Tevatron Collider Overview

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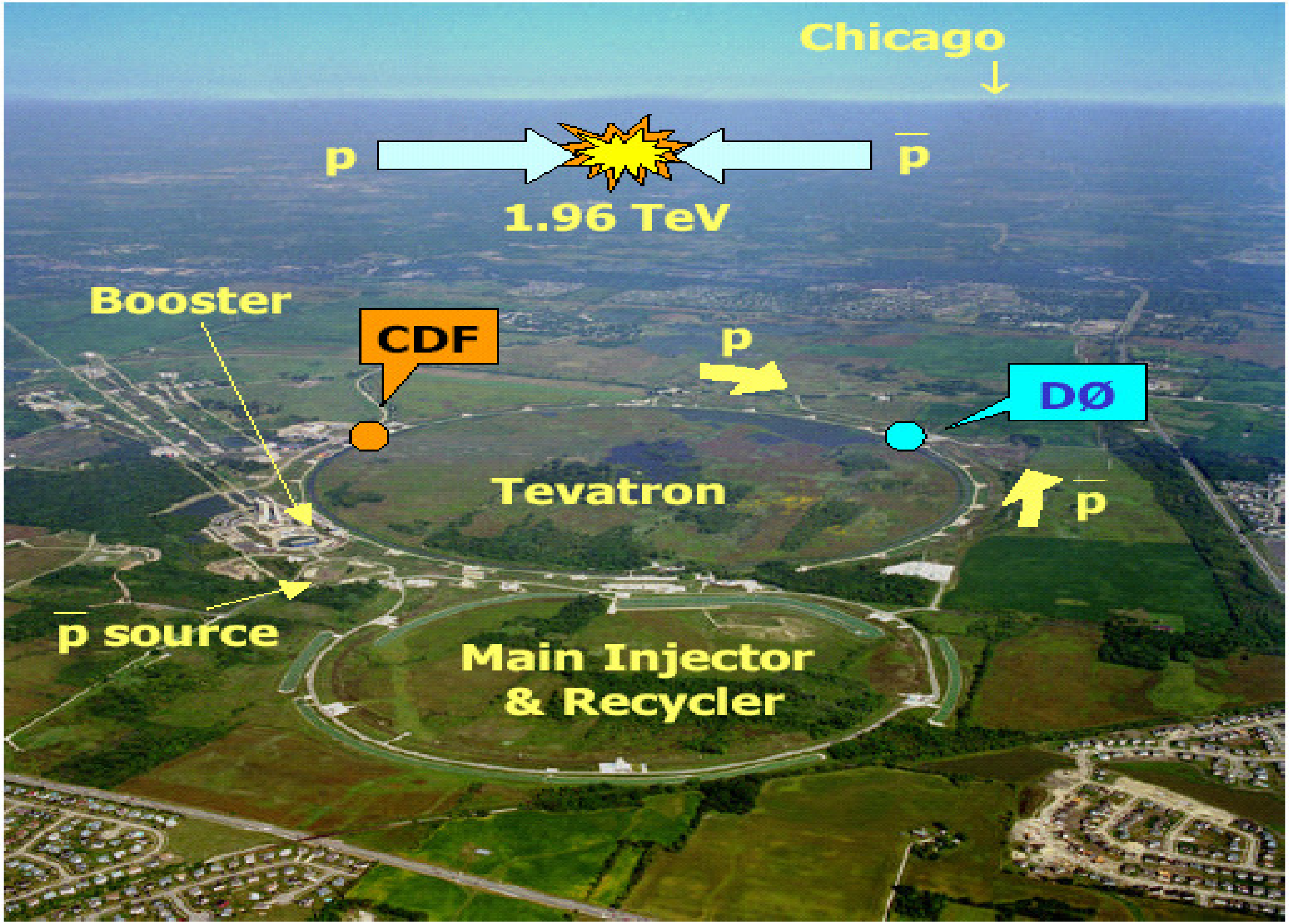
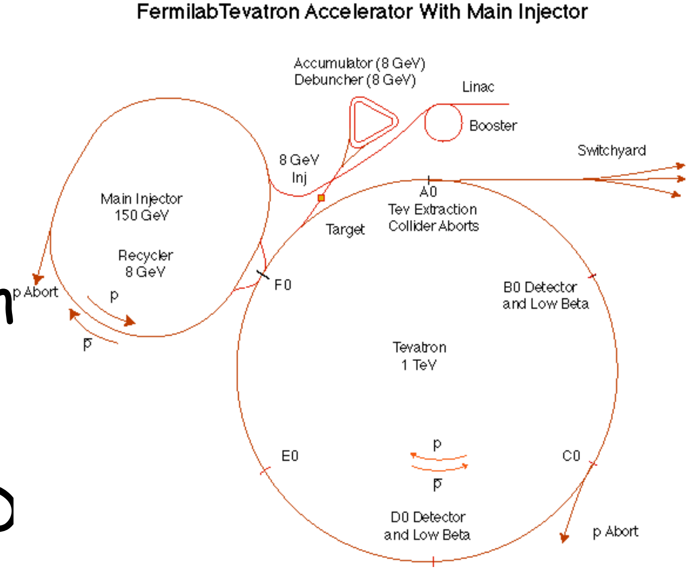
With the help of many D0 and CDF colleagues

More than just a Collider..

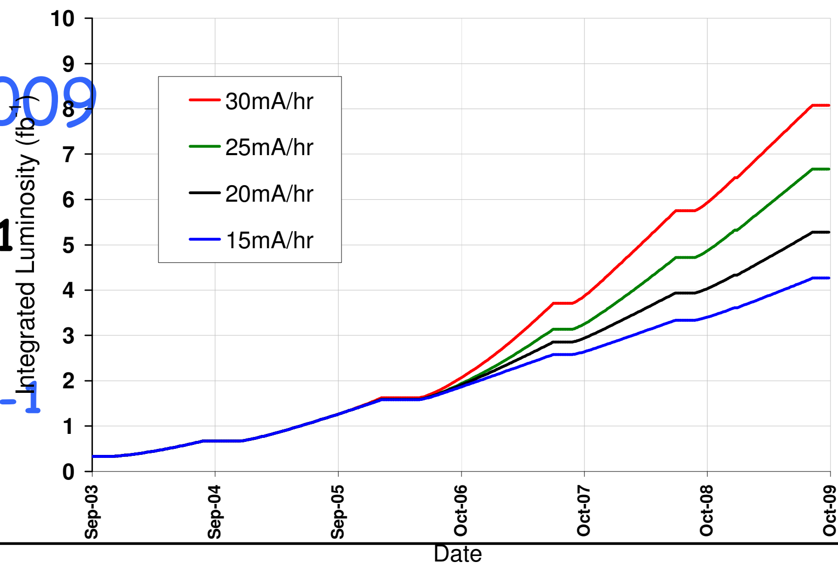


Tevatron- Introduction

The Tevatron collider is an ensemble of accelerators.

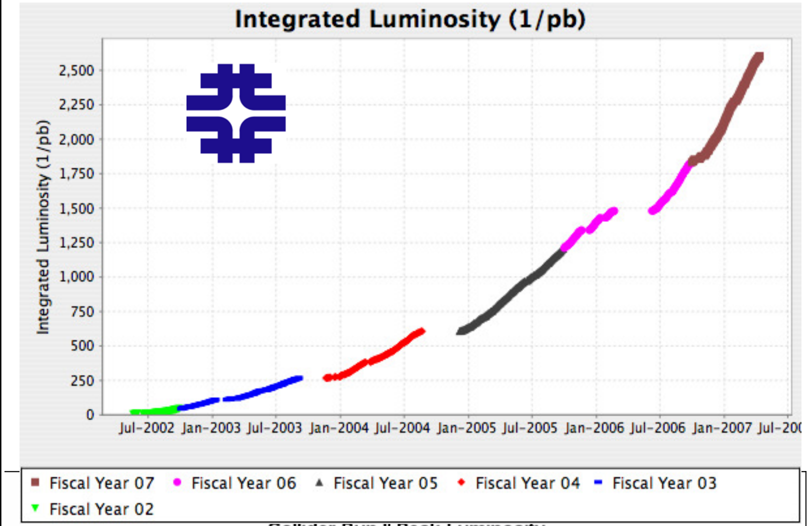


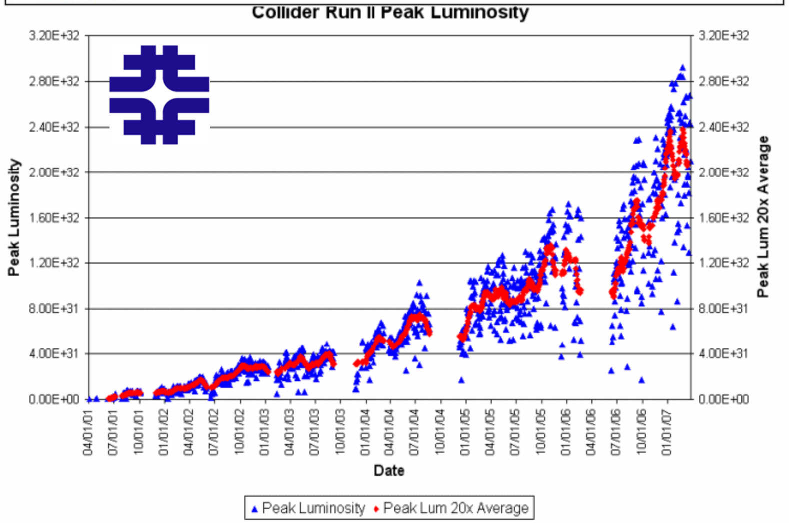
- ☞ "Run II is not a construction project. Run II is a complex campaign of operations, maintenance, upgrades, R& D and studies." (D.Lehman)
- ☞ Luminosity goal:
  - ⇨ 4.4-8.5 fb^{-1} by FY 2009
    - → More later
- ☞ Record: $2.9 \times 10^{32} cm^{-2}s^{-1}$
  - ⇨ Keep improving
  - ⇨ In one week 44.8 pb^{-1}
    - → record



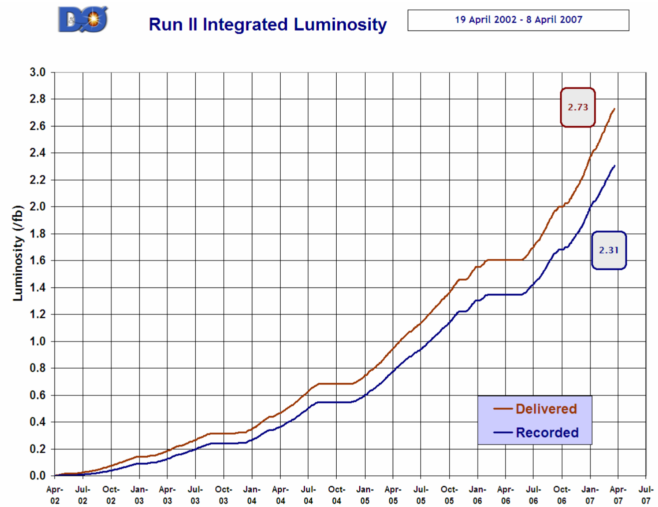
Data taking...2.9×10^{32}...

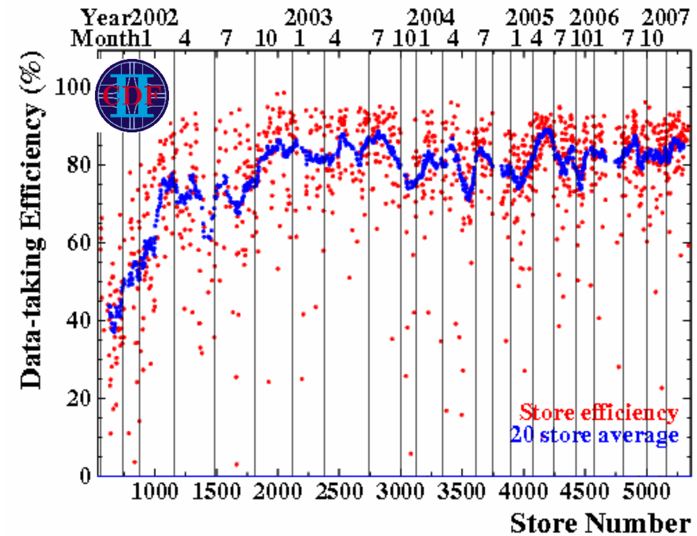
Accelerator delivers..





Detectors use:





Giorgio Chiarelli, DIS 07

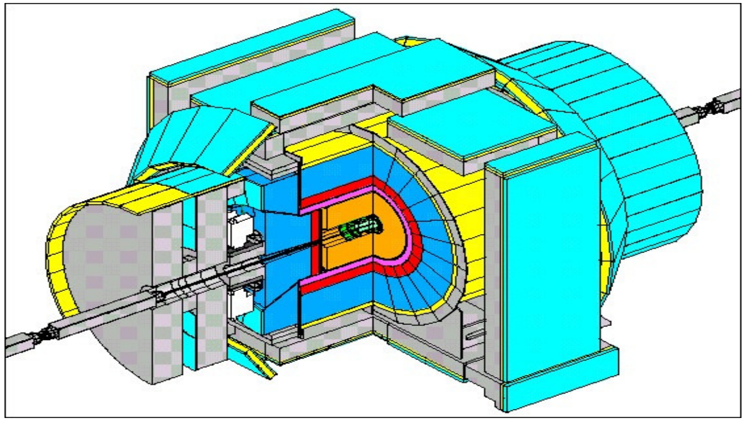
Two detectors

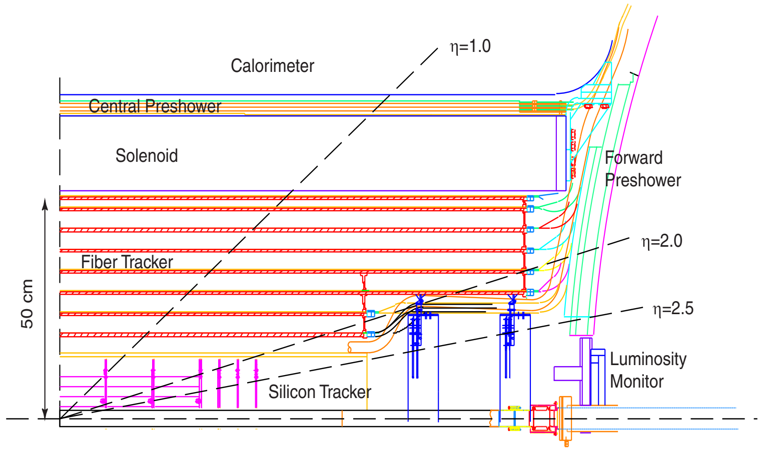
CDF underwent serious upgrades:

- New tracking system
  - COT, new silicon tracker (6-7 layers DS+1 SS)
- New forward calorimetry
- Tracking at trigger level
  - Tracks at L1
  - Displaced from PV@L2

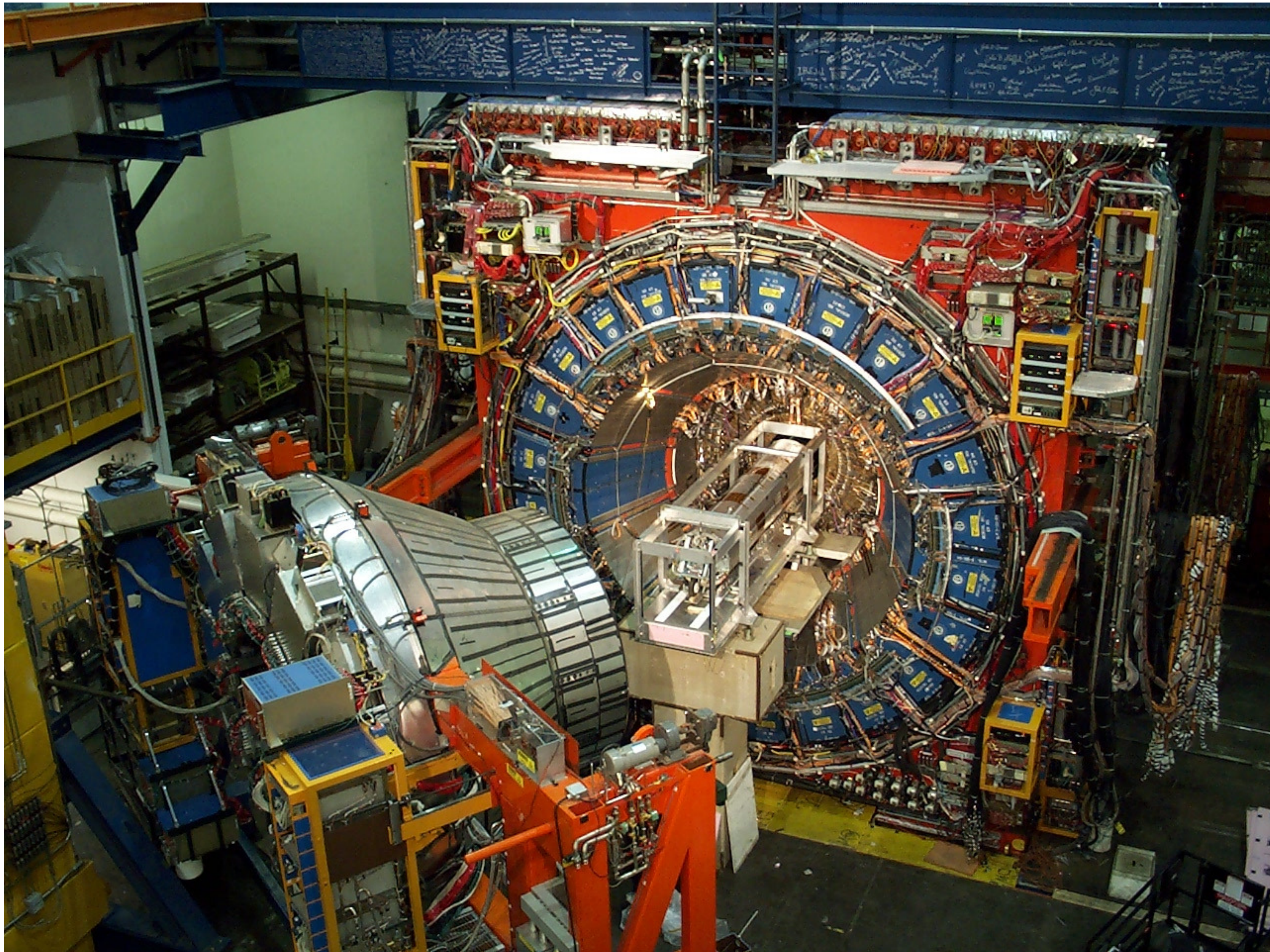
D0: change of philosophy

- New tracking system
  - Based on a 2T solenoid
  - New 8 layers fiber tracker
  - Secondary vertices capability (SVX)
  - Recently added (IIb) an extra layer of silicon sensors
- Improved muon coverage
- Upgraded trigger (IIa, IIb)

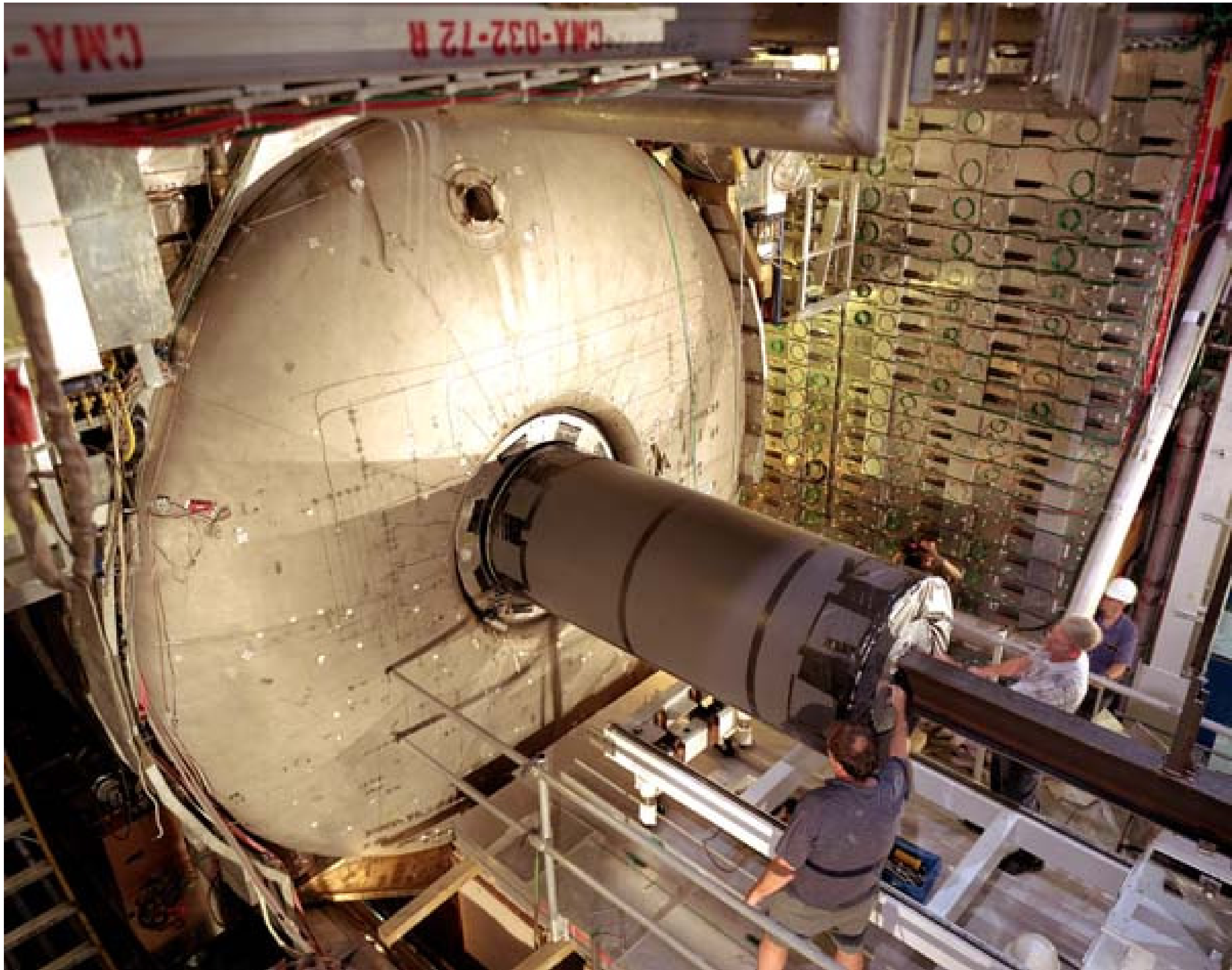




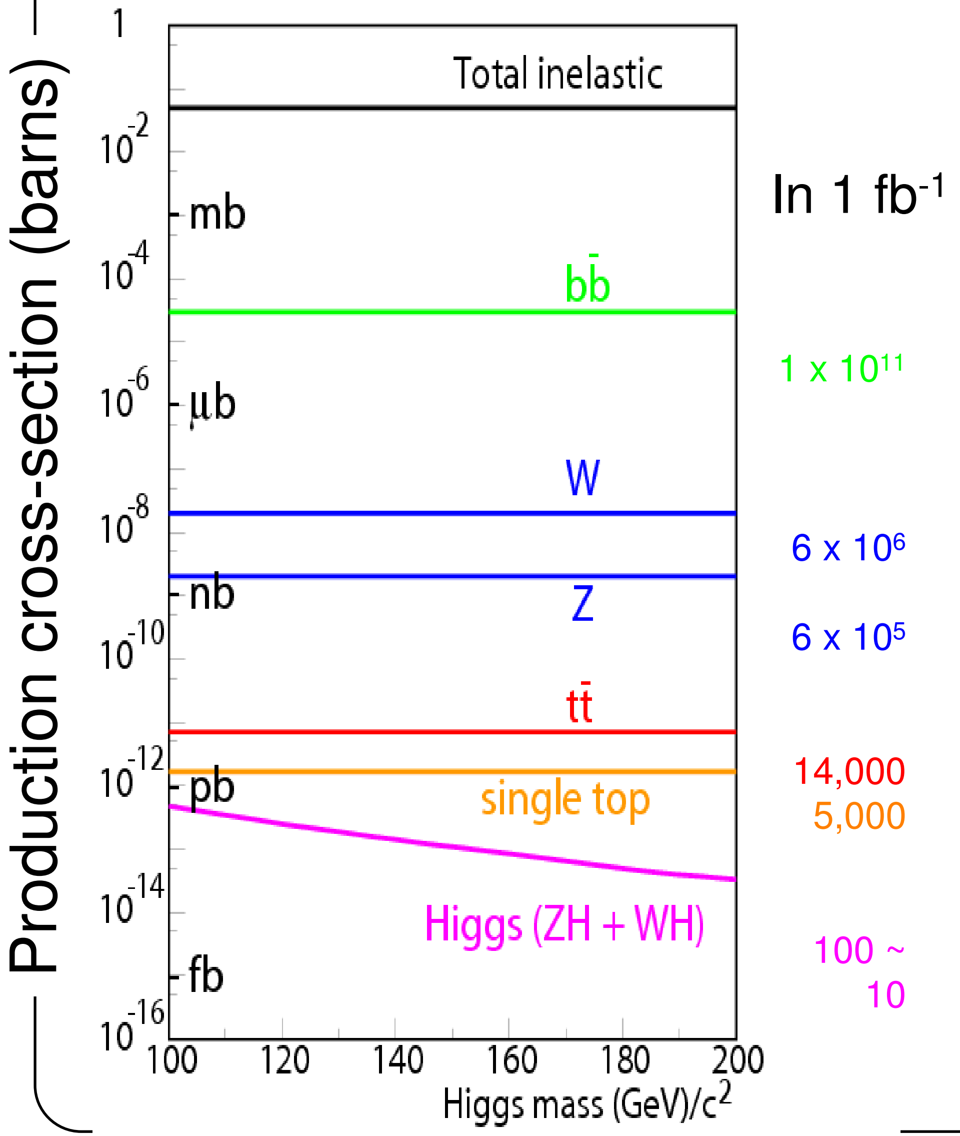
Experiments: CDF



Experiments: D0



Tevatron Collisions I



Two main areas

- B Physics
- "High" Pt Physics
  - SM (QCD)
  - SM(EWK)
  - SM(Top)
  - Higgs, BSM

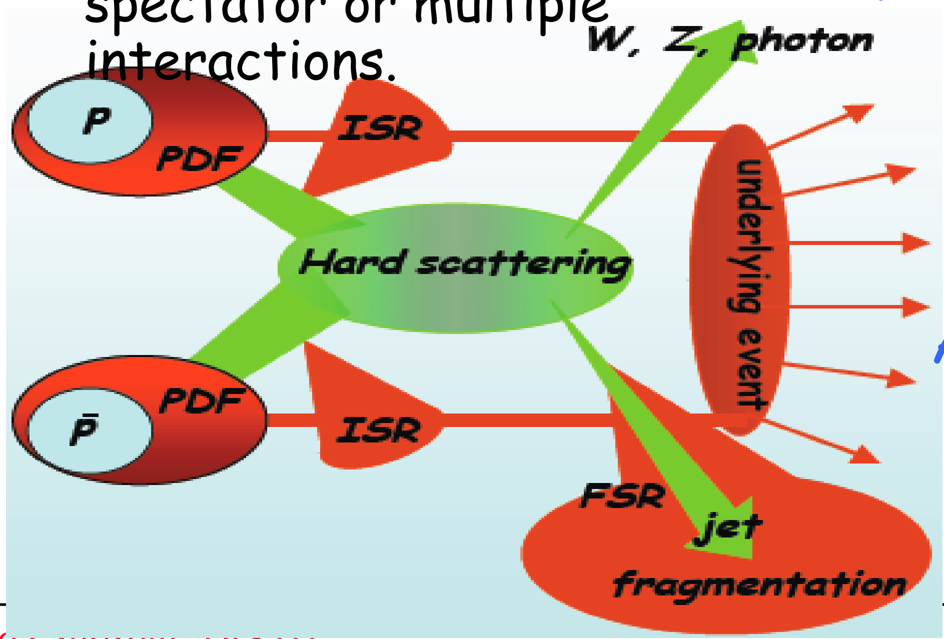
- Trigger and analyses being retuned to match the challenge
- As luminosity increases experiments are forced to deal with new challenges

At stake the capability to go down the ladder and explore the fb region

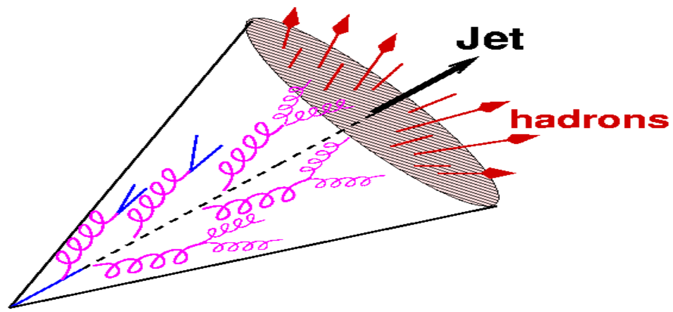
Tevatron Collisions II

The hard scattering is not all there is!

- ☞ Parton Distribution Functions (PDF): fraction of (anti)proton carried by incoming partons.
- ☞ Underlying Event (UE): extra stuff produce by spectator or multiple interactions.



- ☞ Initial and Final State Radiation (ISR, FSR): extra gluons radiating off the original/final partons.
- ☞ Jets: fragmentation of quark/gluons and recombination into hadrons reconstructed inside a cone.



All of these processes, and more, have an impact on what we measure

Some CDF results for Win 07

QCD
- b-bbar dijet production cross section (260 pb^{-1})
- Z+jets cross section measurement (1.1 fb^{-1})
- Z→ b-bbar
- Dijet production cross section measurement (1.13 fb^{-1})

B Physics
- Lifetime measurements:
  - B+, B0, Bs and Λ_B (1fb^{-1})
- Rare decay searches:
  - $B^+ \to \mu^+\mu^-$ K+, $B^0 \to \mu^+\mu^-$ K*, $B_s \to \mu^+\mu^- \phi$ (1fb^{-1})
  - B→hh

EWK
- Observation of WZ production
- Evidence for ZZ production
- W mass, width

Top
- Top mass in all-jets channel
- Production cross section (lepton+isolated track)
- Search for W' using the single top sample
- Top Production Mechanism (gg vs qq)
- Top Charge

New Phenomena
- Search for New Particles Coupling to Z+jets (b'->Z+b) in 1.1 fb^{-1}
- SUSY trilepton combined limit - 0.7 to 1 fb^{-1}
- High-mass dielectron (Z' search) - 1.3 fb^{-1}

Higgs (fb^{-1})
- $H \to \tau\tau$ SUSY Higgs
- H→WW ME-based analysis
- ZH→llbb 2D-NN and MET fitter analysis

Some results from D0

After ICHEP

- B physics:
  - LB lifetime in 1.3 fb^{-1}
  - Search for Bs oscillations in 1.2 fb^{-1}
- QCD
- EWK
  - Wg in 900 pb^{-1}
- Top
  - σ(ttbar)
- Searches
  - GMSB SUSY
  - Fermiophobic Higgs
  - ZH

Winter 07

- B Physics
  - $B_s \rightarrow \mu\mu$ 2 fb^{-1}
- QCD
  - Triple jet differential cross section 1.1 fb^{-1}
- EWK
  - $Z\gamma^* \rightarrow 4l$ 1 fb^{-1}
- Top
  - σ(ttbar)
    - → Dilepton
    - → L+jets
  - Top mass
  - Single top
- Searches
  - 2^{nd} generation LQ
  - WH (many channels)
  - Updated SM Higgs limit
  - $H \rightarrow \tau\tau$

B Physics at an Hadron Collider

Thought to be almost impossible

- Exploits large cross section
  - Need tight selection at trigger level
  - Tracking capability at L1 and displaced track trigger at L2 at CDF

  Challenge at high luminosity
- Some very recent results:
  - Bs oscillations [Observed by CDF with 1fb^{-1}]
  - B→hh [1fb^{-1}]
    - A_{CP} in $B^0 \to K\pi$, $B^0_s \to K\pi$
    - BF: B→KK,B→πK, B→Λp
  - Search for rare B decays [D0 with 2 fb^{-1}]
    - $Bs \to \mu\mu$, $B_d \to \mu\mu$
  - Measurement of B_c mass, new B Baryons states, excited states

Talks by M.Corcoran, M.Heck, B.Kehoe, B.Reisert

Bs oscillations

D0 has a limit (900 pb^{-1})

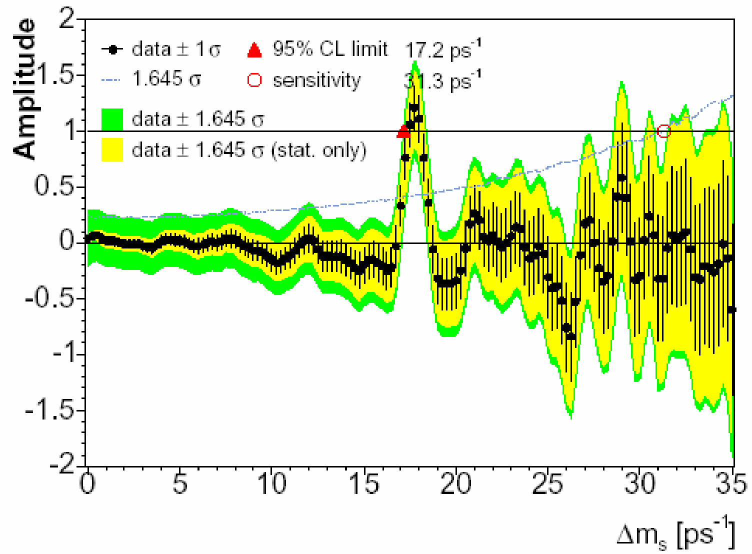
- $14.9 < \Delta m_s < 21\ ps^{-1}$ (90% CL)

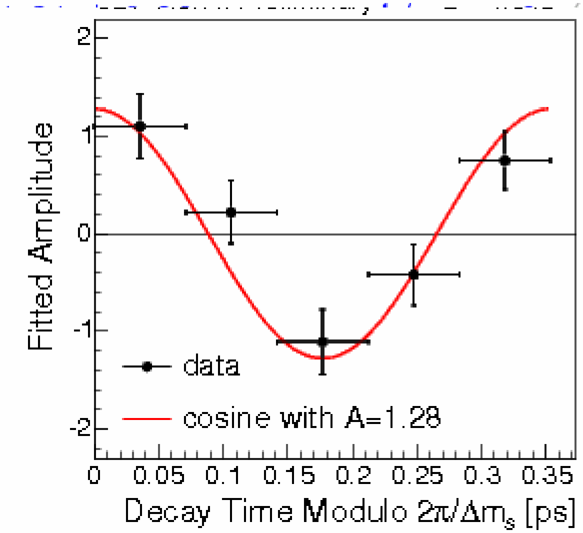
CDF, with 1fb^{-1} presents

- Observation of B_s Oscillations

PRL 97, 242003 2006

- $\Delta m_s = 17.77 \pm 0.10(stat) \pm 0.07$ (syst) ps^{-1} : > 5σ observation
- Same data set used for previous (spring 06) limit
  - Improved selection
  - Improved analysis technique
  - A lot of efforts



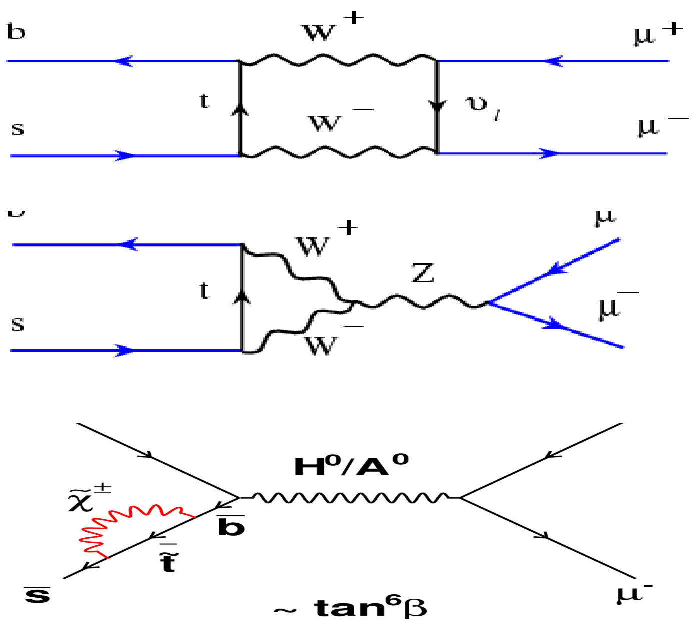


Talk by Bob Kehoe

Rare decays as window to new physics

Some decays are predicted with BF 10^{-9} in the SM but have a potentially much larger rates in SUSY models

$$BR(SUSY) \propto BR(SM) \cdot \frac{m_b^4 \cdot (\tan \beta)^6}{m_{H^0}^4}$$



D0 new result with 2 fb^{-1}

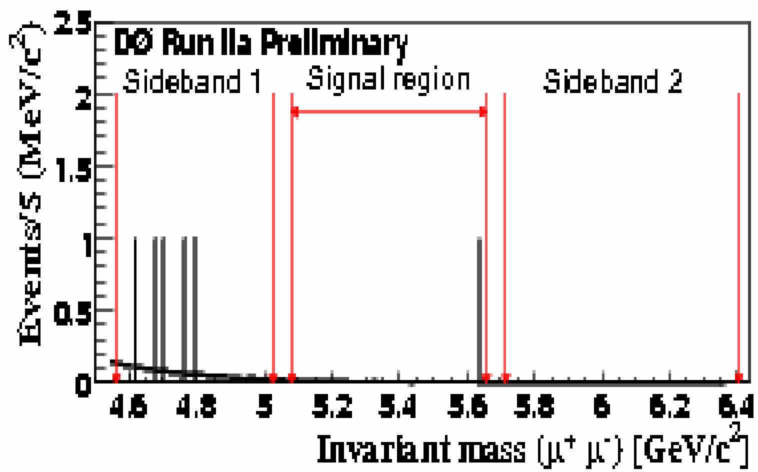
- 3 events (2.3+-0.7 exp.)
- <9.3(7.5)10^{-8}@95(90)% CL

Not yet combined with CDF 0.8 fb-1 CL limits:

- ⇨ B_s<10(8) 10^{-8} 95(90) %
- ⇨ B_d<2.3(2) 10^{-8} 95(90) %

→ To be updated soon..

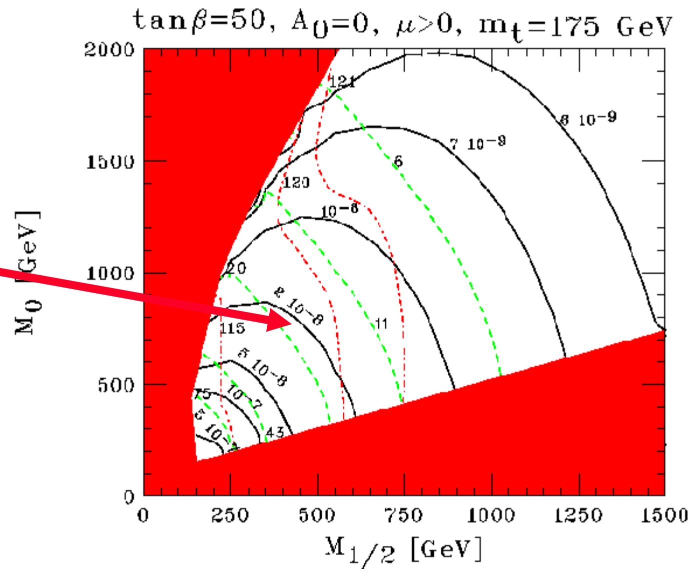
Run IIa data taking (1.3 pb^{-1})
1 evts, 10.8±0.2 exp



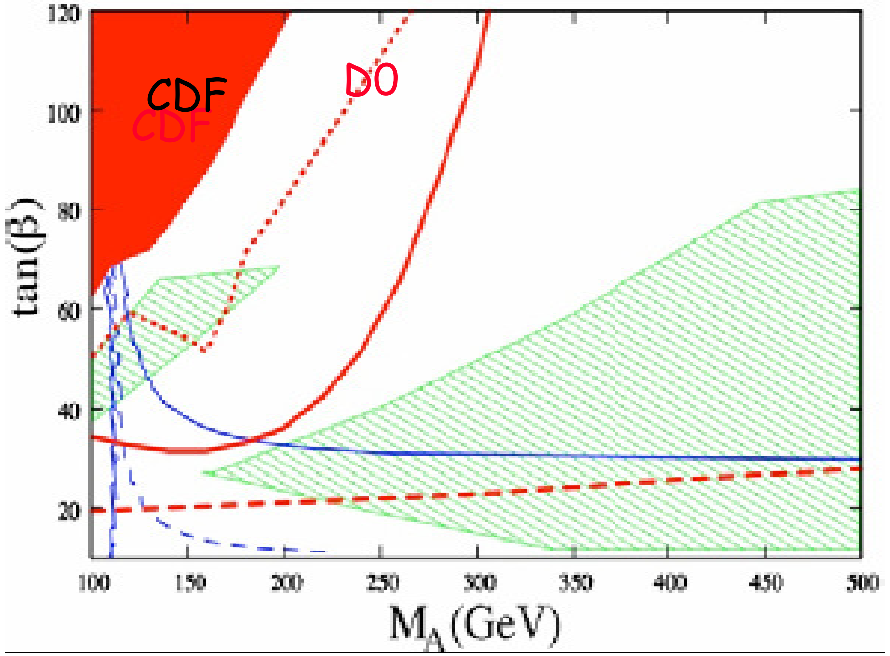
SUSY limits-examples

B_d 2.3(2) 10^{-8}@95(90)%CL,

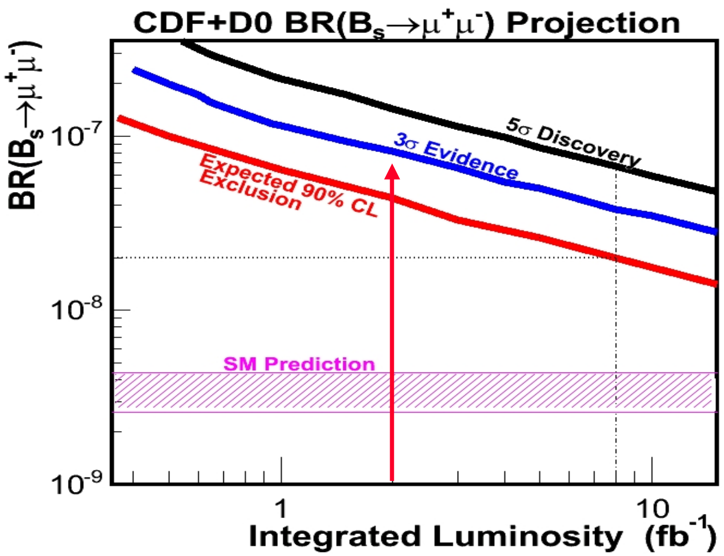
B_s<9.3(7.5) 10^{-8} @95 (90)% CL



M.C., Menon, Wagner



M. Carena
(Moriond 2007)



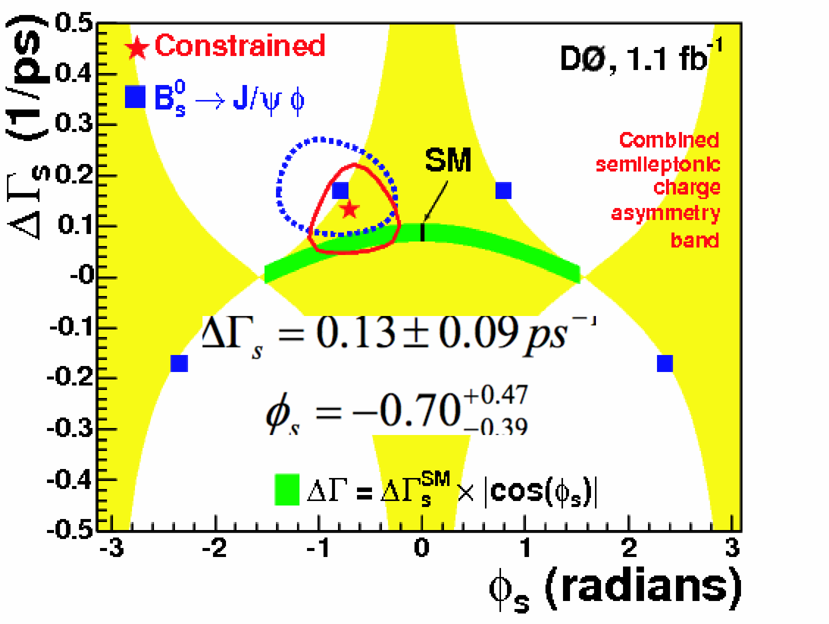
Giorgio Chiarelli, DIS 07

See M. Corcoran

Lifetimes, masses...new states

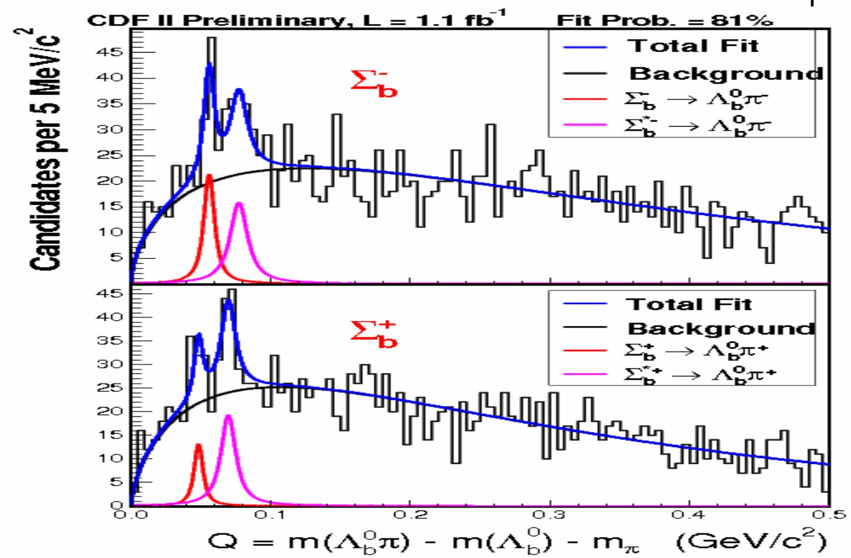
D0

- single measurement of τ_{Bs} using s.l. decays
  - ⇨ Combination of some measurements of its own with the Δm_s from CDF and measurements from B factories



Study of B states:

- B_c mass and properties
- New measurement of Λ_B lifetime (1 fb^{-1})
  - ⇨ D0:
    - → 1.28±.11±.09 ps (sl)
    - → 1.3 ±.14±.05 ps (exc)
  - ⇨ CDF
    - → 1.5±0.77±0.012 ps
- CDF: Observation of Σ_B and Σ_{B^*}

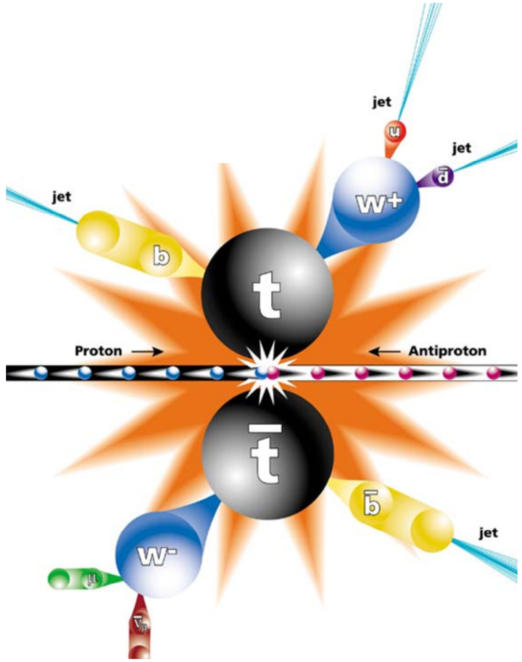


See Bob Kehoe, Martin Heck, M. Corcoran

High P_T Physics

Need to define a clear set of physics objects

- Jets
- High pt charged lepton
- neutrinos
- B tagged jets
  - Displaced tracks
  - Soft lepton id



High mass objects (top, Higgs, New particles) decays into jets, leptons (charged and neutral)

- Challenge: reconstruct initial parton state

QCD Physics

Basics for any possible analysis:

- ☞ Jets carry information about QCD, PDF, couplings
  - ⇨ Et and angular distributions, fragmentation
  - ⇨ Comparison to pQCD predictions
- ☞ Measuring jets means understand calorimetry and tracking
- ☞ Can be tools (or background) in many physics topics

Results:

- ☞ Inclusive jet cross section (inherited *discrepancy* with pQCD from Run I)
- ☞ Jet fragmentation
- ☞ Dijet mass x-section
- ☞ W+jets, Z+jets production
- ☞ Underlying events
- ☞ Diffraction

See talks by

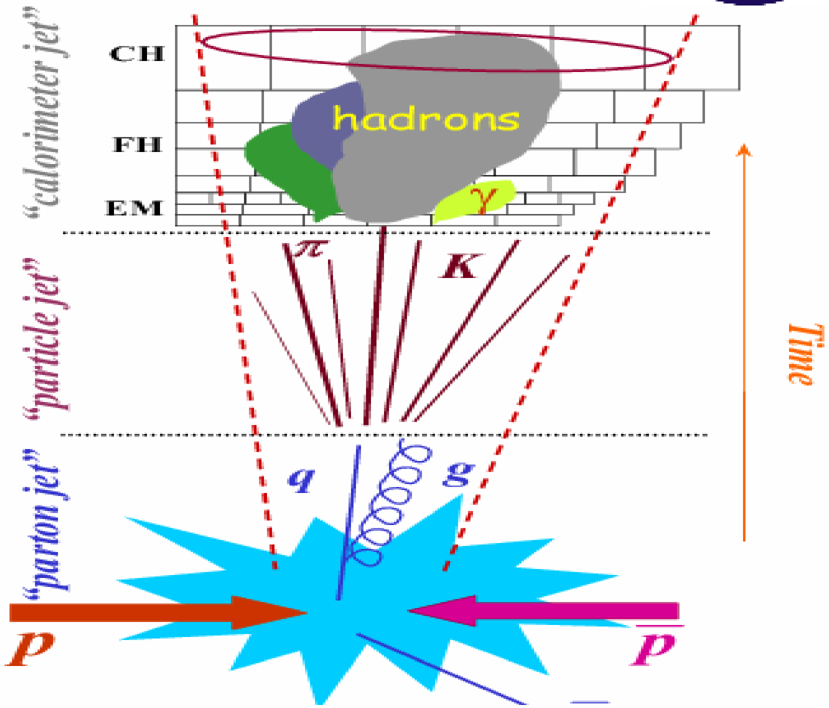
O. Atramentov, J. Cammin, M. D'Onofrio, L. Pinera, C. Mesropian, S. Vallecorsa

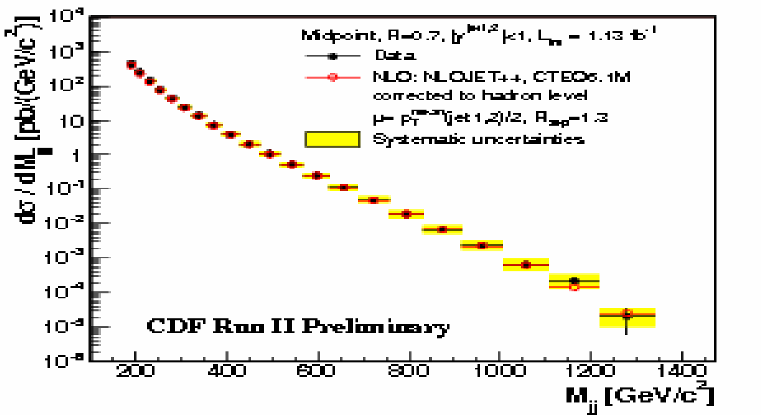
Inclusive jet Physics

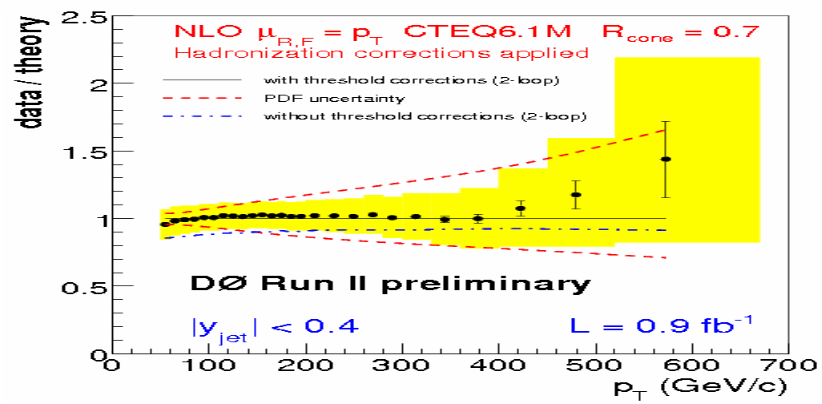
Jets are a key probe

- ☞ Fundamental in measuring top mass, search for new physics, test of the SM..
- ☞ Can show early appearance of new physics!

Large effort by both experiments in understanding production and properties



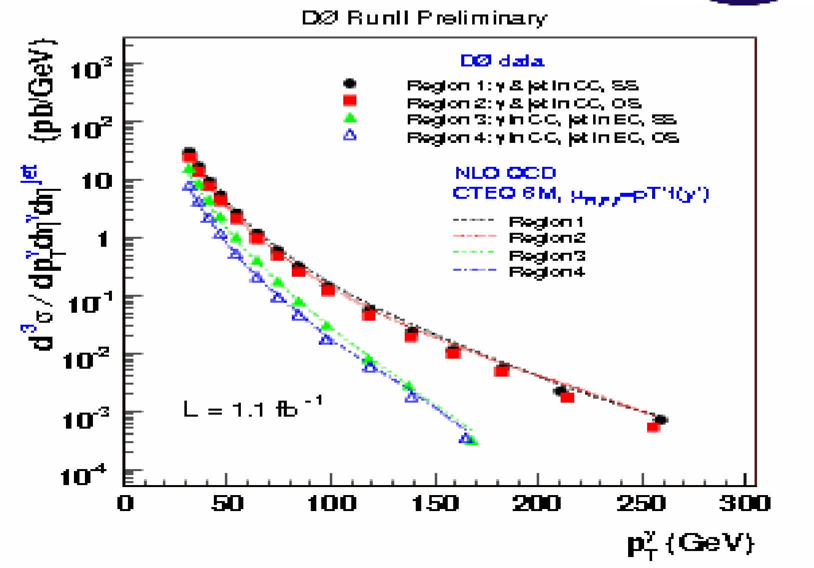


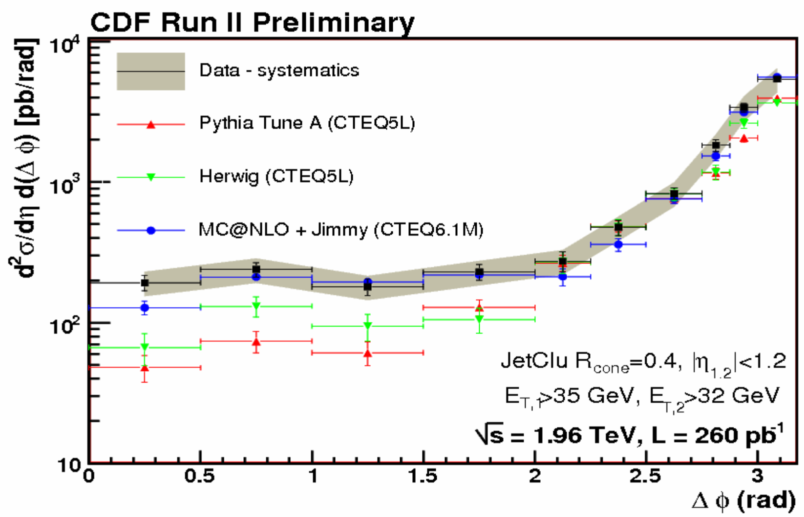


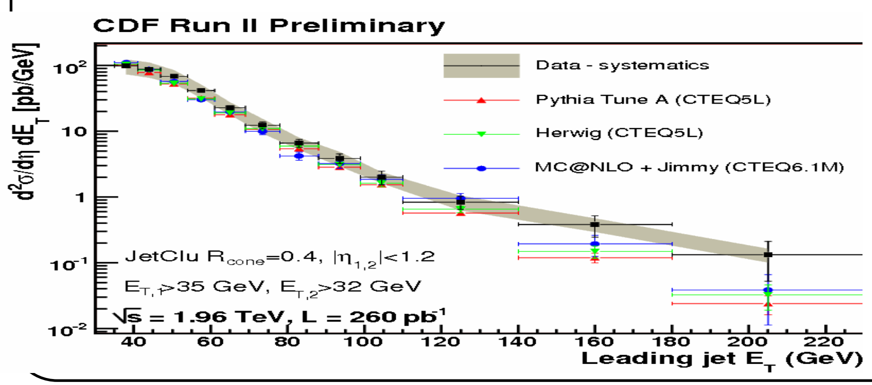
Less inclusive states

With larger statistics and improved detectors more and more results from prompt photons:

- D0 measures the triple γ–jet differential cross sections in 1 fb^{-1}
- CDF exploits smaller data sample collected with trigger devoted to detect secondary vertices and studies bbar







EWK Tests of the SM

Basics for top, searches

- Decay, associated production
- Often background for rare processes
- Discrepancy from SM would signal new physics

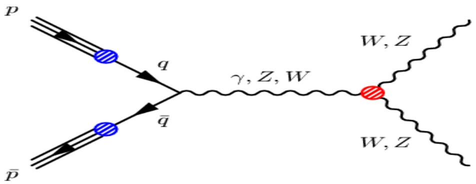
Both CDF and D0 measure

- Inclusive and differential production cross section (PDFs..)
- Multiboson production (WW, ZZ, WZ, Wγ, Zγ: really at the boundaries of the Tevatron reach
  - ⇨ WZ:
    - → First observation by D0 (3.3 σ)
    - → CDF WZ at 6 σ
  - ⇨ WW production observed with 0.35 fb^{-1}
    - → CDF, D0
  - ⇨ CDF evidence for ZZ at 3 σ (winter 07)
  - ⇨ Zγ, Wγ test of trilinear gauge coupling
    - → Zγ measured by CDF (0.35 fb^{-1}) and D0 (1 fb^{-1})
    - → Wγ: D0 measures an angular distribution looking for the radiation amplitude zero.
- CDF measures W mass and width

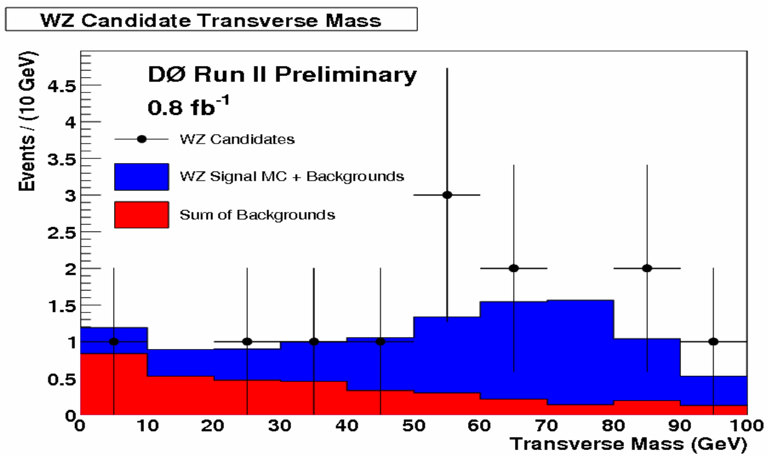
See talks by S.Malik, Y.Maravin, A.Robson

ZZ, WZ

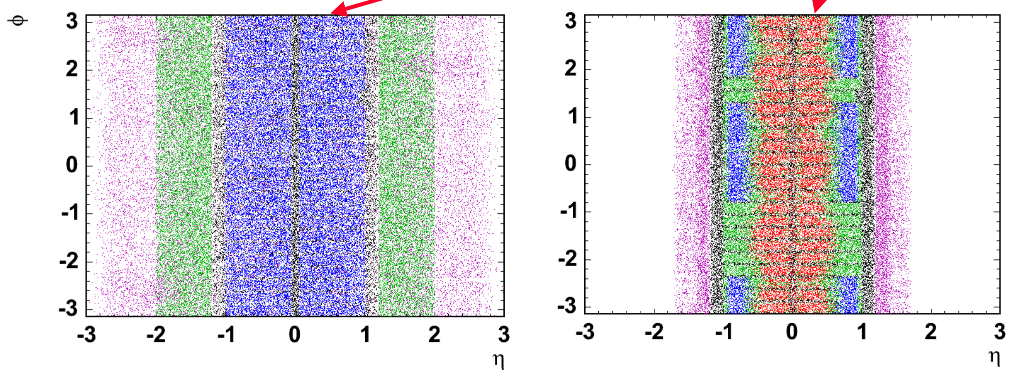
Intermediate steps towards *WH*, WZ→lllν has a NLO σ=3.7±0.1 pb



- D0 presented a 3.3 σ evidence in Summer 06
- $\sigma=3.98^{+1.91}_{-1.53}$ (stat+sys)pb



- Winter 07: CDF improved its analysis by extending acceptance for e and μ



Source	Expectation ± Stat ± Syst ± Lumi
Z+jets	1.22 ± 0.27 ± 0.28 ± -
ZZ	0.89 ± 0.01 ± 0.09 ± 0.05
$Z\gamma$	0.48 ± 0.06 ± 0.15 ± 0.03
$t\bar{t}$	0.12 ± 0.01 ± 0.01 ± 0.01
WZ	9.79 ± 0.03 ± 0.31 ± 0.59
Total Background	2.70 ± 0.28 ± 0.33 ± 0.09
Total Expected	12.50 ± 0.28 ± 0.46 ± 0.68
Observed	**16**

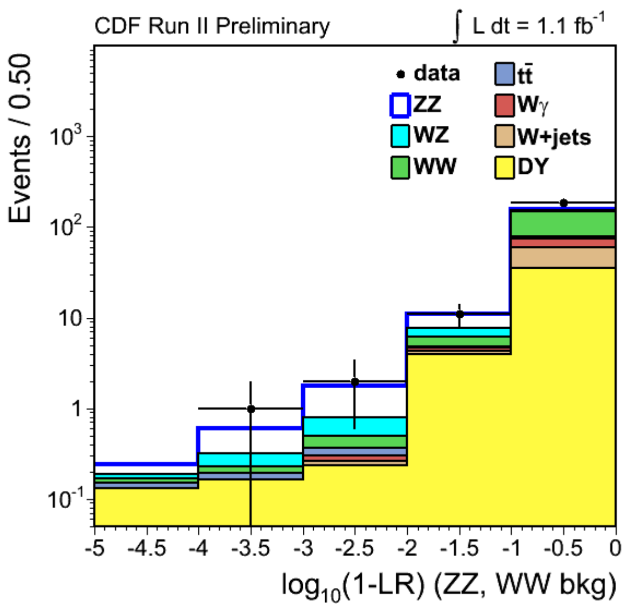
$\sigma(WZ)=5.0^{+1.8}_{-1.6}$(stat.+syst.) pb

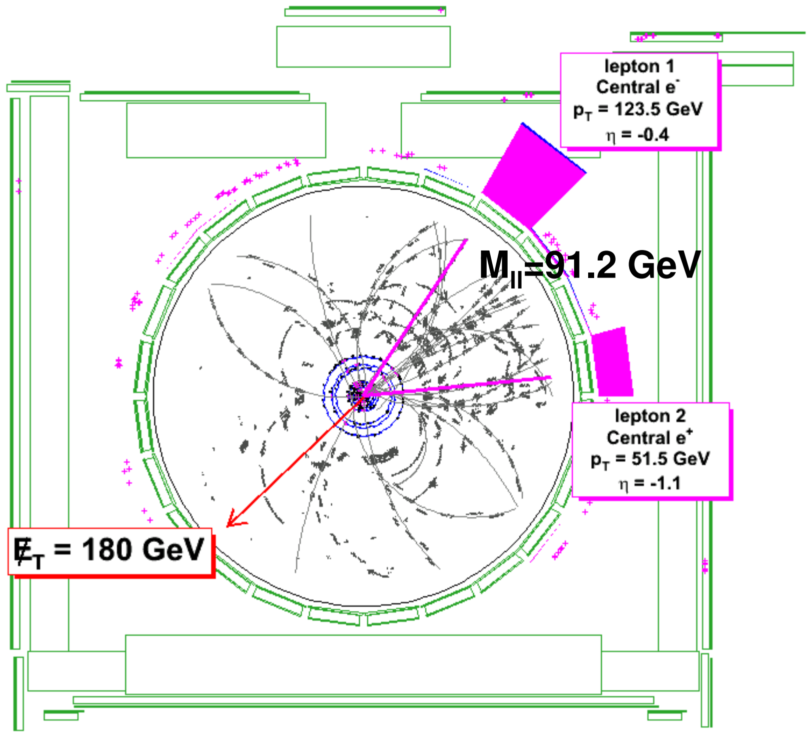
Prob(background only) < 1.5×10^{-7} (5.1σ)

ZZ

ZZ→4l is the smallest σ measured at the Tevatron: σ_{NLO}=2.1 pb

- ☞CDF adds new channel (ZZ→llνν) to summer 06 analysis and, in 1.4 pb^{-1}, finds
  - ⇨$\sigma=1.14^{+1.1}_{-0.8}$ (stat+syst) pb



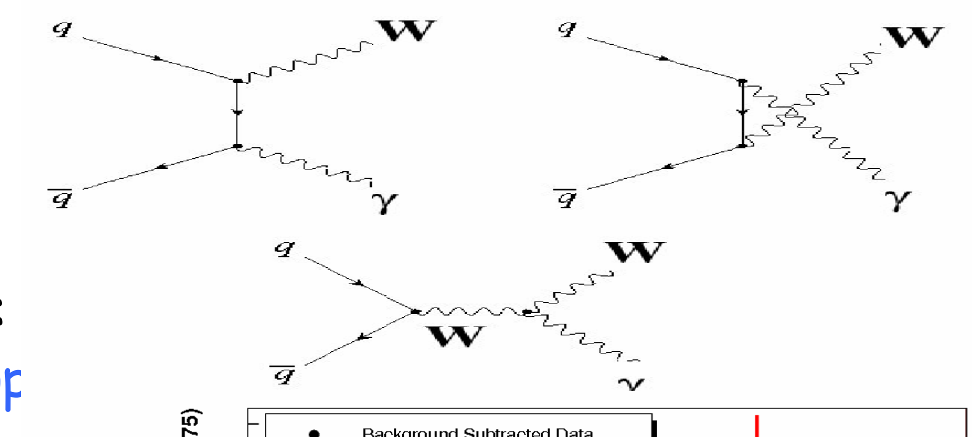


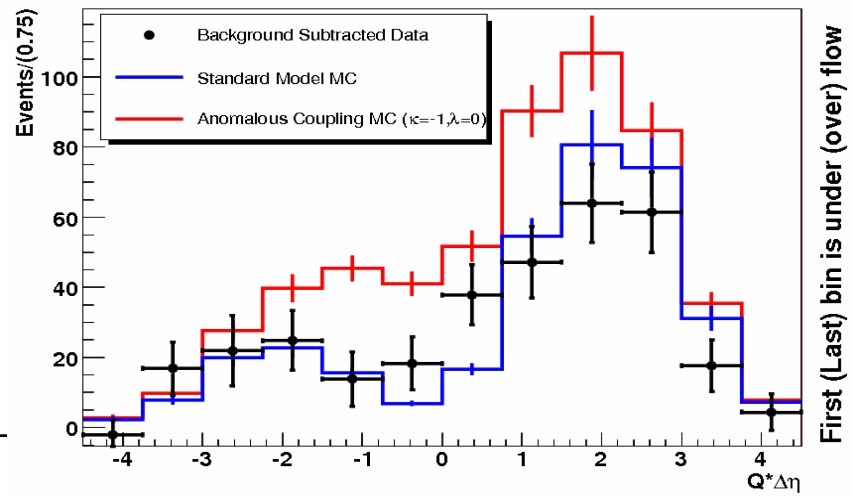
Zγ, Wγ

The gauge structure of the SM has a crucial test in the (destructive) interference in Wγ

- Both CDF and D0 measured Zγ and Wγ cross section in 1 fb^{-1}
- CDF:
  - ⇨ $\sigma(W+\gamma)$ = 19.1±2.8 pb
  - ⇨ $\sigma(Z+\gamma)$ = 4.9±0.5 pb
- D0($E_T\gamma$>7GeV, M_T(lγ,MET)>90:
  - ⇨ $\sigma(W+\gamma)$ = 3.2±0.5±0.2(lum)p
- $\sigma(Z+\gamma)$ =4.51±0.4±0.3(lum) pb

The interference among the three tree-level diagrams below create a zero in the cosϑ* distribution at cos ϑ* =±1/3

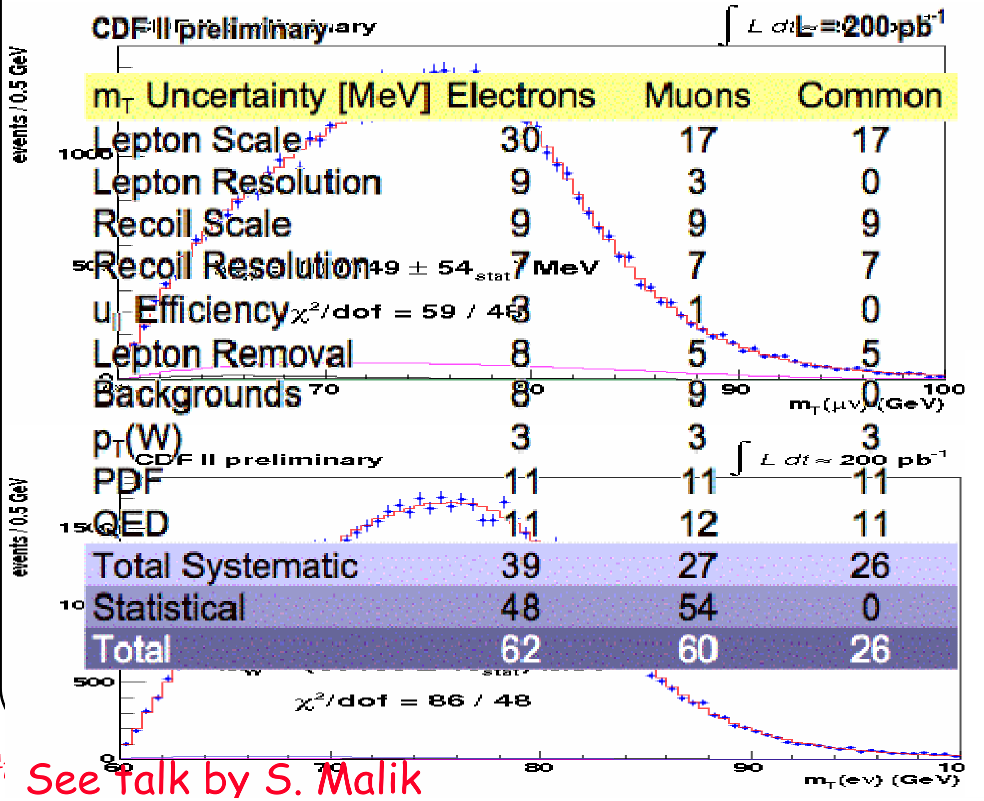




W mass and width

CDF presents the best single-experiment result, which is now statistically limited

MW = 80413±48 MeV/c²

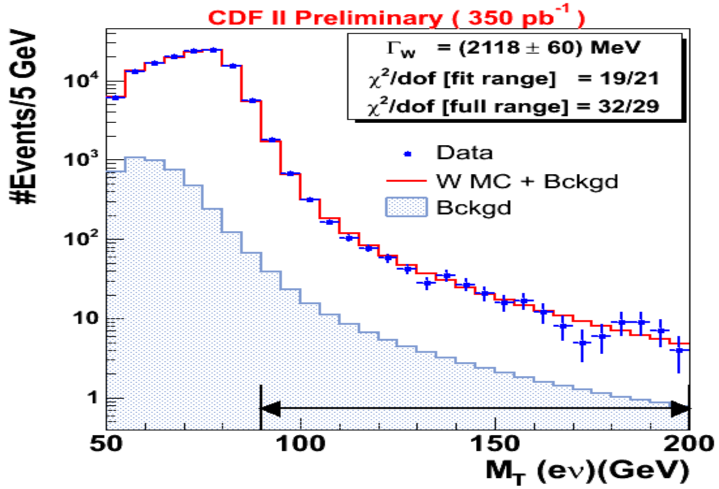


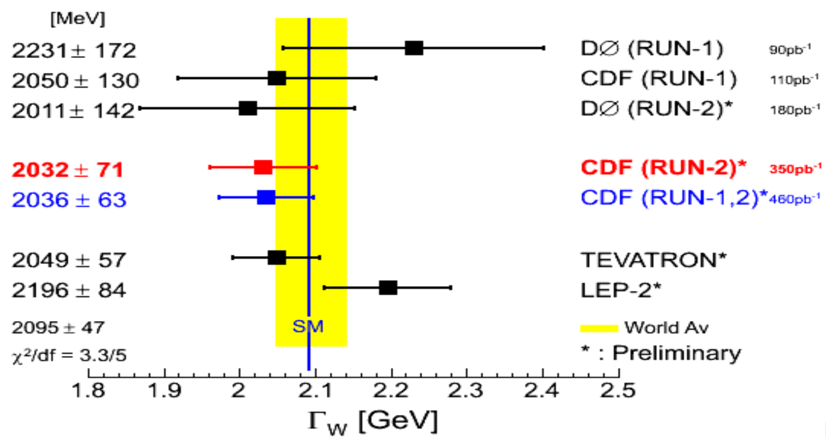
CDF II preliminary $\int L\,dt$ = 200 pb^{-1}

m_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	9	9	9
Recoil Resolution	7	7	7
$u_{\parallel}$ Efficiency	3	1	0
Lepton Removal	8	5	5
Backgrounds	8	9	0
p_T(W)	3	3	3
PDF	11	11	11
QED	11	12	11
Total Systematic	39	27	26
Statistical	48	54	0
Total	62	60	26

CDF also measure the W width

Γ_W = 2032±71 MeV/c²





G. See talk by S. Malik

Top Physics

Top has a strong relation with EWSB

- ⇨Yukawa coupling ~1

Test SM and QCD prediction

- ⇨Study of decay and production (Wtb vertex)

☞ Some studies performed in Run I

☞ With 1 fb^{-1} in Run II, performed precision measurements of:

- ⇨ttbar production cross section
  - →Pre-requirement to select top-enriched samples
- ⇨Top mass
  - →keeps improving

☞ Many ongoing analyses

- ⇨Fundamental: go from evidence (D0 2007) to discovery of EW top production (single top)
  - →Direct measurement of Vtb
  - →Critical test of the SM
- ⇨Helicity meaurement, top charge etc.

Talks by C.Gerber, S.Jabeen, J. Wagner

12 years of top

13 years ago (24/4) CDF "Evidence of top"

☞February 1995 CDF and D0 "Top Discovery"

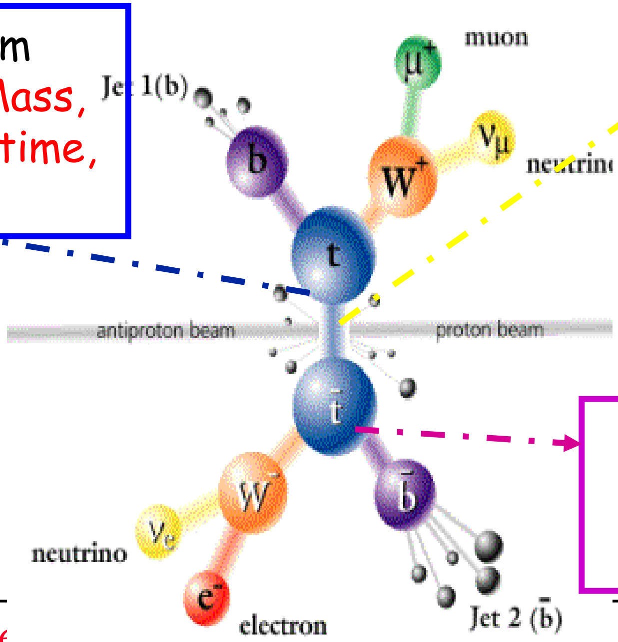
⇨Run I studies with 110 pb^{-1}, Run II 1 fb^{-1}

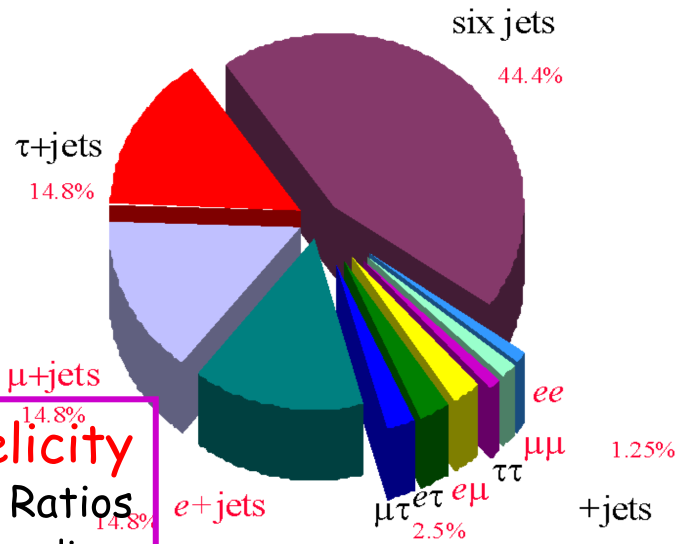
→Top produced (mostly) in pairs…

→Lots of decay channels to look at

Production cross-section
Production Kinematics

Top Quantum Numbers (Mass, Charge,Lifetime, Spin)

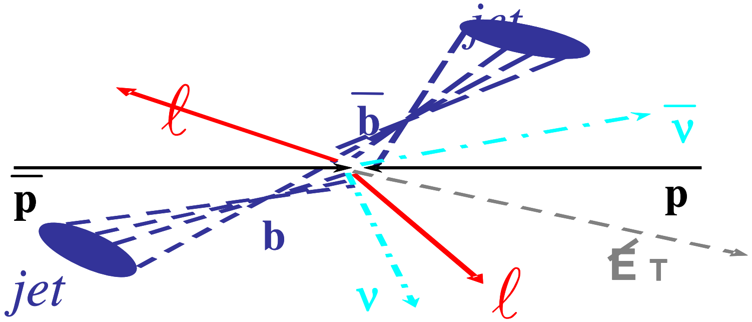




- W helicity
- Branching Ratios
- Anomalous Couplings

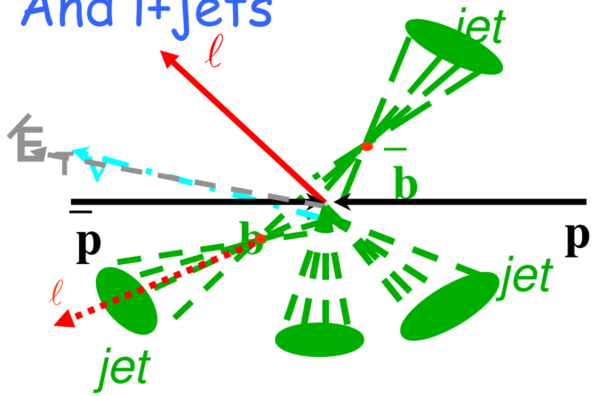
Top Production

Out of the different channels, select dilepton

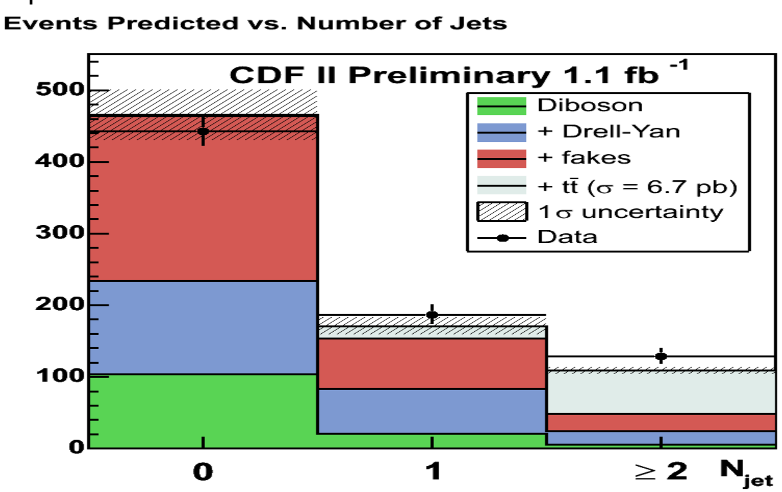


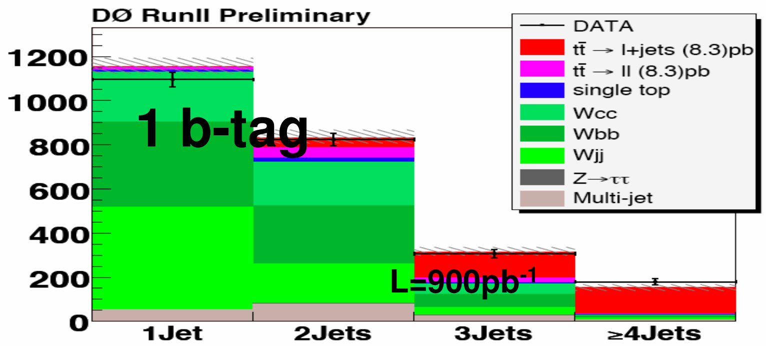
☞ to improve statistics use "identified lepton" + "isolated track"

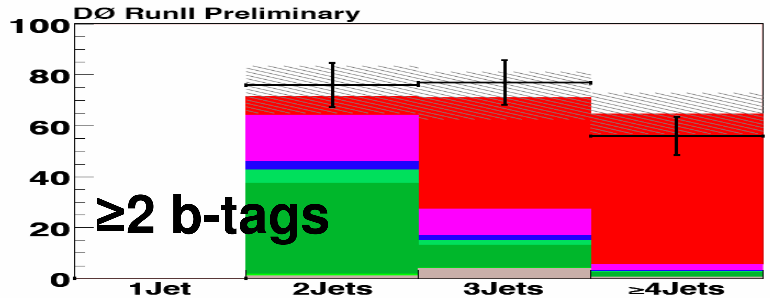
And l+jets



Use tagging to enrich sample
ε≈55% (bckg 0.5%)







Top cross section

Exp.& Th. Errors comparable:

- σ(all had): $8.3\pm1^{+2}_{-1.5}\pm0.5$ pb

$\sigma_{tt}=6.8\pm0.6$ pb (Kidonakis, Vogt)

$\sigma_{tt}=6.7+0.7-0.9$ pb (Cacciari et al.)

- Decay channel in dilepton more and more important, 1 fb^{-1}

D0: $\sigma_{tt}= 6.8^{+1.2}_{-1.1}(stat)^{+0.9}_{-0.8}(syst)\pm0.4(lumi)$pb

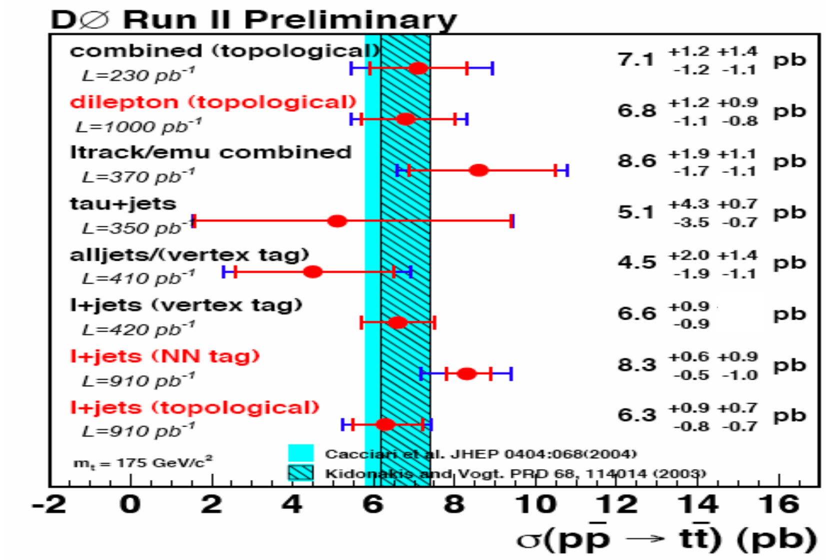
CDF $\sigma_{tt}= 9.0\pm1.3(stat)\pm 0.5(sys)\pm0.5(lum)$pb

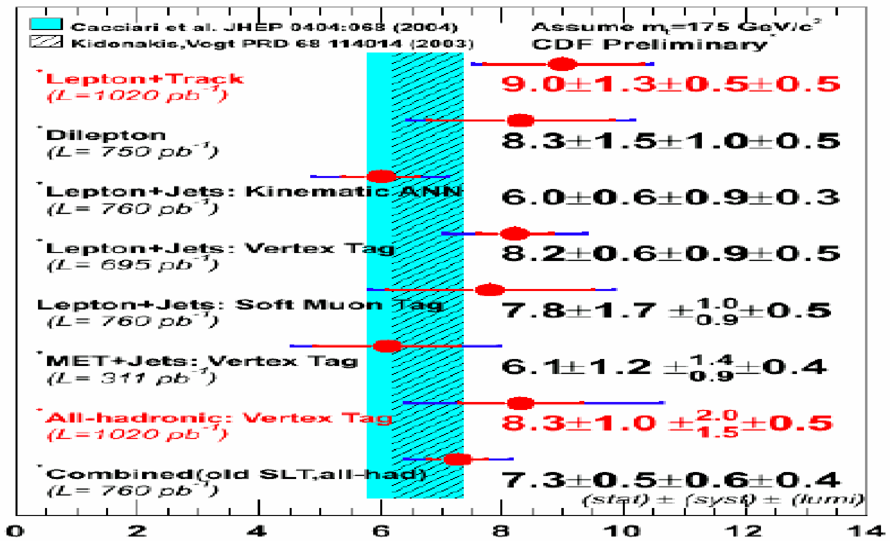
- D0 shows two results in l+jets with 1 fb^{-1}:

$\sigma_{tt} = 8.3\ ^{+0.6}_{-0.5}(stat)^{+0.9}_{-1.0}(syst) \pm 0.5\ (lumi)$ pb

Experimental accuracy reaching (in 2 fb^{-1}?) theoretical predictions

- More work ?
  - ⇨ Need NNLO calculation

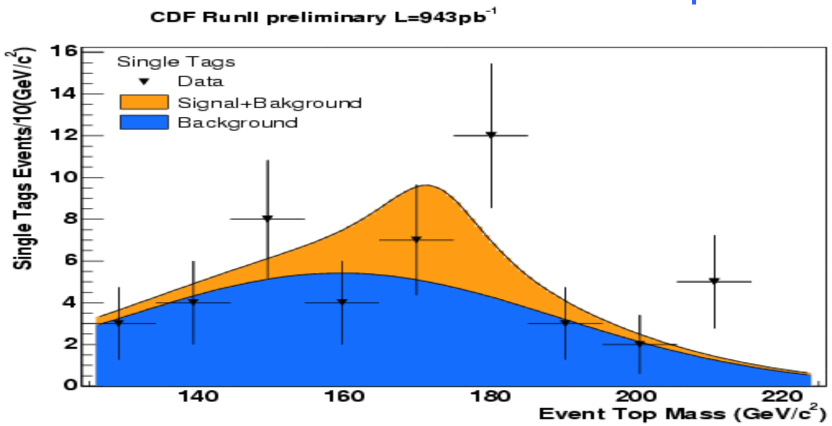


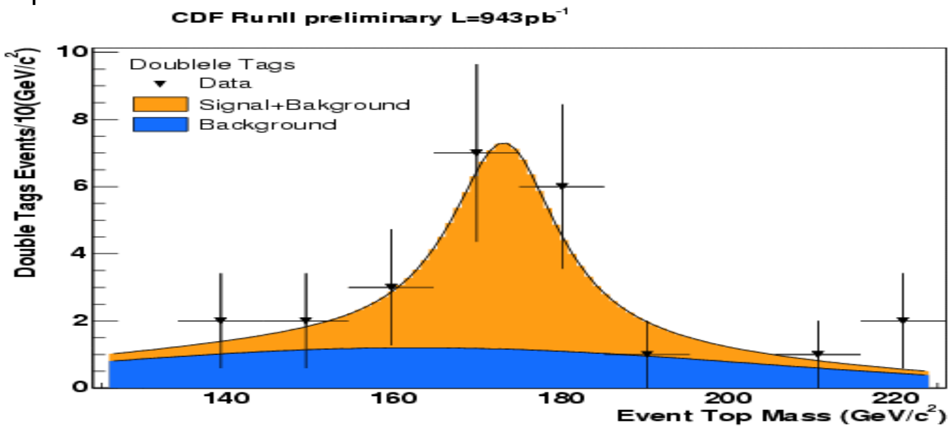


More on x-section and properties in Cecilia Gerber's talk

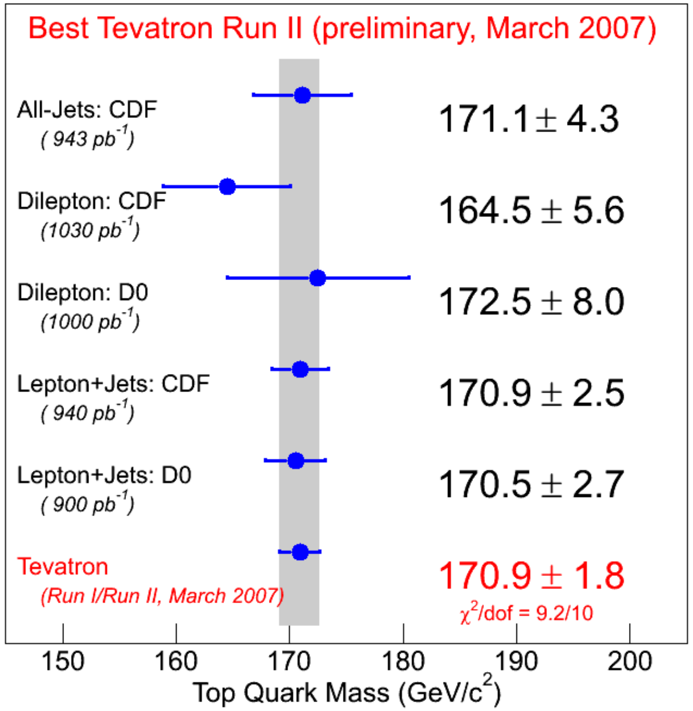
Top Mass, present and future

In each decay channel we also measure M_{top}





Great effort in understanding JES



New WA (March 07): Mtop= 170.9±1.8GeV/c^2

Talk by Jeannine Wagner

Top future (at the Tevatron)

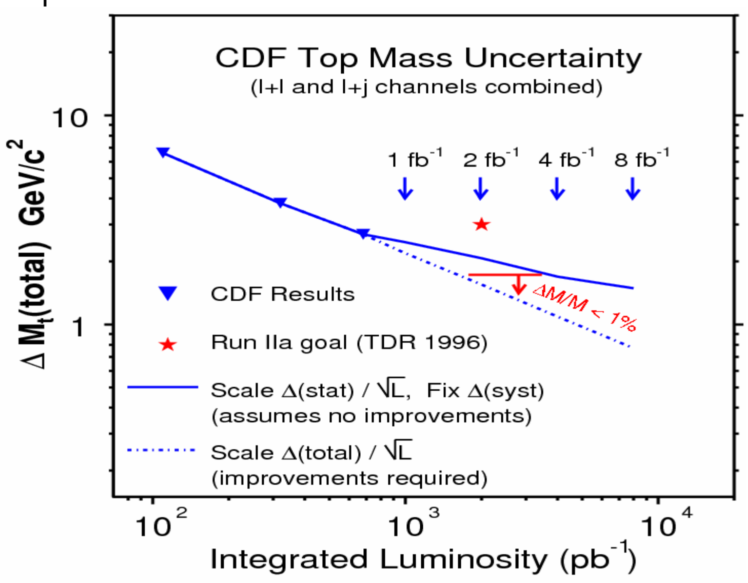
CDF and D0 can do well…

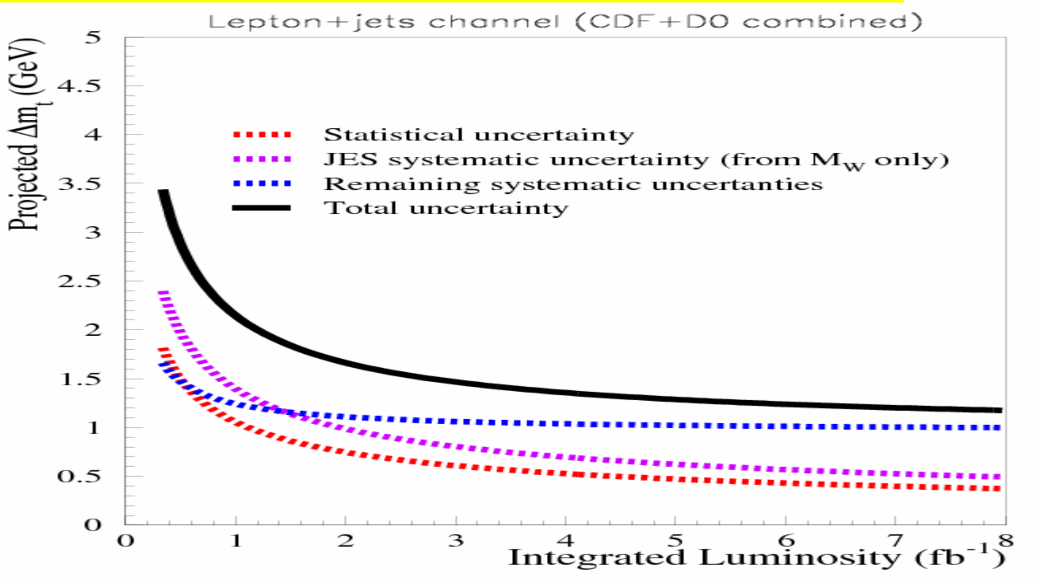
- Improved B tagger
- Z→bb calibration
- JES improves with the dataset

Together we can do even better…

- Possibility of better than 1% accuracy
  - ⇨ Tevatron legacy?

Already better than the TDR [3 GeV/c^2] (2fb^{-1})





Discussion on the meaning of a 1% accuracy (ongoing work with theoreticians)

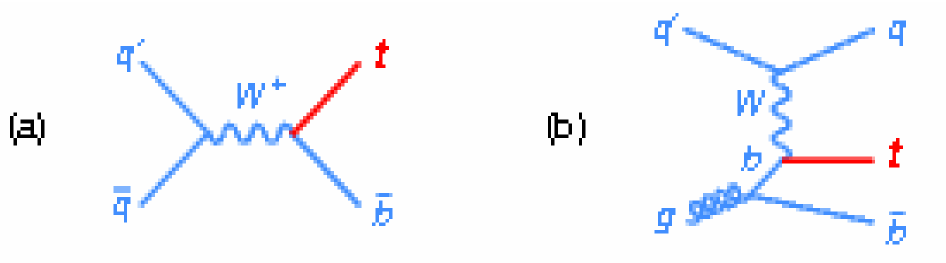
Single top

While top was detected in pairs, SM predicts that can be produced alone by EWK processes

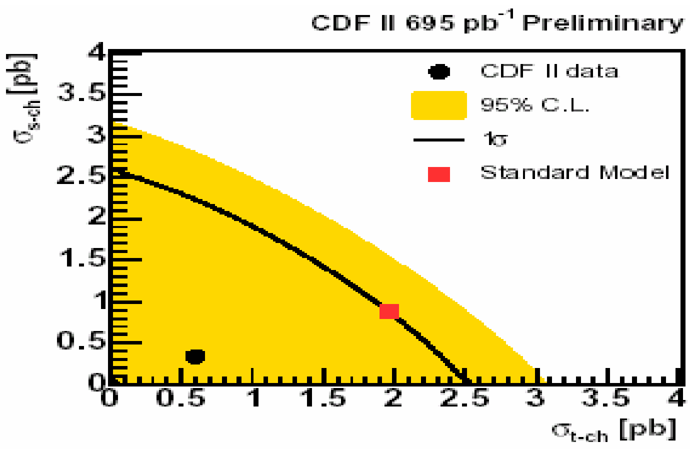
- ☞ Tiny production cross section in both channels:
  - ⇨ s-channel(a)=0.88 pb
  - ⇨ t-channel(b)=1.98 pb A.Robson,
- ☞ 1 fb^{-1} CDF set limit:
  - ⇨ $\sigma(s+t)<2.6pb$ @95%CL

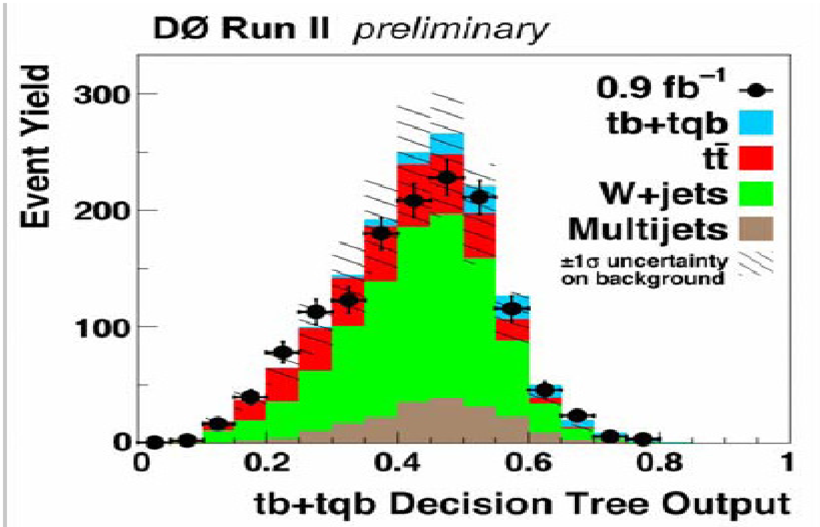
$\sigma \propto |Vtb|^2$

- ☞ Direct Vtb measurement



- ☞ D0 find a 3.4 σ signal in 0.9 fb^{-1}:



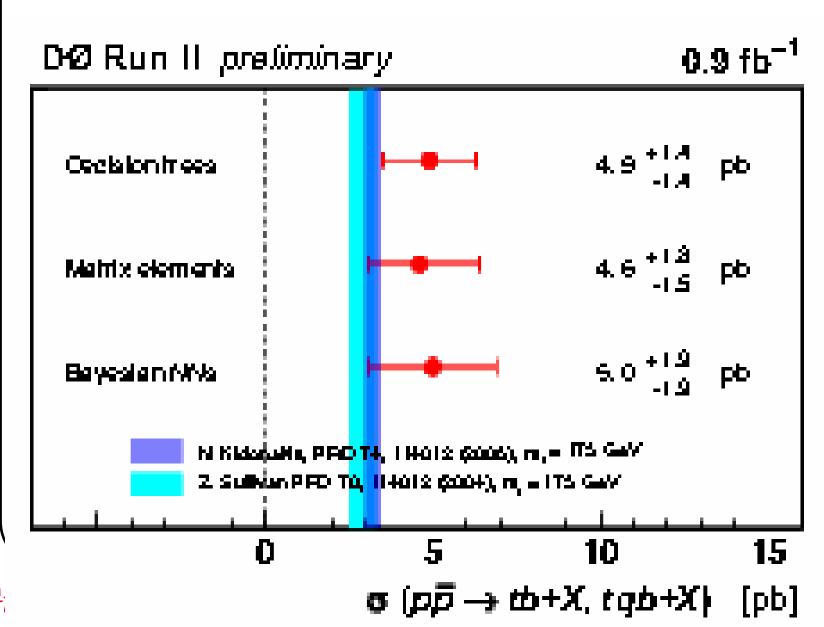


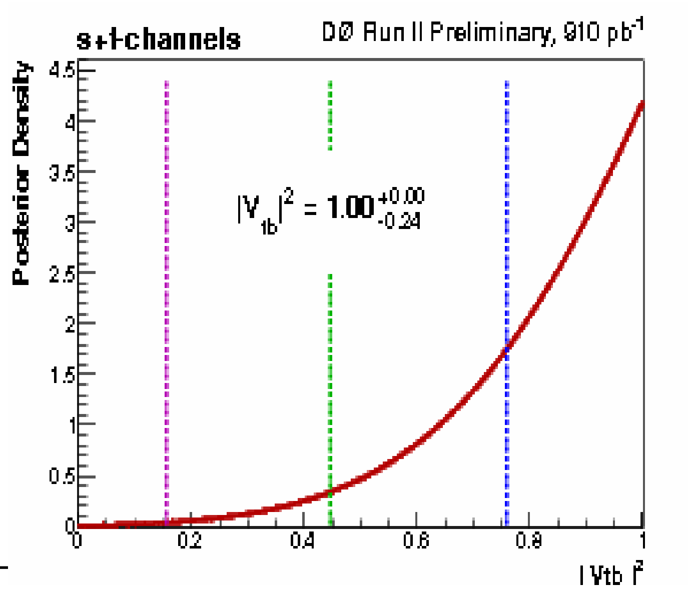
Talk by Shabnam Jabeen

Single top

D0 presented first evidence for single top this year

- ☞ Very challenging analysis
  - ⇨ Several statistical methods used
    - → One chosen (most powerful)
  - ⇨ $\sigma(s+t)=4.9\pm1.4$pb
    - → $0.68<|Vtb|<1$ @95%CL

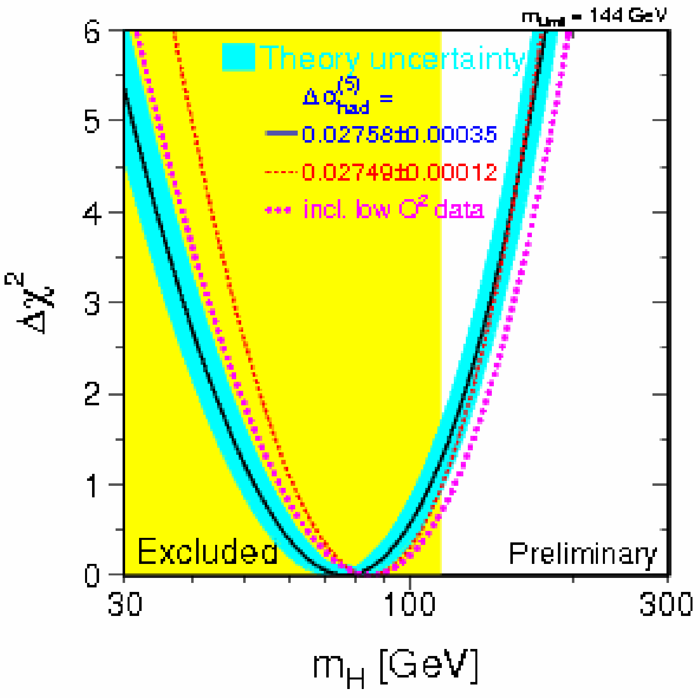




Indirect bounds for the Higgs

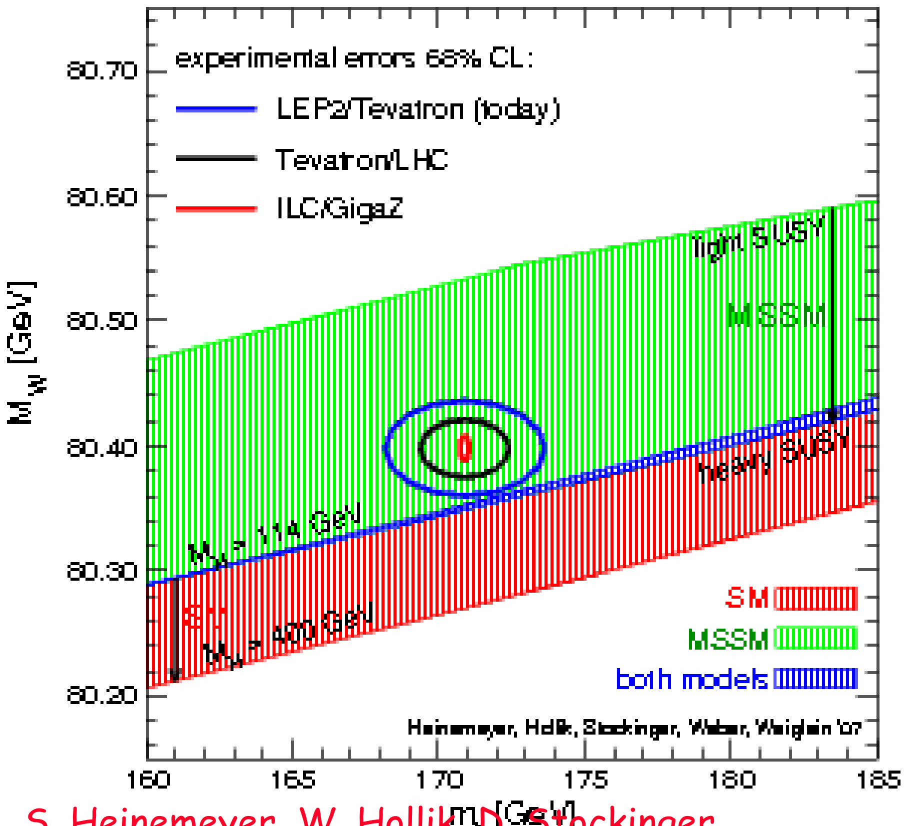
Tevatron is improving the understanding of the Higgs every day:

- ☞ M_H< 144 (182) GeV/c^2 @95% CL



TEWKG March 2007

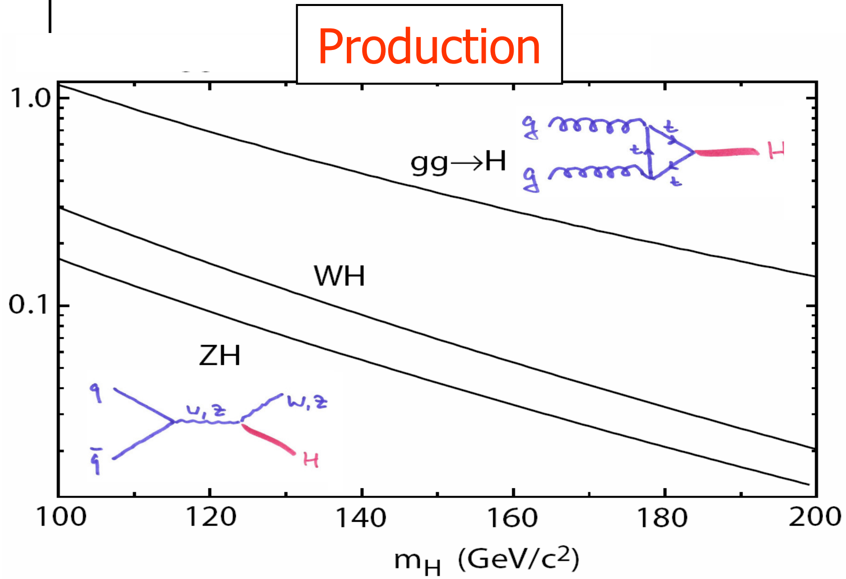
Can bring us beyond the SM ?



S. Heinemeyer, W. Hollik, D. Stockinger, A.M. Weber and G. Weiglein, hep-ph/0604147

A direct path towards the Higgs

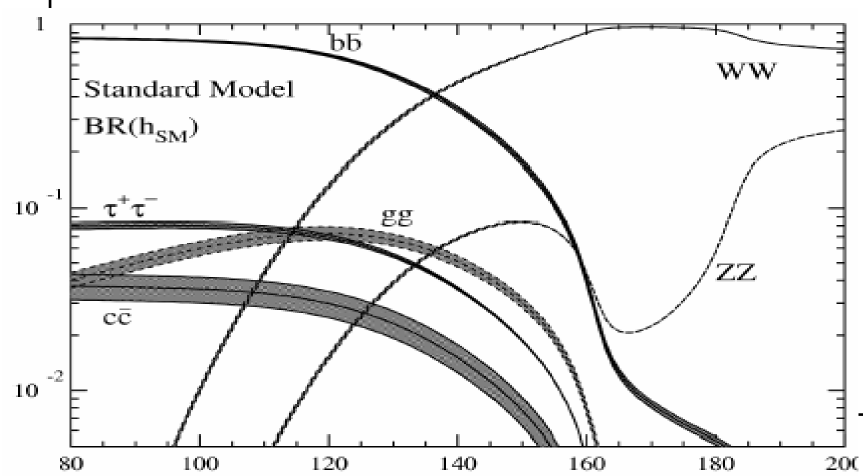
Light or heavy Higgs?

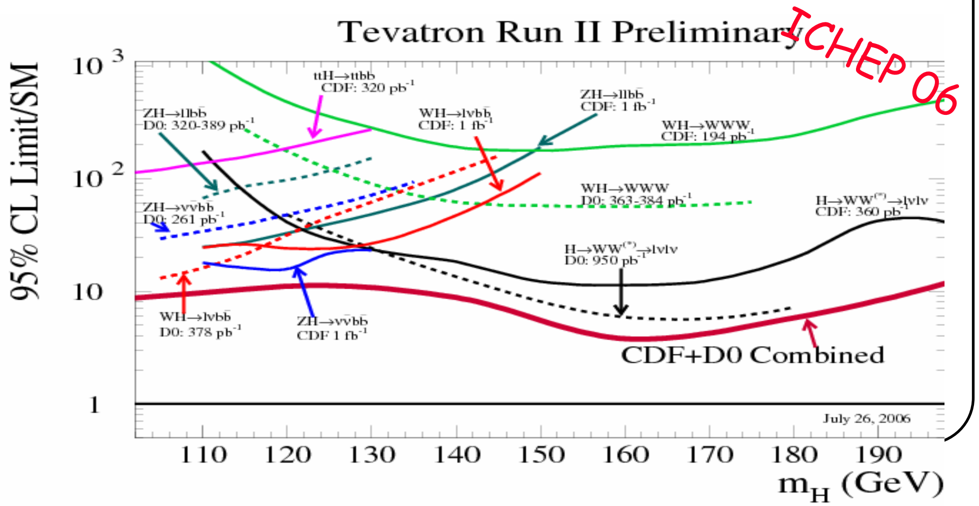


Strong b-tagging, large lepton coverage

☞ X-section shows that we must use channels with large BF (no γγ)

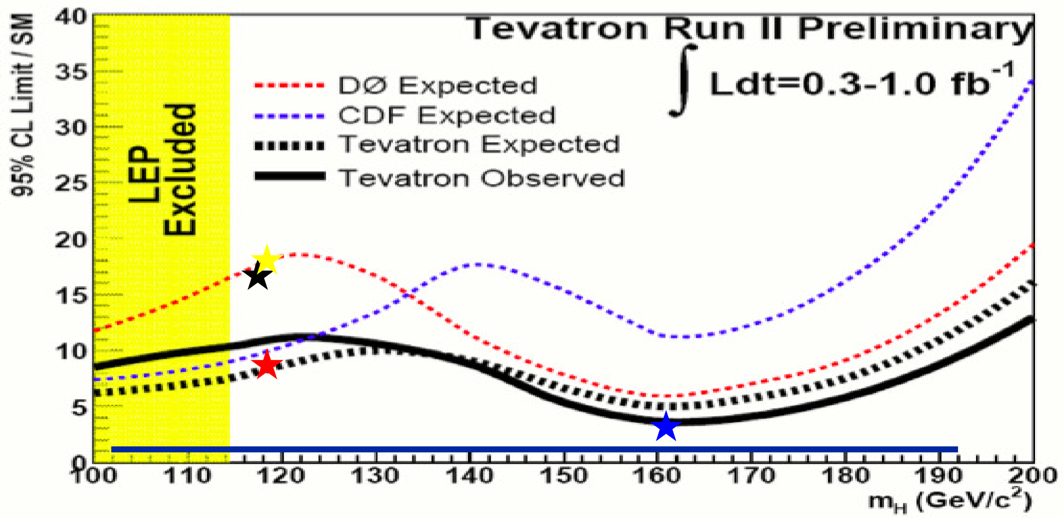
m_H (GeV)	Limit/SM Exp.	Obs.
115	7.6	10.4
160	5.0	3.9
180	7.5	5.8



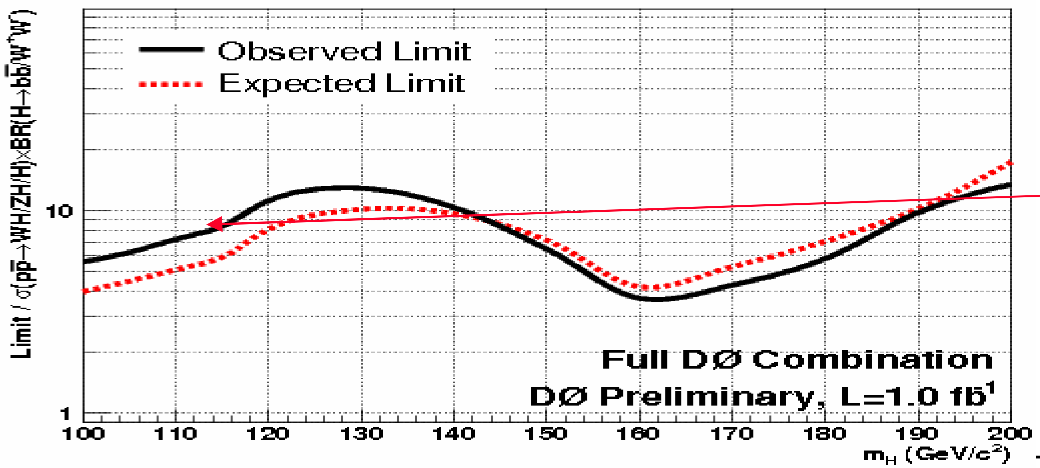


Ongoing effort

Last update in mid March (new CDF result on WW, ZH and from D0 on WH, ZH→new)



Analysis	CDF limit ($1fb^{-1}$) factor above SM observed (expected)	D0 limit ($1fb^{-1}$) factor above SM observed (expected)
ZH → νν bb @ 115 Technique: M_{jj}	16 (15)	~~40 (34)*~~
WH → lν bb @ 115 Technique: M_{jj} Technique: ME	26 (17)	★ 10 (9) ★ 13 (10)
ZH → llbb @ 115 Technique: NN2D	★ 16 (16)	33 (34)
H → WW → lνlν @ 160 Technique: ΔΦ (l,l) Technique: ME	9 (6) ★ 3.5 (5)	4 (5)



New, April 6 2007

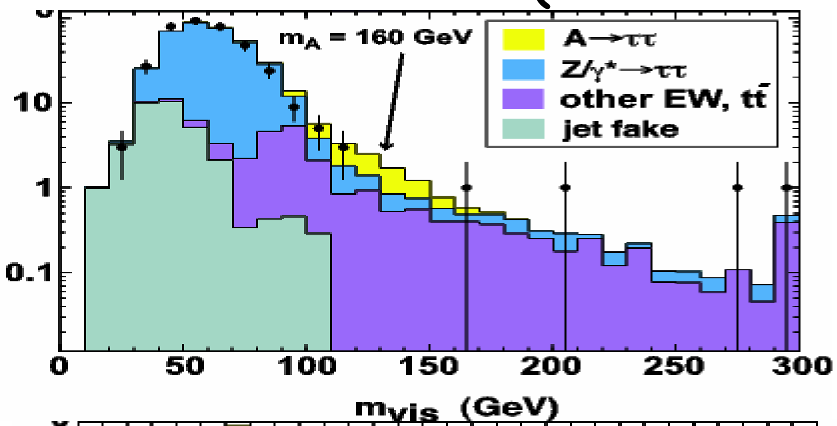
(post Winter Conferences)

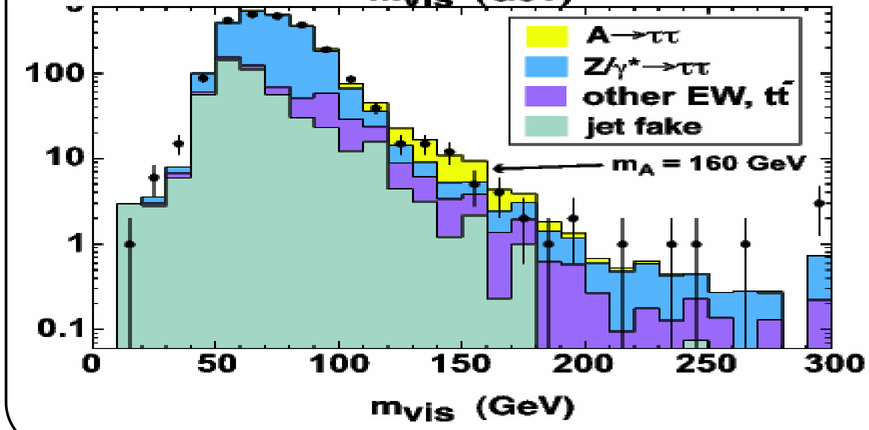
Data used: less than 50% of what on tape by now!

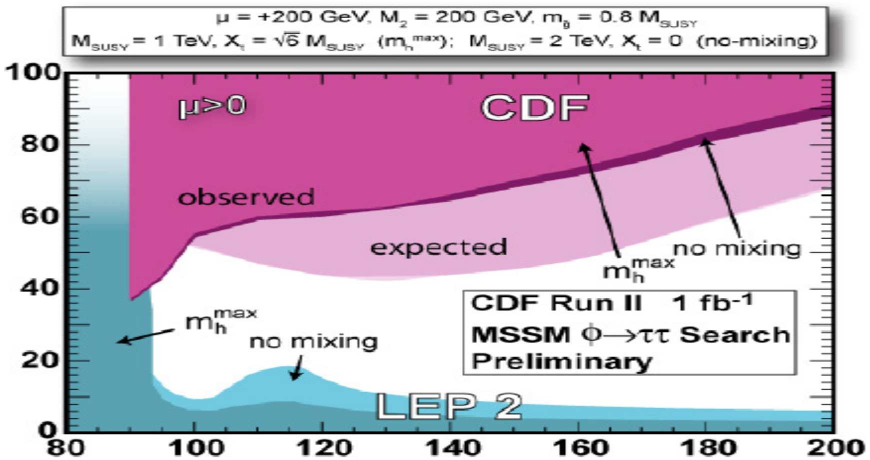
Non SM Higgs

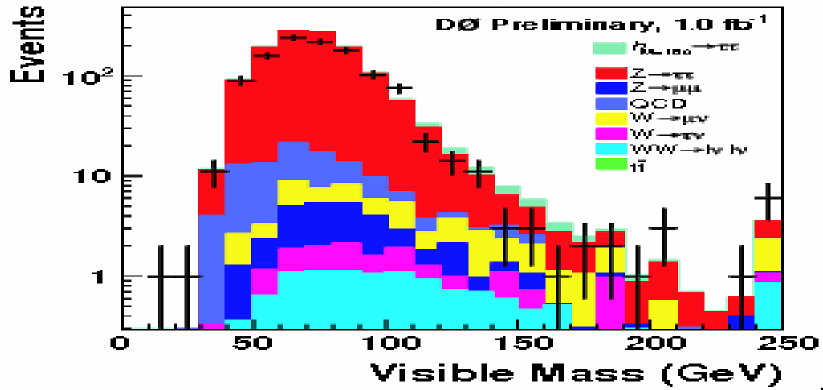
Non SM Higgs(es) have sizeable decay rate to ττ pairs

- Large efforts to bring up efficiency to trigger on tau events (and to detect tau)







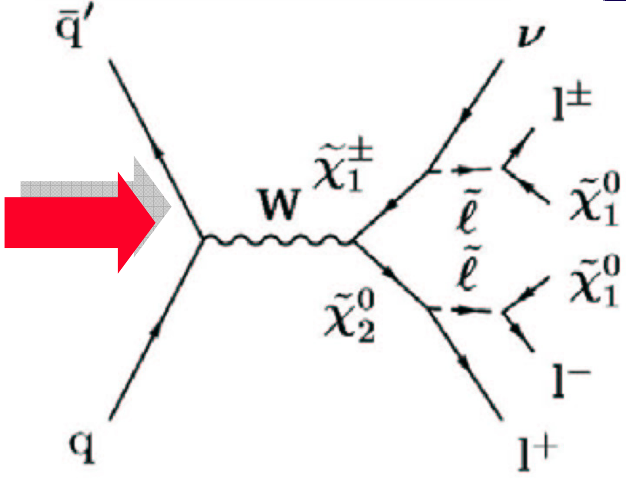


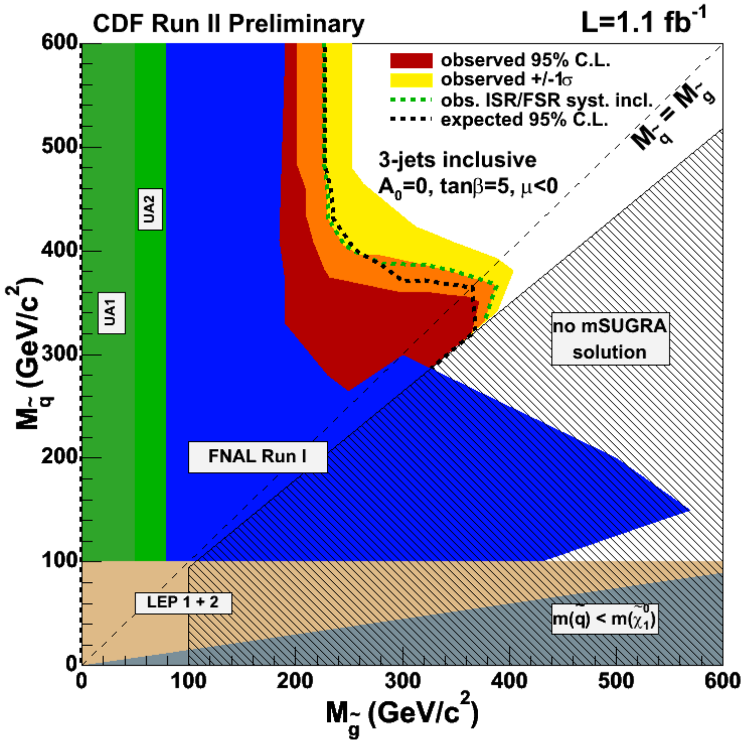
R. Strohemer

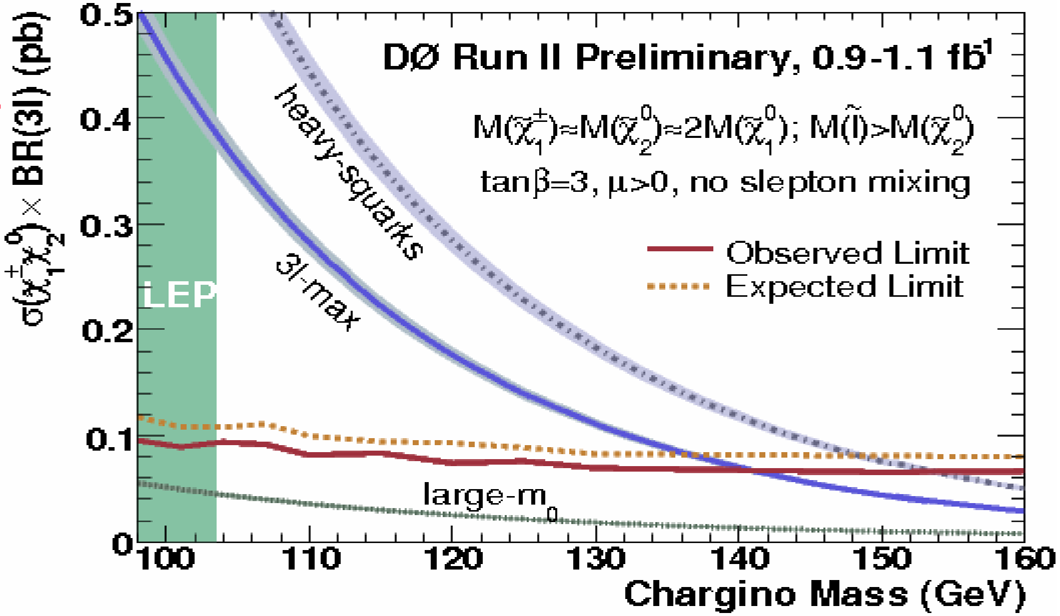
Chargino and Neutralino searches

Both experiments look for SUSY signals

- ☞ Chargino and neutralino are produced with sizeable cross sections
- ☞ More difficult search for squarks and gluinos







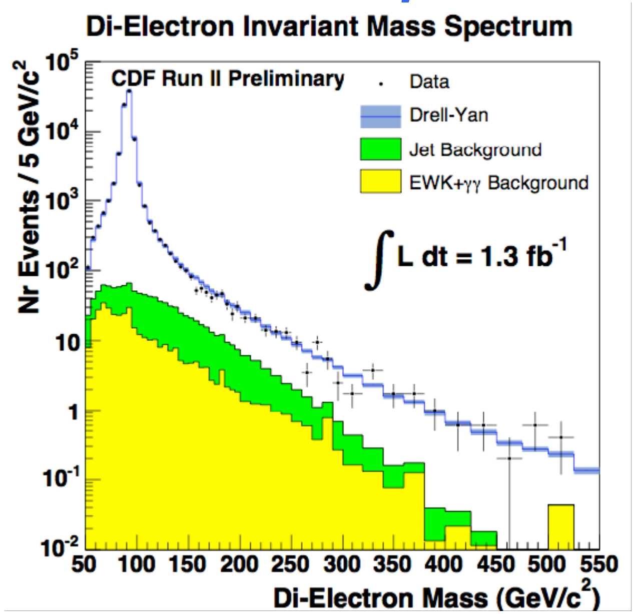
Giorgio Chiarelli, DIS 07

R. Strohemer

More "exotic" searches

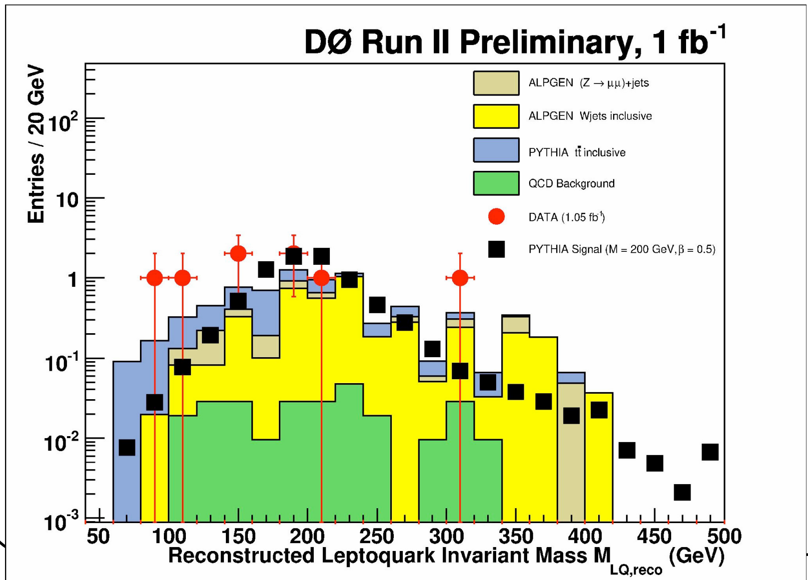
Drell Yan at large masses can be the key

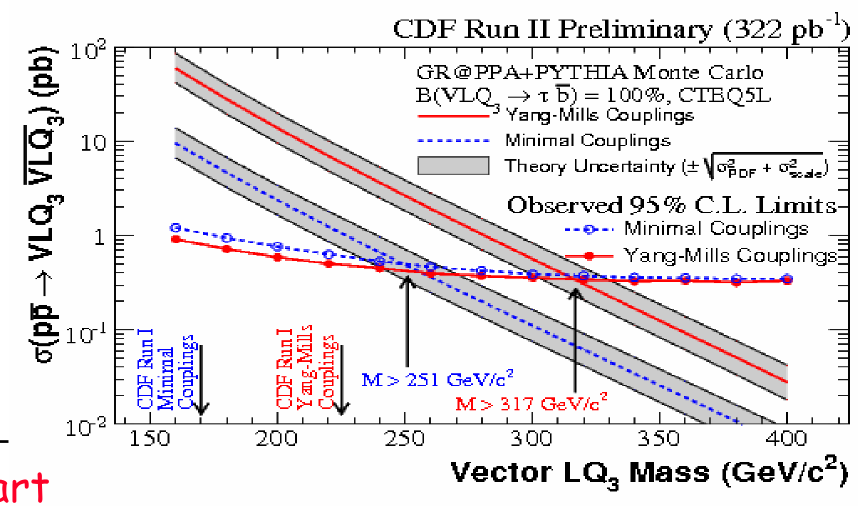
- ☞Z'→ee at CDF



New limits on LQ

- ☞2nd and 3rd generation LQ (pair produced at the Tevatron)





Conclusion-I

Tevatron experiments are digging a gold mine of $2fb^{-1}$

- ☞ The accelerator complex is working well
  - ⇨ We now collect more data in one week than we used to gather evidence for top
- ☞ In the fb region many interesting processes at the boundary of the Standard Model
  - ⇨ CDF and D0 are well equipped to study physics in this region
- ☞ The interest of our program stays in the combination of an accelerator performing well with two well-understood detectors
    - → We considerably shortned the time from data taking to publication of results
  - ⇨ 19 contributions in parallel sessions will discuss the subtleties of many analyses

Conclusion II

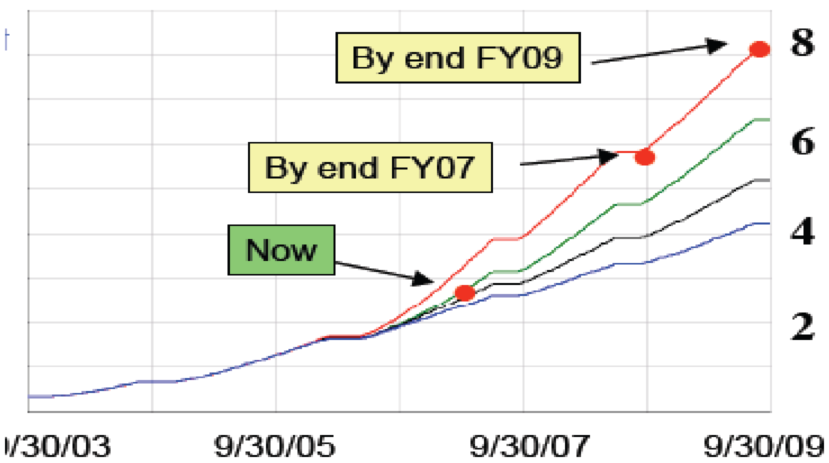
Detectors are performing well

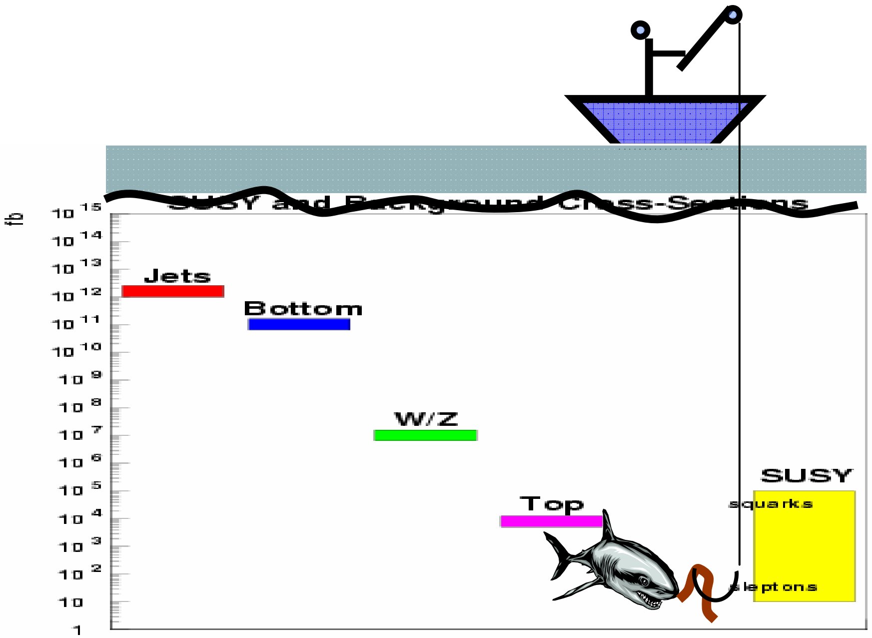
☞ Continuous effort

More and more challenging analysis are being performed

☞ We are exploring a new region…

⇨ The prize?





Many thanks to my CDF and D0 colleagues

and to the Organizers