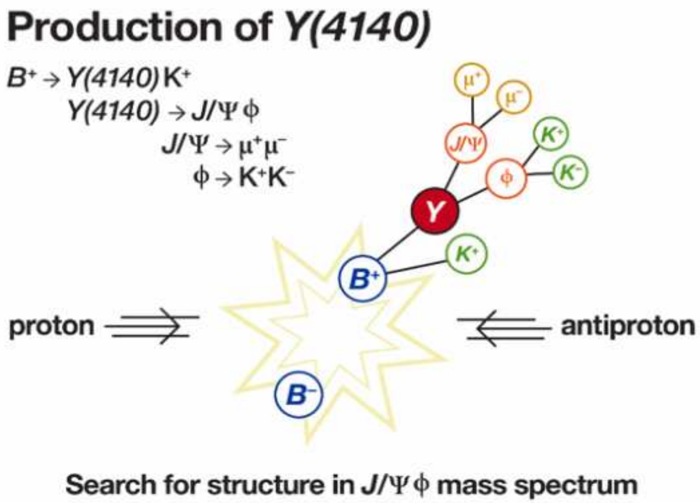
A new particle!

- **Reconstruct B^+ as $B^+ \rightarrow J/\psi\phi K^+$, with $J/\psi \rightarrow \mu^+\mu^-$ and $\phi \rightarrow K^+K^-$**
- **Search for structure in $J/\psi\phi$ mass spectrum inside B^+ mass window**

Yield =14±5

Δm = 1046.3± 2.9 (stat) MeV/c^2





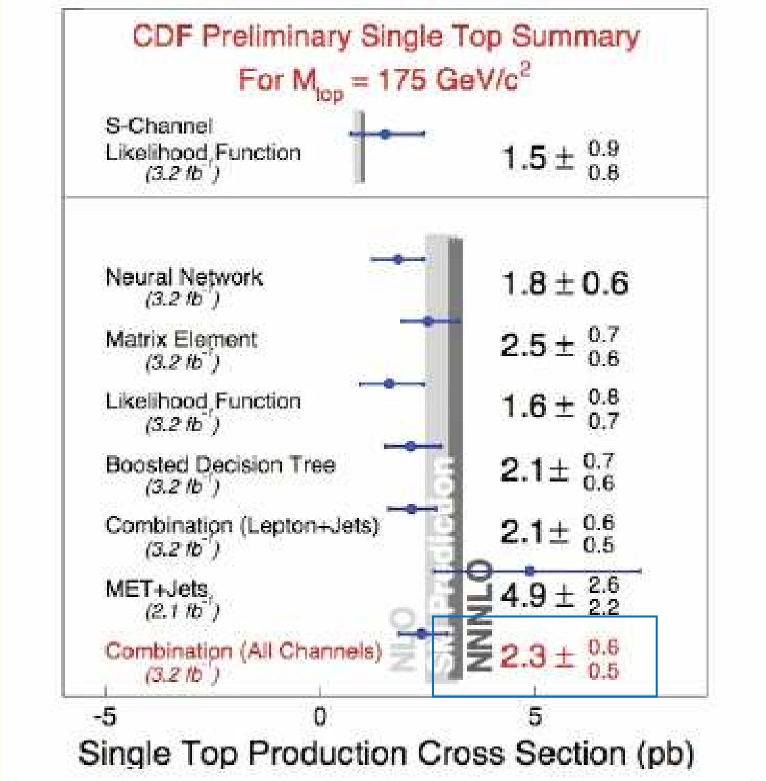
m = 4143.0 ± 2.9 (stat.) ± 1.2(syst.) MeV/c^2

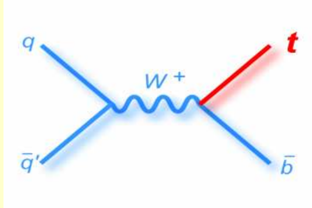
Γ = $11.7^{+8.3}_{-5.0}$ (stat.) ± 3.7(syst.) MeV/c^2

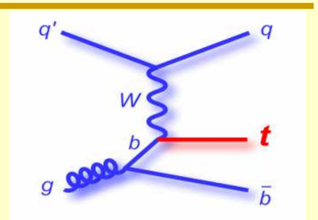
- **Significance: at least 3.8σ for most unphysical conservative background**
- **Width indicates a strong decay**

Single Top

EWK top production





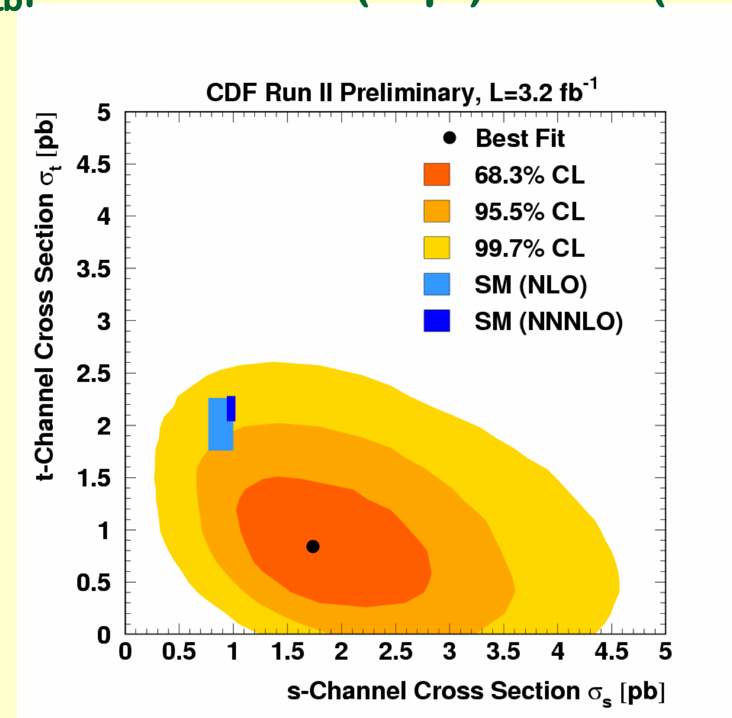


s-channel: σ = 1.12±0.05 pb   t-channel: σ = 2.34±0.13 pb

Measure $|V_{tb}|$ without assuming 3 generations

Sensitive to: 4th quark generation, anomalous couplings at Wtb vertex, new particles (H+, W'), FCNC.....

$|V_{tb}| = 0.91 \pm 0.11$ (exp.) ± 0.07 (theory)

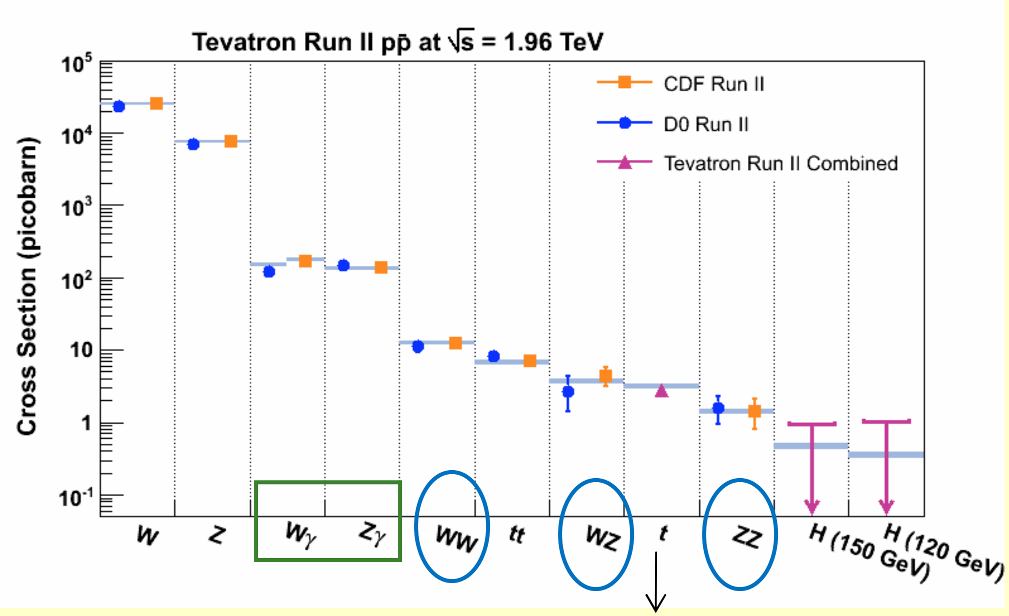


Observation in April 2009!

s+t channel = 2.76 +0.58 -0.47 pb

- **Test s vs t [new physics]**
- **Lifetime [new physics]**

Di Boson measurements

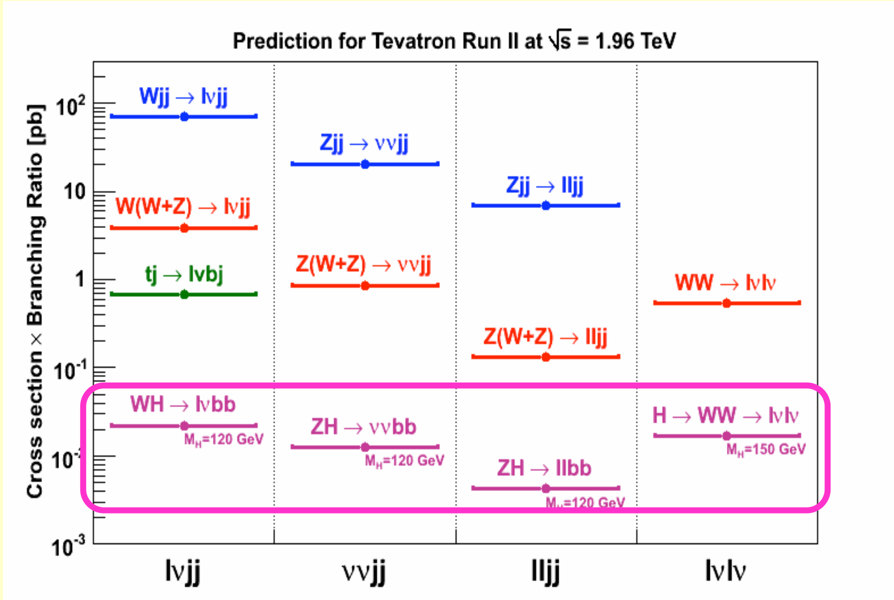


Single top

Before, observed "clean" channels (including lepton/photons)

Wγ → lνγ ; Zγ → ll γ;

WW → lνlν; WZ → lνll; ZZ → llll



Recently: more data and optimized tools allowed to explore channels with jets, MET (larger bkg and uncertainties):

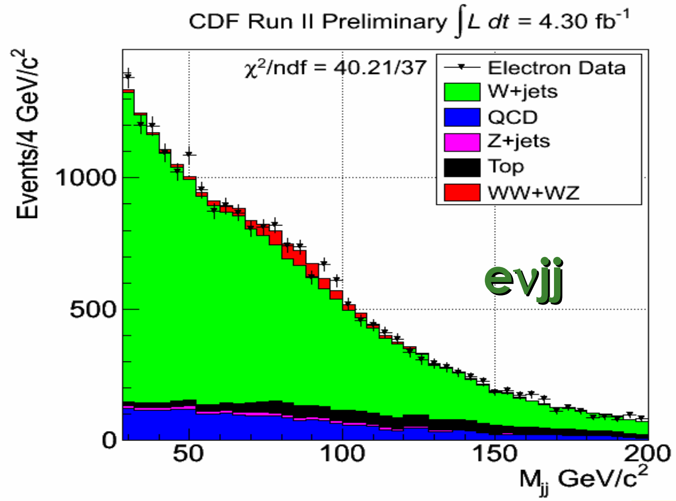
Zγ →ννγ;

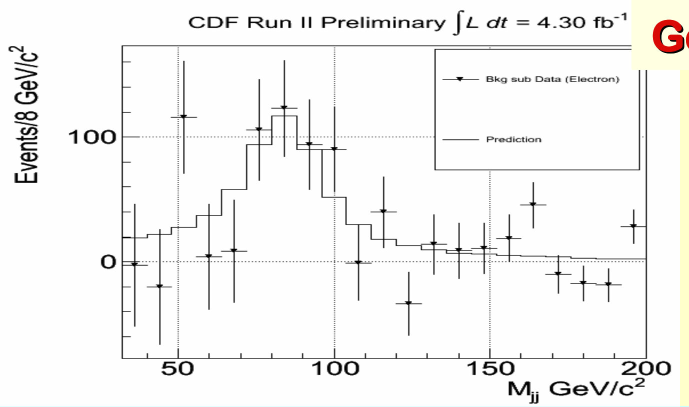
WW → lνjj; WZ → lνjj; ZZ → ννjj;

Important processes as backgrounds in the Higgs searches

(Some) Results on WW/WZ/ZZ

- $l\nu jj$ final states
- Binned Fit to the jj Invariant Mass



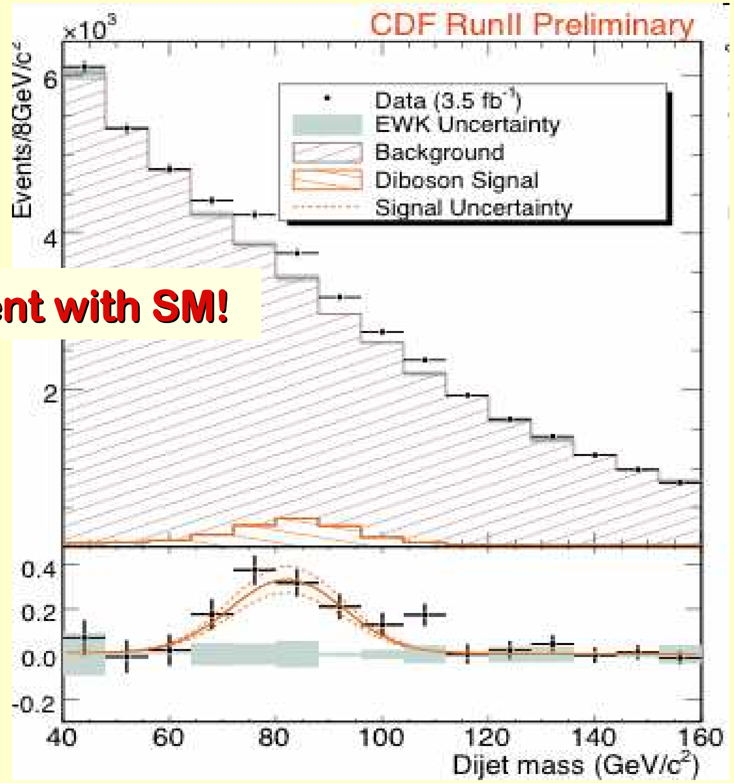


$\sigma_{ww/wz}$ = 18.1 ± 3.3(stat.) ± 2.5(syst.) pb

Signal Significance: 5.24 σ (5.09 Expected)

- Use MET+jets final states
  - QCD background well-modeled from data
  - use γ+jets to model non-QCD bkg
- Signal significance 5.3σ
- $\sigma_{ww/wz/zz}$ = 18.0 ± 2.8(stat) ± 2.4(sys) ± 1.1(lumi) pb

  (theory prediction: 16.8 ± 0.5 pb)



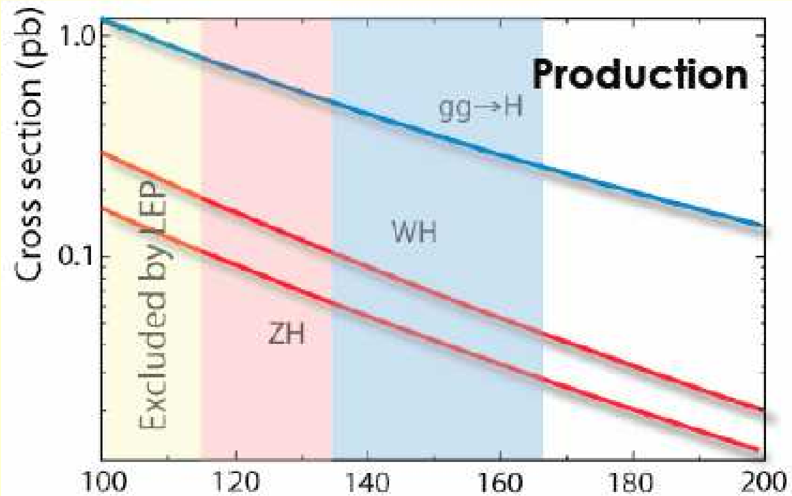
Good agreement with SM!

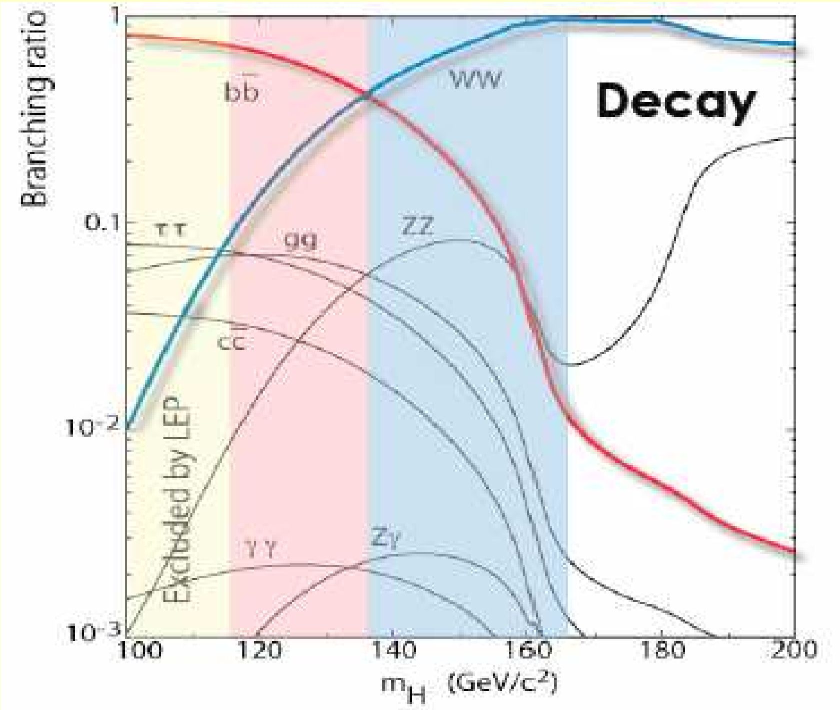
The SM Higgs Boson

To find the needle in the haystack, need to look everywhere possible….

Search strategy

- **Do them all!**
  - Direct production gg→H
    - Highest Production rate, Largest background
  - Associated production ZH/WH
    - Leptonic vector boson decay helps for triggering and signal extraction

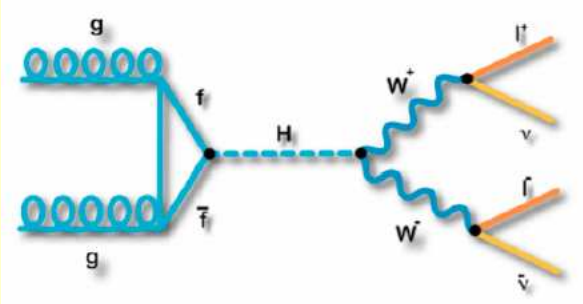


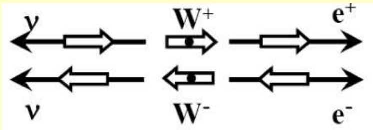


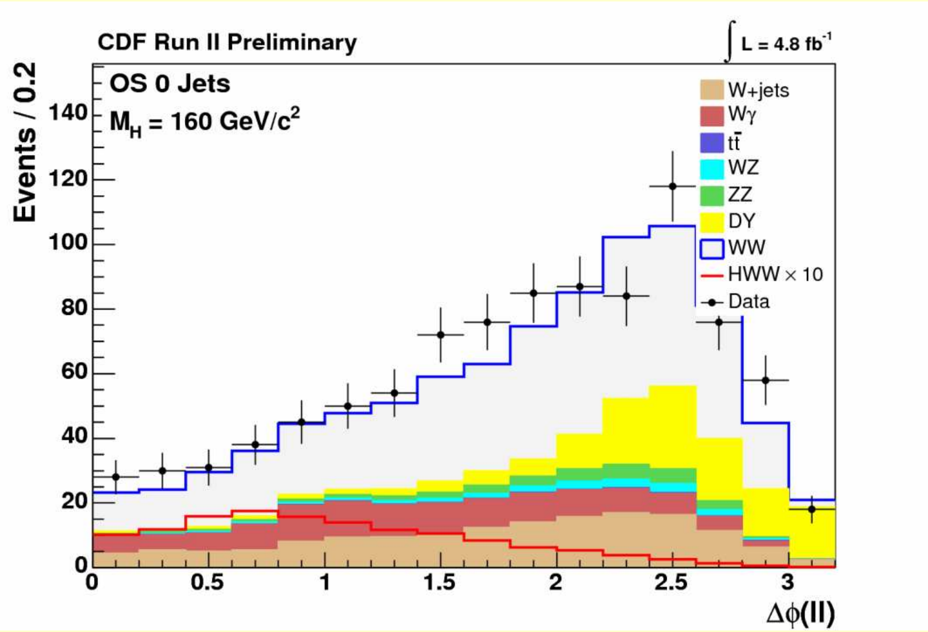
- **Low Mass (M_H<135 GeV/c^2)**
  - H→bb mode dominates
  - → WH→lνbb, ZH→ννbb , ZH→llbb VBF Production, VH→qqbb, H→ττ(with 2jets), H→γγ, WH->WWW, ttH
- **High Mass (135<M_H<200 GeV/c^2)**
  - H→WW mode dominates

Higgs→WW→lνlν*

- **Most sensitive channel for high mass Higgs**
- **Unbalanced transverse energy (MET) from ν**
- **2 leptons: e,μ,τ→e,μ (must have opposite signs)**
  - ***Key issue*: Maximizing lepton acceptance**
  - **Primary backgrounds: WW (and top in di-lepton decay channel)**
    - **Higgs is scalar ⇒ leptons travel same direction**
    - **In t-channel WW, W are polarized along the beam direction**







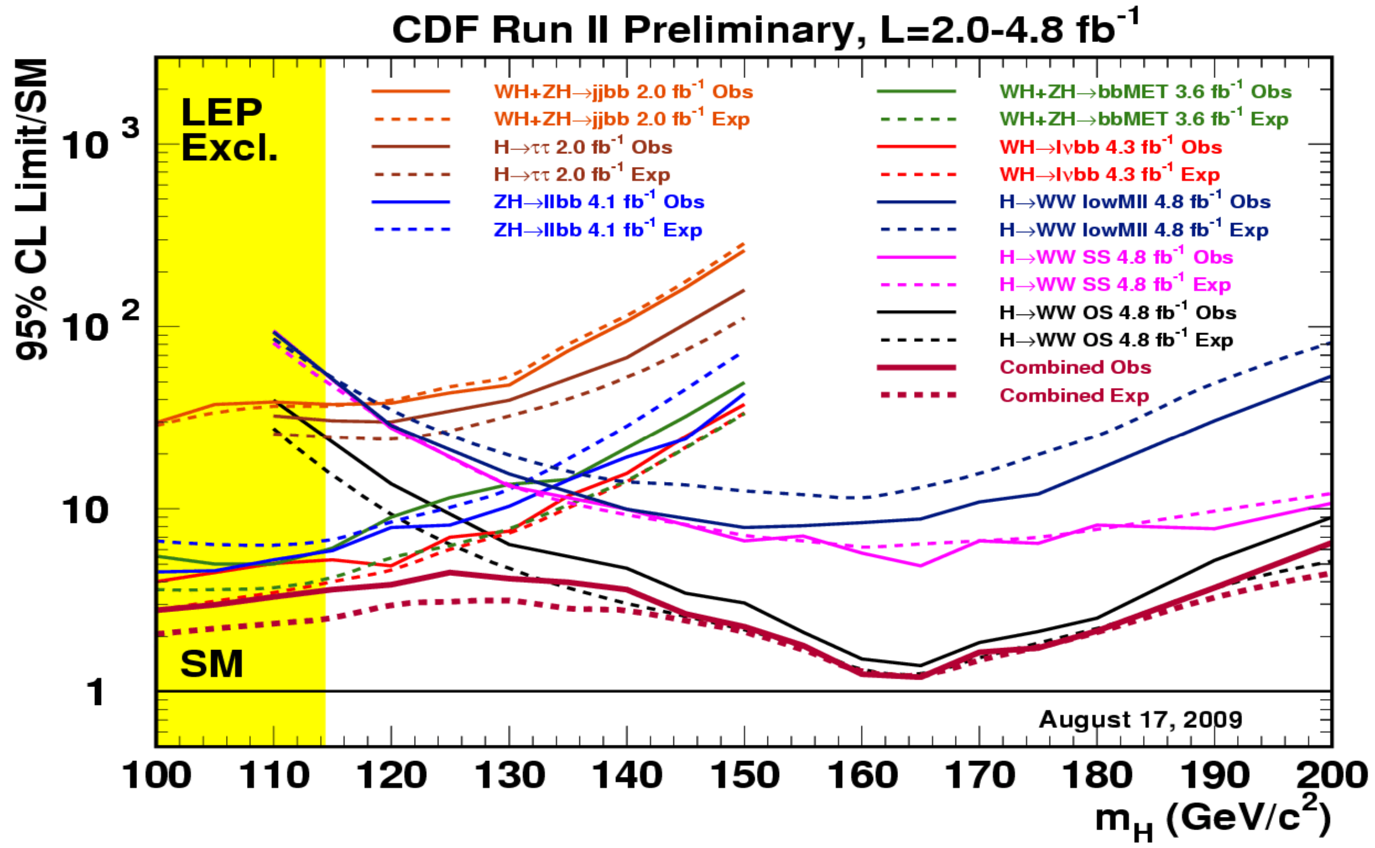
- **Use Matrix Element and Neural Network methods**

Results at m_H = 165GeV : 95%CL Limits/SM

L (fb^{-1})	Higgs Events	Exp.	Obs.
4.8	1.9±0.2	1.21	1.21

Approaching SM sensitivity!

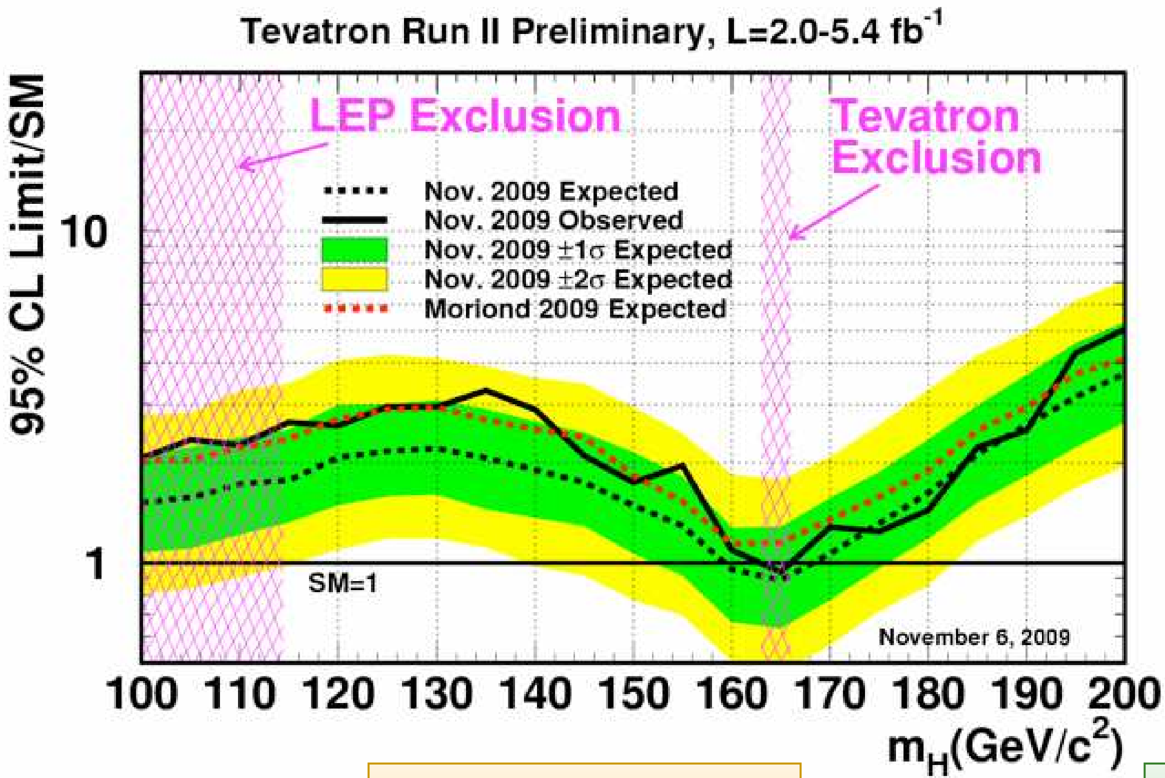
The CDF Analyses

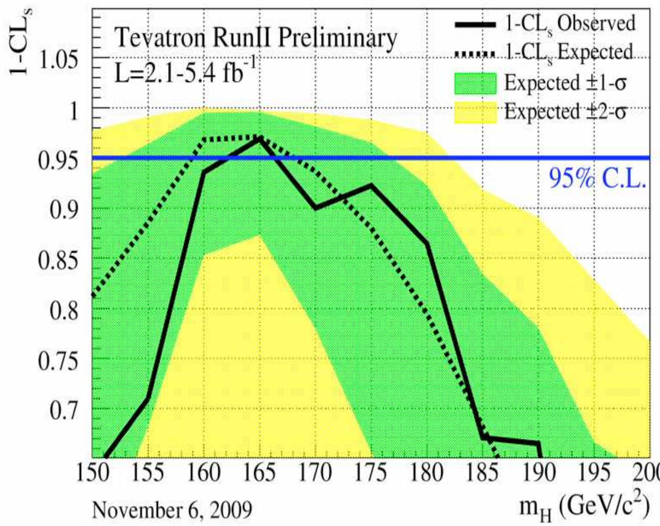


60 independent sources of systematic uncertainty at low mass
sources of uncertainty affect rates and shapes of signal and background predictions in correlated ways
Bin-by-bin MC stat. uncertainties included too.
30 sources at high mass

Current results

Tevatron combination for HCP 2009

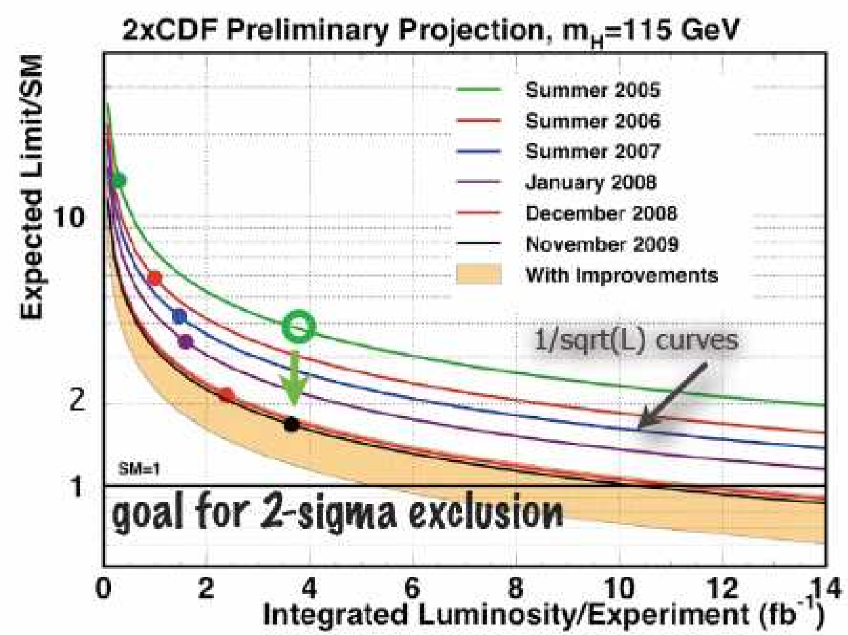


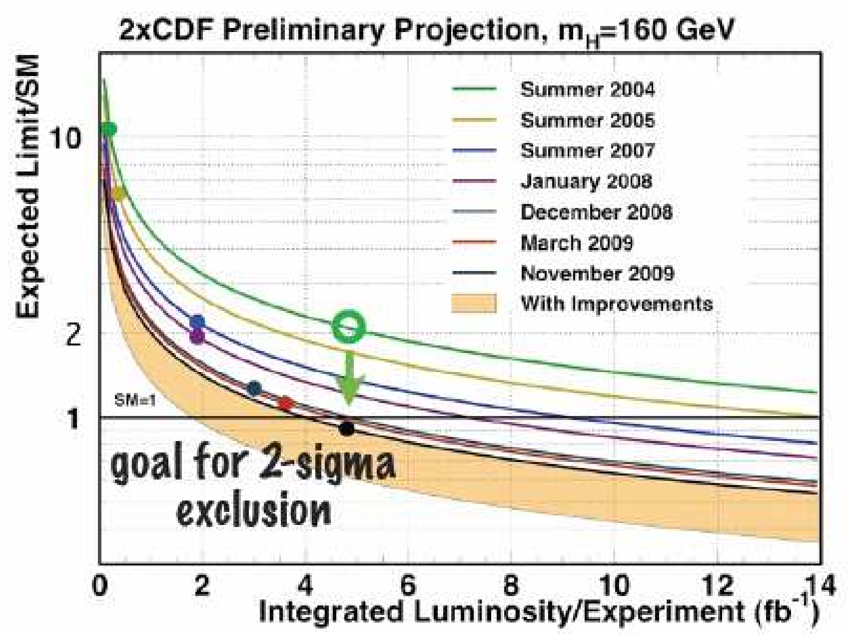


@m_H=115 GeV,
Obs: 2.70xSM
Exp: 1.78xSM

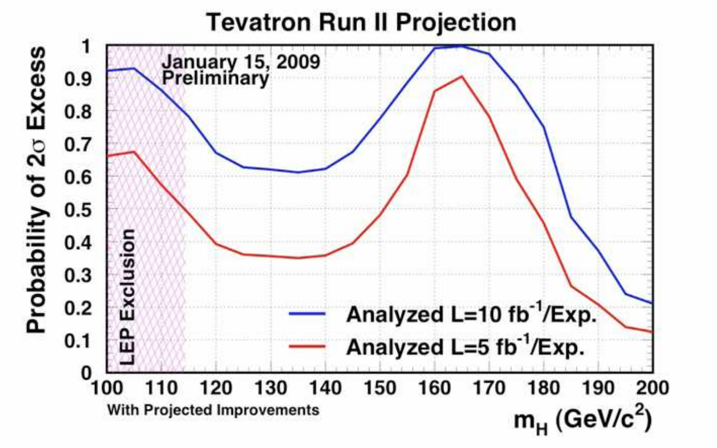
@m_H=165 GeV,
Obs: 0.94xSM
Exp: 0.89xSM

Tevatron Projections





Higgs reach with FY11 running and continued analysis improvement [bottom orange band]

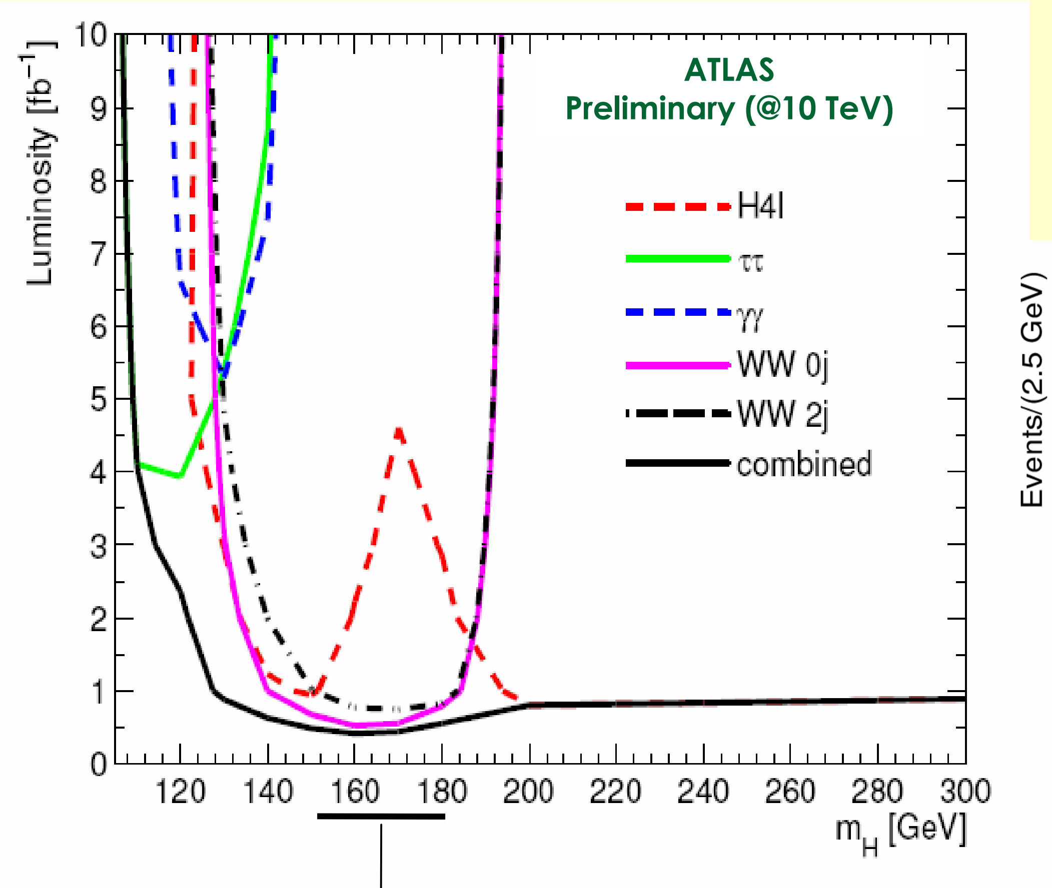


- **Expected improvement factors from 2007 analyses [x1.5 and x2.25]**

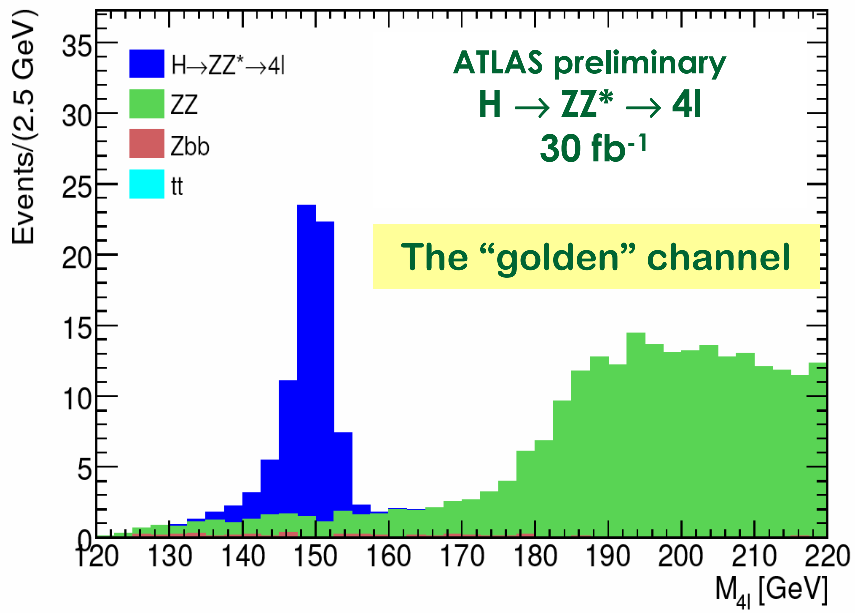
LHC prospects for SM Higgs

SM Higgs: a challenge!

Required luminosity for 95% C.L. exclusion



For low mass of ~120 GeV need to combine many channels with small S/B or low statistics ($H \to \gamma\gamma$, $H \to \tau\tau$, $H \to ZZ^* \to 4l$, $H \to WW^* \to l\upsilon l\upsilon$)



most promising in the range 150-180 GeV, again with $H \to WW^* \to l\upsilon l\upsilon$

→ Partially excluded at the Tevatron!

The Search for the unknown: BSM

Supersymmetry

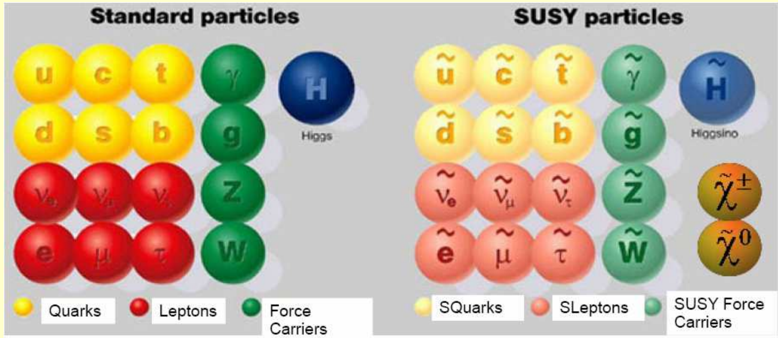
Extra-Dimension

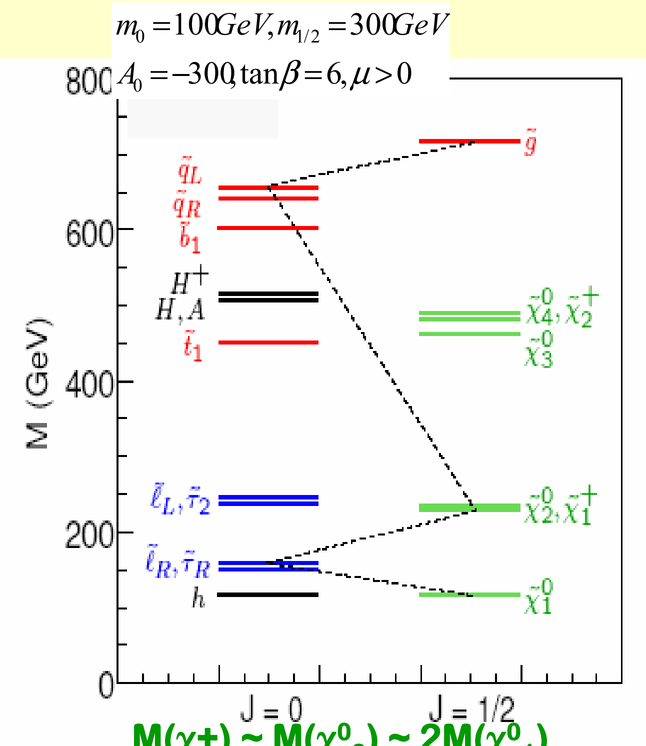
New Gauge Bosons

New physics in Top sector

Search for Supersymmetry

- New spin-based symmetry relating fermions and bosons
- Minimal SuperSymmetric SM(MSSM):
  - Mirror spectrum of particles
  - Enlarged Higgs sector: two doublets (5 physical states)





$M(\chi+) \sim M(\chi^0_2) \sim 2M(\chi^0_1)$

$M(\tilde{g}) \sim 3M(\chi+)$

- **Broad searches and strong exclusion limits (some world's best!)**

  mSUGRA:
  - charginos/neutralinos > 165 GeV
  - squarks > 390 GeV (all gluino masses)
  - gluinos > 280 GeV (all squark masses)

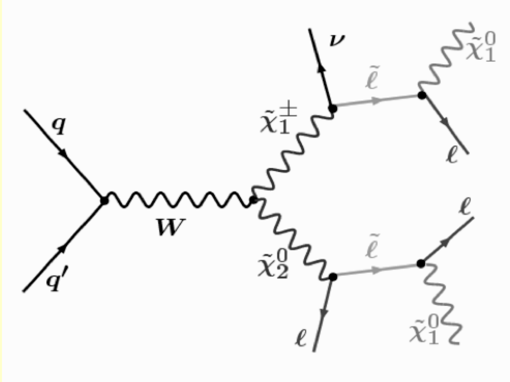
  GMSB:
  - Neutralinos > 150 GeV

  General MSSM
  - stop > 200 GeV
  - sbottom > 240 GeV
  - limits on tanβ & BSM higgs

  Miguel Vidal's PhD thesis!

$\tilde{\chi}^0_2 \tilde{\chi}^\pm_1$ production

"trileptons"

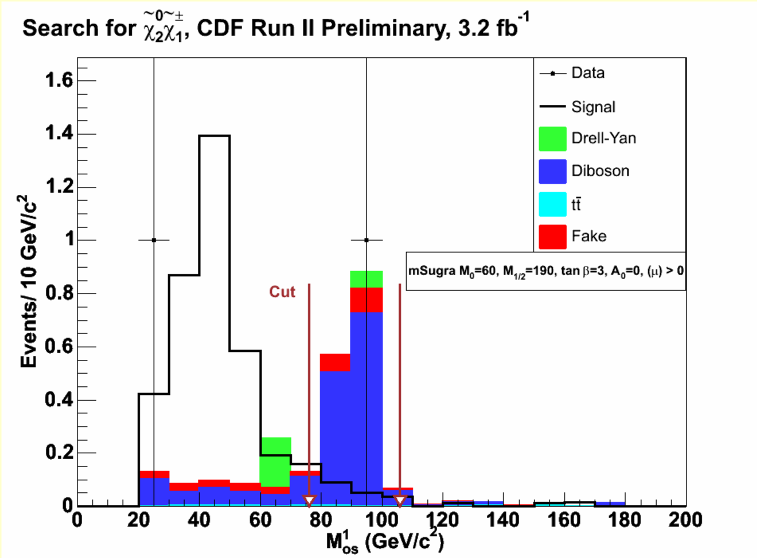


- Assume R_P conservation, $\tilde{\chi}^0_1$ is LSP
- Low cross sections (σ x Br < 0.5 pb)
- Very clean signature:
  - Missing E_T due to undetected ν, $\tilde{\chi}^0_1$
  - 3 isolated leptons

Golden mode @ Tevatron: very competitive with the LHC (low bkg, similar σ)

3.2 fb^{-1}

- 3 identified leptons (e,μ)
- 2 identified leptons + track (l)
- "Tight" and "loose" e,μ categories



Main backgrounds:

- WW, WZ, Drell-Yan, W+jets, ttbar

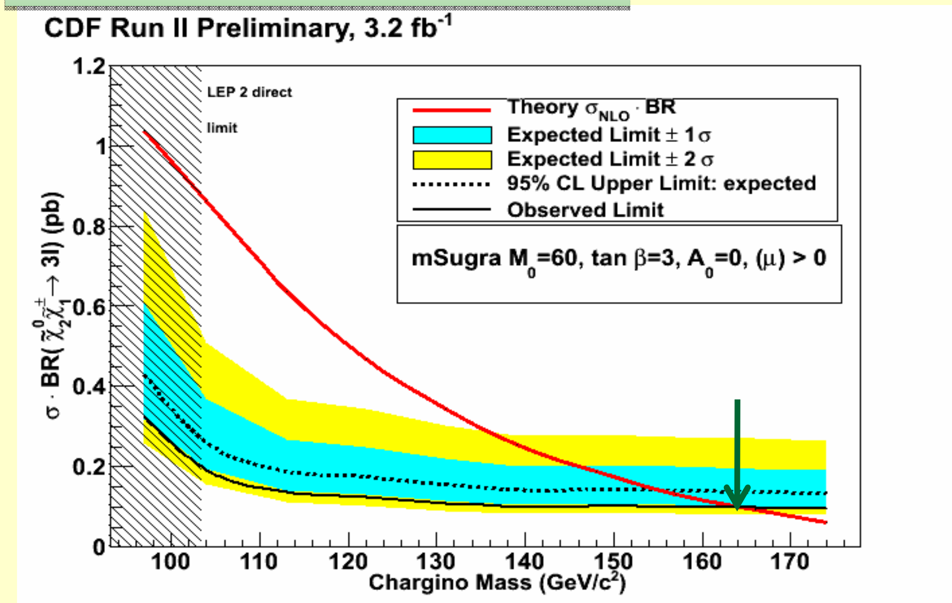
→ Rejection using kinematic selections on:
M_{l+l-}, N jets, Missing E_T, $\Delta\phi$ between leptons...

$\tilde{\chi}^0_2\,\tilde{\chi}^\pm_1$ results

Good agreement between data and SM prediction → set limit

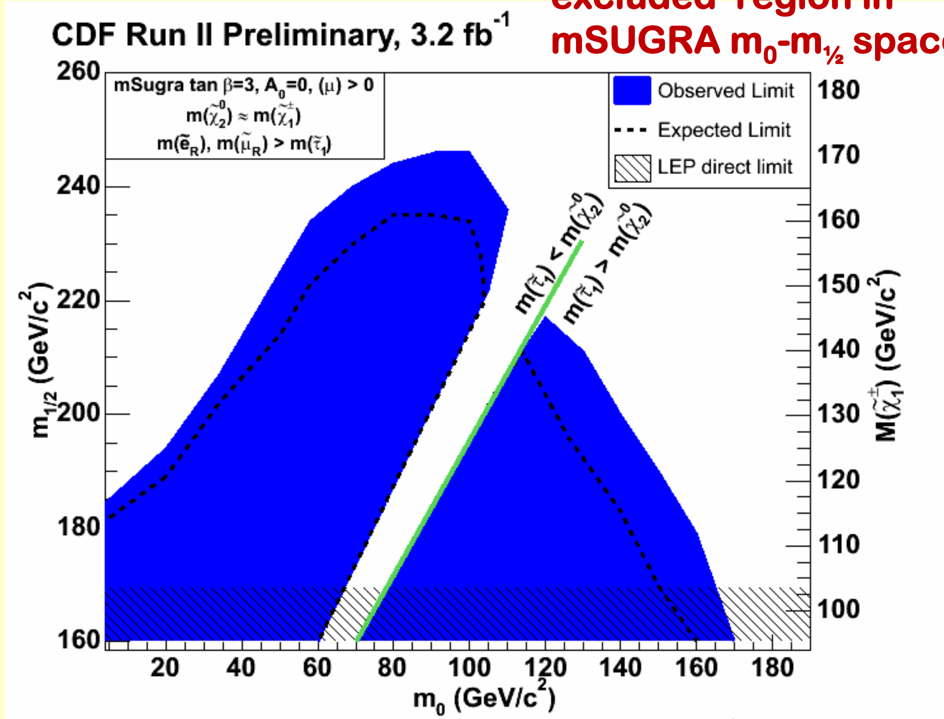
Channel	SM expected	Data
Trilepton	1.5 ± 0.2	1
Lepton+trk	9.4 ± 1.2	6

m_0 = 60 GeV, tan β=3, A_0=0, m>0



Excludes $m\tilde{\chi}^\pm_1 < 164$ (154 Exp.) GeV/c^2

excluded region in mSUGRA m_0-$m_{1/2}$ space



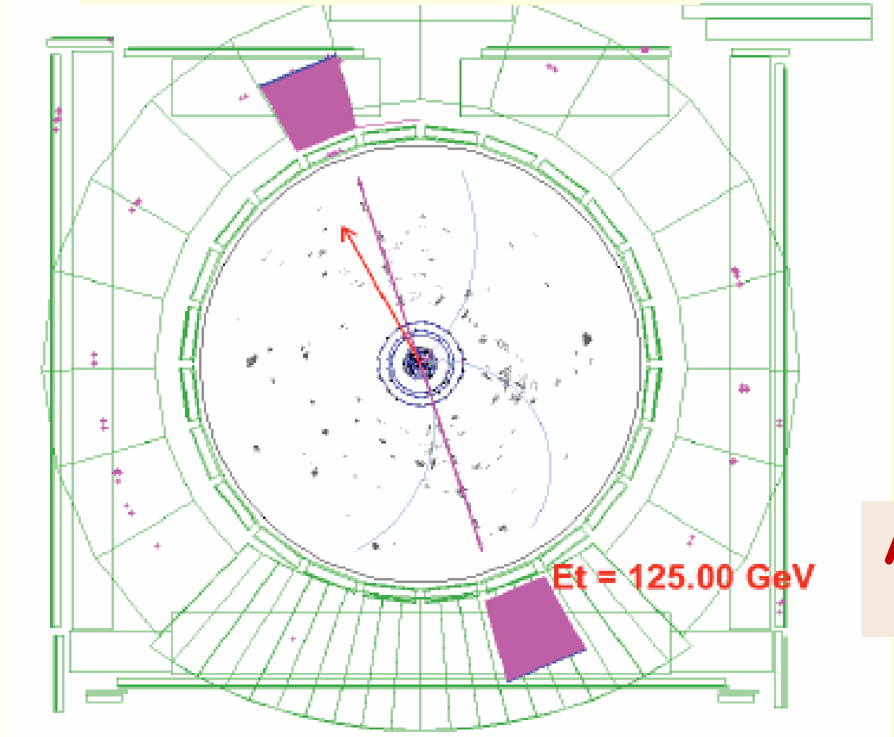
Limits depend on relative $\tilde{\chi}^0_2$-$\tilde{l}$ masses

- $m_{\tilde{\chi}2} > m_{\tilde{l}}$ increases BR to e/μ
- $m_{\tilde{\chi}2} \approx m_{\tilde{l}}$ reduces acceptance

Search for high mass resonances

- ***Di-lepton resonances*** **have a strong track record for discovery → J/ψ, ϒ, Z**
  - **Enlarge the possible final states looking also in *dijet, ditop or dibosons*!**
- **Construct the pair invariant mass and look for any excesses in the high mass spectrum**

Example of di-lepton events



Advantage

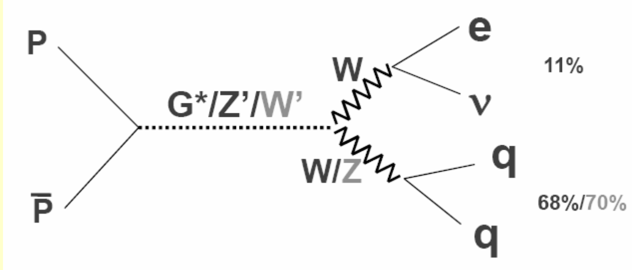
Sensitive to many BSM scenarios:
•Extra-Dimensions
•Extended SUSY-GUT groups
(SO(10),E6,E8…leading to additional gauge bosons, Z' and W')
•R-parity violating SUSY
and more…

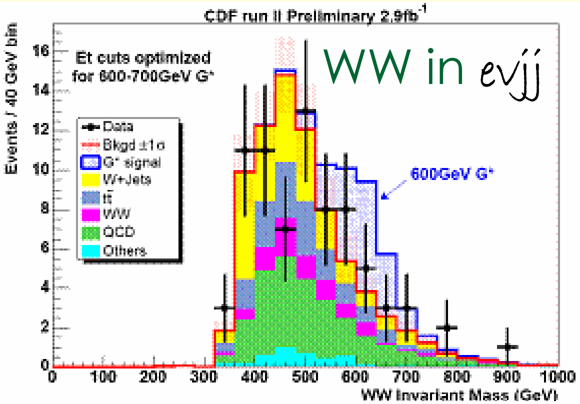
At CDF all modes have been explored!

Diboson resonances

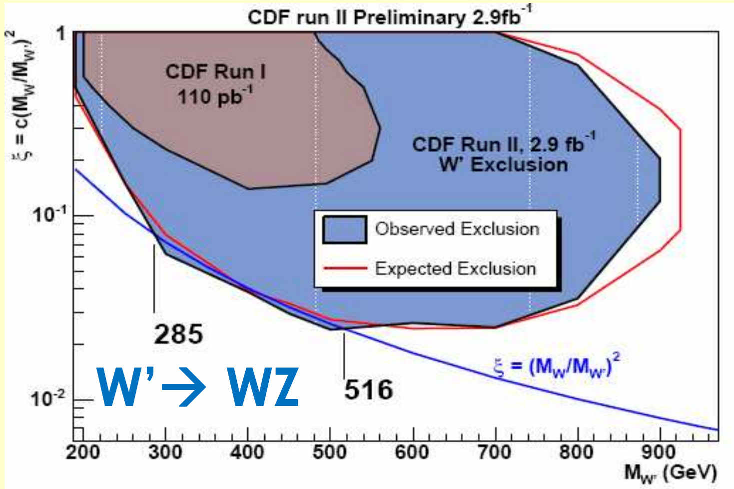
- **Clean final states + mass constraints**
- **Final state: electron+MET+ 2jets**
- **Interpretation given in different models, optimized for expected resonance mass**

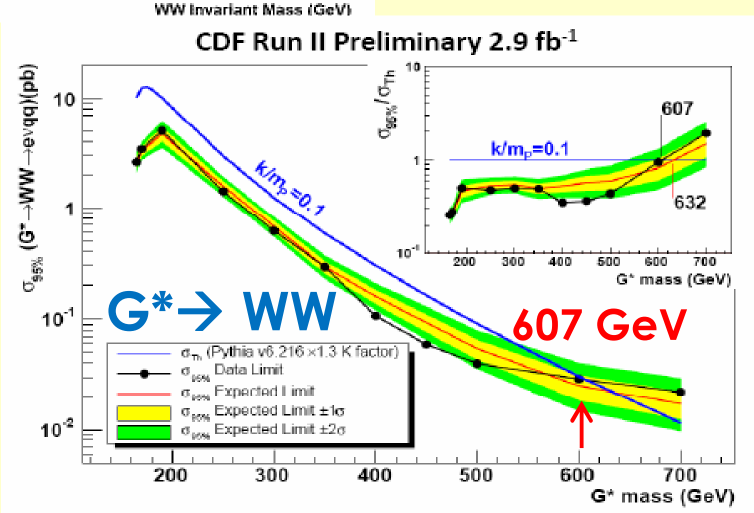
L=2.9 fb^{-1}

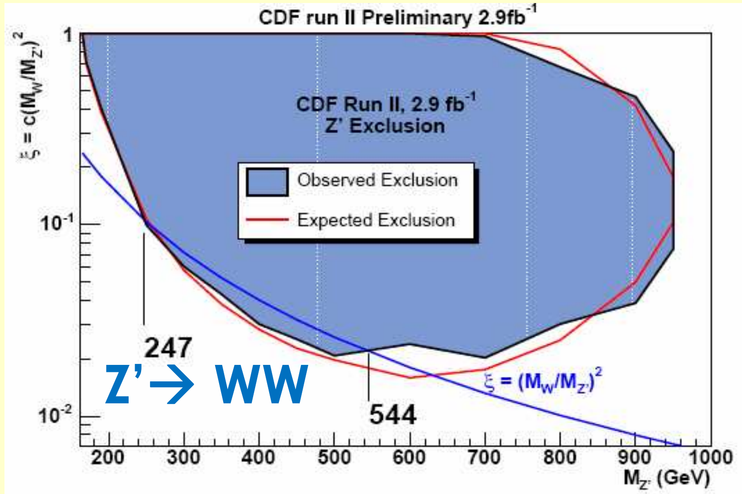




W→ νe with two solutions
Dijets in [65,95] (for WW)
Dijets in [70,105] (for WZ)
3-jet events also considered

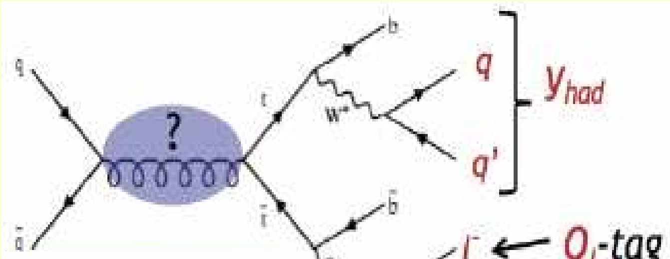




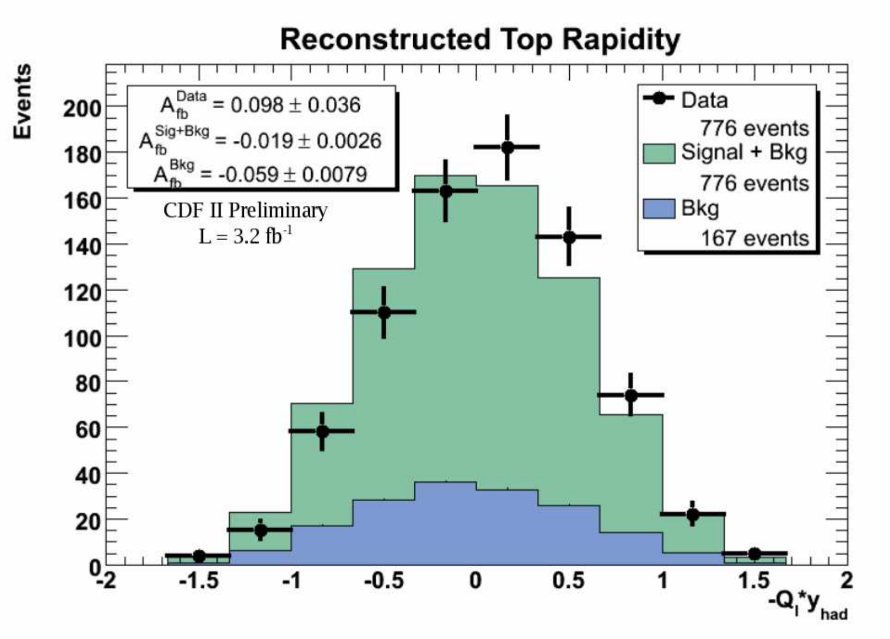


Top Forward-Backward Asymmetry

- **Top pair SM prediction → Symmetric at LO**
- **At NLO in ttbar rest frame, asymmetry due to interference of ME amplitudes for same final state → A_{fb} = 0.05 +/- 0.015** PRL 81,89 (1998)
- **Several BSM production mechanism predict an observable asymmetry (Z', Axigluons)**



$$A_{fb} = \frac{N_t(p) - N_t(\bar{p})}{N_t(p) + N_t(\bar{p})}$$



→ Lepton charge provides an information about top/anti-top

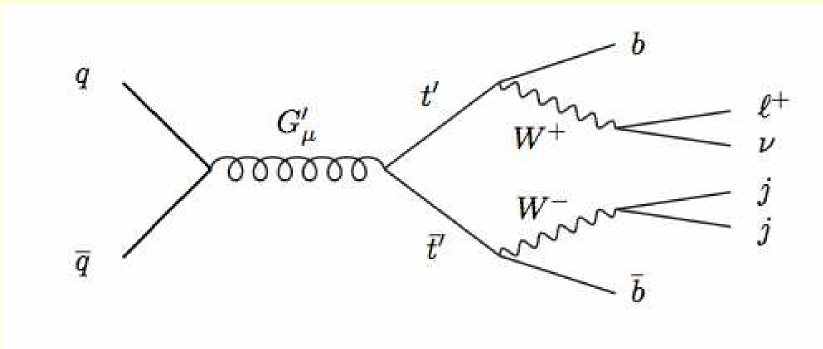
→ Kinematic event reconstruction similar to top mass analyses

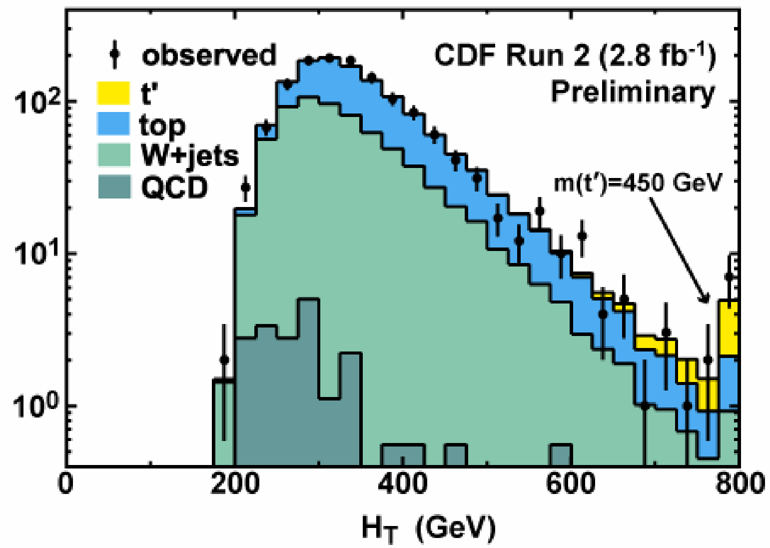
→ Use the system of jets from hadronically decaying top quark

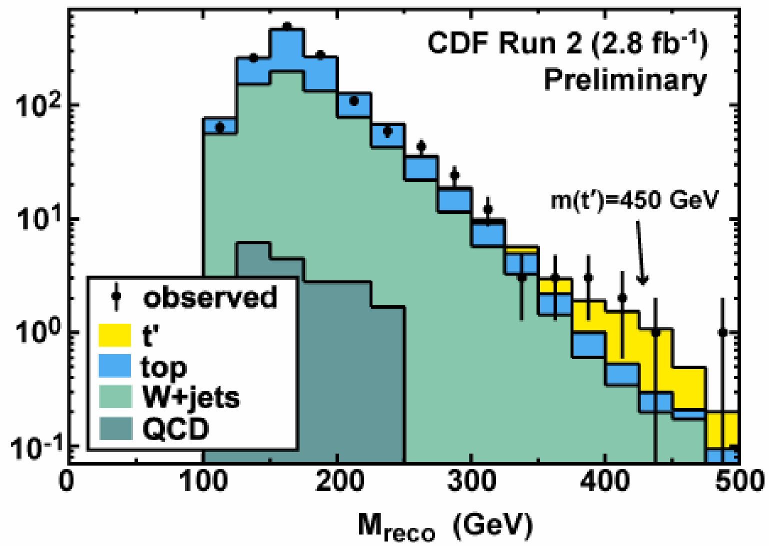
A_{fb} = 19.3% ±6.5% (stat) ± 2.4% (syst)

Search for t'

- Signal Region: Lepton + >= 4 jets
- Use H_T – scalar sum of all transverse momenta
- Perform mass reconstruction similar to top mass
- Possible new physics mechanism:



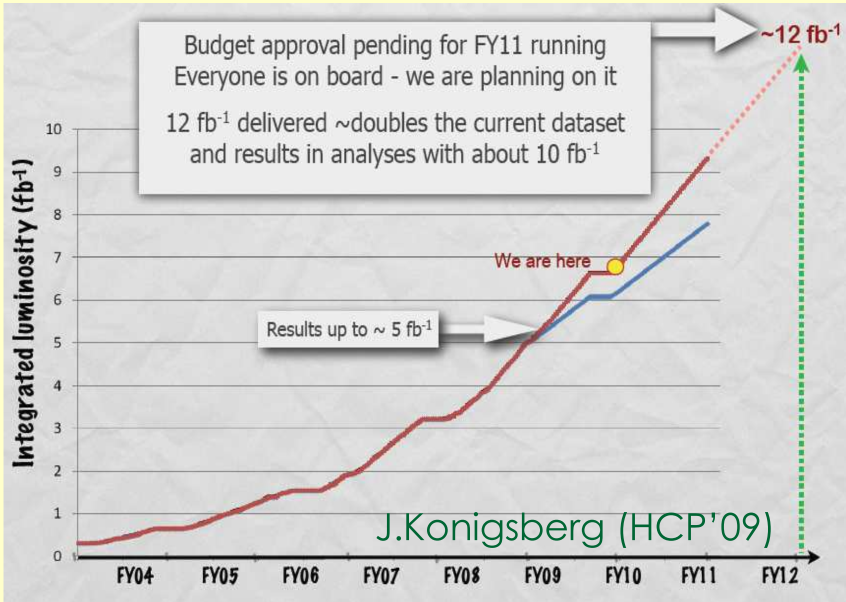




Conclusions and remarks

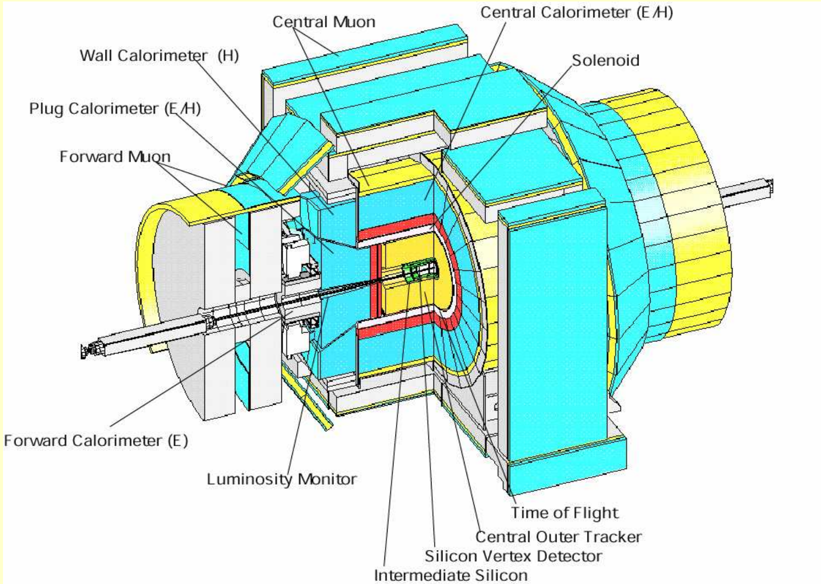
- The CDF physics program continues to be remarkably successful:
  - Continuously on-going updates of existing results
  - Use more sophisticated techniques, more data, new ideas!
- No evidence of new physics yet, but interesting hints
- Exciting potential, especially in the Higgs sector
- A lot of more data ready to be analyzed…

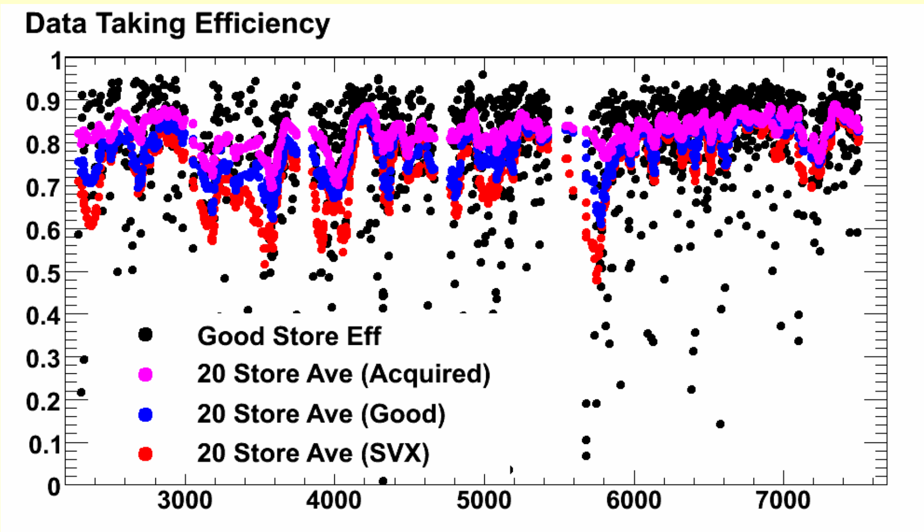
With LHC impressive start up and Tevatron performing at its best, physics at hadron colliders will be a lot of fun next years ☺



Back-up

The CDF experiment





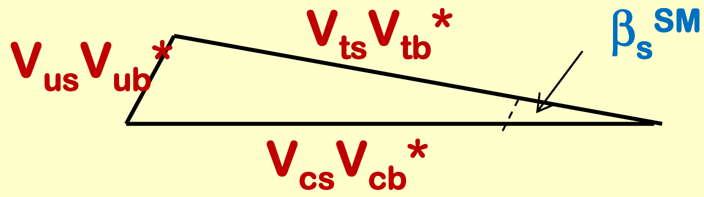
Multi-purpose experiment

- **Silicon detectors**
  - **Precision vertex detection**
  - **Displaced decays: heavy-flavour tagging**
- **Drift chamber (in B = 1.4 T)**
  - **Charged particles up to $\eta \sim 1.5 - 2$**
  - **High efficiency and excellent resolution**
- **Sampling calorimeters**
  - **4π coverage (fundamental for E_T)**
  - **Jets and electron reconstruction**
- **Muon detectors**
  - **Covering up to $\eta \sim 1.5$**

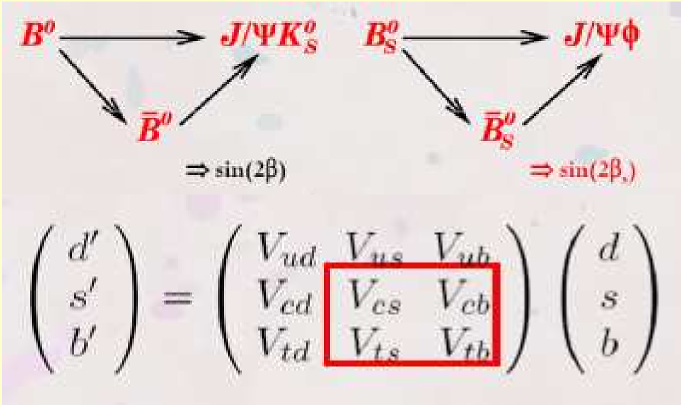
record: 85-90 % of delivered luminosity

~ 7 fb^{-1} collected data per experiment

CPV in $B_s \rightarrow J/\varphi\ \phi$



B_s Mass eigenstates: B_s^L, B_s^H



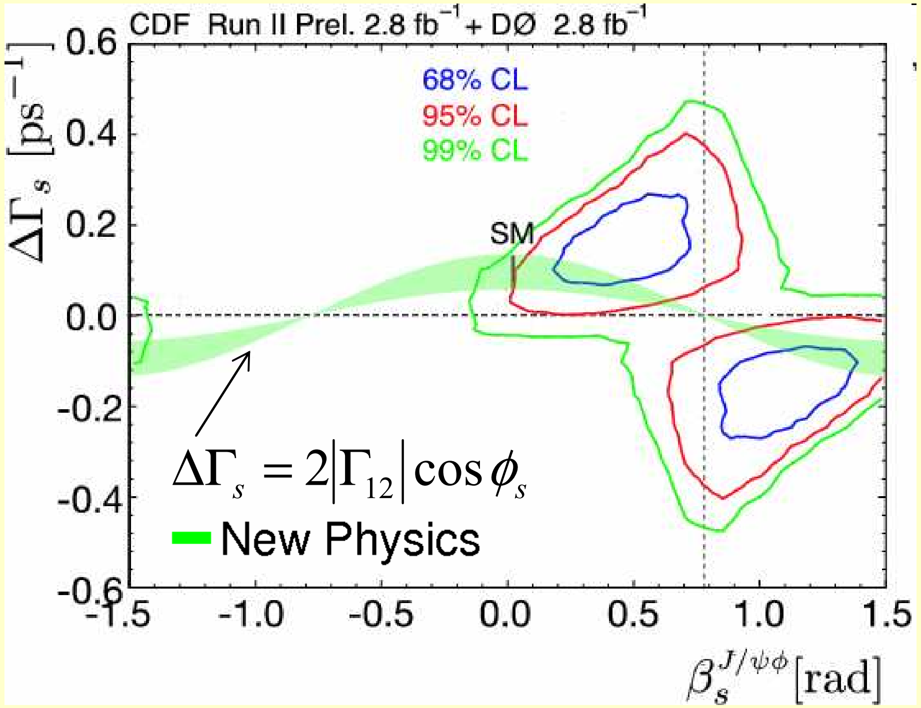
CP violating phases

$$\beta_s \equiv \arg(-V_{ts}V_{tb}^* / V_{cs}V_{cb}^*) \overset{SM}{\approx} 0.02$$

$$\phi_s = \arg(M_{12} / \Gamma_{12}) \overset{SM}{\approx} 0.004$$

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H = 2|\Gamma_{12}|\cos\phi_s$$

φ_s^{NP} contributes to both φ_s and β_s
$\rightarrow 2\beta_s = -2\beta_s^{SM} + \varphi_s^{NP}$
if φ_s^{NP} dominates, $2\beta_s = \varphi_s^{NP}$



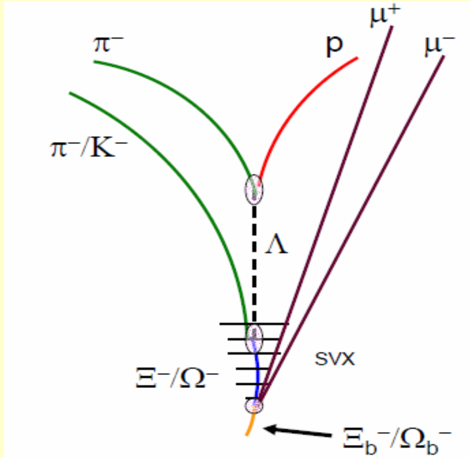
- **Combination of D0 and CDF results on $\Delta\Gamma_s$ and CP-violating phase $\beta_s^{J/\psi\varphi}$**

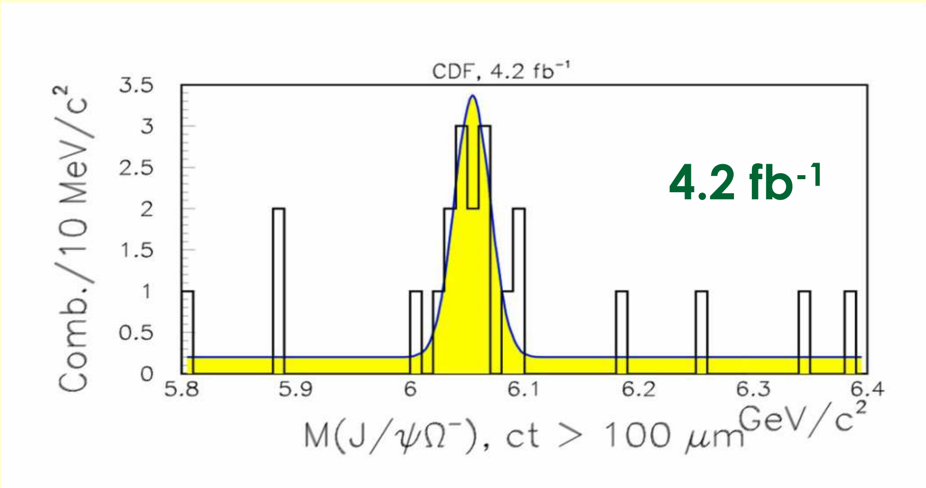
$\beta_s^{J/\psi\varphi}$ within [0.27, 0.59] U [0.97, 1.30] at 68% C.L.
p-value(SM) = 3.4% (~2.12 σ)

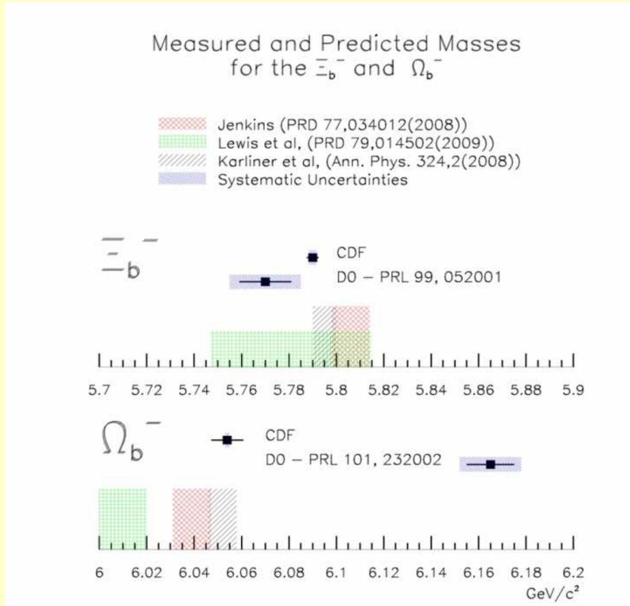
New heavy baryons

- **2009: Observation of the Ω^-_b and measurement of the properties of the Ξ^-_b (2007) and Ω^-_b**

→ **production of the Ω^-_b through the decay chain $\Omega^-_b \to J/\psi\ \Omega^-$, $J/\psi \to \mu^+\mu^-$, $\Omega^- \to \Lambda K^-$, $\Lambda \to p\ \pi^-$, measure mass and lifetime (NEW!)**





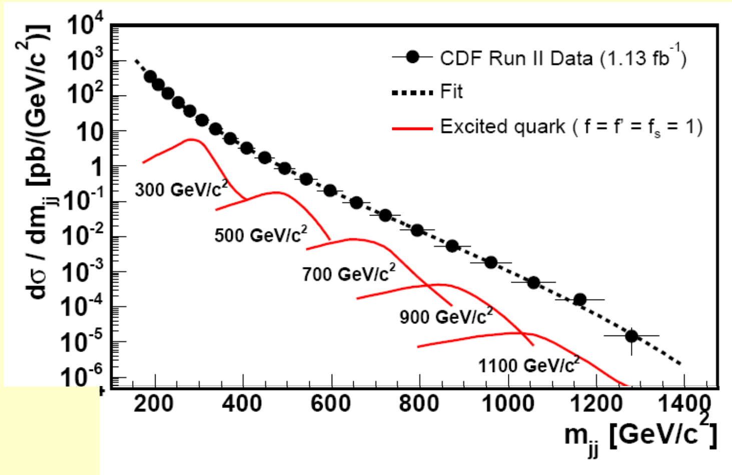


	Mass (MeV/c²)	Lifetime (ps)
Ξ_b^-	$5790.9 \pm 2.6 \pm 0.8$	$1.56^{+0.27}_{-0.25} \pm 0.02$
Ω_b^-	$6054.4 \pm 6.8 \pm 0.9$	$1.13^{+0.53}_{-0.40} \pm 0.02$

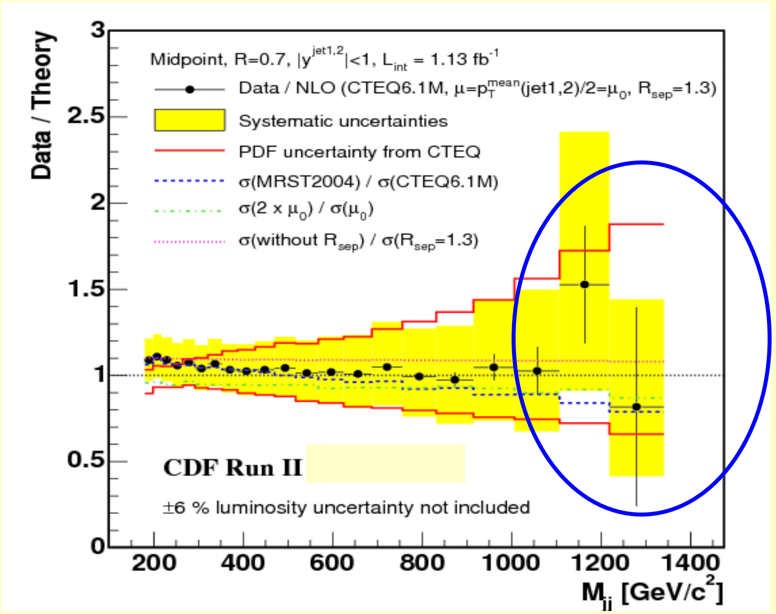
Puzzle: **mass measurement of Ω^-_b inconsistent with the only previous observation of this particle (D0)**

Dijet Mass Spectrum

- **Test pQCD predictions**
- **Sensitive to new particles decaying into dijets: excited quarks, heavy gluons, techni-ρ, etc**

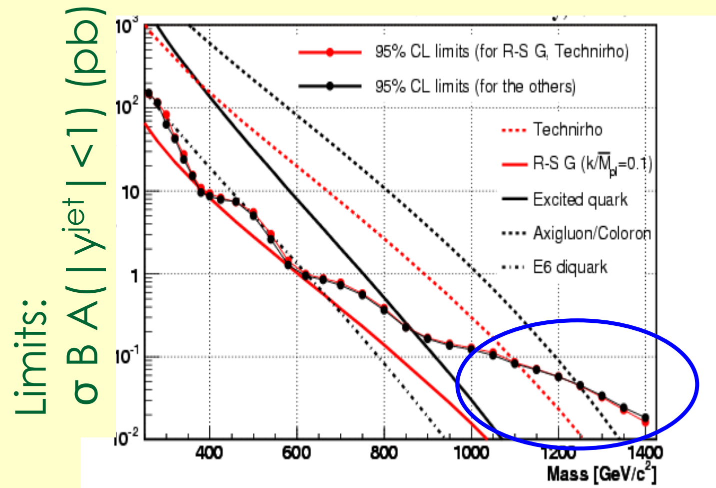


Dijets with jets $|y^{jet}|<1$



Mass reach up to ~ 1.2 TeV/c^2

- **Consistent with QCD - no resonance**
- **Most stringent limits on many new heavy particles**



Top production: LHC vs Tevatron

- σ(W) increases by factor of 10 but σ (W+4 jets) is a factor 100, just like σ(ttbar)

** note that these numbers consider 10 TeV as c.o.m.

W+Multijet rates

σxB(W→eν)[pb]	N jet=1	N jet=2	N jet=3	N jet=4	N jet=5	N jet=6
LHC	3400	1130	340	100	28	7
Tevatron	230	37	5.7	0.75	0.08	0.009

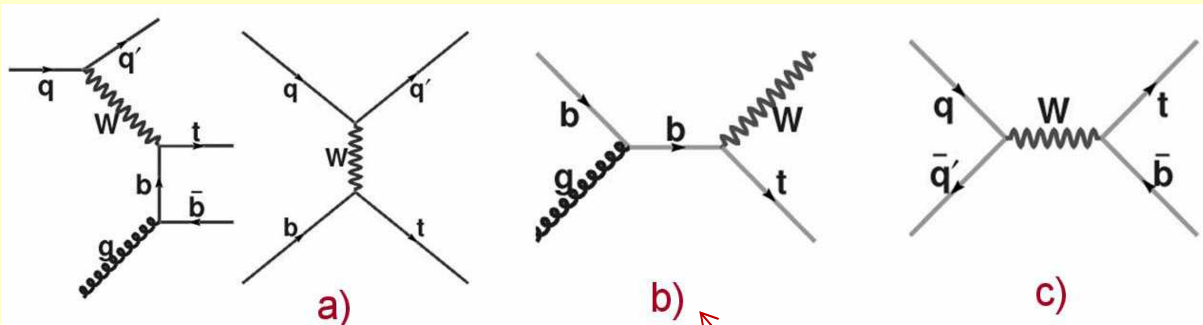
E_T(jets) > 20 GeV , $|\eta|$<2.5 , ΔR>0.7

From M. Mangano

3400/230 = 15

100/0.75 = 130

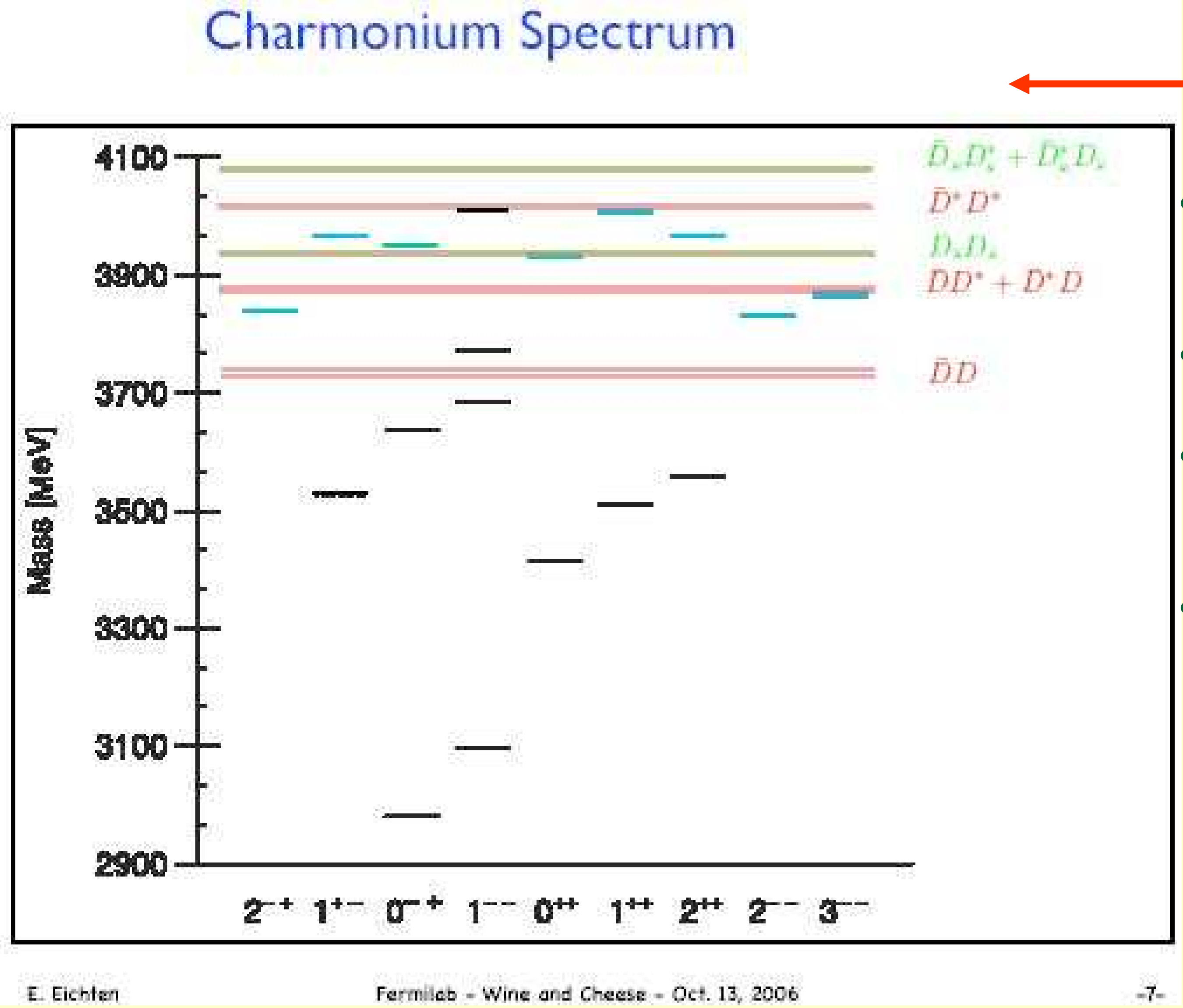
- On the other hand, single top will be easier at the LHC



t-channel tW s-channel

negligible at the Tevatron!

What is it?



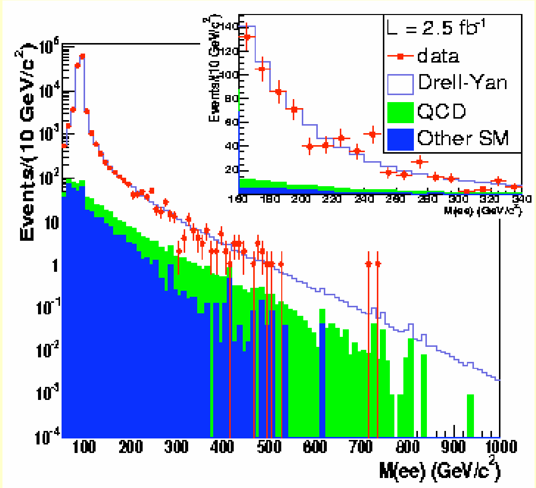
Y(4140)

- Well above charm pair threshold
- Expect tiny BF to $J/\psi\phi$
- Does not fit into charmonium
- Close $J/\psi\phi$ threshold like Y(3940)

arXiv:0903.2529[hep-ph]
molecular?

Di-lepton resonances

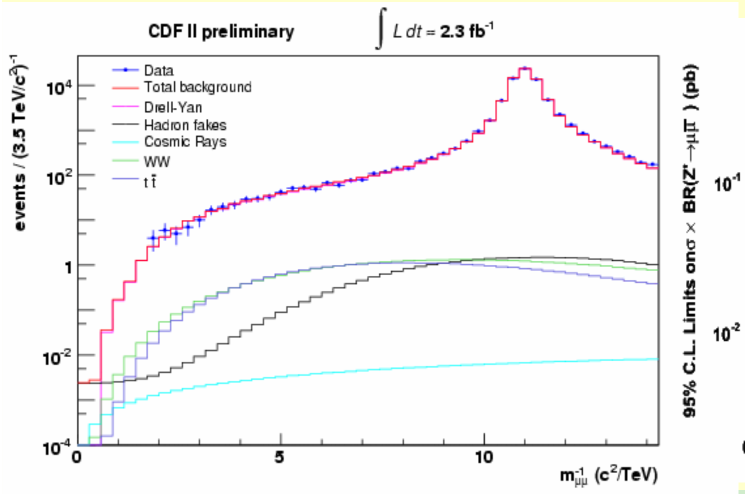
- **Dielectron**
  - Central ($|\eta_{1,2}|$<1) or Central-Forward ($|\eta|$<2) e^+e^- pair with E_T>25 GeV
  - Resonance search performed in mass range 150-1000 GeV/c^2
  - No evidence for NP



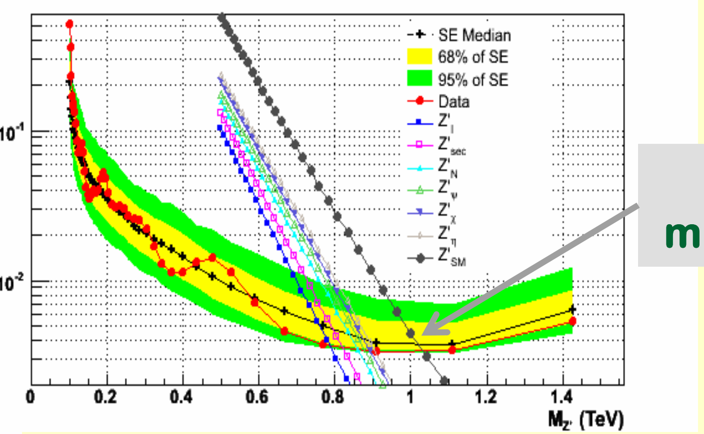
Exclude:
M(G*) < 850 GeV/c^2 for k/M_{Pl}=0.1

SM-like Z'>966 GeV/c^2

- **Dimuon: Search in 1/$m_{\mu\mu}$ (constant detector resolution)**



95% C.L. limits in different models



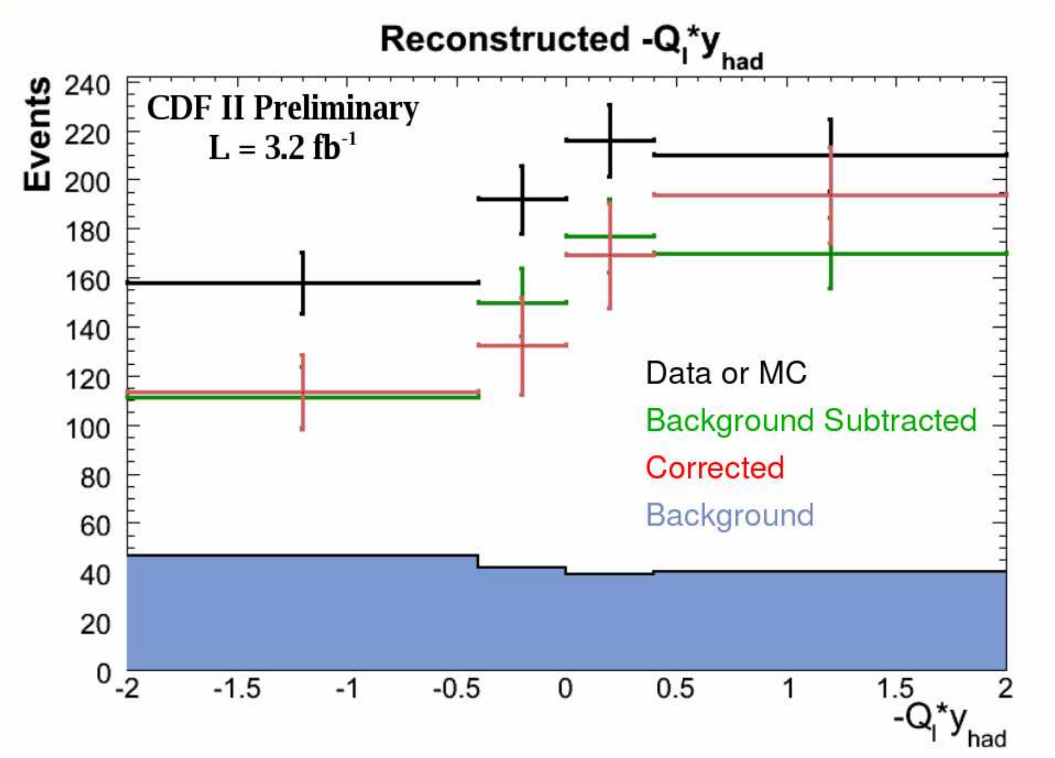
Sneutrino(spin 0)
m > 397 – 866 GeV/c^2

Z'(spin 1)
m > 1.03 TeV/c^2 (SM-like)

RS G*(spin 2)
m > 293 – 921 GeV/c^2

Update with 5 fb^{-1} and alternative method will be ready soon!

Forward/Backward Asymmetry



Systematic uncertainty includes various assumptions about the shape of –Ql-Y_{had} distribution

- **Employ an unfolding procedure to go from reconstructed to parton level:**

  1. Subtract the background

  2. Unfold for bin-to-bin migration effects due to detector resolution and event selection effects