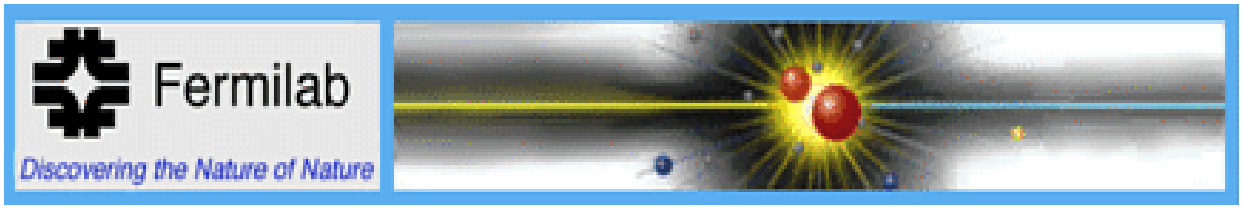
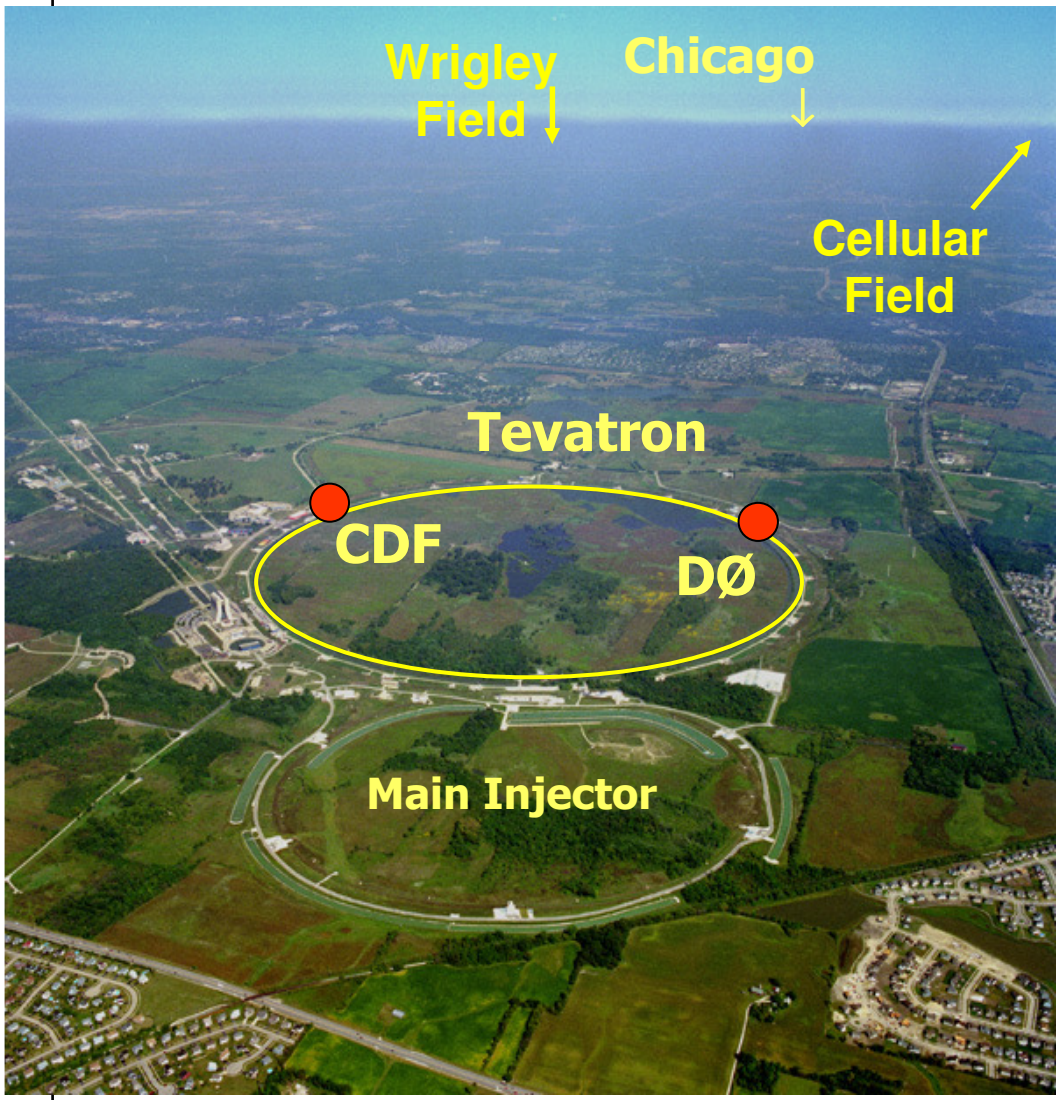
Recent Results from CDF



Giorgio Chiarelli
Istituto Nazionale di Fisica Nucleare
Sezione di Pisa

Tevatron



Highest energy collider

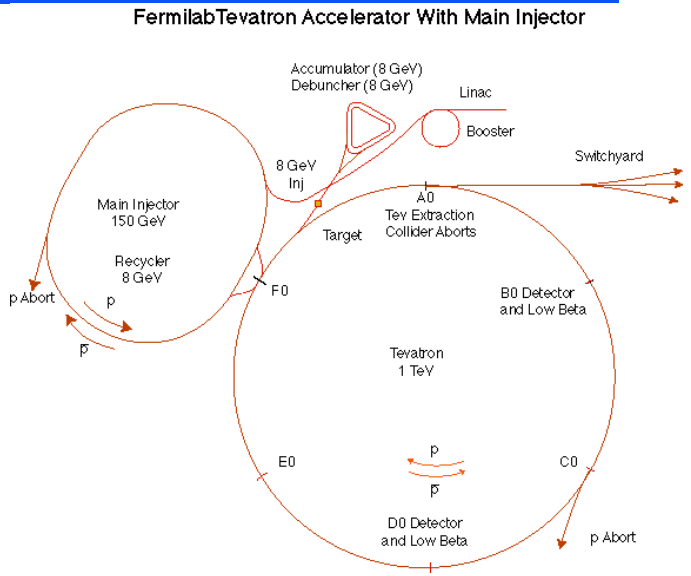
- Proton on Pbars at 1.96 TeV
  - ⇨ This record will hold!
- Originally designed to run at $10^{30}cm^{-2}s^{-1}$
- Upgraded in 1996-2001 and now running at $3.7x10^{32}cm^{-2}s^{-1}$ (record initial luminosity) with an interbunch of 396 ns (36x36 bunches)

- CDF upgraded in 1996-2001 to cope with increased luminosity but…
  expected to run at 132 ns interbunch at $3x10^{32}\ cm^{-2}s^{-1}$
  - ⇨ Running with 396 ns instead..
    - → More interactions/x-ing

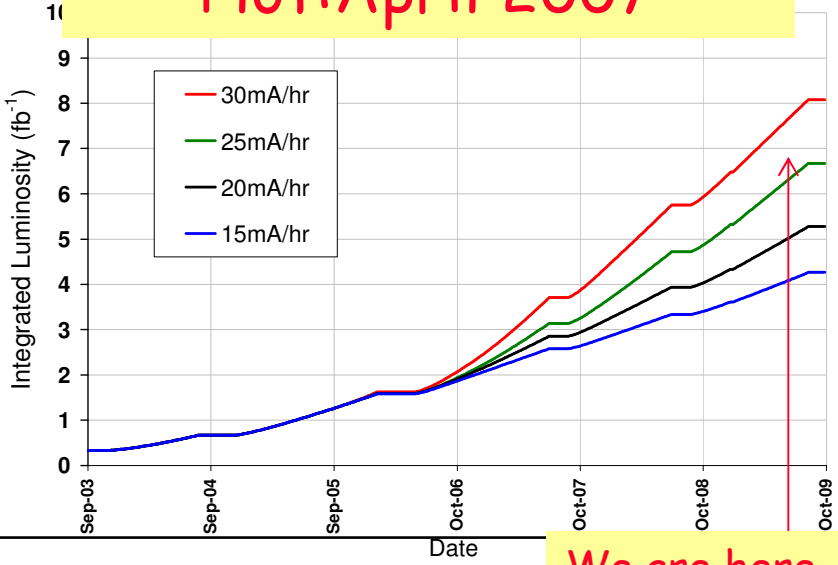
Tevatron- Introduction

The Tevatron collider is an ensemble of accelerators.

- "Run II is not a construction project. Run II is a complex campaign of operations, maintenance, upgrades, R& D and studies." (D.Lehman)
- Luminosity goal (2007):
  - 4.4-8.5 fb^{-1} by FY 2009
    - → More later
- Record: $3.72 \times 10^{32} cm^{-2} s^{-1}$
  - Keep improving
  - In one week >70 pb^{-1}
    - → record



Plot:April 2007



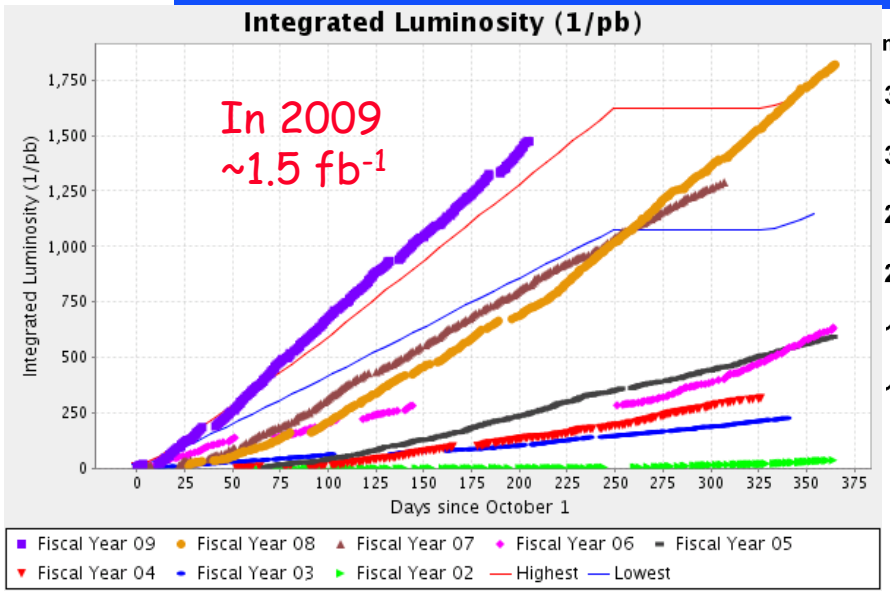
We are here

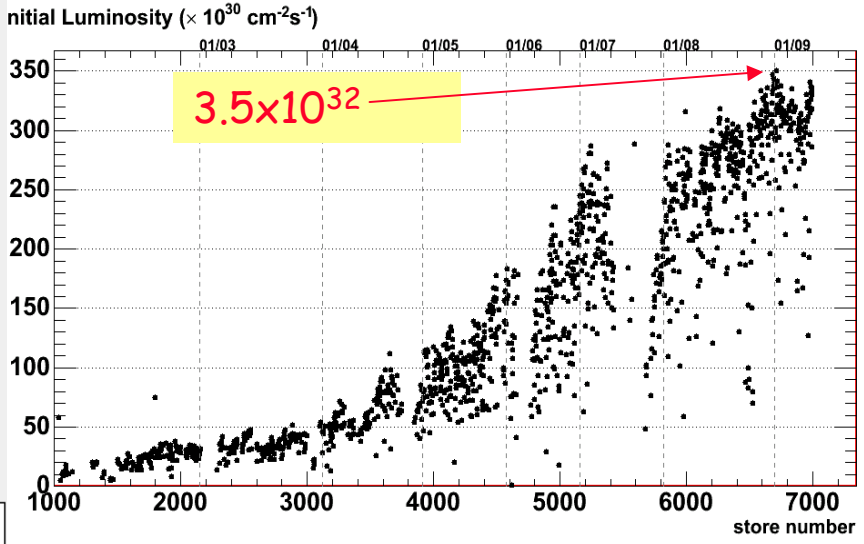
Key point

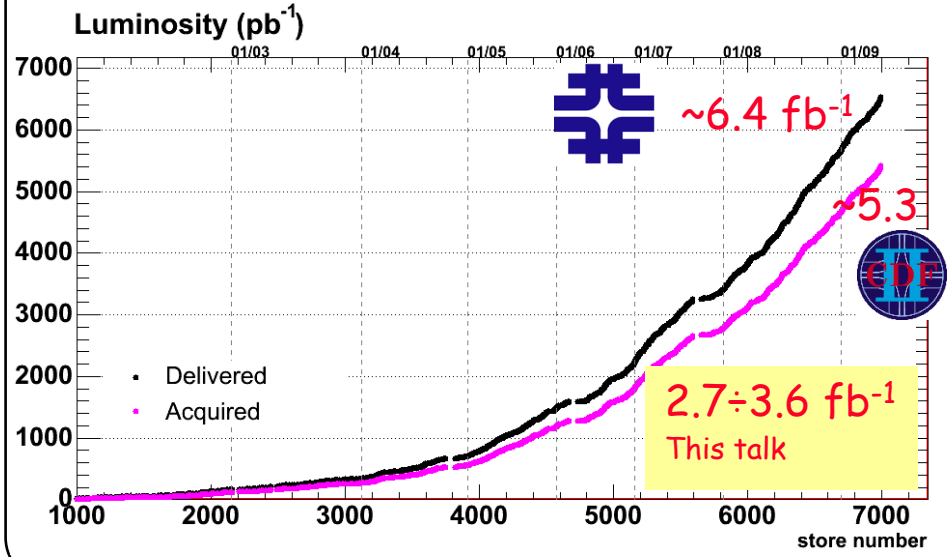
The large integrated luminosity provides us with the chance to access new frontiers

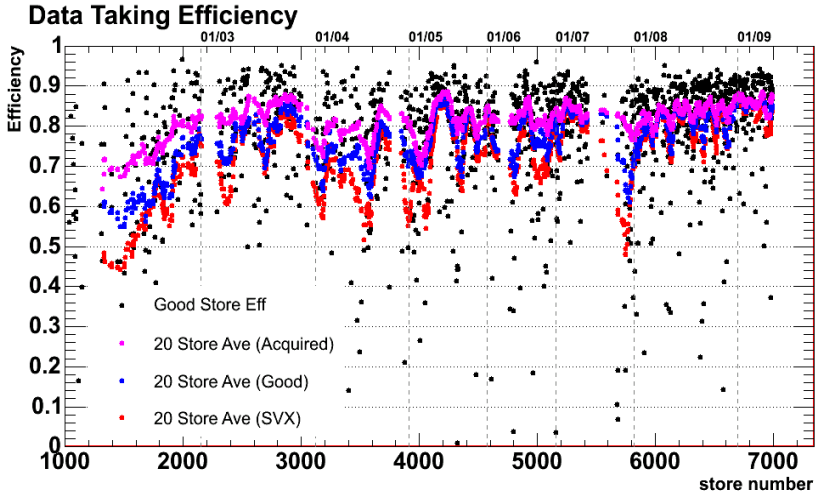
- Combination of High Energy Frontier
  - ⇨ with "intensity"
- It is an opportunity and an experimental challenge
  - ⇨ CDF is up to this challenge
- In this Conference many new results
  - ⇨ In my presentation I will focus on a few of them, leaving you the pleasure to listen to individual presentations

Luminosity is the key





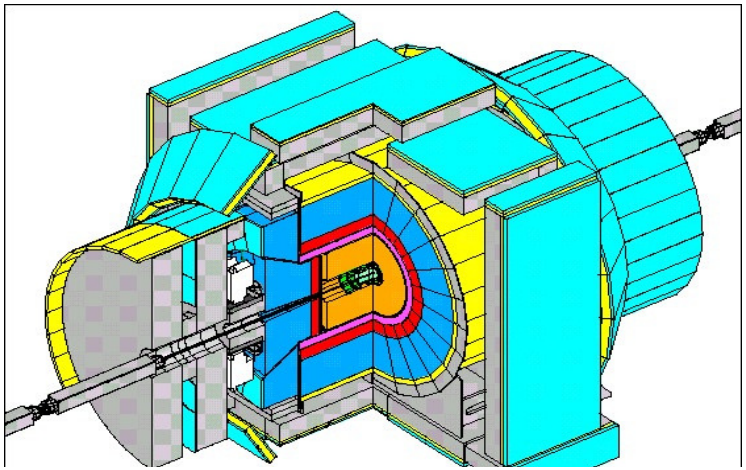




Physics program in a single plot

Improvements along the way of this run

- Mostly upgrades to the trigger system
- Continuos effort to keep the system running and to tune our triggers to physics priorities and to changing accelerator performances



Production cross-section (barns)

Process still unseen in red

Strong effort to keep the system up and running. The system was NOT designed to run at such instantaneous luminosity but is working fine

Physics, today

The exceptional good running of the Tevatron opened new perspectives

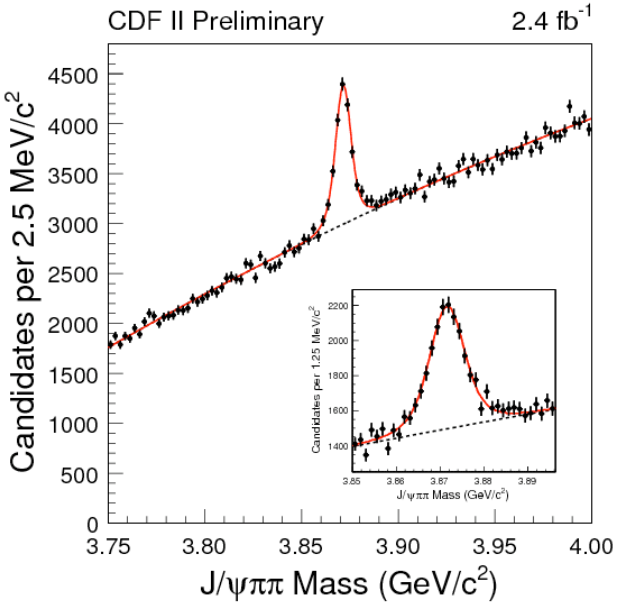
- First, and foremost we start taking seriously the chance to compete in the Higgs hunt
  - ⇨ Step up and reorganize efforts
    - → New triggers implemented
      - Even hw upgrades
    - → Reorganization of physics groups (HiggsDiscoveryGroup)
  - ⇨ Most important:
    - → Get new people involved
- Many other analyses gained from increased ∫Ldt, I will show:
  - ⇨ Rare B decays (Bs, baryons, resonances)
  - ⇨ Precision studies of SM (QCD, EWK) processes
  - ⇨ Rare Ewk processes (dibosons, single top)
  - ⇨ Top physics
  - ⇨ Searches for physics BSM

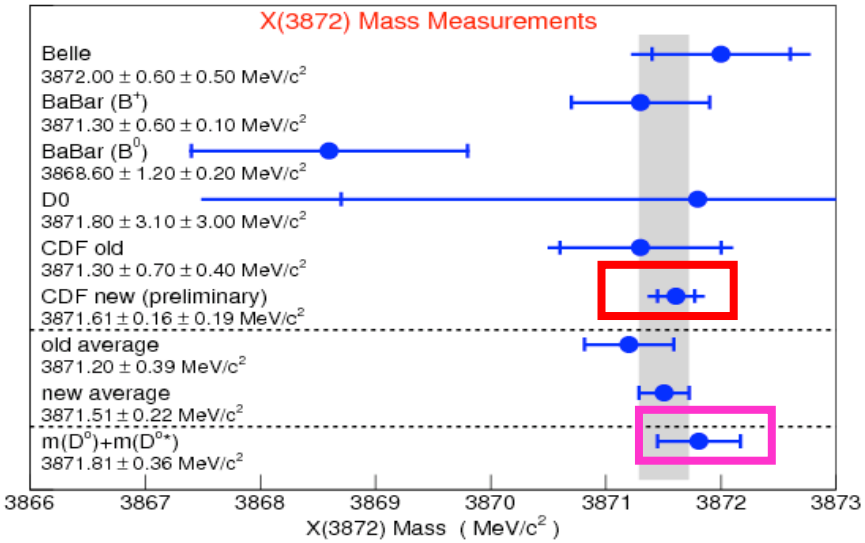
Results for DIS 09 mostly based on 2.7÷3.6 fb^{-1}

B physics- Searches

New states became an hot topic over recent years (X, Y, Z states). Thanks to the large statistics CDF studied

- X(3872)





$m(X(3872)) = 3871.61 \pm 0.16\ (stat) \pm 0.19\ (syst)\ MeV/c^2$

Large X(3872) sample

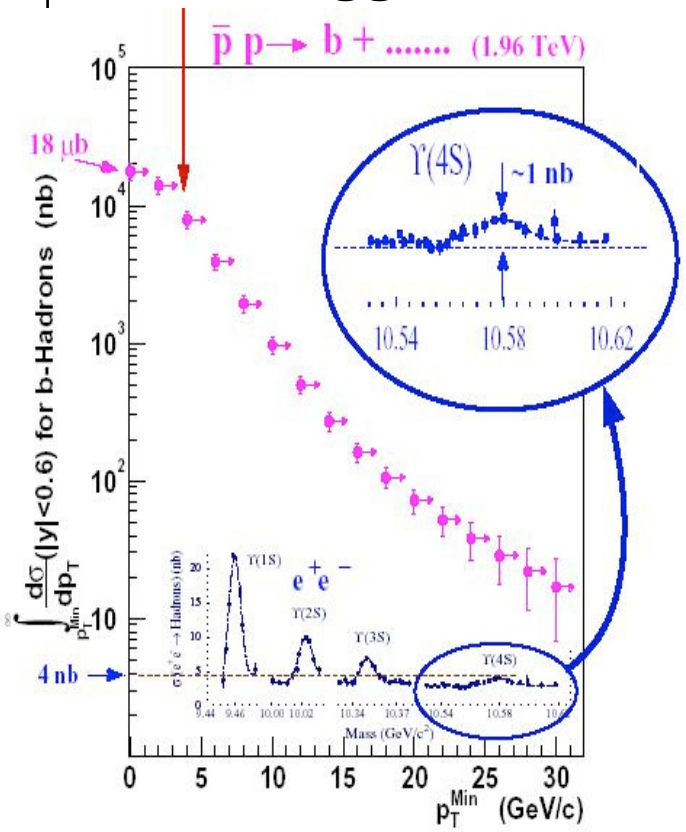
→precision measurement of the mass, check whether 1 or 2 states

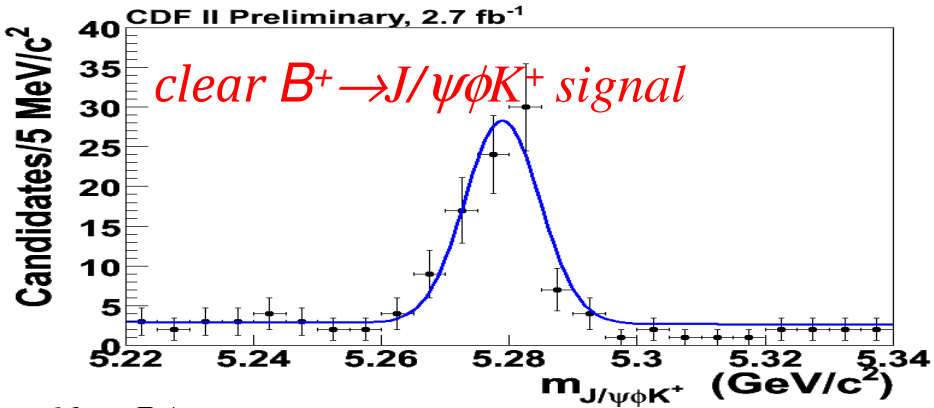
More in Kay Yi's talk

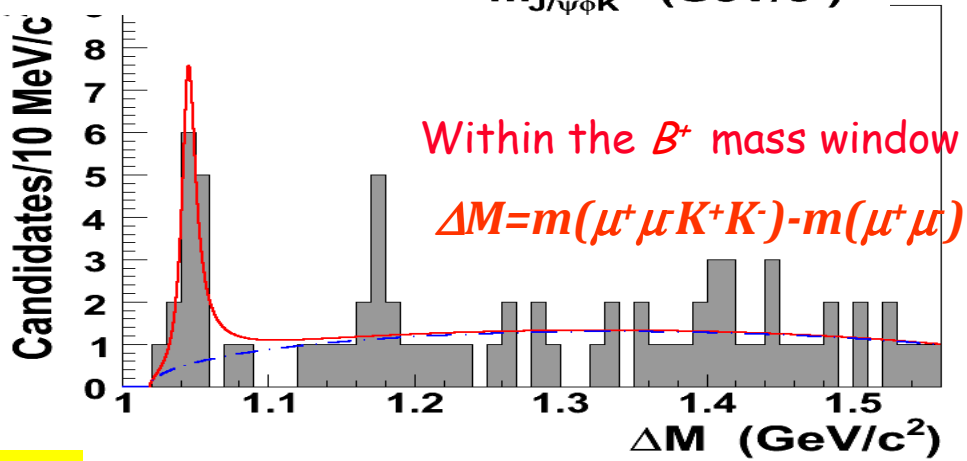
B-Physics Searches

CDF is now contributing with the observation of the narrow Y(4140)→J/Ψϕ

- Besides large production x-section CDF has good trigger (μμ), PID and an excellent spectrometer







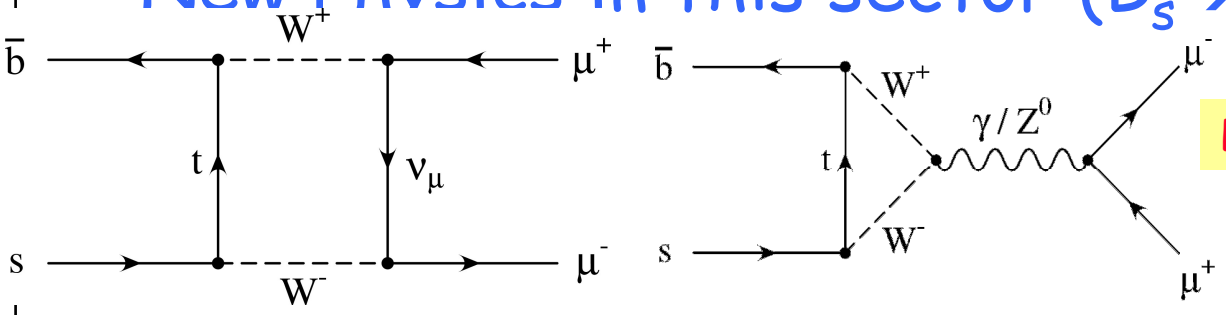
More in Kay Yi's talk

More on B-physics

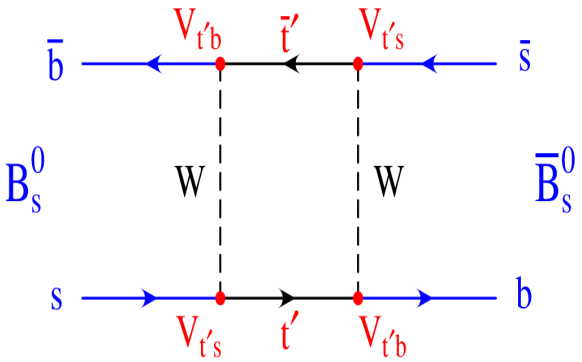
Study of B Baryons

See Juan Fernandez

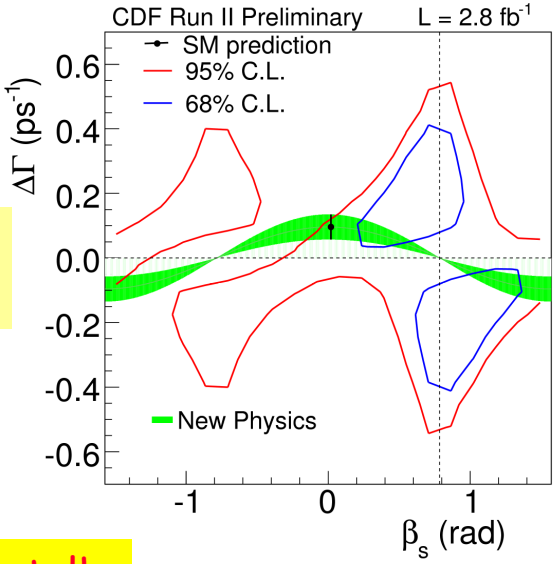
Unique opportunity to study Bs and search for New Physics in this sector ($B_s \to \mu\mu$, phase)



$Bs \to \mu\mu < 4.7 \times 10^{-8}$ 95% CL



In ϕ_s phase, still room for NP contributions



More in Thomas Kuhr's talk

Understanding QCD

The large statistics allows extensive studies of exclusive processes

Most recent results:

- ☞ Diffraction and low-Pt interactions
- ☞ Photo-production of charm states
- ☞ Inclusive photo-production
- ☞ Jet inclusive
- ☞ Structure Functions
- ☞ Z,W+ (b) jets
  - ⇨ Key ingredient for frontier analyses

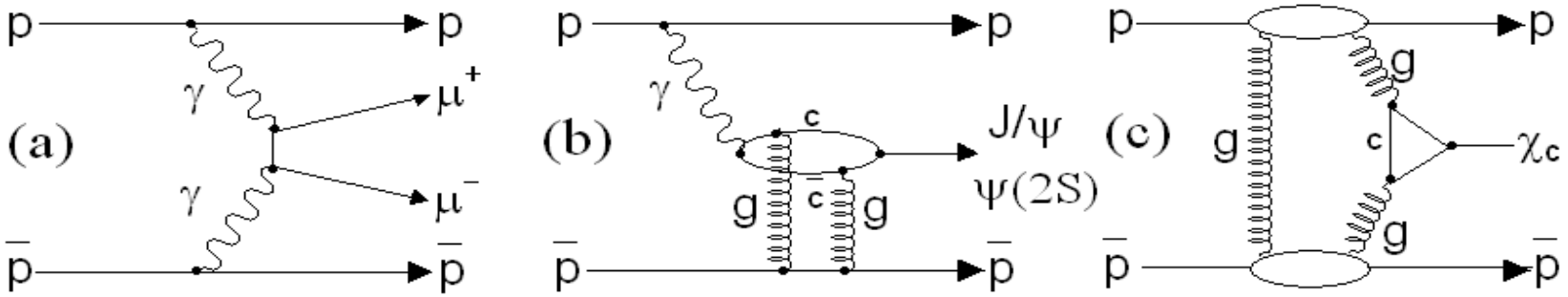
} pQCD

Talks by Mario Martinez, Christina Mesropian, Carolina Deluca Silberberg, Tara Shears, James Pinfold..

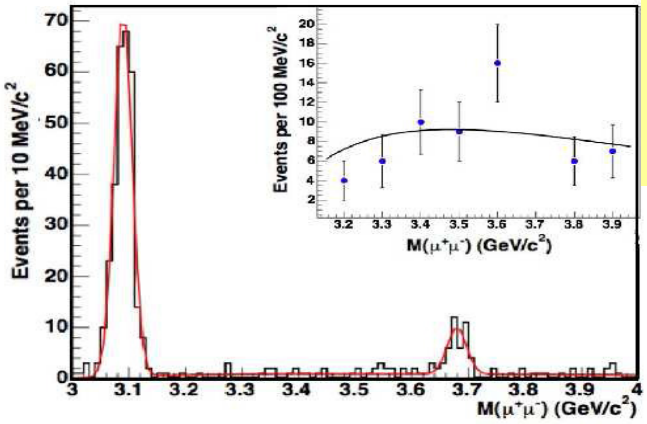
Photoproduction of charm states

CDF observes photoproduction of c-states

- We expect to see:



- Trigger and offline requirements select exclusive dimuons events with nothing else



Left: $M_{\mu\mu}$ for the 402 exclusive events

We also find 65 events with an EM cluster whose invariant mass $\mu\mu\gamma$ is consistent with χ_c production

Important implications for LHC where production of heavy central objects is expected!

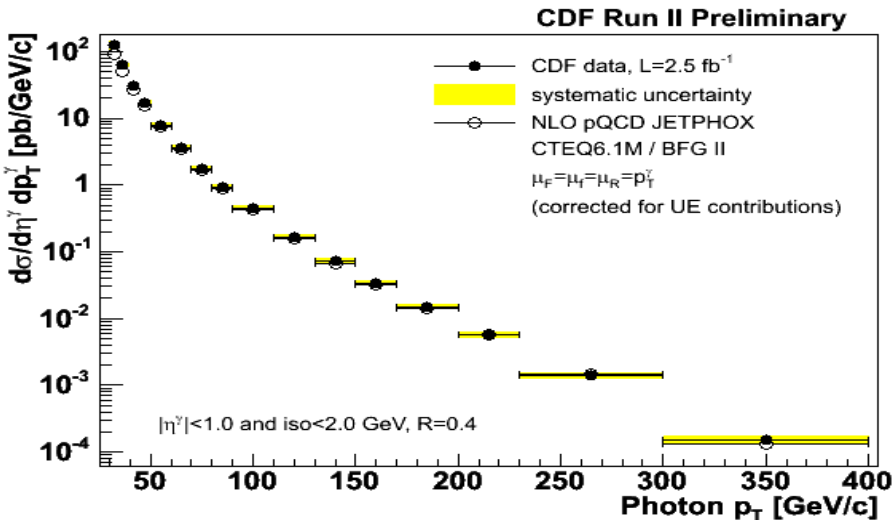
More details in J.Pinfold's presentation

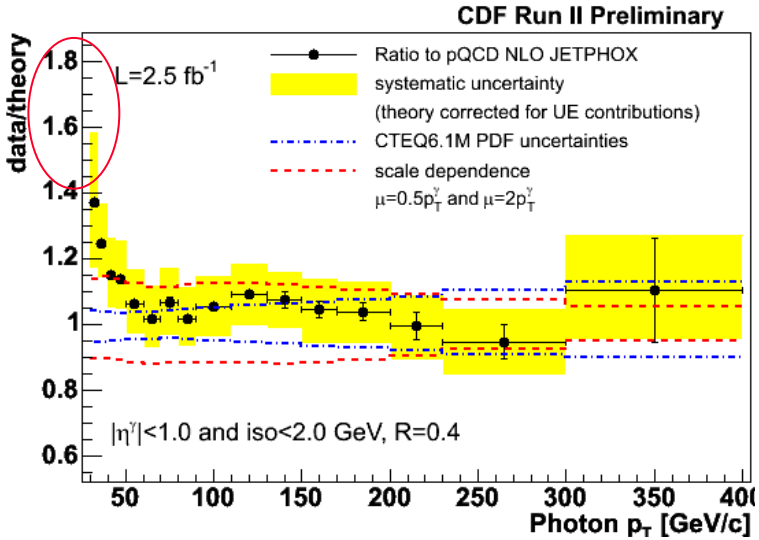
Prompt photon production

Thanks to large statistics, CDF studied the inclusive prompt γ spectrum

- ☞ Purity increases at large P_T
  - ⇨ ~95% at P_T~100 GeV/c

pQCD tested on 6 orders of magnitude





Low Pt discrepancy (already seen in Run 1 D0&CDF, UA2…)

See Carolina Deluca Silberberg

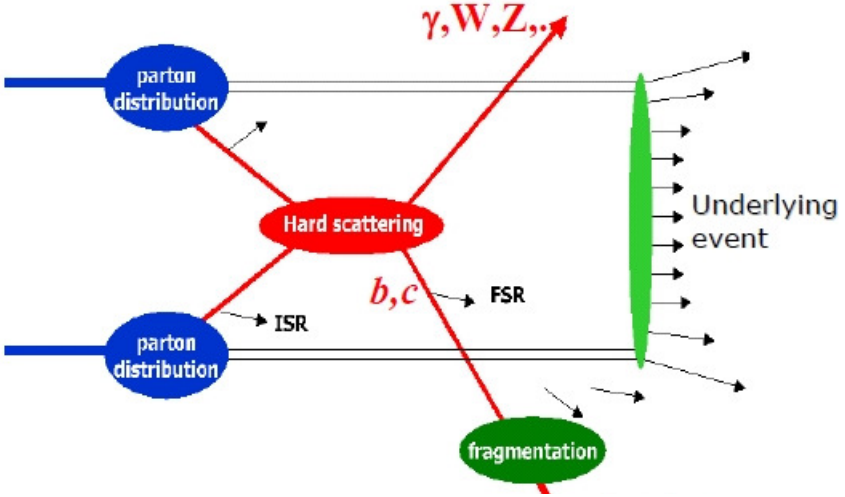
W, Z+jets

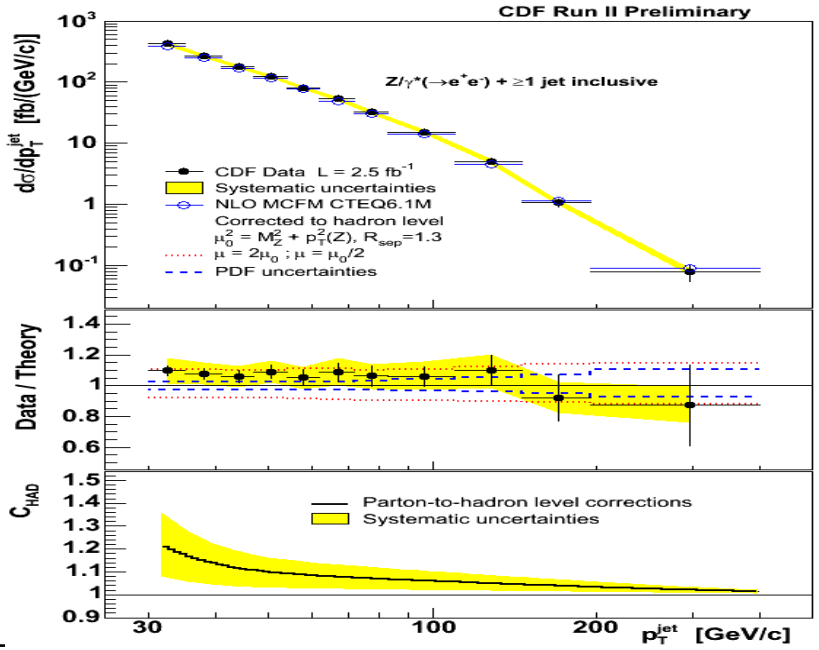
Associated production of W,Z+jets is key to many searches

- Test of QCD calculation and our understanding of theoretical uncertainties
- Important background in top physics, MOST important in s-top, V+Higgs production

Results on both inclusive (W,Z+jets) and exclusive (W,Z+b, W+c) channels

- Good agreement of NLO calculations for inclusive processes



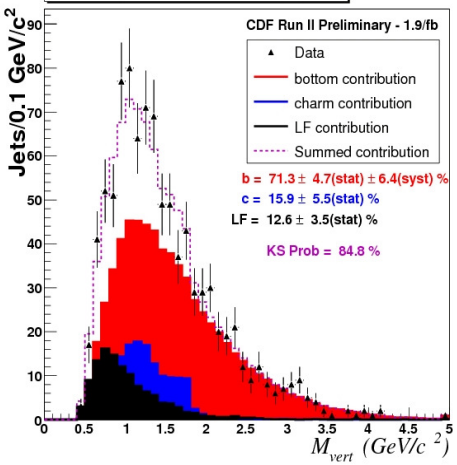


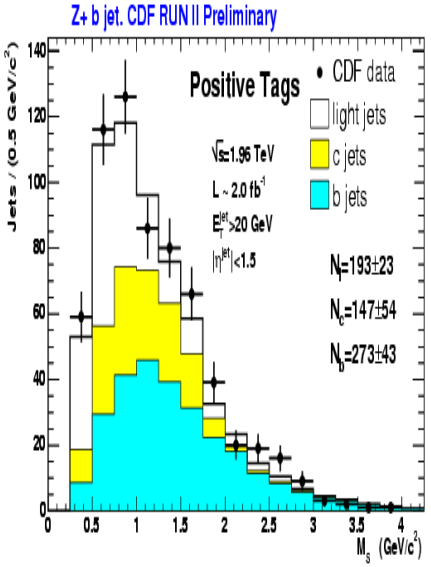
W, Z+HF

Largely based on capability to identify b-jets

- Kinematical quantities in data are fitted to templates reproducing various components to extract signal fraction
  - ⇨ Good fit to data but…
  - ⇨ Disagreement with LO/NLO expectations

W+b analysis, 1.7 fb^{-1}





Results Z+b 2fb^{-1}

	CDF Data	PYTHIA	ALPGEN	HERWIG	NLO	NLO +U.E+hadr.
$\sigma(Z+b\,\text{jet})$	$0.86 \pm 0.14 \pm 0.12$ pb	–	–	–	0.51 pb	0.53 pb
$\sigma(Z+b\,\text{jet})/\sigma(Z)$	$0.336 \pm 0.053 \pm 0.041\%$	0.35%	0.21%	0.21%	0.21%	0.23%
$\sigma(Z+b\,\text{jet})/\sigma(Z+\text{jet})$	$2.11 \pm 0.33 \pm 0.34\%$	2.18%	1.45%	1.24%	1.88%	1.77%

Results for *W+b* (1.7 fb^{-1}):
Data: $\sigma \cdot BR = 2.74 \pm 0.27(\text{stat}) \pm 0.42(\text{syst})$ pb
LO: ALPGEN: $\sigma \cdot BR = 0.78$ pb
LO factor 3 low
awaiting NLO comparison.

Poor agreement with predictions?

See Tara Shear's presentation

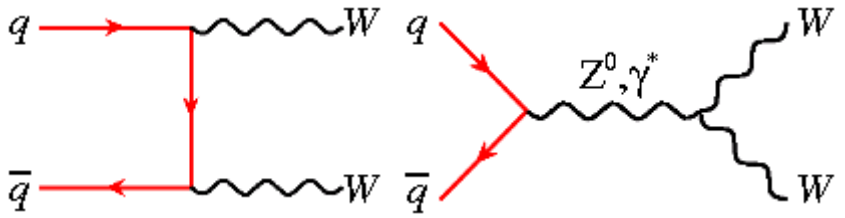
EWK- Diboson

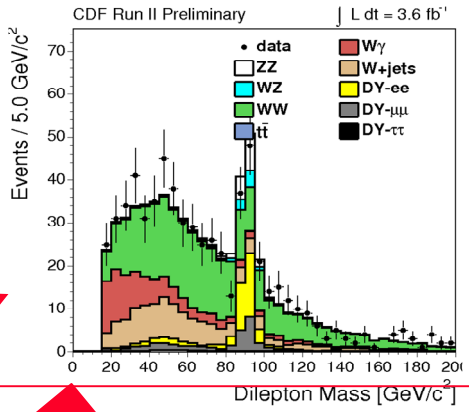
Dibosons are one of the cornerstone of EWK

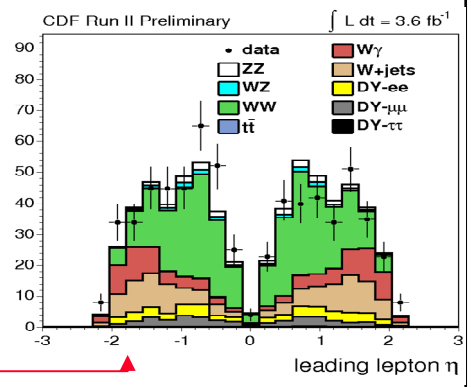
- ⇨ Tiny x-section, large backgrounds
- ⇨ So far identified in the dilepton channel

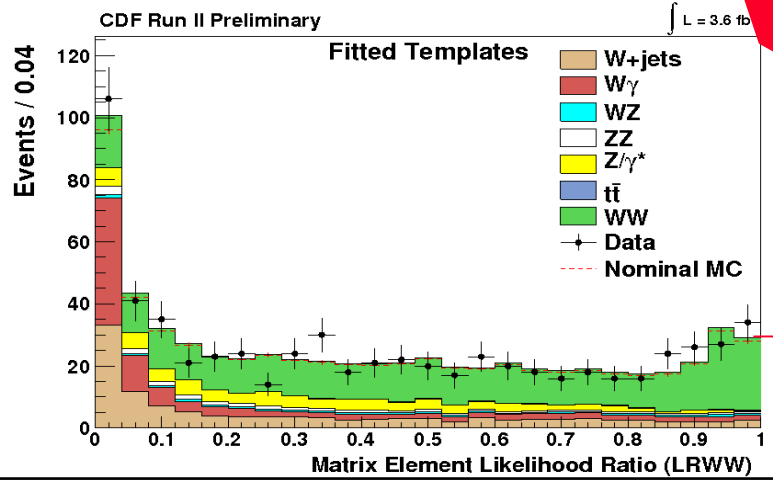
☞ Recent CDF results with 3.6 fb-1

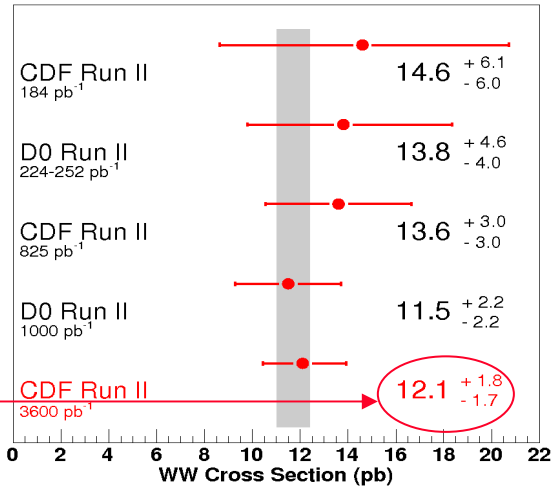
- ⇨ Use of multivariate technique (ME LR)









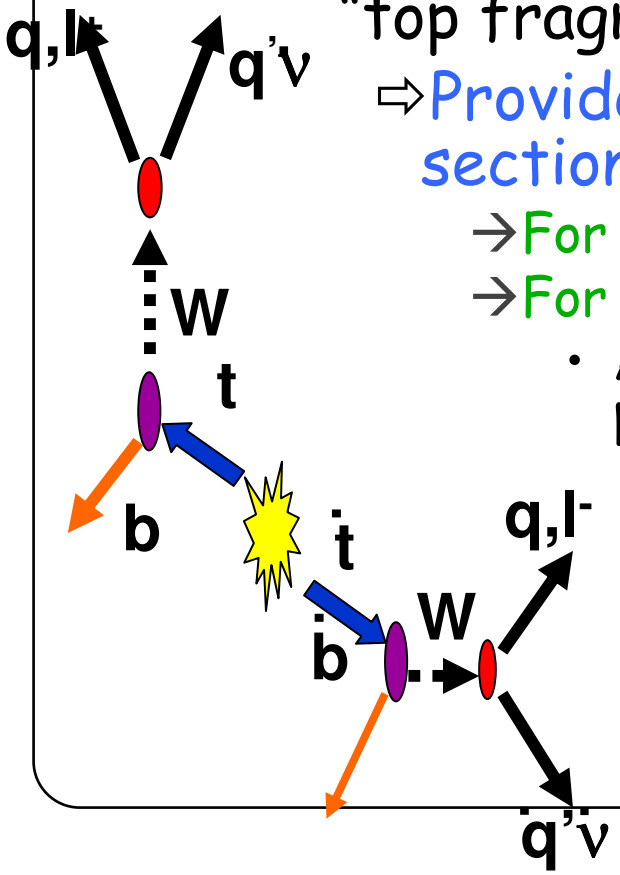


For more: see Bo Jayatilaka's presentation

Top

Since its discovery in 1994-1995 top physics is a real focus for CDF

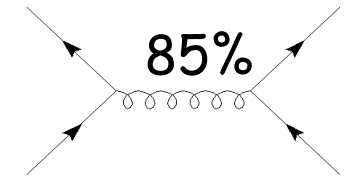
- ☞ Sheds light on the 3rd family (Vtb)
- ☞ Represents a unique place to test QCD : "top fragments before hadronization"
  - ⇨ Provides a way to measure mass and cross section
    - → For the latter comparison wrt expectation
    - → For Top mass: provides insight on the Higgs sector
      - All results, so far, obtained through events produced in strong interactions

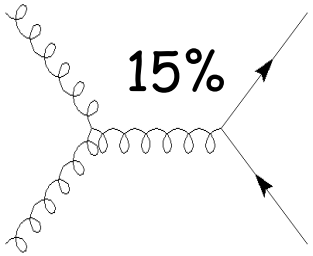


Cross Section

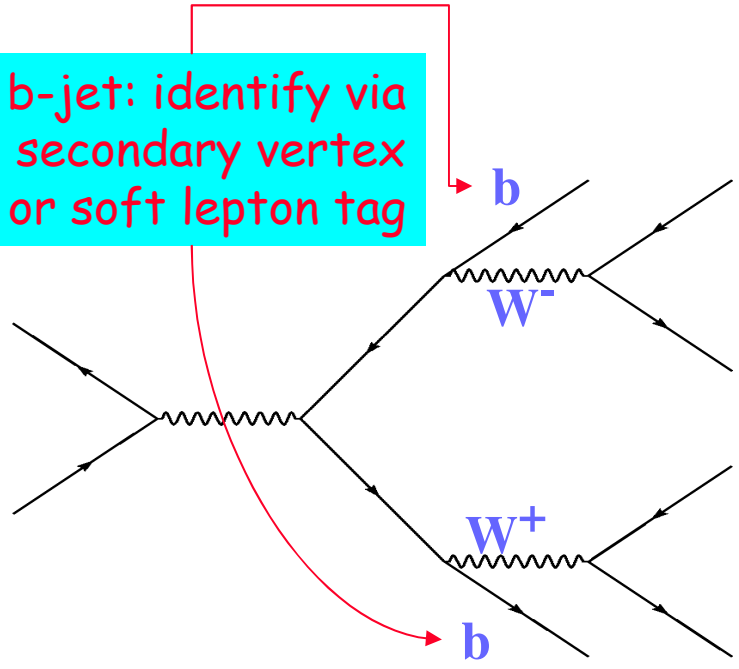
Results obtained with 2.8 fb^{-1}

- l+jets
- Dileptons





b-jet: identify via secondary vertex or soft lepton tag



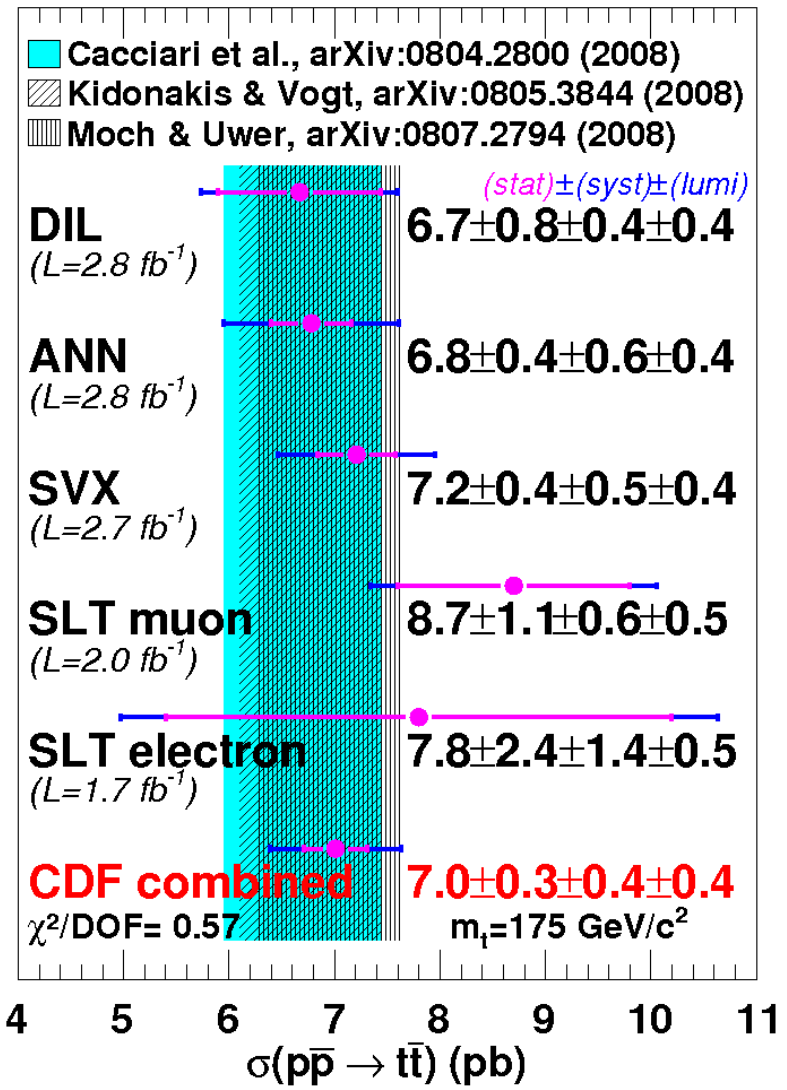
Event topology determined by the decay modes of the 2 W's (W^+W^-) in final state

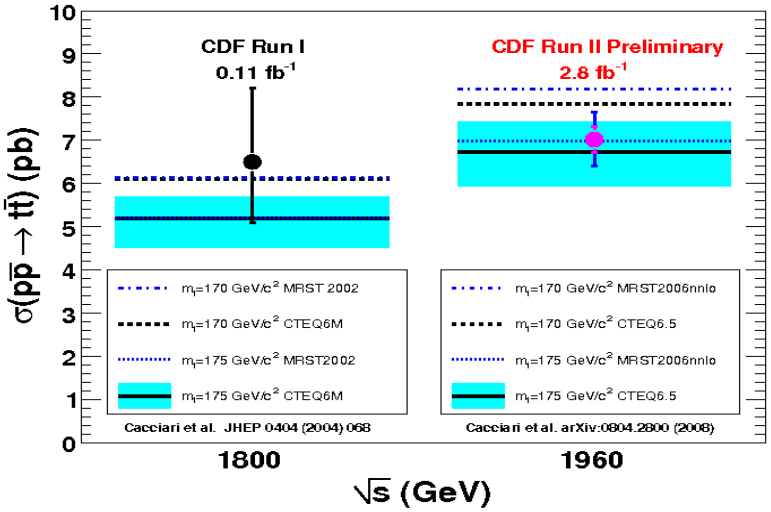
If you need a number:

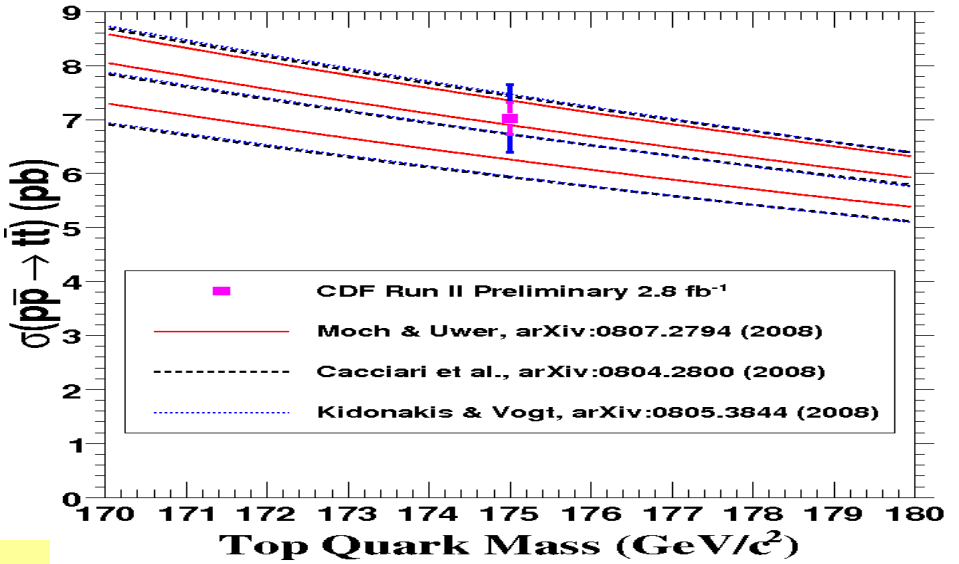
Combined result: σ=7.0±0.63 pb (for M_{top}=175 GeV/c^2)

Where uncertainties are (pb): 0.30 (stat) 0.38(syst) 0.41 (luminosity)

What can we learn ?







Challenge to NLO calculation accuracy

More details in Gervasio Gomez's presentation

Top Mass...present and future

Measurement of M_{top}: at Tevatron, LHC:

- ☞ kinematic reconstruction, fit to invariant mass distribution
- ☞ Best measurement from lepton +jets

Experimental accuracy of M_{top}:

- ☞ Measurement ⇔ comparison data from Monte Carlo
- ☞ you measure the mass that is implemented in your MC
  - ⇨ measured mass is not strictly model independent

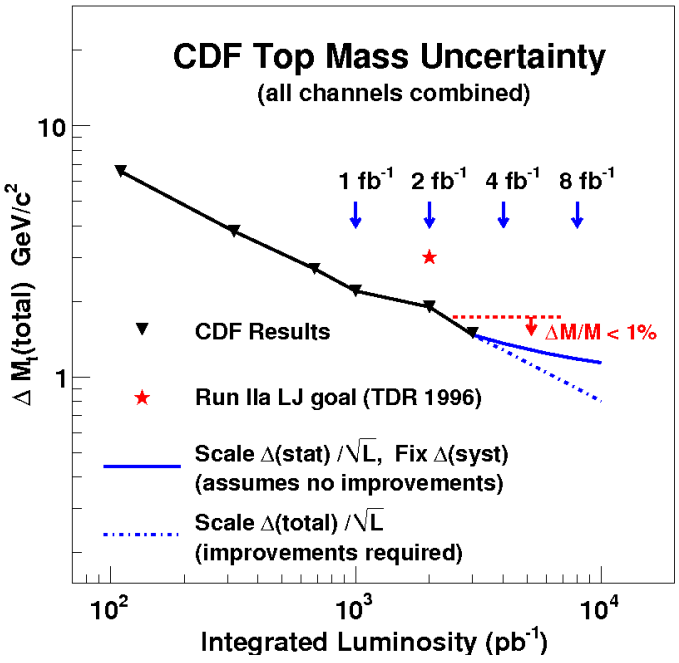
Situation at the Tevatron:

- ☞ δM_{top} = 1.2 GeV (Tevatron today, was 2.3 two years ago)

Projections at the LHC:

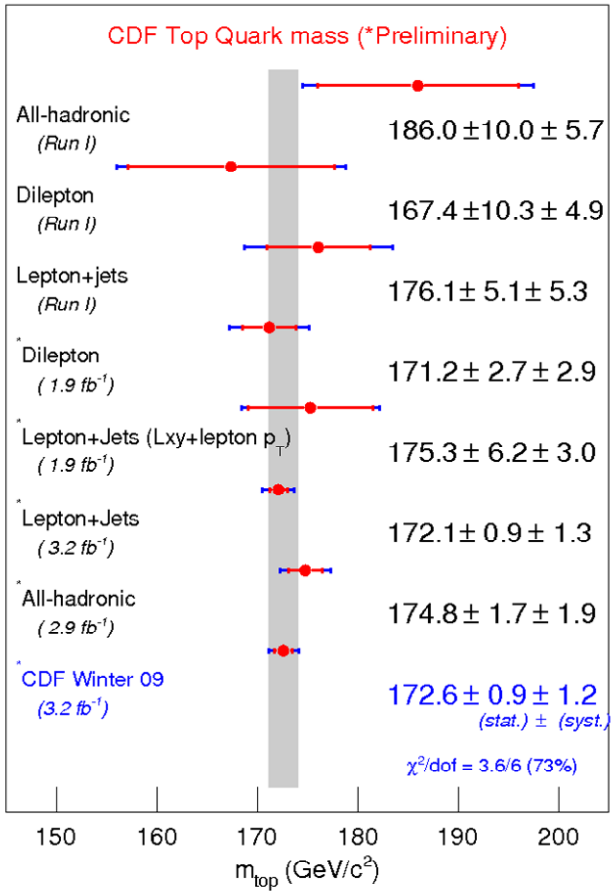
- ☞ δM_{top} < 1 GeV with 10 fb^{-1}

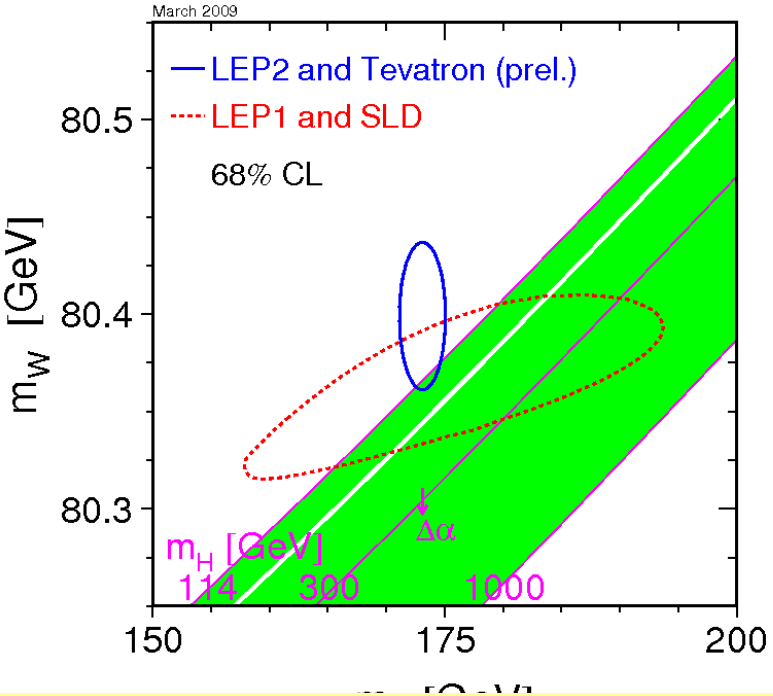
→Will Tevatron get there first?



Top Mass at CDF& Tev

Overall a striking measurement < 1%





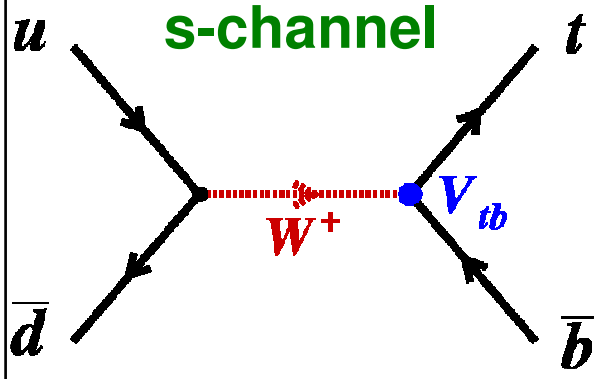
Most precise measurement by one experiment

Tevatron combined:

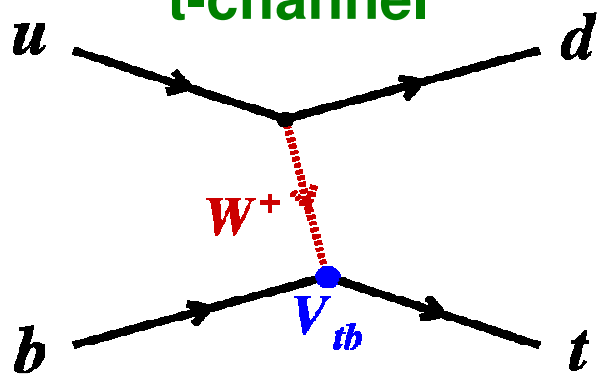
$173.1 \pm 0.6(\text{stat}) \pm 1.1(\text{syst})$ GeV/c^2 (3.6 fb^{-1})

Single Top Quark – Why look for it?

s-channel



t-channel



LHC

$\sigma_s = (11 \pm 1)$ pb

$\sigma_t = (247 \pm 10)$ pb

$\sigma_a = (56 \pm 6)$ pb

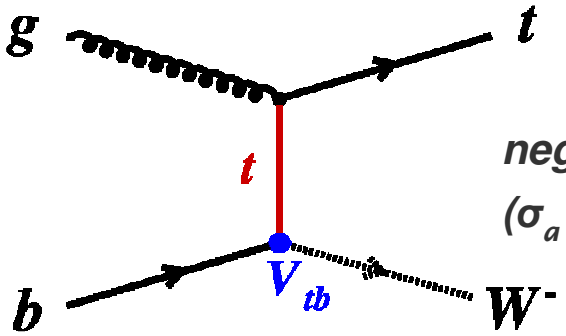
SM NLO predictions (Tevatron):

$\sigma_s = (0.88 \pm 0.11)$ pb

$\sigma_t = (1.98 \pm 0.25)$ pb

B.W. Harris et al., Phys. Rev. D 66, 054024 (2002),
Z. Sullivan, Phys. Rev. D 70, 114012 (2004),
N. Kidonakis, Phys. Rev. D74, 114012 (2006)

associated production



negligible

(σ_a ~ 0.3 pb)

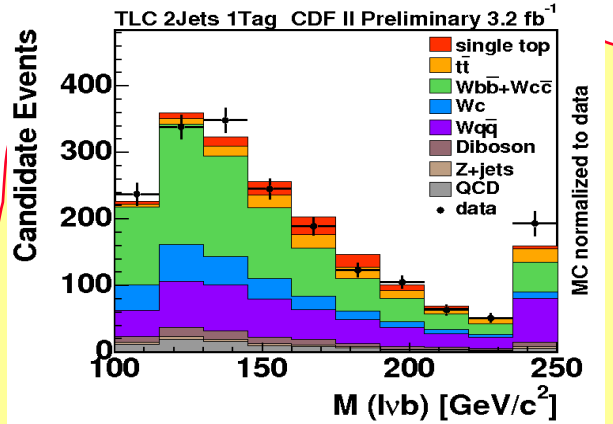
- EWK production
- topology similar to WH
- tiny cross section
- $\sigma_{\text{single top}} \sim |V_{tb}|^2$

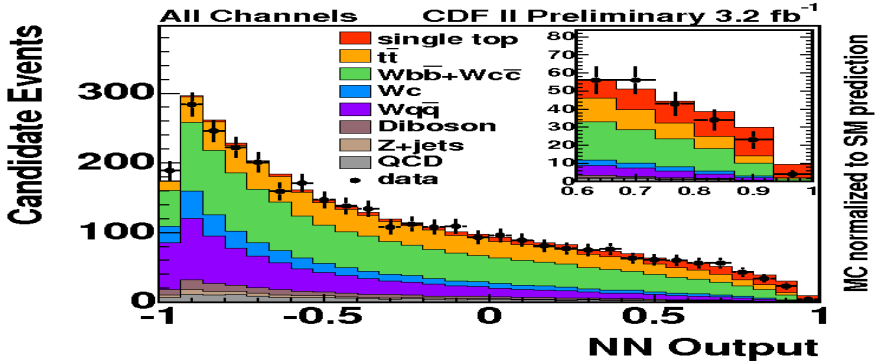
→ measurement of V_{tb}

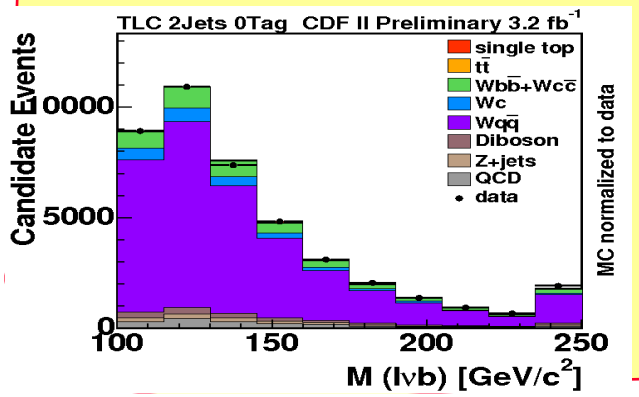
It took 14 years from ttbar to s-top

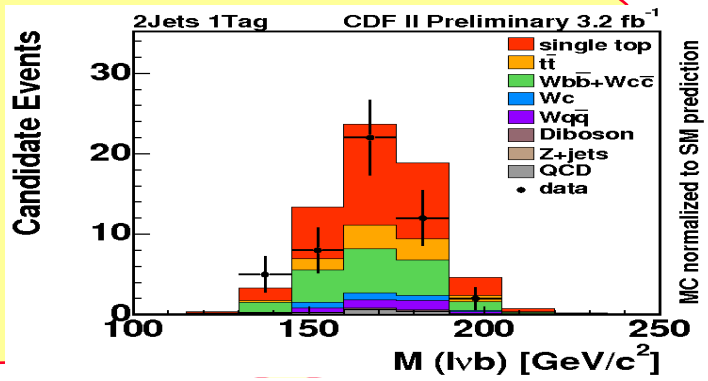
Tiny cross section
Large background } Counting exp. not possible, use MV techniques

- ☞ imply a very good knowledge of the detetor response in order to combine many variables with separating powers
  - ⇨ NN, BDT, Likelihood.., as example NN:









$\sigma = 2.3^{+0.6}_{-0.5}$ pb

$V_{TB} = 0.91 \pm 0.11 \pm 0.07(th)$

See Gomez's talk

Higgs- the Tevatron situation

Large cross section from gg→H

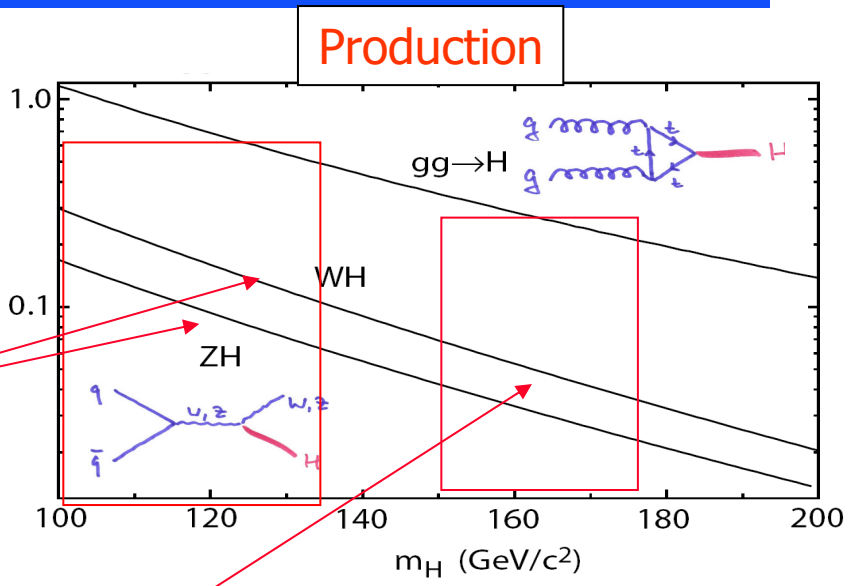
- Swamped by QCD background
  - ⇨ But some brave souls are tackling it!

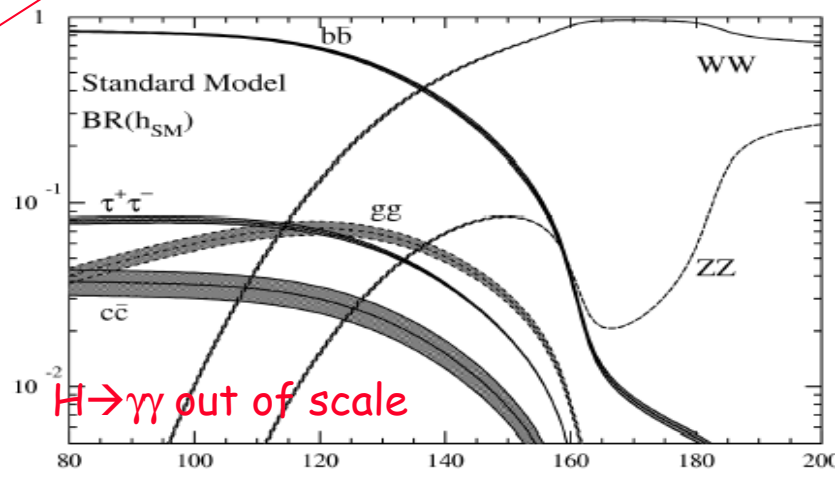
WH, ZH clean trigger signature

- Low cross section and large background from W+hf, Z+hf
  - ⇨ b tagging

WW* channel

- Poor but beautiful
  - ⇨ Integrated luminosity helps
    - → Ingenuity helps a lot



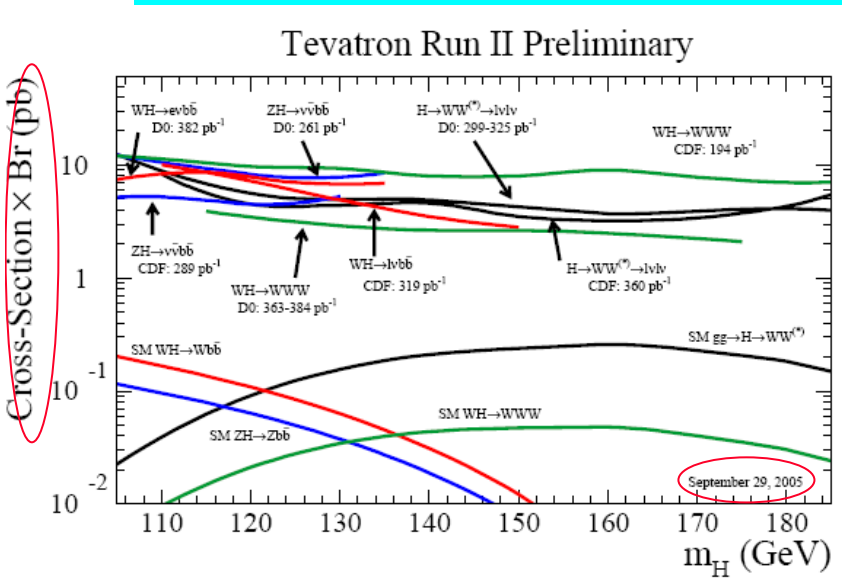


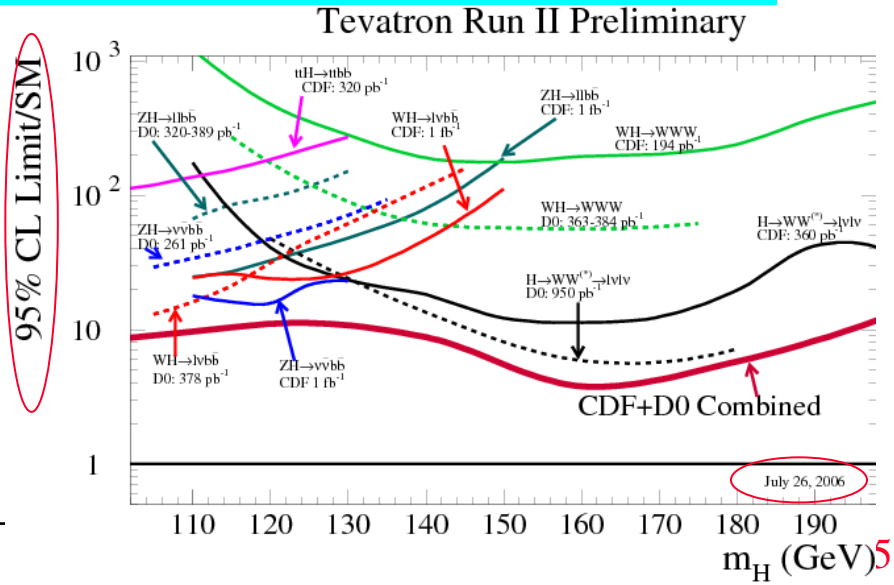
Higgs- the turning point

The large ∫Ldt allows CDF (and D0) to re-focus on Higgs…

- ☞ New triggers, hw improvements
- ☞ Restructuring of the groups, with a focus to gather on the Higgs the expertise acquired elsewhere

In less than 1 year start expressing the limits in terms of SM x-section





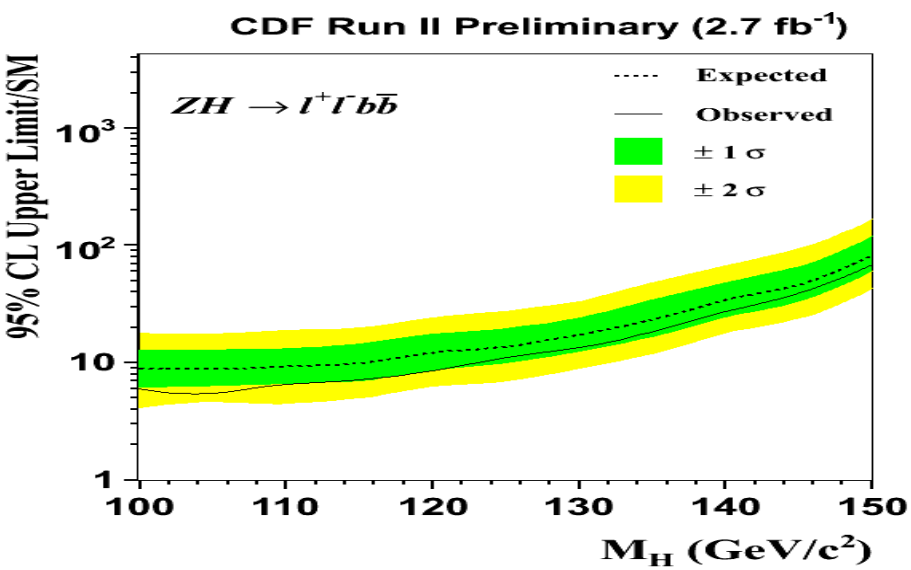
Low mass Higgs

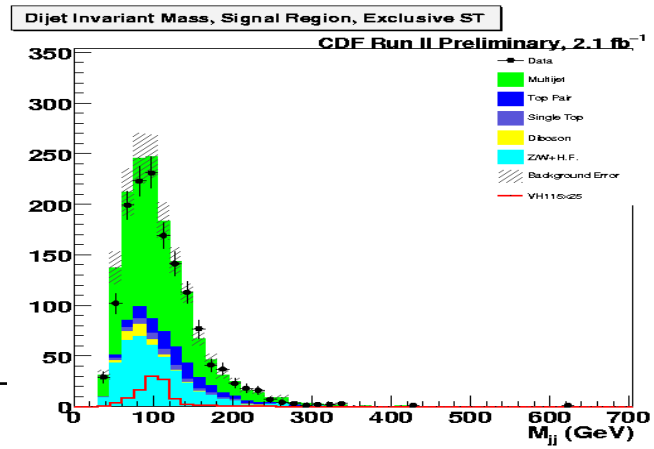
Low mass Higgs, although preferred by indirect fits is very challenging due to low rate and large backgrounds

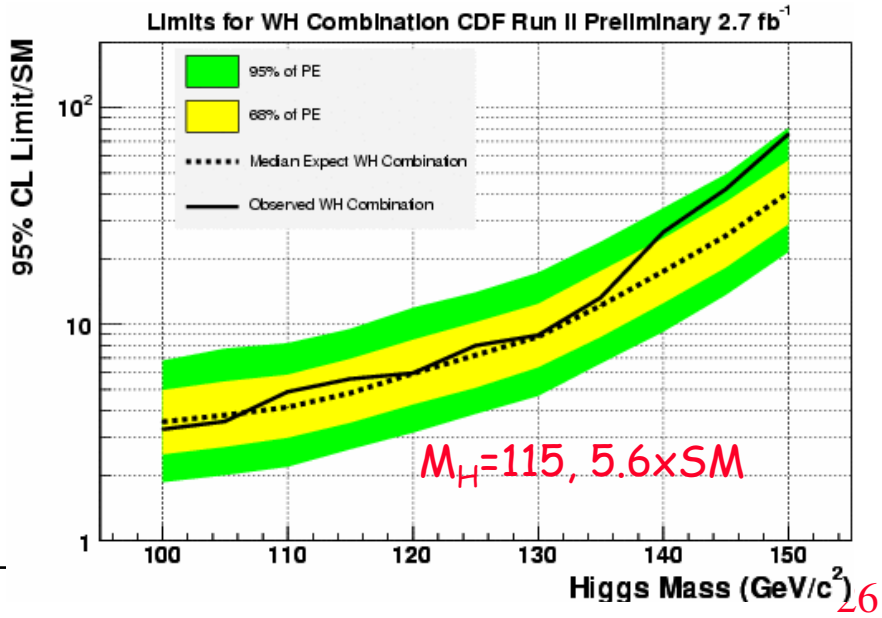
- As a sobering reminder, at LHC, the H→γγ channel (suppressed) is considered the golden one in this region

Not a single approach:

- Many channels explored, different strategies tried
  - ⇨ As for s-top no counting experiment possible
    - → Several channels: MET+bb,llbb,l-MET+bb







High-mass

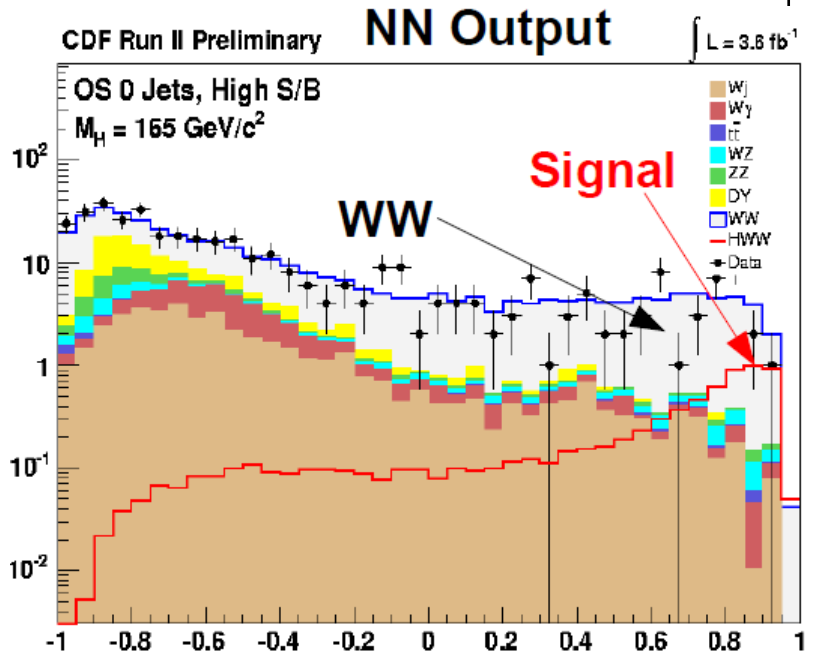
Dominant decay for M_H>135: WW*

- Look for final state with leptons only (low stat:6%)
- Background due to dibosons, top, DY..
- Name of the game: acceptance+
  - ⇨ Multivariate analysis (NN)

$\mathcal{L} = 3.6$ fb^{-1}, $M_H = 160$ GeV

Channel	Signal	Bkgd	Data
0 Jets	9.5 ± 1.4	637 ± 67	654
1 Jet	5.98 ± 0.78	278 ± 35	262
2+ Jets	4.53 ± 0.52	173 ± 23	169

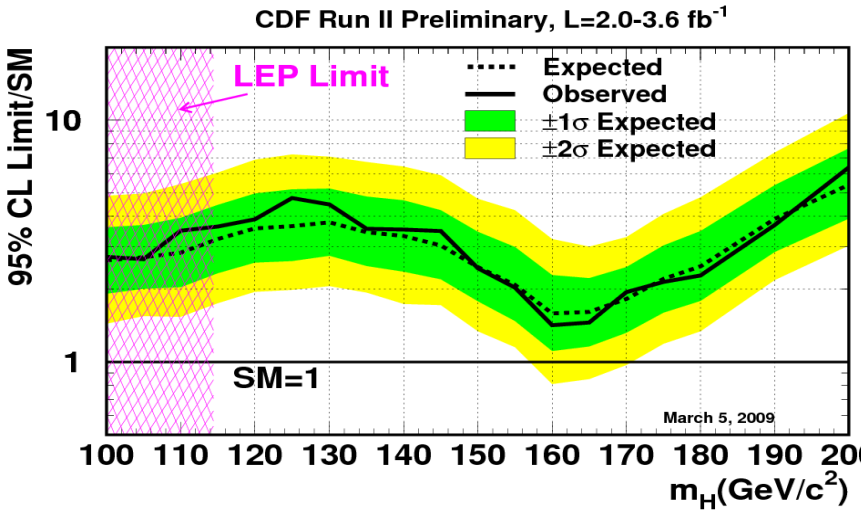
Signal extraction by creating a NN using several kinematical variables



Hunting the Higgs

As everybody knows we do not see the Higgs

- Limits are getting close to SM expectations

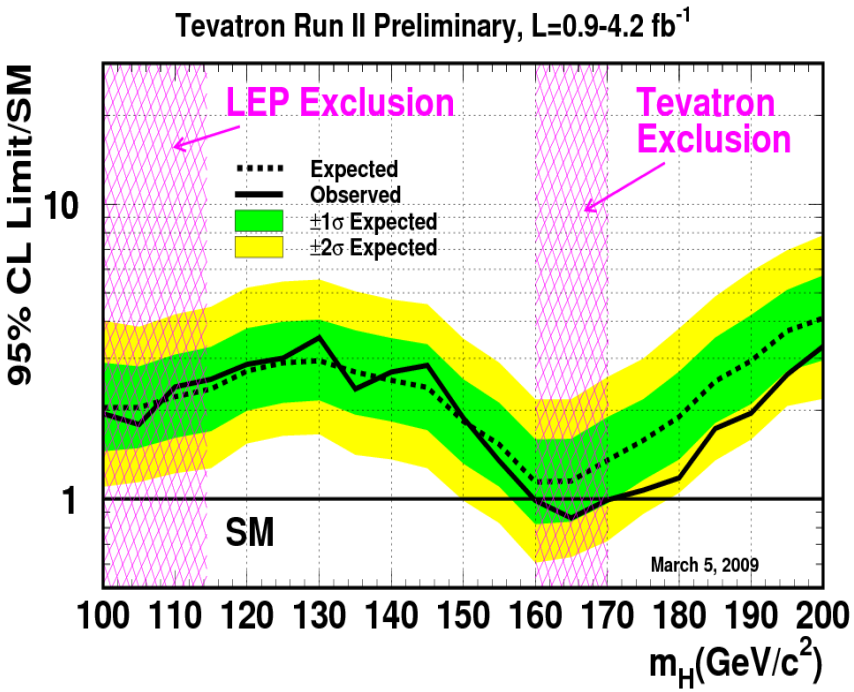


- When combined with D0:

SM Higgs excluded at 95%CL

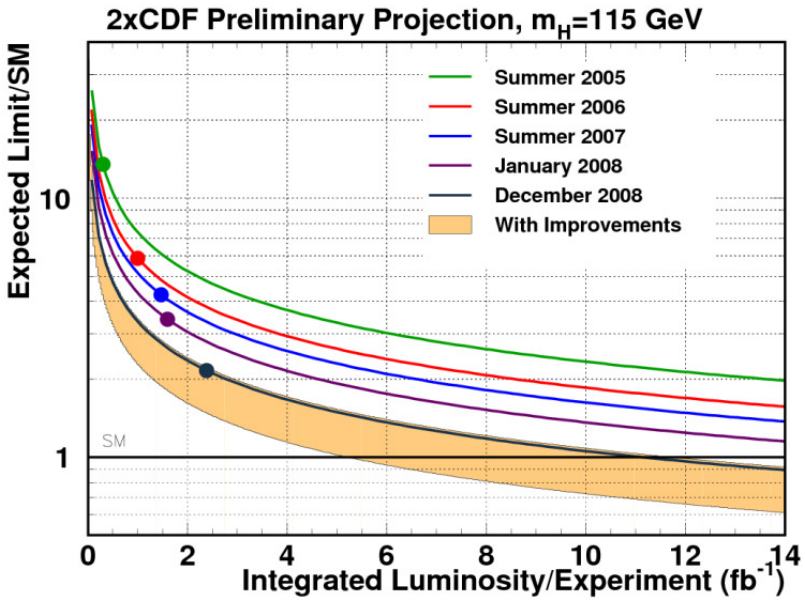
$160 < M_H < 170$ GeV/c^2

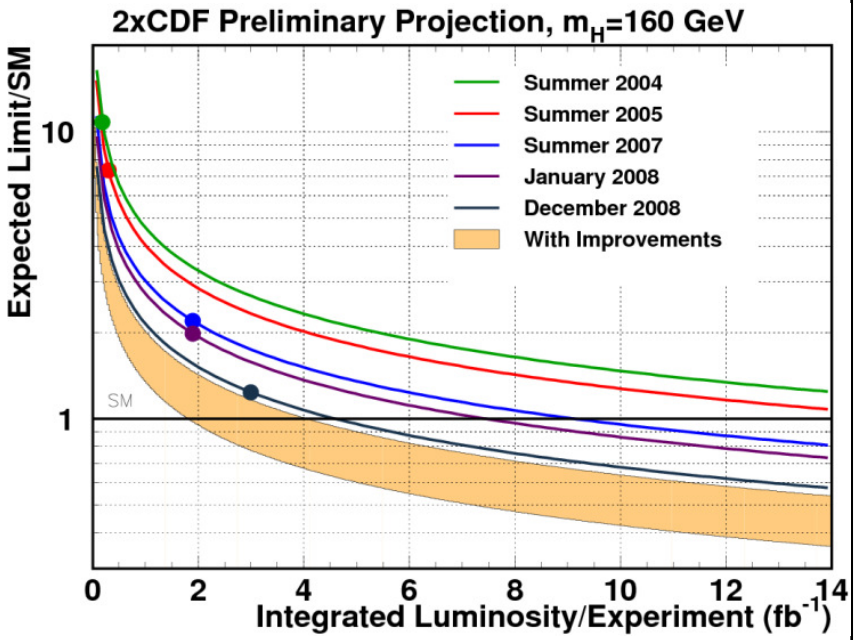
First direct limit since LEP2

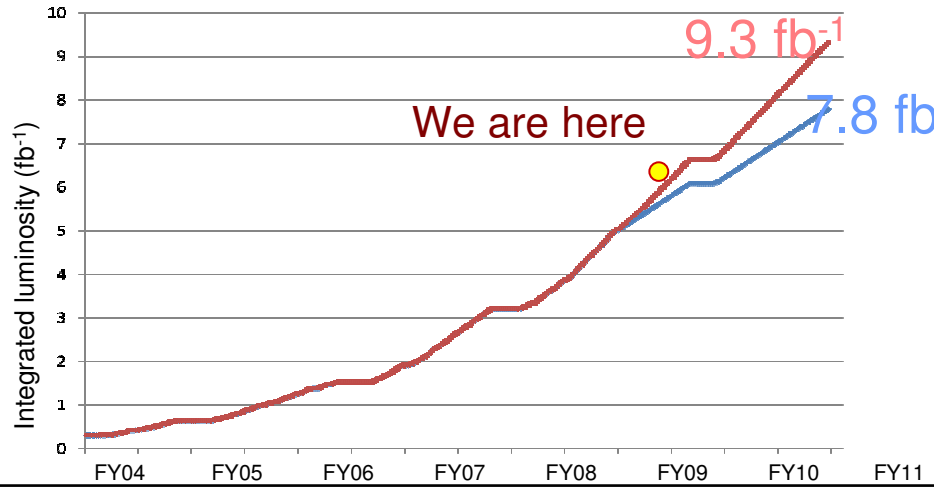


Much more in Anton Anastassov's presentation

Higgs, where are we going?







Challenge is to keep improving while still taking data

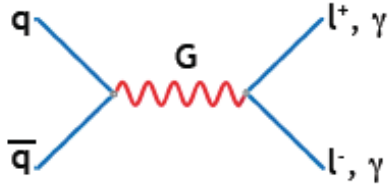
Beyond the Standard Model

Many possibilities for extension of the SM

- CDF investigates at 4π!
- SUSY, RS, TC, resonances

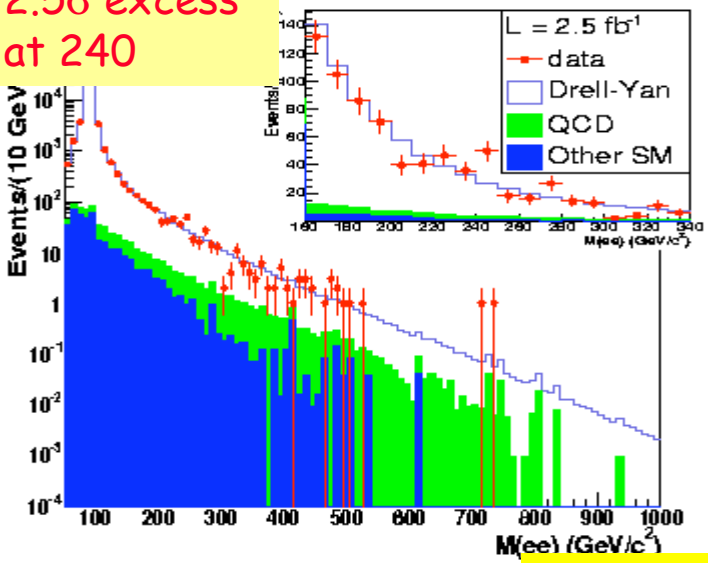
In μμ channel, 2.3 fb^{-1}first limit above 1 TeV

Z' model	Z' mass limit
Z'_I	789
Z'_{sec}	821
Z'_N	861
Z'_ψ	878
Z'_χ	892
Z'_η	982
Z'_{SM}	1030

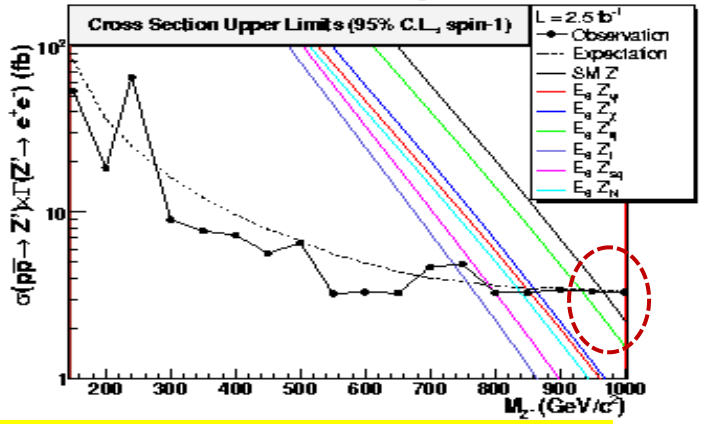


In ee channel, 2.5 fb^{-1}

2.5σ excess at 240



CDF Run II Preliminary



Z'→ee: 966 GeV

See presentations by Loginov and Safonov

Conclusion

CDF is running well and keeping up with the challenges provided by the excellent performances of the Tevatron accelerator complex

- ☞ Thanks, Beams Division!

>5 fb^{-1} on tape, and on its way to get more

- ☞ Those data open the possibility of studying very rare processes
  - ⇨ The SM is being extensively tested
    - → Higgs being hunted both directly and indirectly (top,W)
  - ⇨ Understanding of QCD is improving and discrepancies are being checked throughly
  - ⇨ We keep our eye open for the unexpected
    - → Possibly in the B sector?

Stay Tuned !
Running through 2010 granted!

More data in 2011?