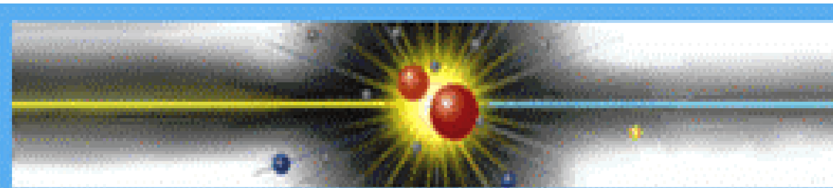
Risultati recenti e prospettive di fisica al Tevatron Collider

Fermilab

Discovering the Nature of Nature



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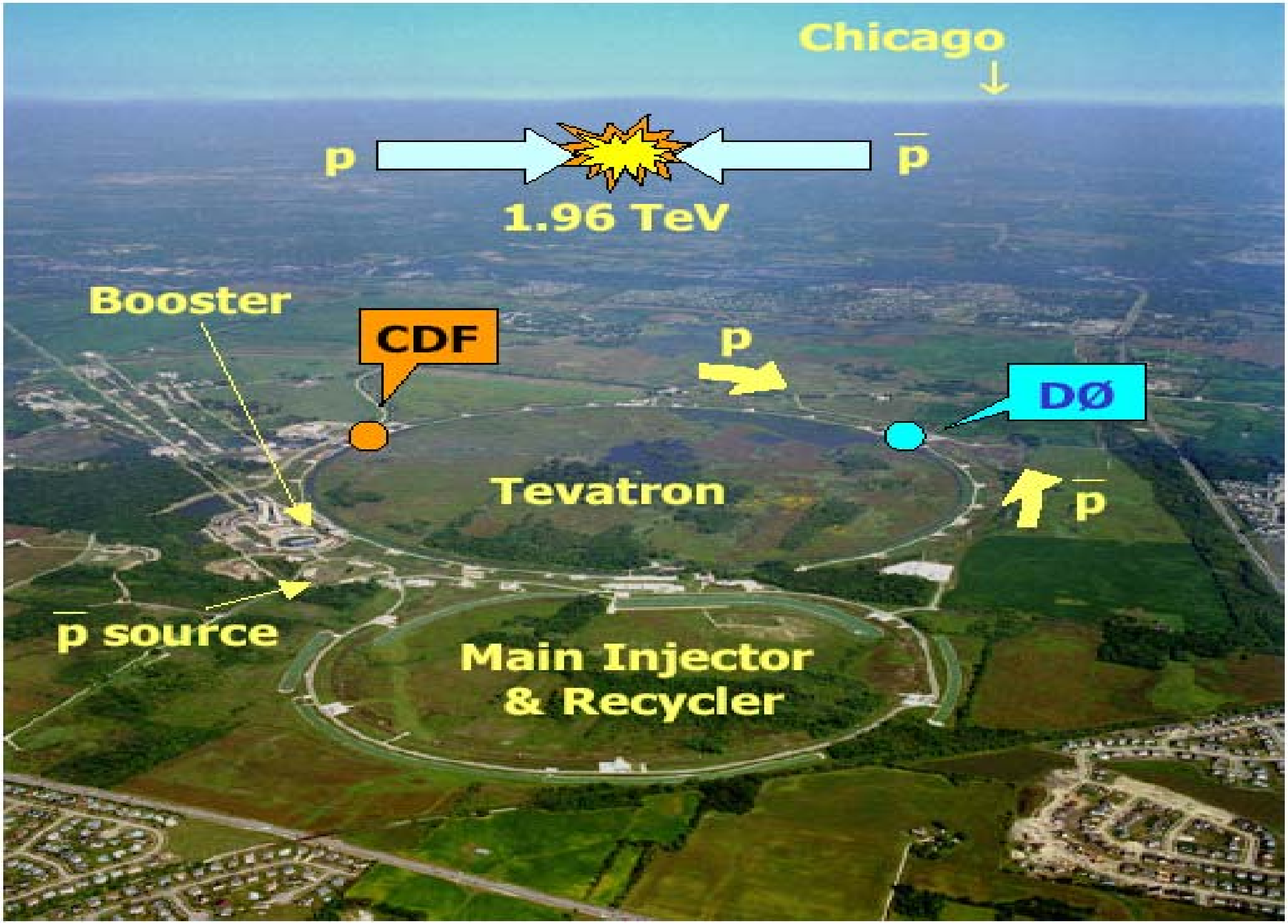
Outline of this talk

- Tevatron status and near (2005) future
  - current performances and future improvements
- D0 and CDF:
  - analysis
    - selected topics (mostly 200 pb^{-1})
      - Details are given in parallel sessions (Monica, Simona, Antonio, Carmine, Giovanni, Mapo, Mario, Tommaso)
- Future perspectives (Higgs?)
- Personal remarks

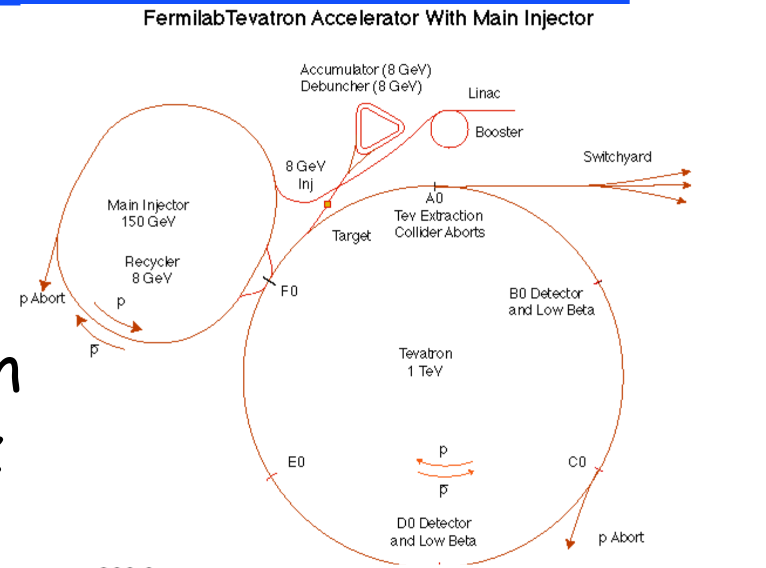
More than just a Collider..

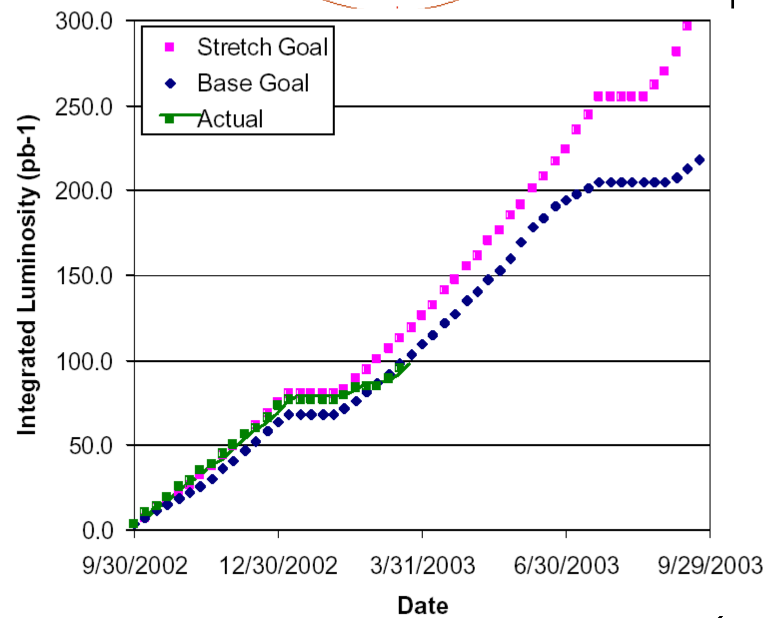


Tevatron- Introduction

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: $6.8\times10^{31} cm^{-2}s^{-1}$

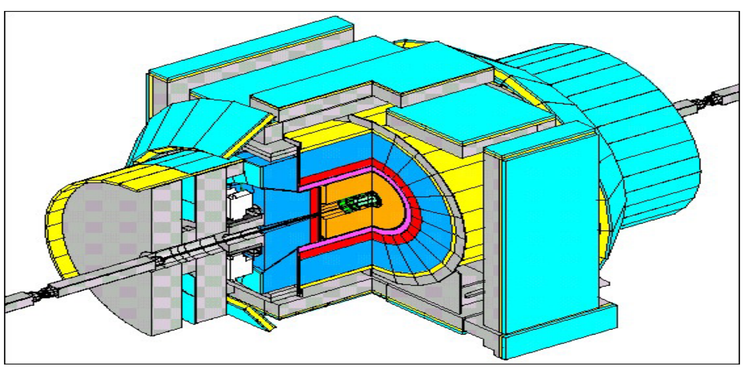




Two detectors

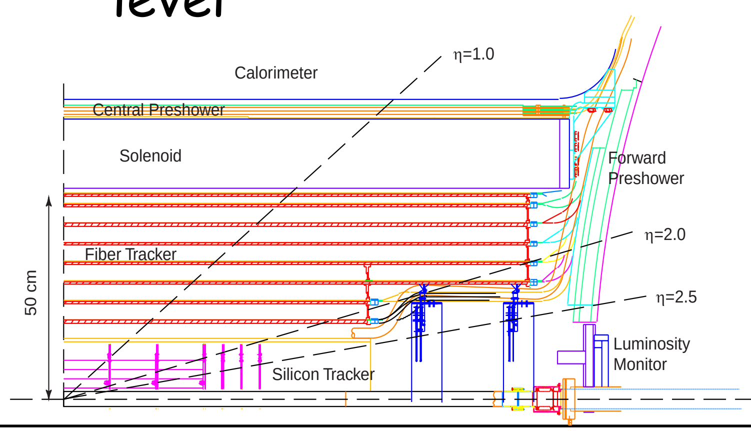
CDF underwent serious upgrades:

- 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



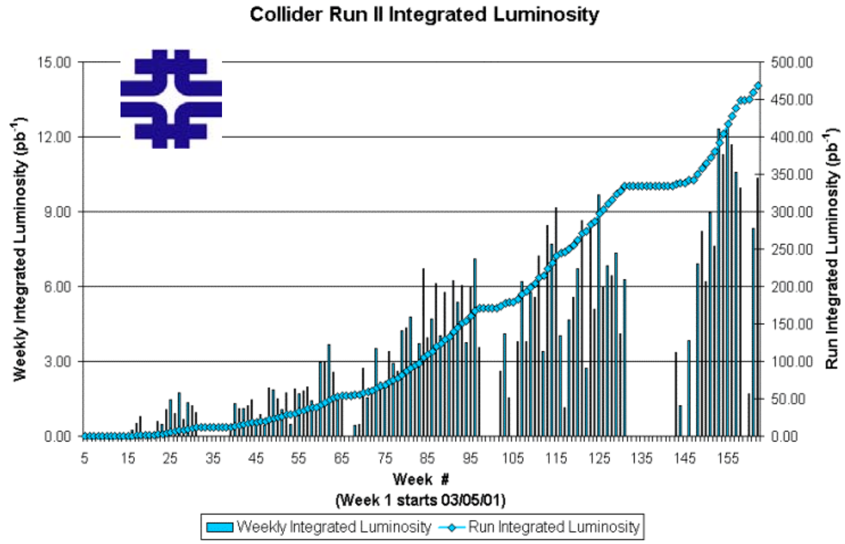
D0: change of philosophy

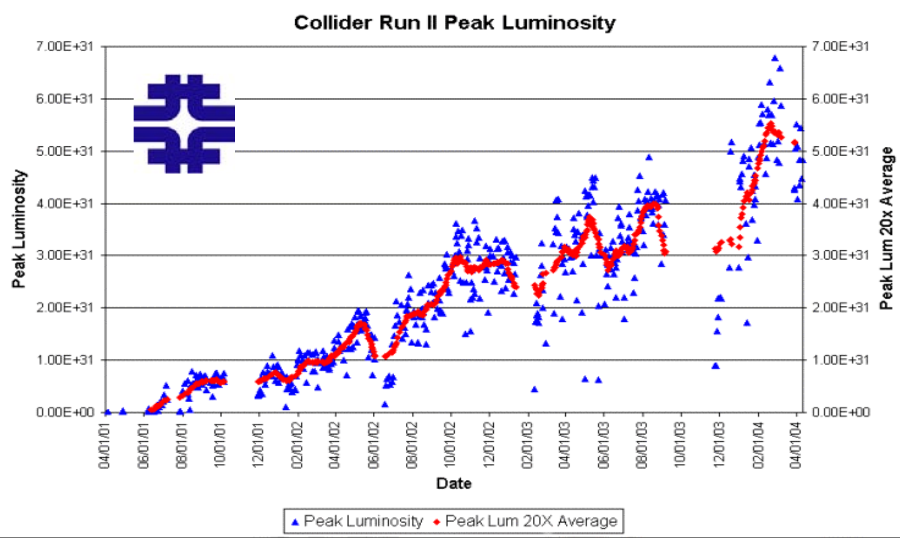
- New tracking system
  - Based on a 2T solenoid
  - New 8 layers (fiber) tracker
  - Secondary vertices capability (SVX)
- Improved muon coverage
- New features at trigger level



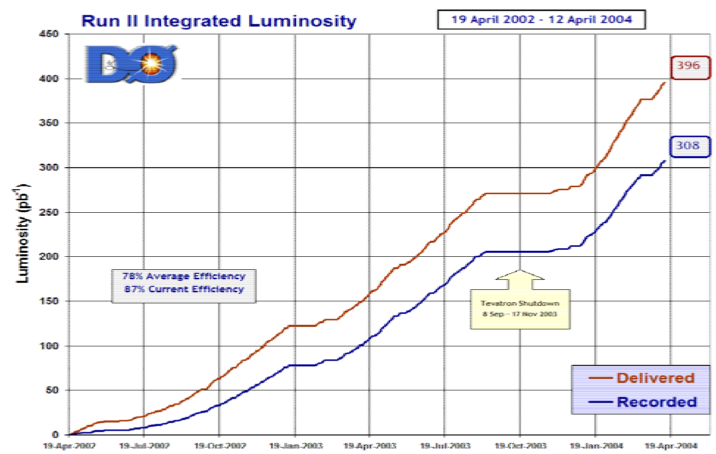
Data taking...7×10^{31}...

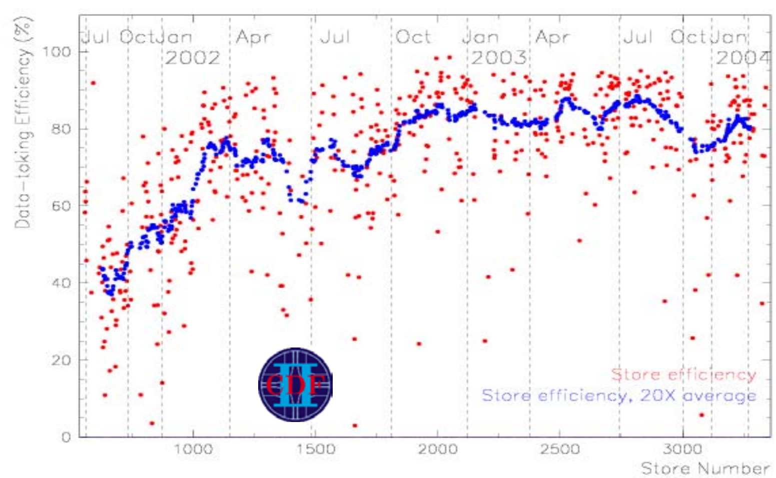
Accelerator delivers..





Detectors use:





B Physics at an Hadron Collider

Thought to be almost impossible

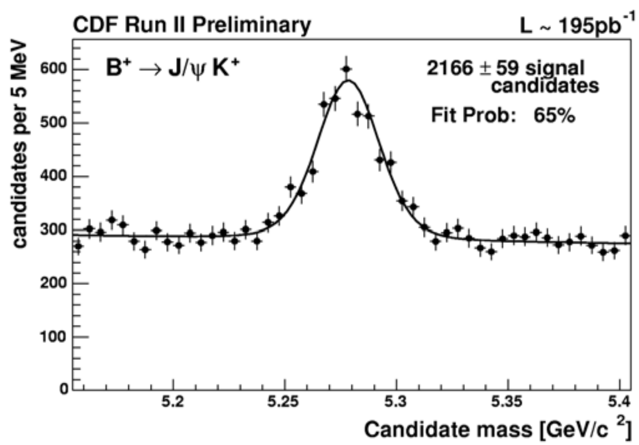
- Exploits large cross section
  - Need tight selection at trigger level
  - Tracking capability at L1 and displaced track trigger at L2 at CDF
    - D0 is commissioning its trigger..
  - Challenge at high luminosity

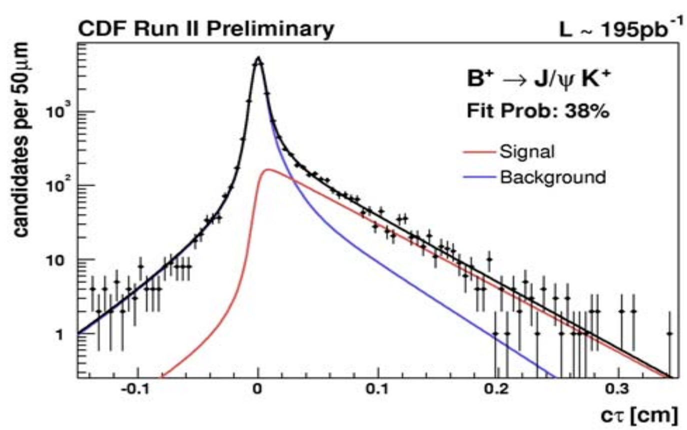
By the way…

- Charm physics came (almost) for free (i.e. w/o white/yellow books…)

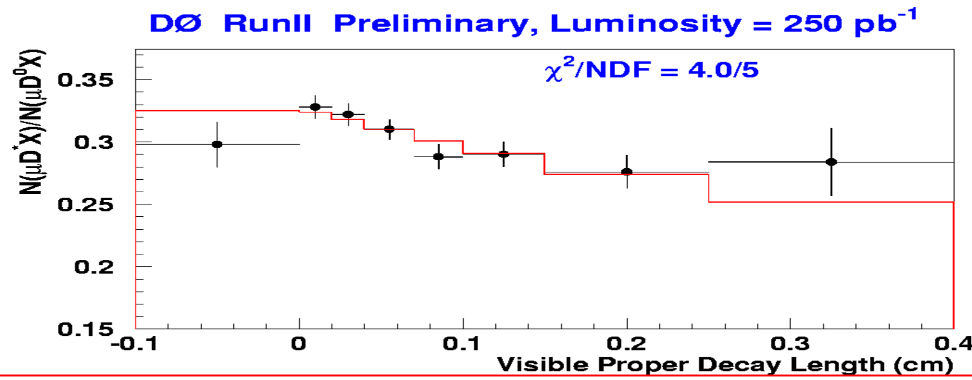
B Physics/Lifetimes

CDF: fit to mass and lifetime





D0: fit to ratio



D0:

$\tau(B^+)/\tau(B^0)$ = 1.093 ± 0.021 (stat) ± 0.022 (syst)

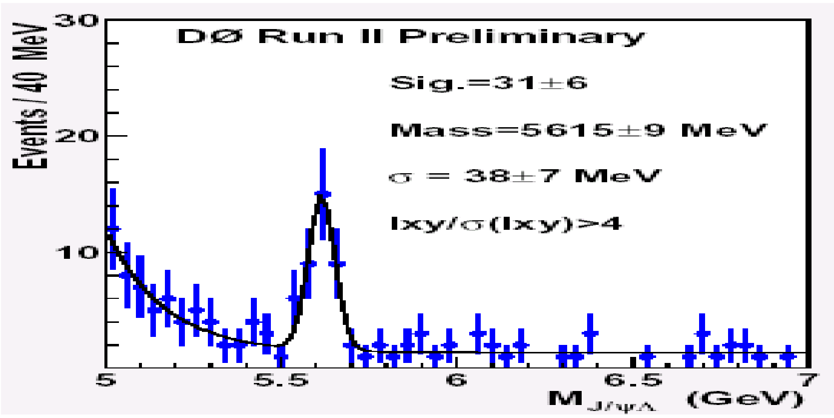
B hadron	CDF measurement	PDG value
B^+	1.66 +/- 0.04 +/- 0.02	1.674 +/- 0.018
B^0	1.49 +/- 0.05 +/- 0.03	1.542 +/- 0.016
Λ_b	1.25 +/- 0.26 +/- 0.10	1.229 +/- 0.080
B_s	1.33 +/- 0.14 +/- 0.02	1.461 +/- 0.057

$\tau(B^+)/\tau(B^0)$ = 1.119 +/- 0.046 (stat.) +/- 0.014 (syst.)

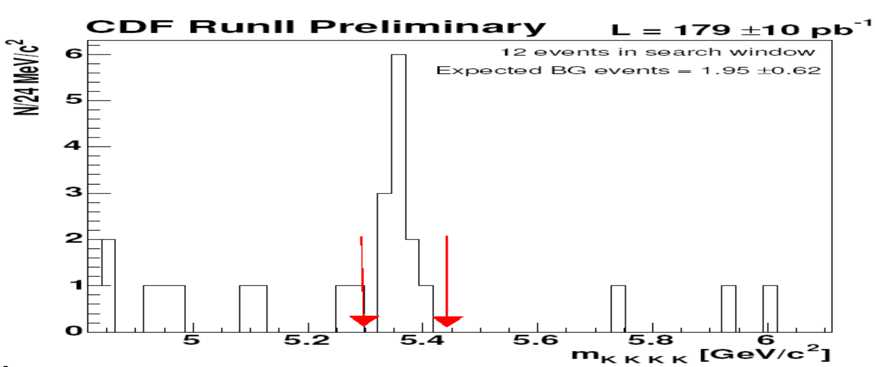
$\tau(B_s)/\tau(B^0)$ = 0.88 +/- 0.11(stat.)

B Physics/Masses

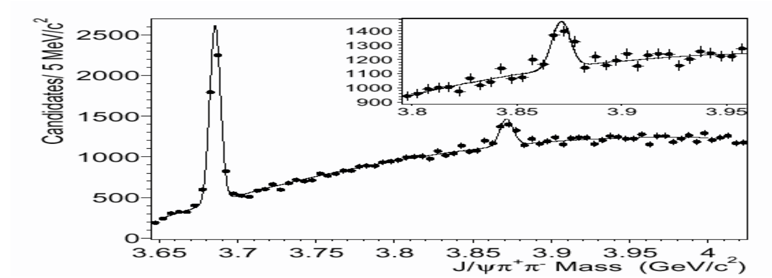
Identifying exclusive channels is mandatory..

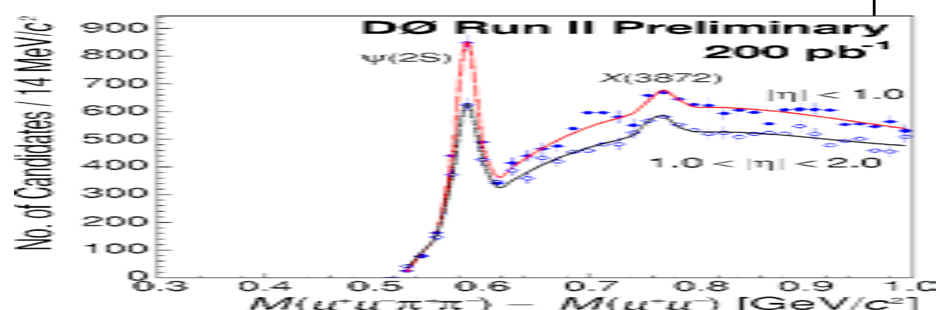


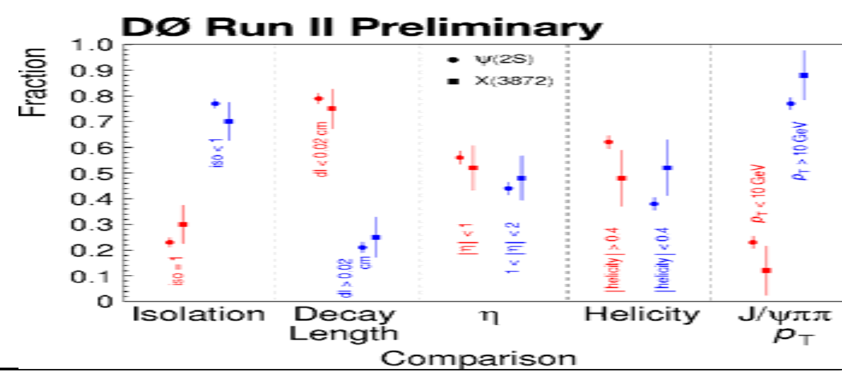
$$BR_{B_s\to\phi\phi} = \left(1.4\pm0.6(stat.)\pm0.2(syst.)\pm0.5(BRs)\right)\cdot10^{-5}$$



Looking for the unexpected (?)[X(3872)]



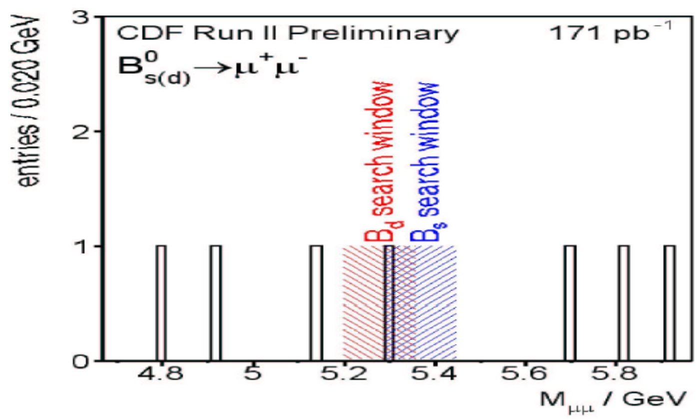




B rare decays

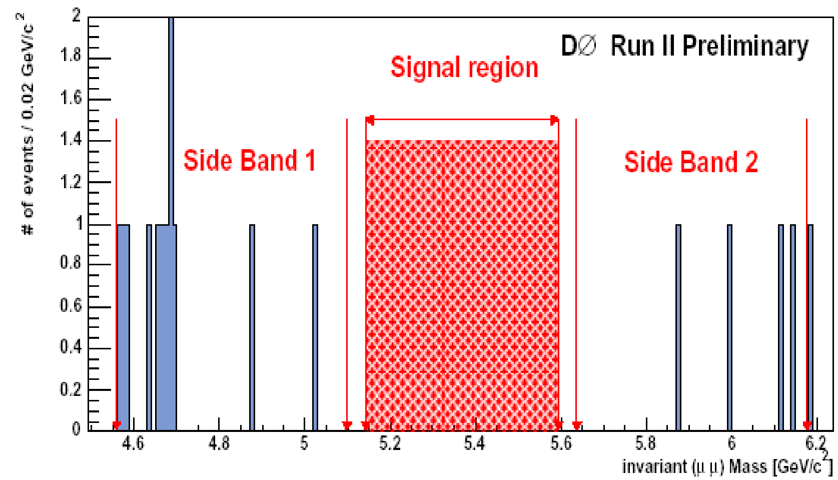
CDF searches for B_s and B_d decays into dimuons

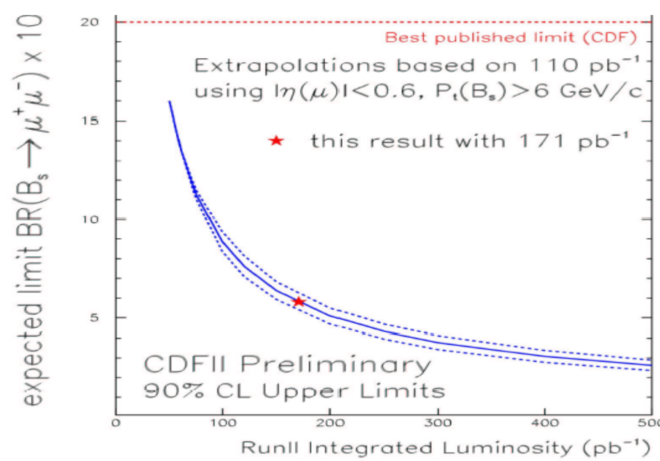
- Expected at $O(10^{-9})$ level



- 95% CL limits:
  - $B_s < 7.5\ 10^{-7}$
  - $B_d < 1.7\ 10^{-7}$
- 90% CL:
  - $B_s < 5.8\ 10^{-7}$
  - $B_d < 1.5\ 10^{-7}$ ($1.6\ 10^{-7}$ Belle)

D0 is searching, expect to set limits at 10^{-6} level



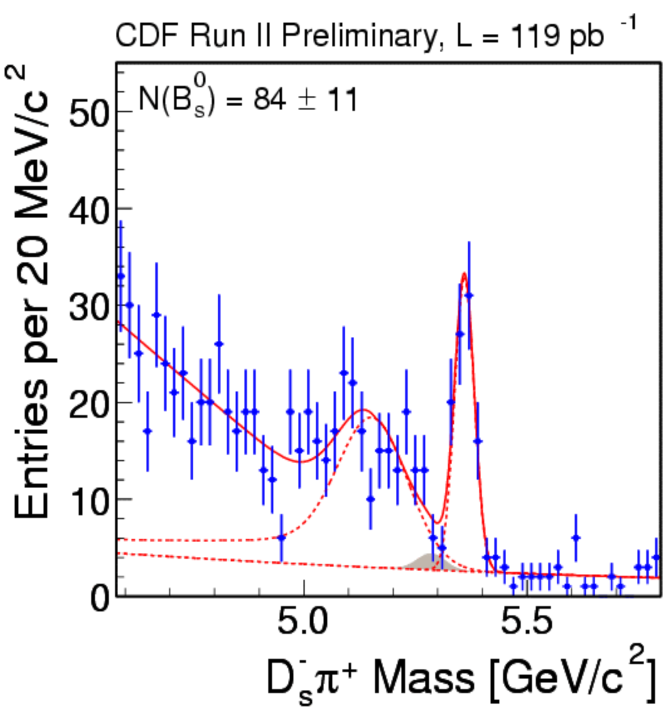


Future...

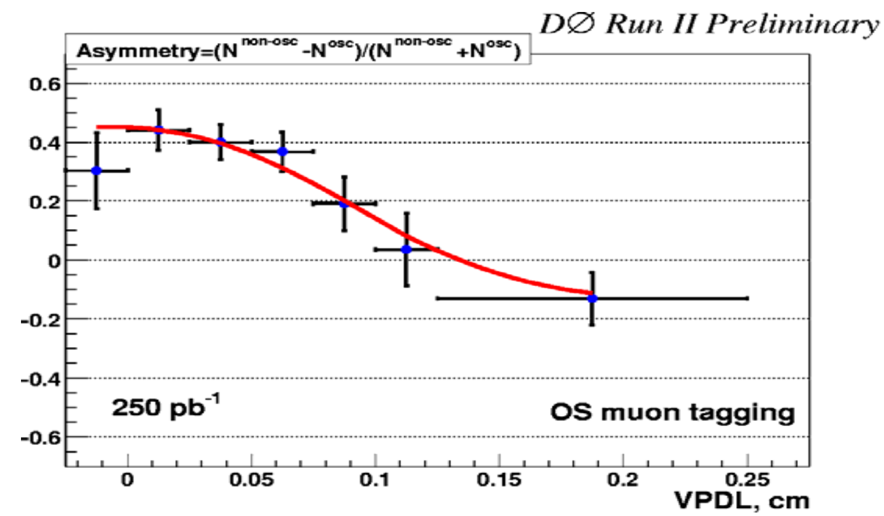
CDF, golden channel for x_s: $B_s \rightarrow D_s \pi$

↳ Low yield ($0.7/pb^{-1}$)

⇨ More channels



D0:



Tagging procedure

- opposite side tight muon
- muon $p_T > 2.5$ GeV/c
- $\cos \Delta\phi(\mu, B) < 0.5$

Preliminary results:

$\Delta m_d = 0.506 \pm 0.055(stat) \pm 0.049(syst)\ ps^{-1}$

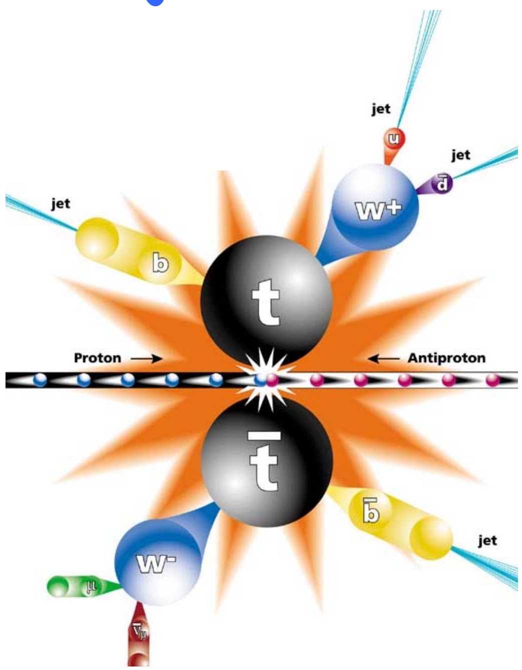
Tagging efficiency: 4.8 +/- 0.2 %

Tagging purity: 73.0 +/- 2.1 %

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 partons from a complicated final 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:

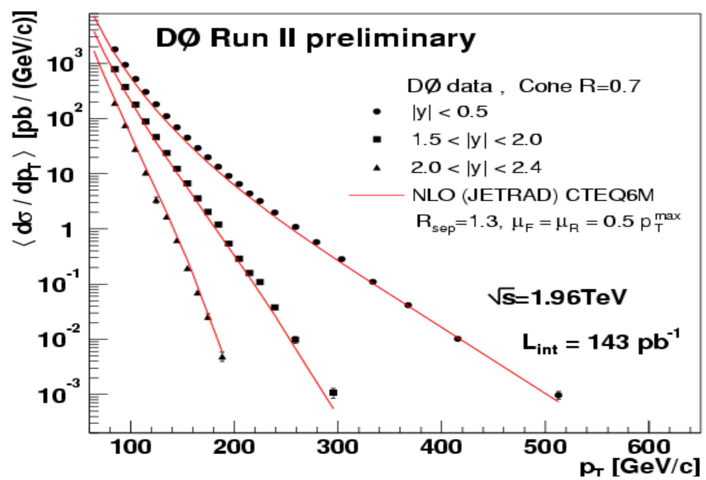
- Inclusive jet cross section (inherited *discrepancy* with pQCD from Run I)
- Dijet mass x-section
- W+jets production
- Underlying events

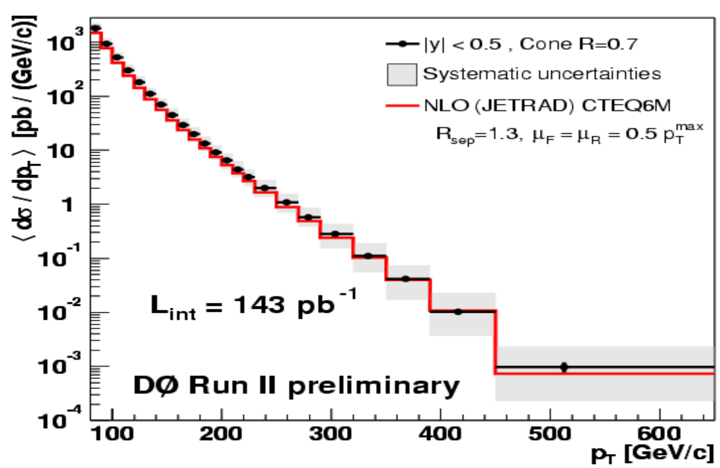
Future: new cone algorithms (k_T, midpoint)

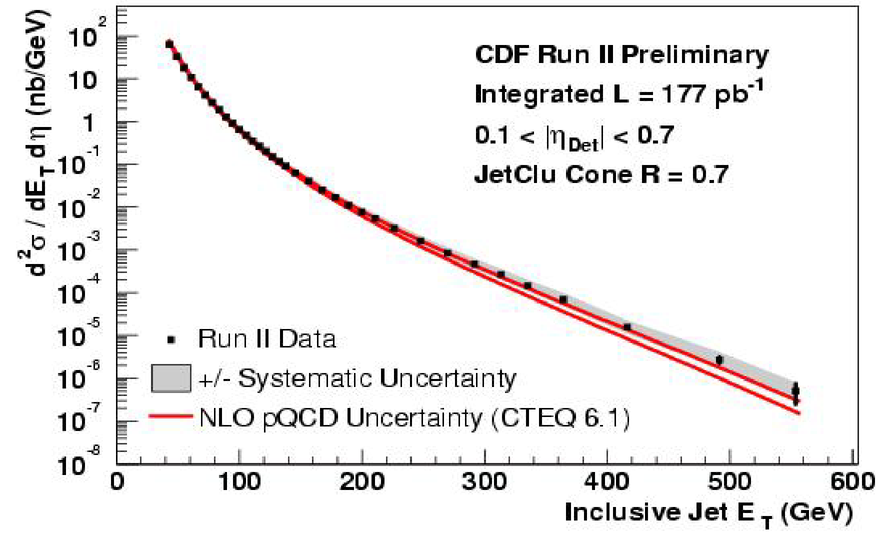
Inclusive jets

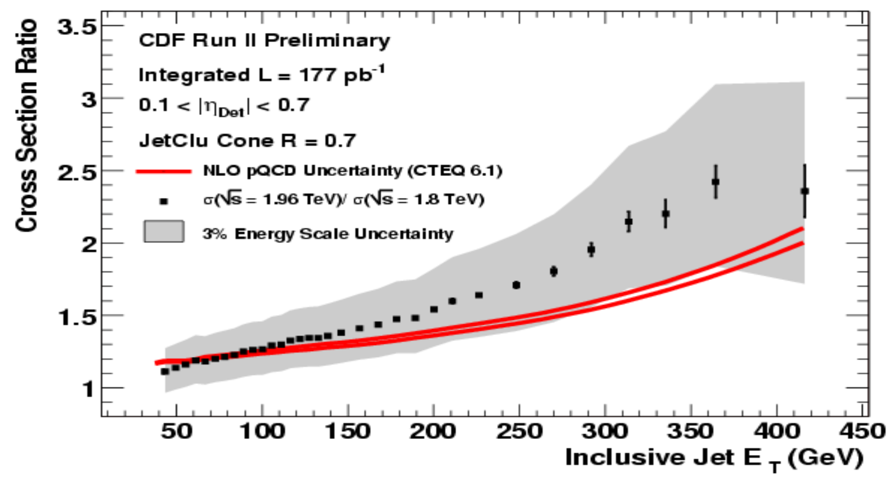
Both CDF and D0 measure jet

NLO predictions look OK



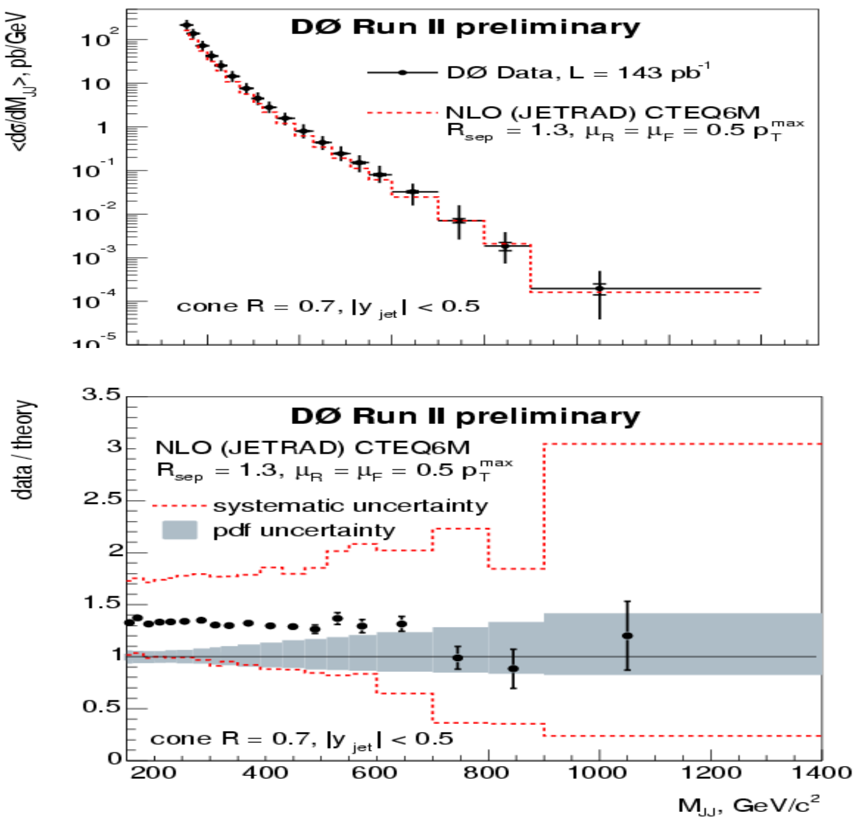




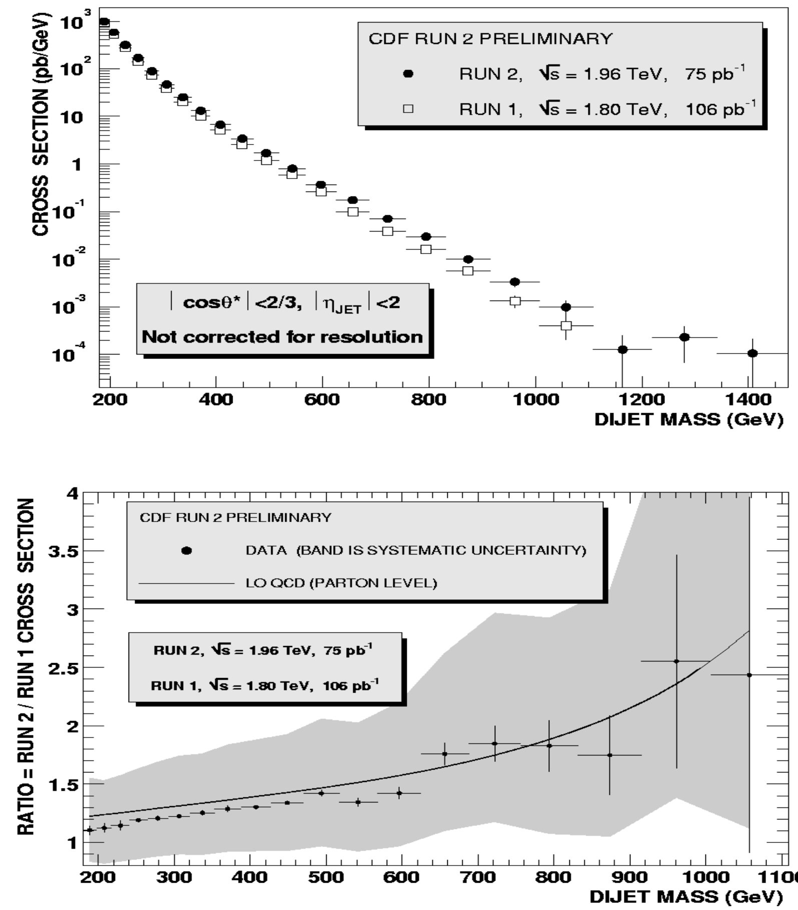


Dijet mass

DO measures in central region:



CDF compares to Run I

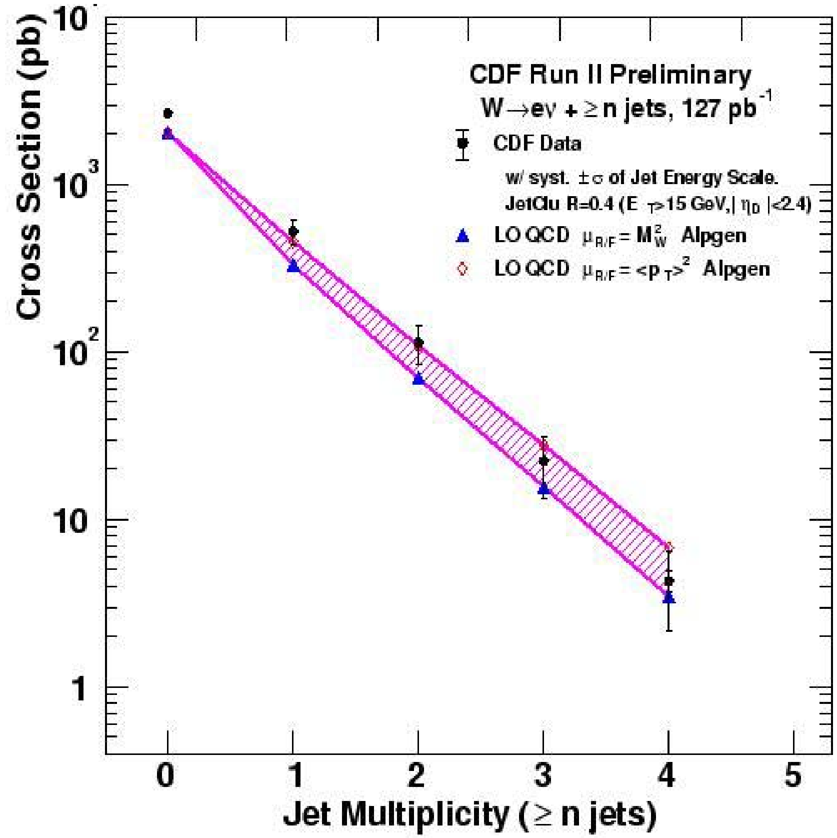


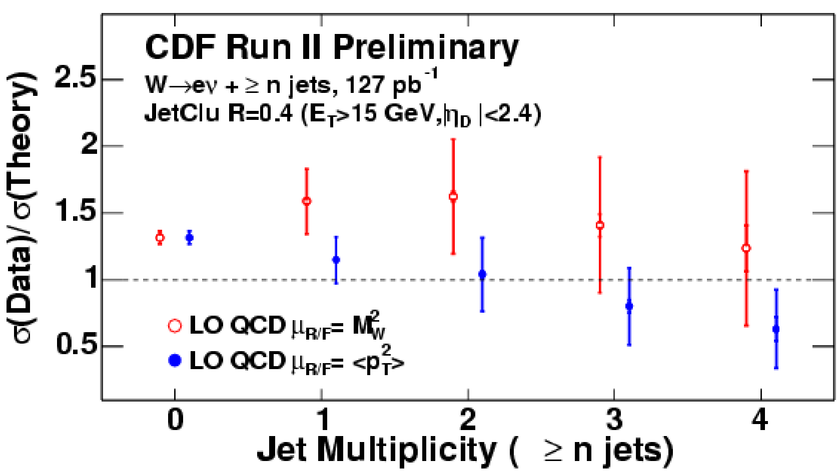
Good agreement with NLO QCD

$W \rightarrow e\nu$ + jets cross section

Important test of QCD, background for top, Higgs searches

- Selection:
  - Central W (E_T>20 GeV, MET>30 GeV,|η|<1.1)
  - Jets: E_T>15 GeV, |η|<2.4
- Bckg: QCD(all bins),top



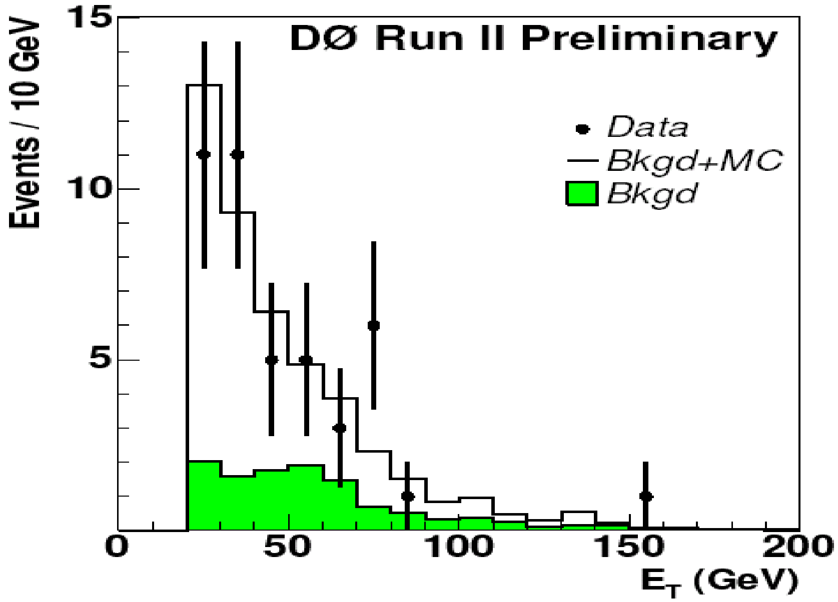


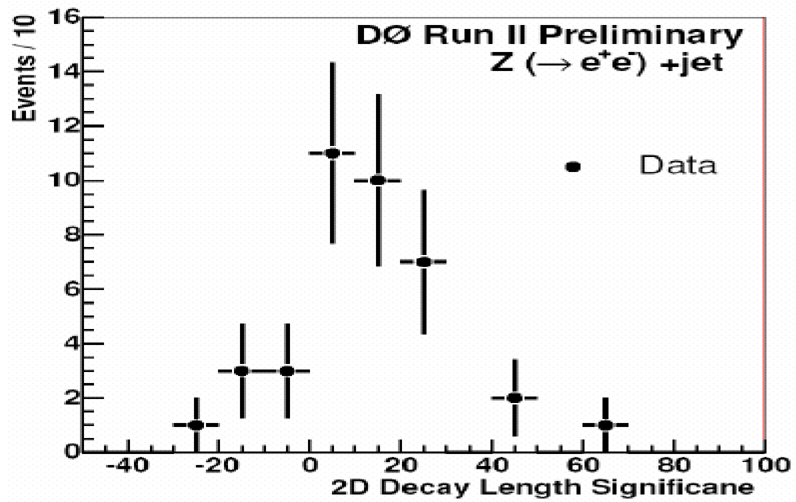
Systematic uncertainty (10% in σ_1 to 40% in σ_4) limits the measurement sensitivity

$\sigma(Z+b)/\sigma(Z+jet)$

Understanding background, MC checks and tuning... bread and butter for any search:

- D0 measures the HF fraction associated to Z production for jets with E_T>20 and $|\eta|$<2.5
  - Ratio $\sigma(Z+b)/\sigma(Z+jet)$= 0.024±0.007(stat+sys)
- Theory:
  - R~0.02 (Campbell, Ellis, Maltoni, Willenbrock)

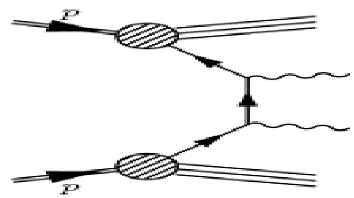




γγ production

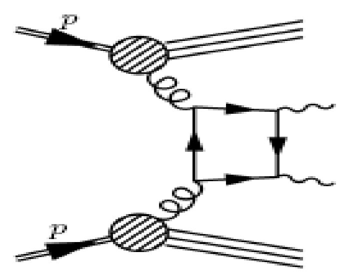
CDF studies γγ production

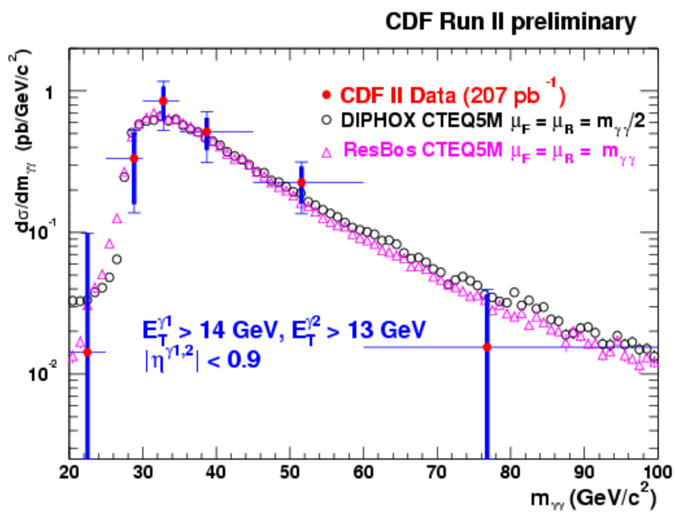
- Future background for Higgs..

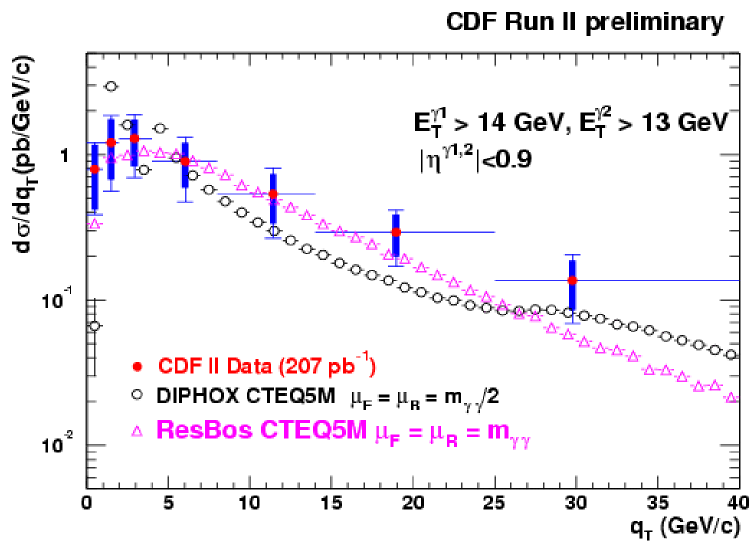


Two central photons

- Mγγ in agreement with expectations
- P_T of diphoton system…







EWK Physics

Basics for top, searches

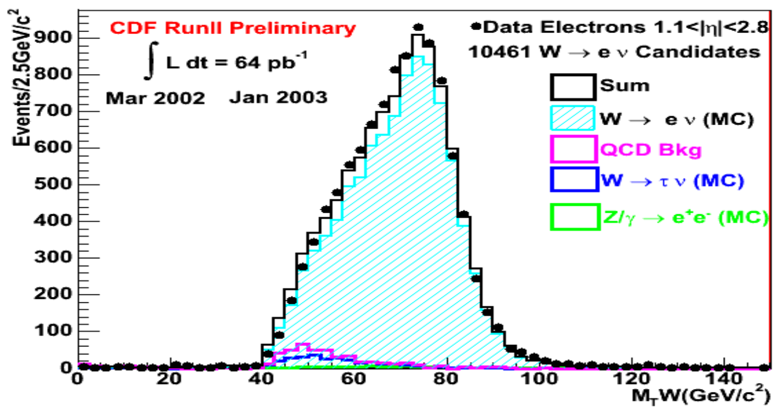
- Decay, associated production
- Often background for rare processes
- Discrepancy from SM would signal new physics

Both CDF and D0 measure

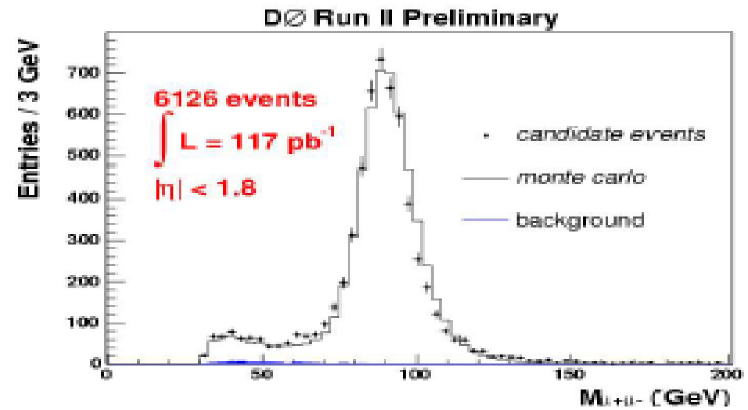
- Inclusive production cross section
- Multiboson production ($W\gamma$,$Z\gamma$,WZ,WW,ZZ)
  - W mass: work in progress

W and Z at CDF and D0...

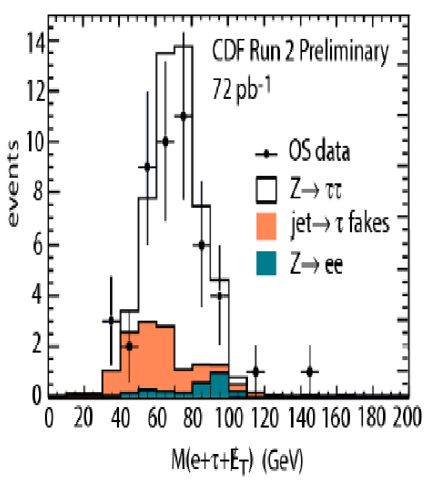
CDF extends its acceptance at |η|>1:

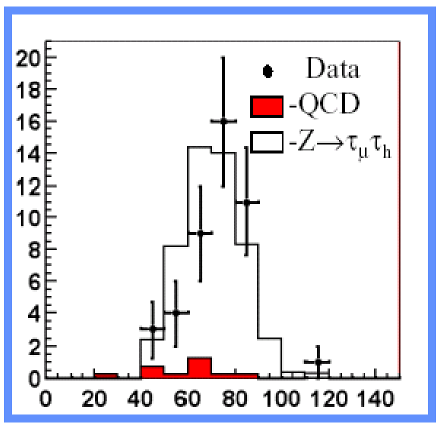


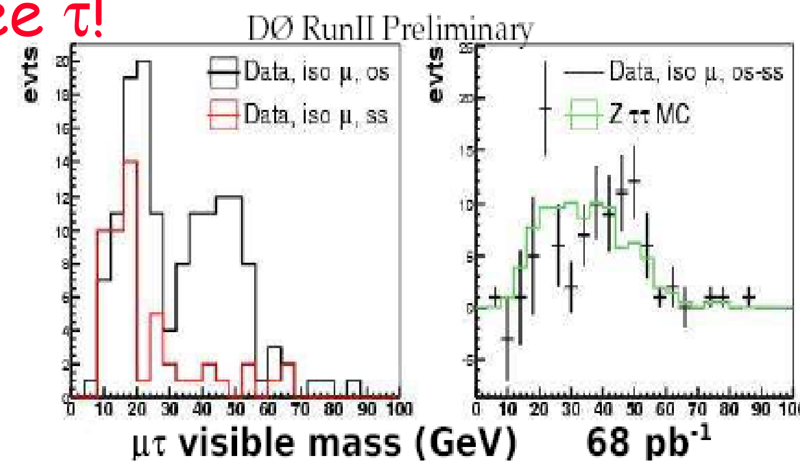
D0 exploits its improved muon spectrometer:



both see τ!

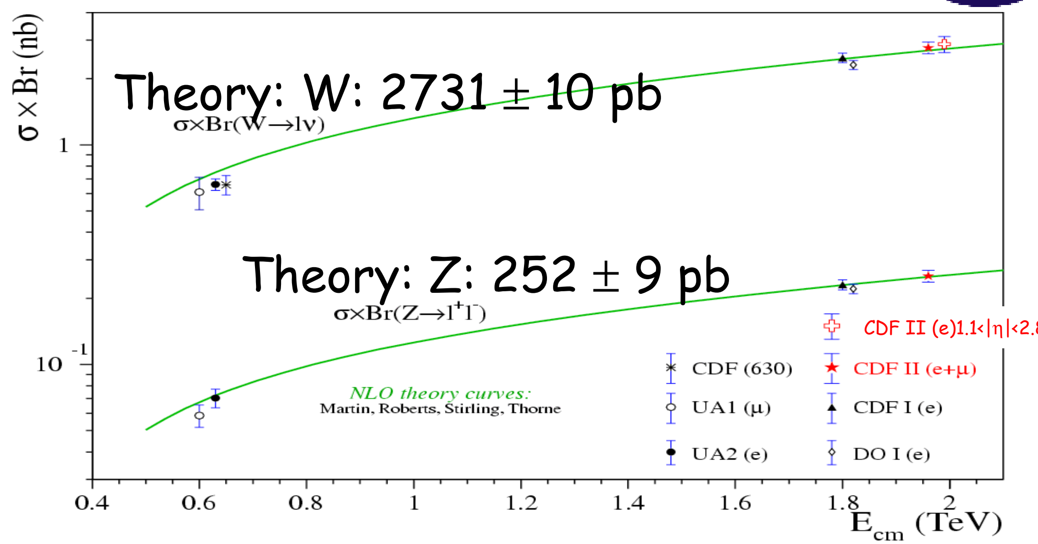




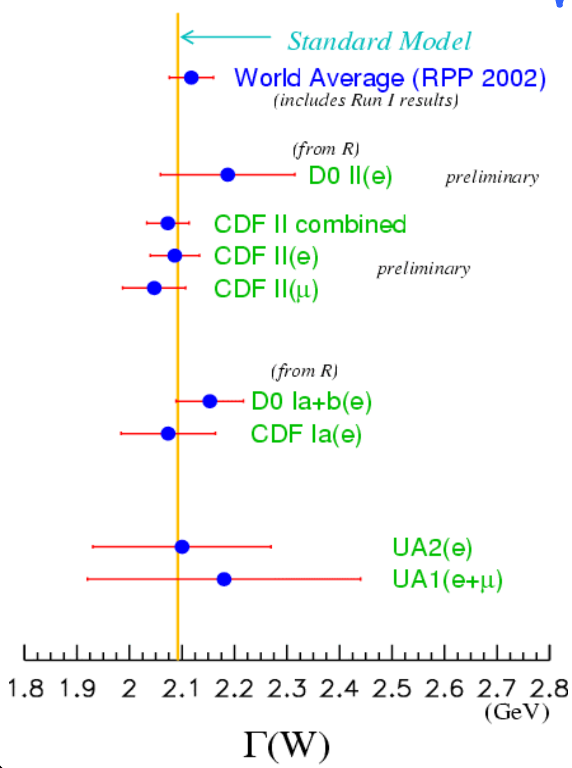


W,Z Summary

$\sigma(W,Z)$:



Using the ratio to extract Γ_W:



Γ_W

CDF: 2071 ±40 (MeV/c^2)

D0: 2187±128 (MeV/c^2)

World avg: 2092 ± 40 (MeV/c^2)

LEP direct: 2150 ± 90(MeV/c^2)

EWK couplings

CDF measures the ratio of couplings in W to μ and W to τ channel wrt e channel:

$$U = \frac{R_\mu}{R_e} = \frac{\Gamma(W \to \mu\nu)}{\Gamma(W \to e\nu)} = \frac{g^2_{W\mu}}{g^2_{We}}$$

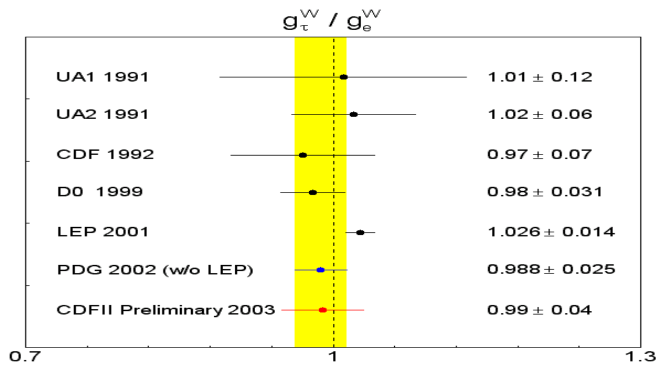
g_μ/g_e

CDF measurement	1.011±0.018
World Average	0.993±0.025

$$U = \frac{R_\tau}{R_e} = \frac{\Gamma(W \to \tau\nu)}{\Gamma(W \to e\nu)} = \frac{g^2_{W\tau}}{g^2_{We}}$$

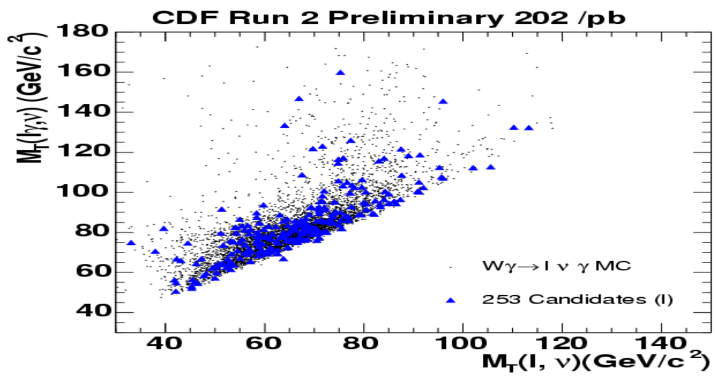
g_τ/g_e

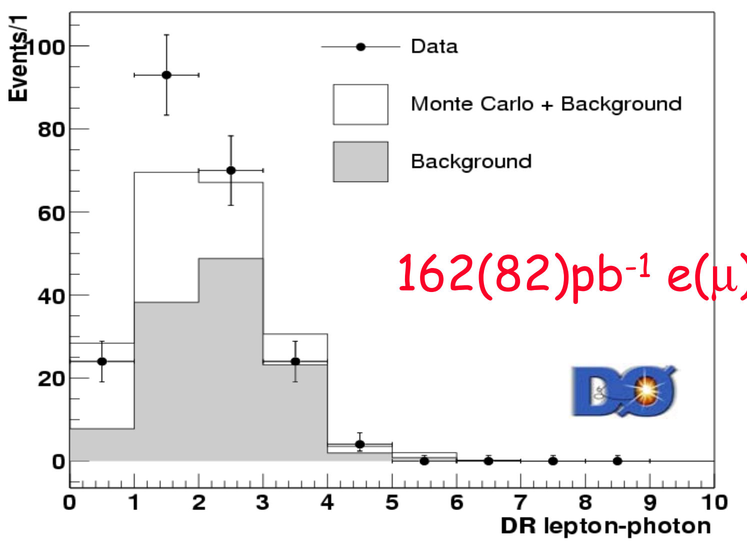
CDF measurement 0.99±0.04±0.07



Diboson Production

Wγ and Zγ are key to new physics





162(82)pb^{-1} e(μ)

Wγ x-sect(pb):

- CDF:Require a W and a γ

  $E_T(\gamma) > 7$ GeV and $\Delta R(l, \gamma) > 0.7$:

$$\sigma(W\gamma)\times BR(W\to l\nu) = 19.7\pm1.7\ (stat)\ \pm2(sys)\pm\ 1.1\ (lum)$$

- D0: $E_T(\gamma) > 8$ GeV and $\Delta R(l, \gamma) > 0.7$

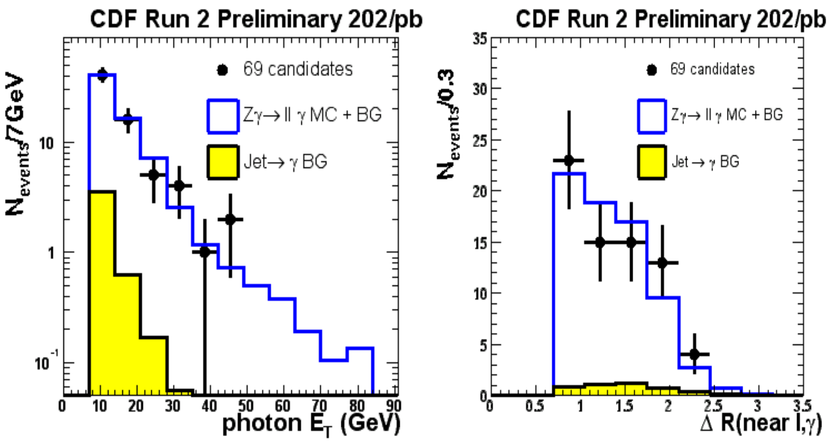
$$\sigma(W\gamma)\times BR(W\to l\nu) = 19.3\pm 6.7\ (stat+sys)\pm\ 1.2\ (lum)$$

- Theory:

  19.3±1.4 pb

Diboson Production

Zγ



$$\sigma = 5.3 \pm 0.6(stat) \pm 0.4(sys) \pm 0.3(lum)\, pb$$

Theory: 5.4±0.4

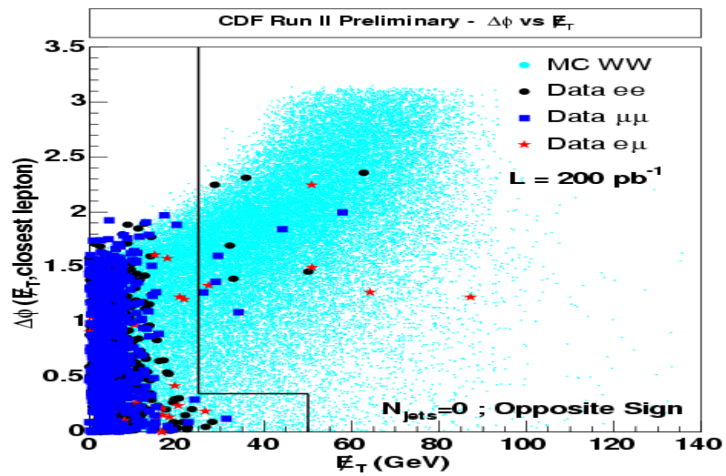
Ready for Wγ,Zγ radiation zero

WW:

CDF uses two selection:

17 evts, Backg:4.8

39 evts, Backg:15.27



$$\sigma = 14.3^{+5.6}_{-4.9}(stat) \pm 1.6(sys) \pm 0.9(lum)\, pb$$

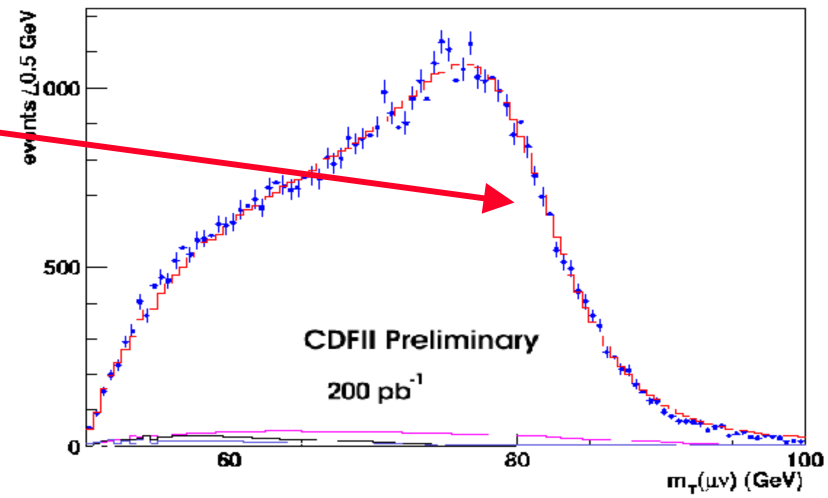
$$\sigma = 19.1 \pm 5(stat) \pm 3.6(sys) \pm 1.1(lum)\, pb$$

Theory: 12.5±0.8 pb

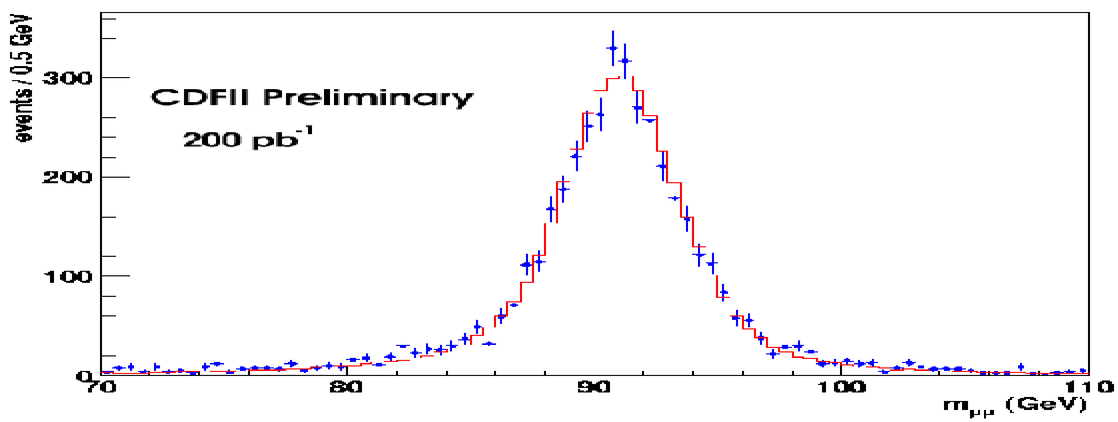
Future...

More forthcoming:

Direct Γ_W



W mass (challenge of detector understanding)



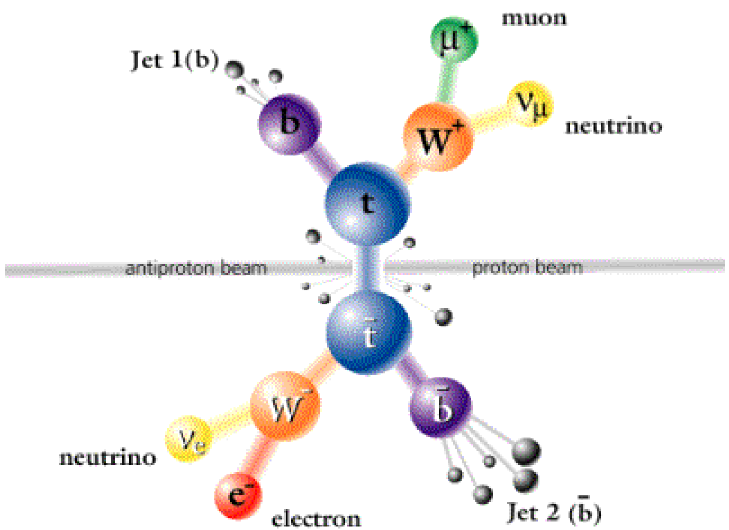
10 years of top

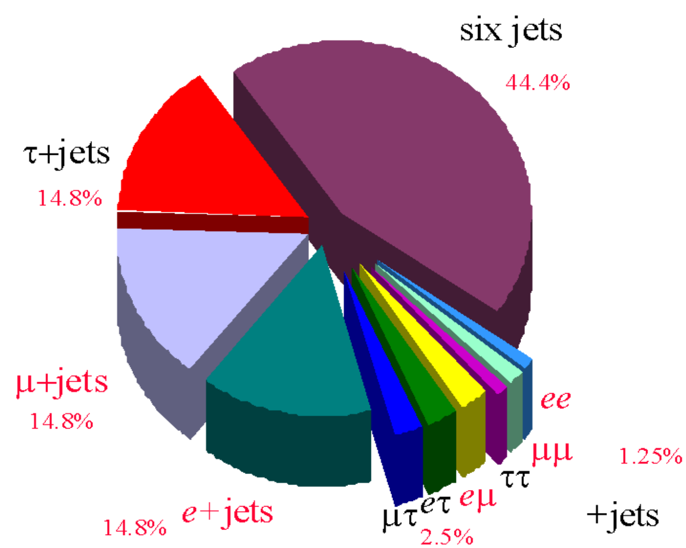
10 years ago (24/4) CDF "Evidence of top"

- February 1995 CDF and D0 "Top Discovery"
  - Run I studies (still ongoing)

What about Run II ?

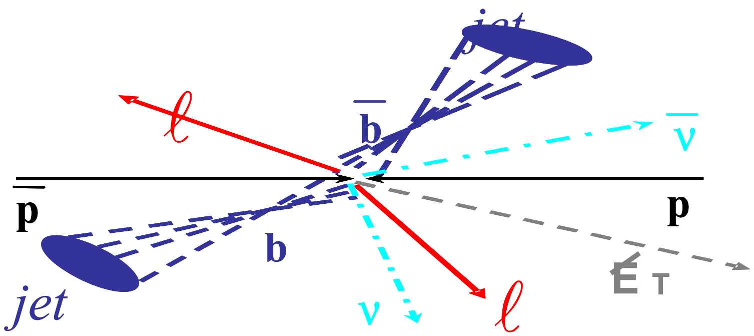
- → Top produced (mostly) in pairs...
- → Lots of decay channels to look at



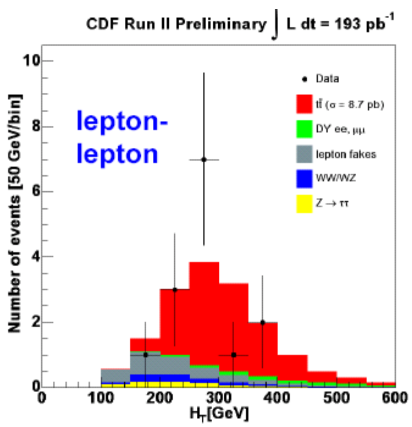


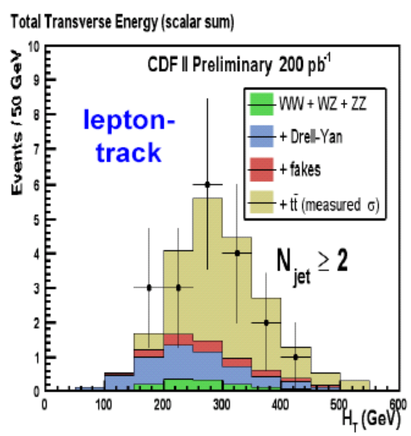
Top…how to find it…

Out of the different channels, select dilepton

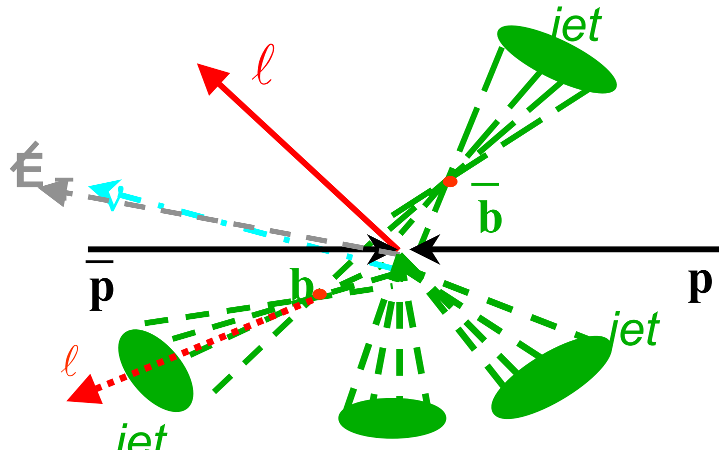


➥ to improve statistics use "identified lepton" + "isolated track"

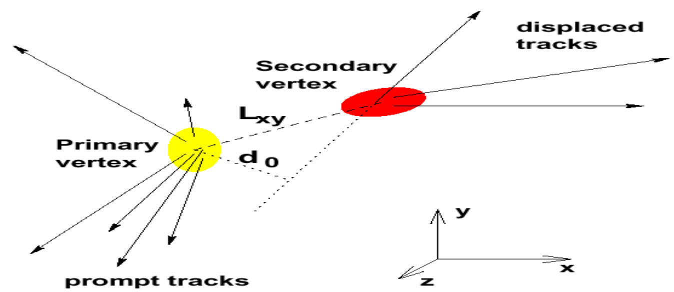




And l+jets



Use tagging to enrich sample

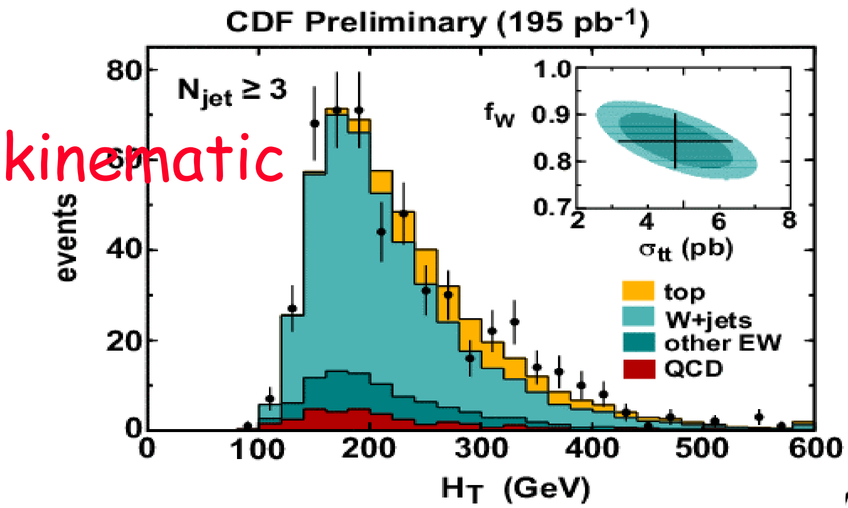


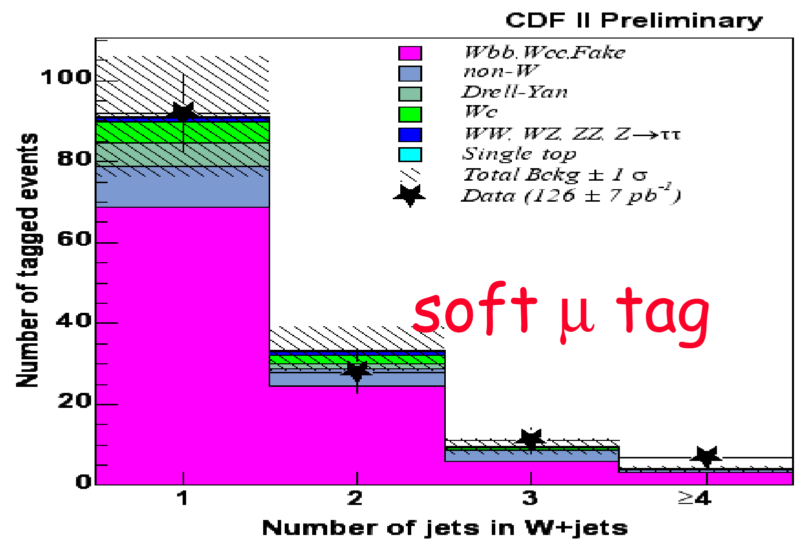
$\varepsilon \approx 55\%$ (bckg 0.5%)

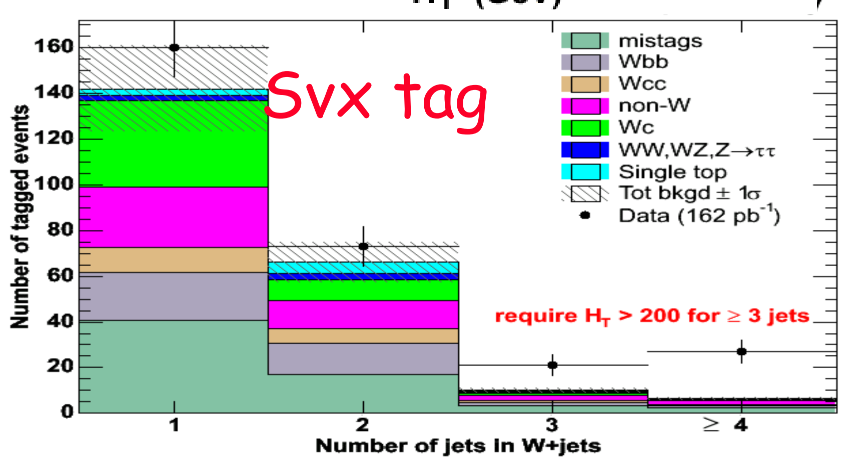
Top x-section

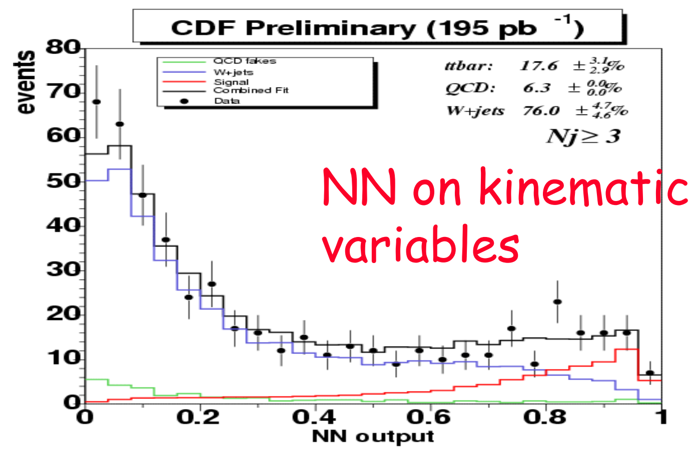
Look for top content in W+jets sample

SLT



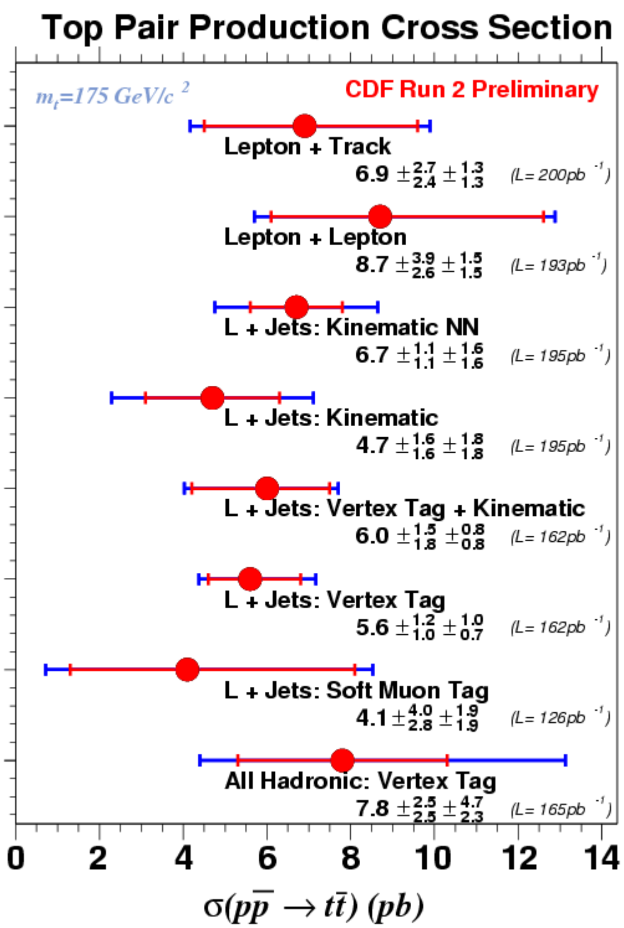




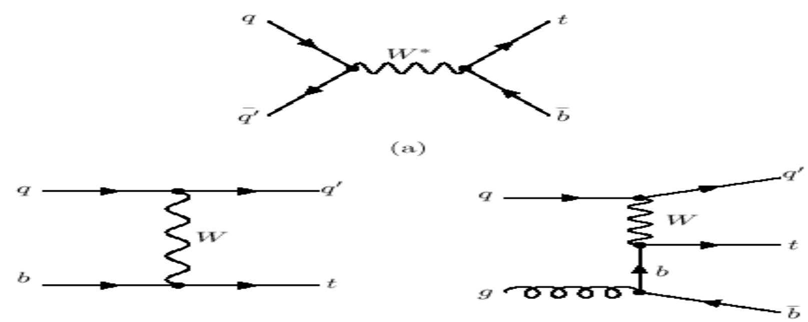


σ top (ttbar and single top)

A summary:

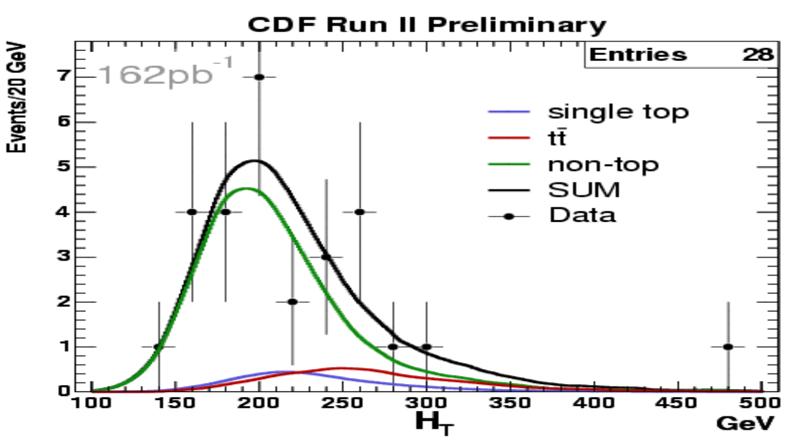


Single top process would measure $|V_{tb}|^2$ directly…



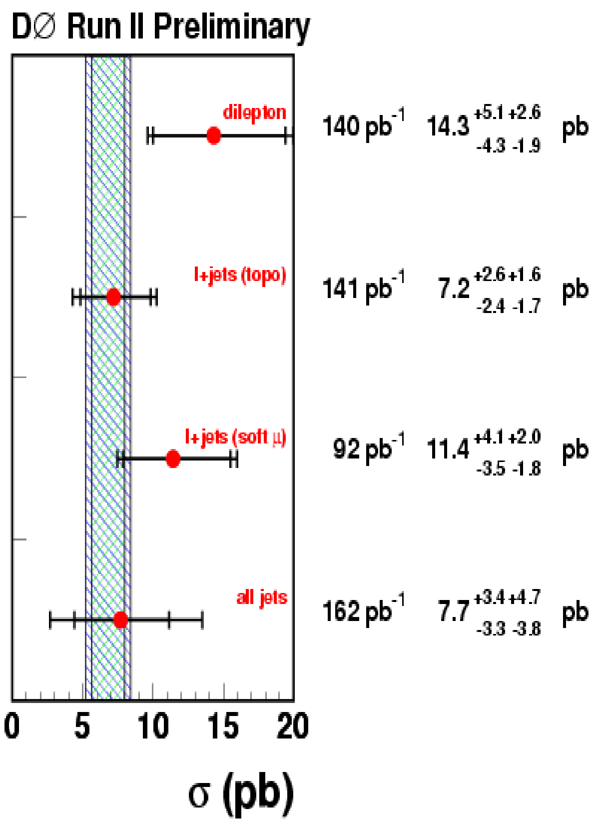
σ <13.7 pb (combined)

σ<8.5 pb (t-channel)

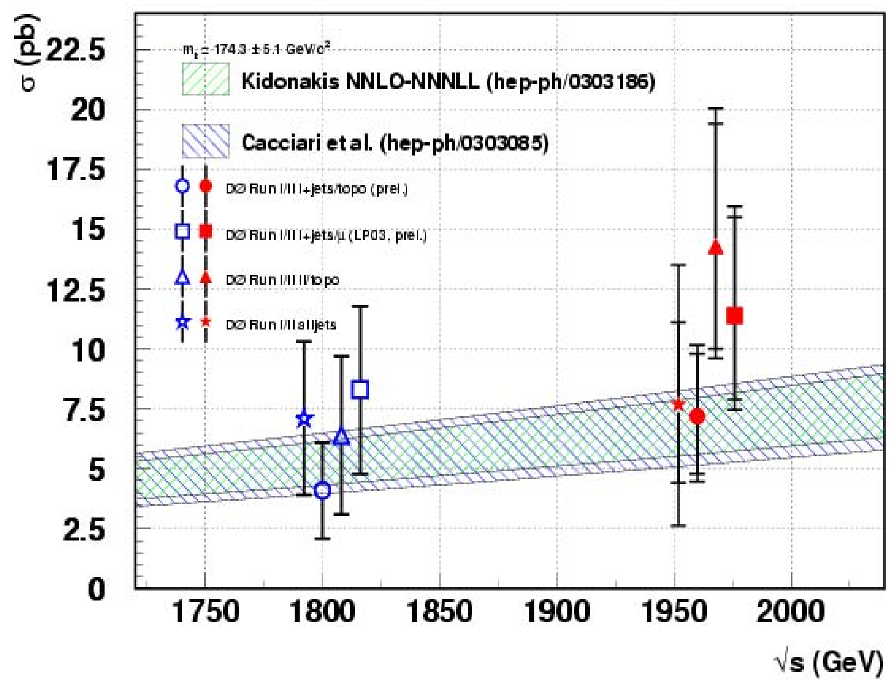


Top – x-section

A number of channels explored by D0



Nice comparison with past and theory…



Top Mass & Higgs...

New **Run I** combined CDF+D0 result

- D0 updates its value from 172.0±5.2(stat) ±4.9(syst) to 179.0±3.5(stat)±3.8(syst)
- Combined: 178.±4.3

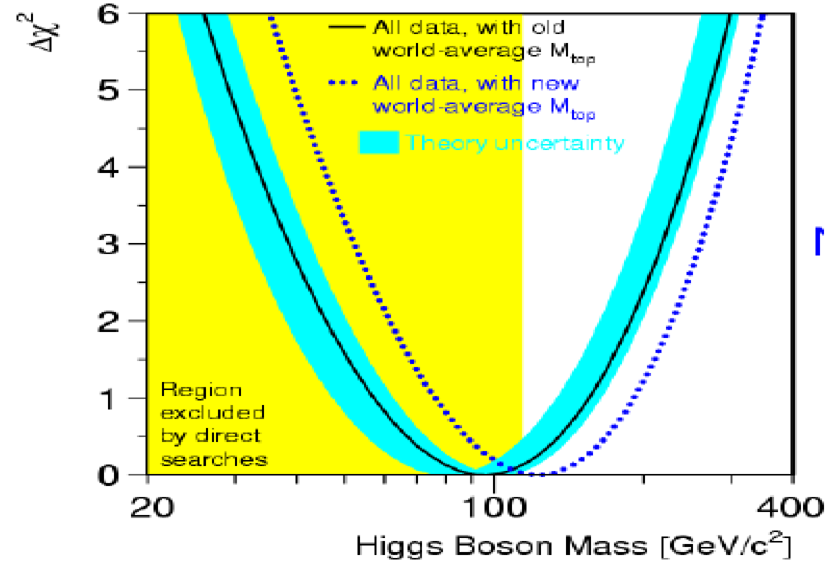
From fit:

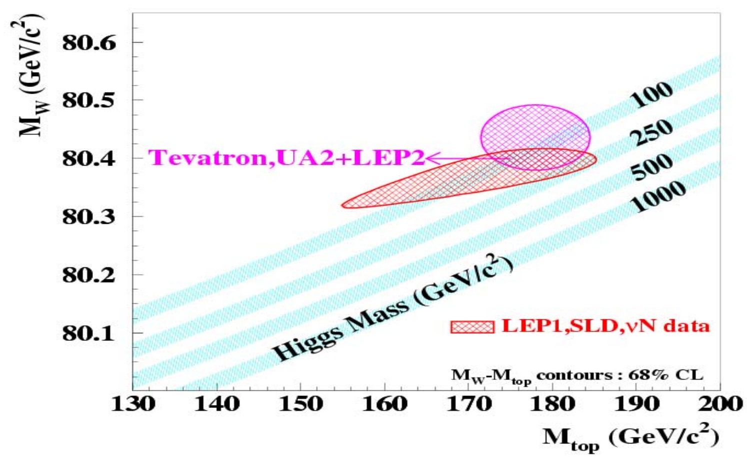
$$M_H = 117^{+67}_{-45}\, GeV/c^2$$

or < 251 GeV/c²(95% CL)

hep-ex 040410

New fit:



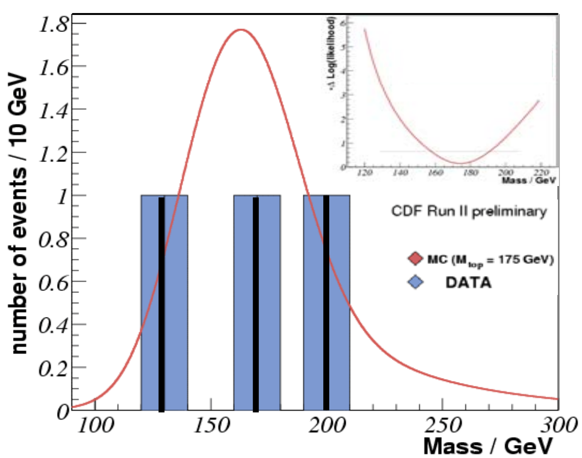


Top Mass- Run II

Use knowledge to improve measurement

- Unconstrained kinematics

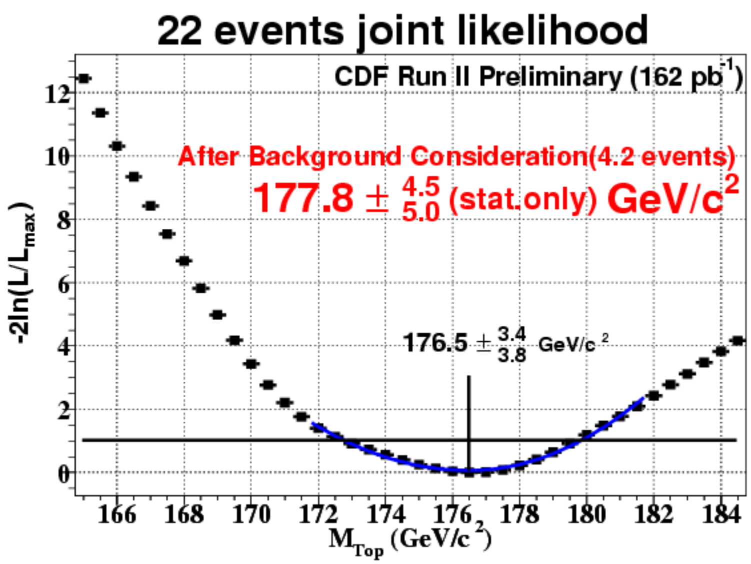
Dilepton: 125 pb $^{-1}$



175±17(stat) ± 8(syst)GeV/c²

In 162 pb^{-1} of single tagged l+jets (22 evts)

- Dynamic Likelihood Method



$177.8^{+4.5}_{-5.0}$(stat)±6.2(syst) GeV/c²

New Physics ?

Higgs

- Search in WH, H→bbar
- Search for H++

High mass

- Dilepton channel and comparison to spin 0, spin 1, spin 2 particles

SUSY

- Search for gluino decaying to sbottom

LQ

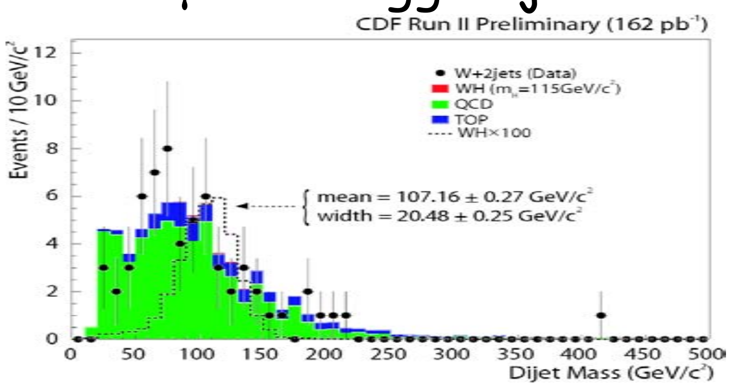
- First generation
- Second generation

…(excited leptons, ED…)

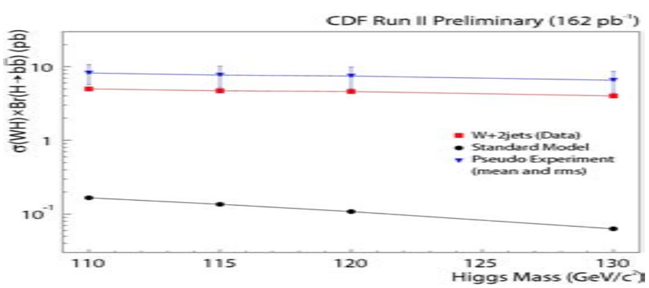
WH, H → bb

Search for H+(central) W

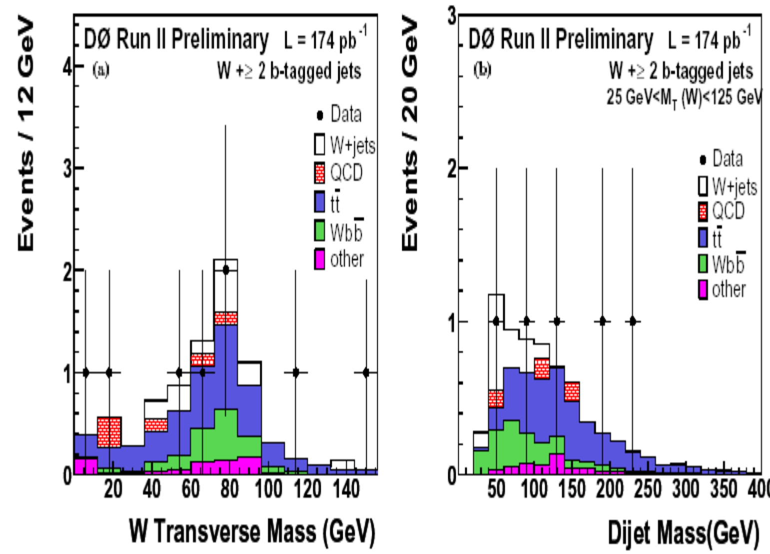
- High (>20 GeV) P_T e or μ≥1 b-tagged jet



	$W^{\pm}+1$ jet	$W^{\pm}+2$ jets	$W^{\pm}+3$ jets	$W^{\pm}+\geq 4$ jets
Total Background	122.84 ± 11.40	60.55 ± 4.43	25.77 ± 2.16	24.62 ± 2.59
Observed positive tags	135	62	23	21



D0:Limit for SM Higgs: σ>12.4 pb-1 @95%CL for M_H=115 GeV/c²



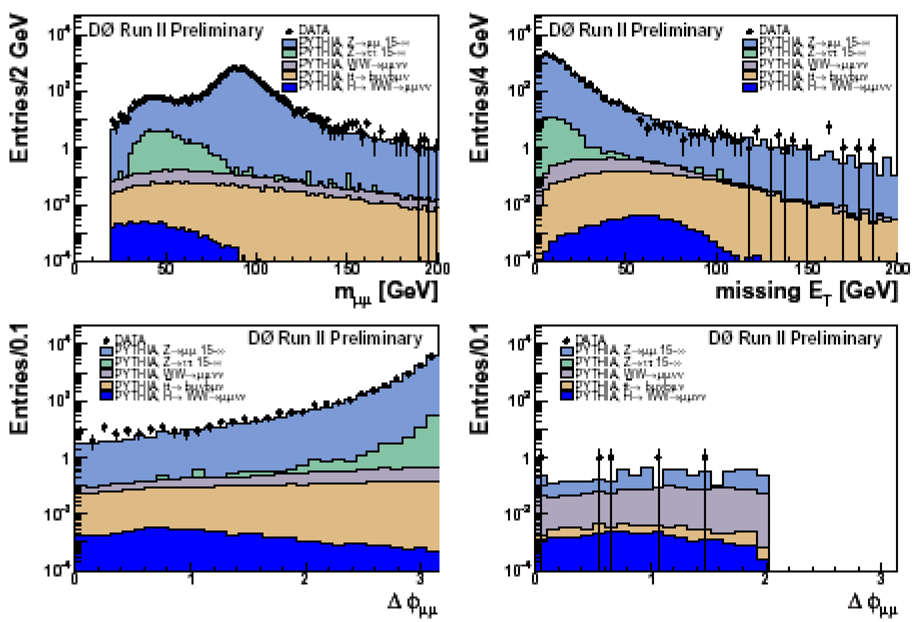
Better than Run I, still a long way to go

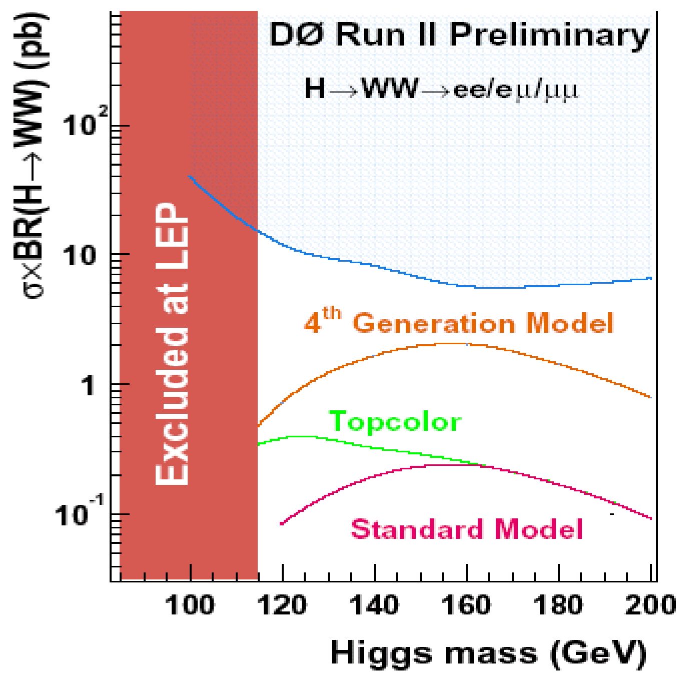
Higgs in WW*

WW* events selection

- Both W→lν (l=e or μ)
  - 2 events (2.7±0.4)
  - Compare to expectations

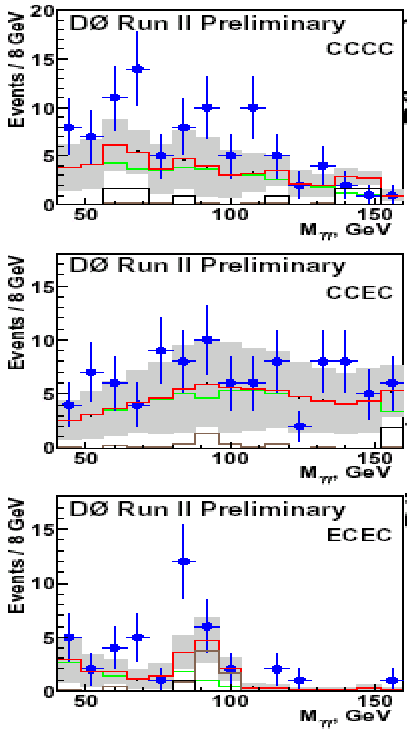
	ee	$e\mu$	$\mu\mu$
cut 1	$p_T^{e1} > 12\,\mathrm{GeV}, p_T^{e2} > 8\,\mathrm{GeV}$ opposite charge, $N^{SMT} > 2$	$p_T^{e} > 12\,\mathrm{GeV}, p_T^{\mu} > 8\,\mathrm{GeV}$ opposite charge, $N^{SMT} > 2$	$p_T^{\mu1} > 20\,\mathrm{GeV}, p_T^{\mu2} > 10\,\mathrm{GeV}$ opposite charge, $N^{SMT} > 2$ $m_{\mu\mu} > 20\,\mathrm{GeV}$
cut 2	$\not{E}_T > 20\,\mathrm{GeV}$	$\not{E}_T > 20\,\mathrm{GeV}$	$\not{E}_T > 30\,\mathrm{GeV}$ and $\not{E}_T > 0.75 \cdot p_T^{\mu1} + 10\,\mathrm{GeV}$
cut 3	$12\,\mathrm{GeV} < m_{ee} < 80\,\mathrm{GeV}$	$m_T^{min} > 20\,\mathrm{GeV}$	$\lvert m_{\mu\mu} - M_Z \rvert > 15\,\mathrm{GeV}$
cut 4	$p_T^{e1} + p_T^{e2} + \not{E}_T > 100\,\mathrm{GeV}$	$p_T^{e} + p_T^{\mu} + \not{E}_T > 90\,\mathrm{GeV}$	$\Delta\phi_{\mu\mu} < 2.0$
cut 5	$\Delta\phi_{ee} < 1.5$	$\Delta\phi_{e\mu} < 2.0$	No jet or ($E_T^{Jet1} < 60\,\mathrm{GeV}$ and $E_T^{Jet2} < 30\,\mathrm{GeV}$)
cut 6	$\not{E}_T^{\,scaled} > 15\sqrt{\mathrm{GeV}}$	$\not{E}_T^{\,scaled} > 15\sqrt{\mathrm{GeV}}$	
cut 7	No jet or $E_T^{Jet1} < 90\,\mathrm{GeV}$ or $E_T^{Jet1} < 50\,\mathrm{GeV}$ and $E_T^{Jet2} < 30\,\mathrm{GeV}$	No jet or $E_T^{Jet1} < 90\,\mathrm{GeV}$ or $E_T^{Jet1} < 50\,\mathrm{GeV}$ and $E_T^{Jet2} < 30\,\mathrm{GeV}$	

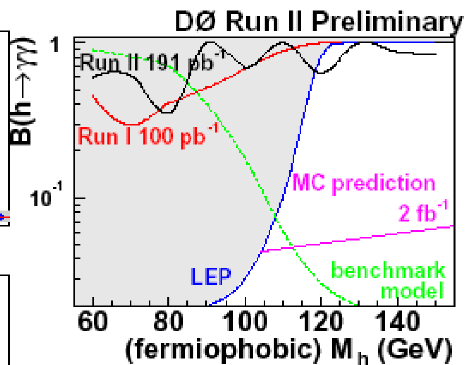


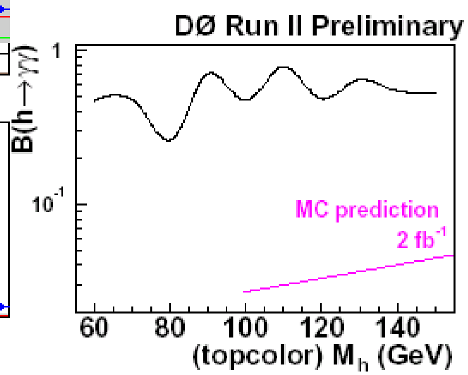


Non SM Higgs

D0 searches for fermiophobic Higgs in the $\gamma\gamma$ channel (191 pb^{-1}).

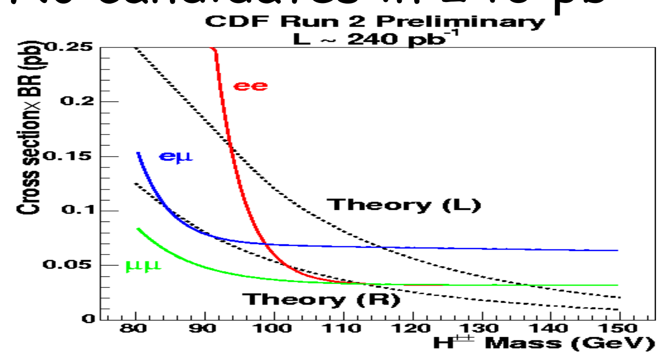


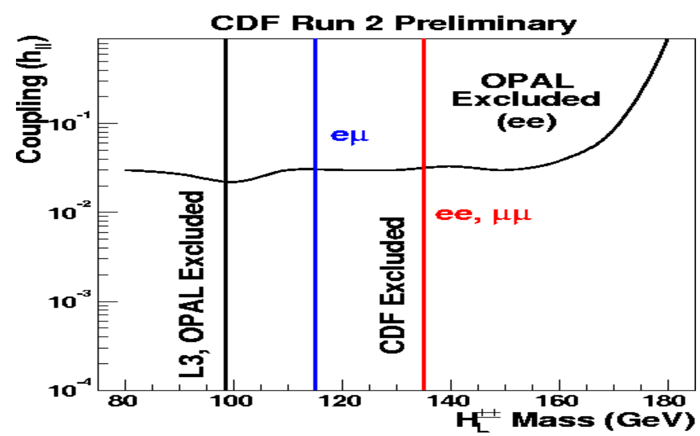




CDF looks for H++…

- Predicted by LR theories, searched by looking at di-lepton (e or μ) events.
- No candidates in 240 pb^{-1}



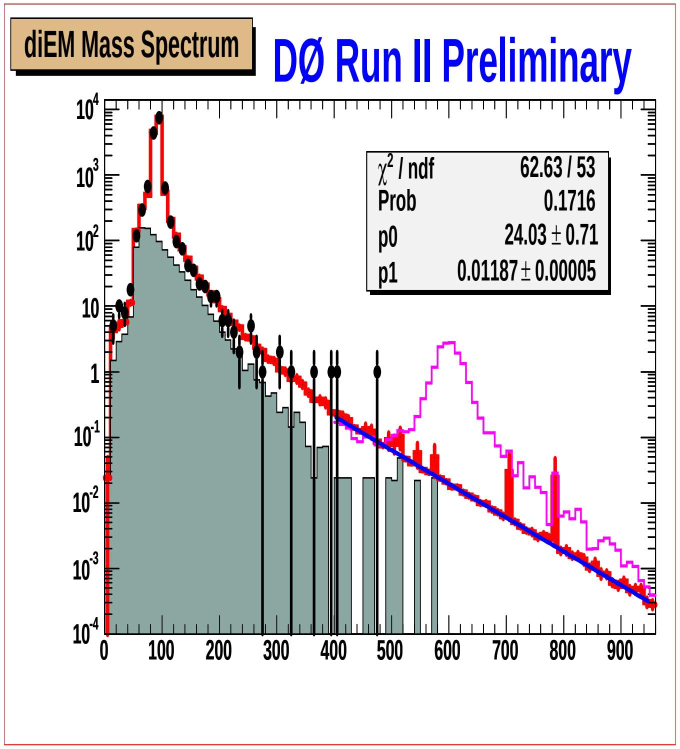


Search for High mass states

Many theoretical possibilities (Z',Z in Little Higgs, RS gravitons, RPV sneutrinos…)

From an experimental point of view, two possibilities:

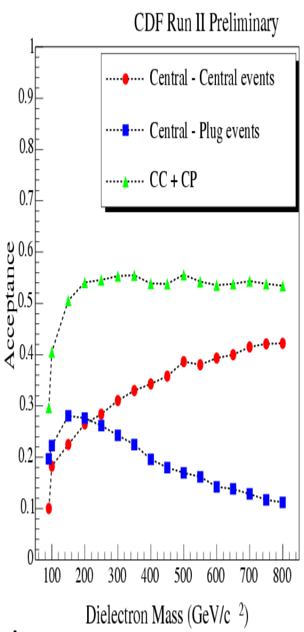
- Jets
- Leptons
  - Search for excess in di-electron (muon) events
    - Opposite sign
    - High P_T lepton
    - At least one in central region



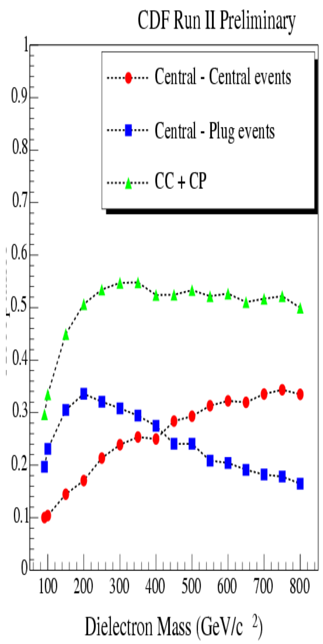
" Z' "

Different acceptance correction if you look for

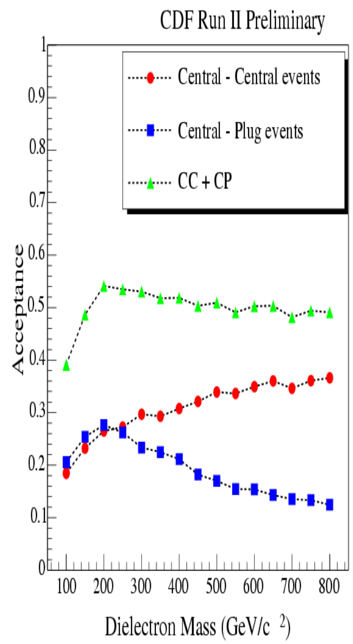
- Spin 1 (Z-like particles)
- Spin 0 (Higgs-like particles)
- Spin 2 (graviton-like particles)



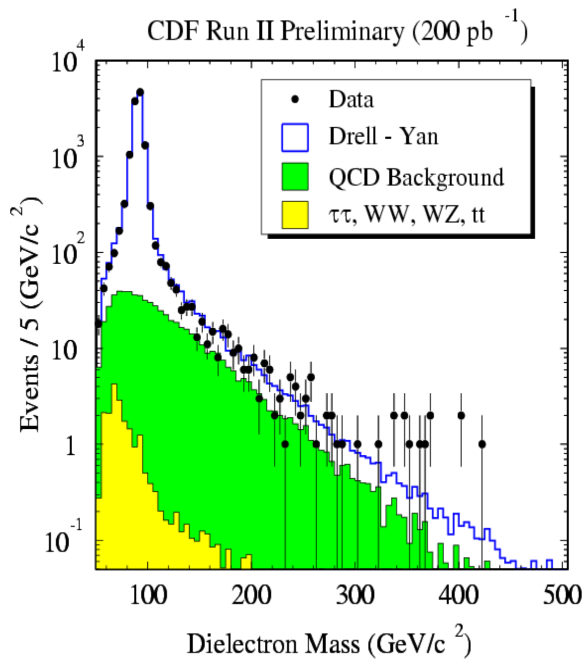
Z'



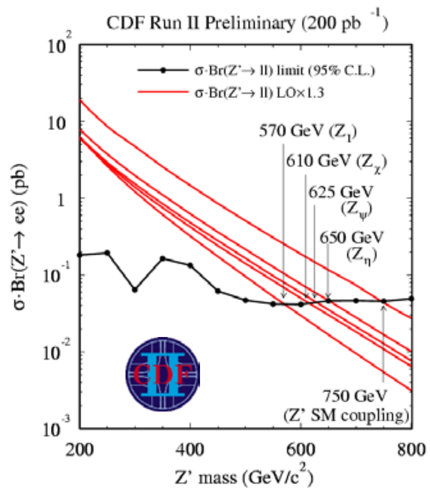
H'

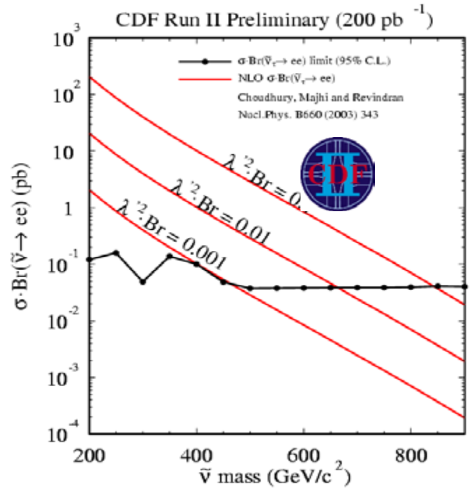


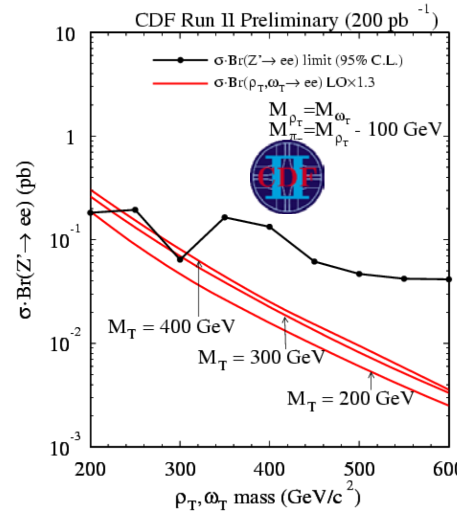
RS

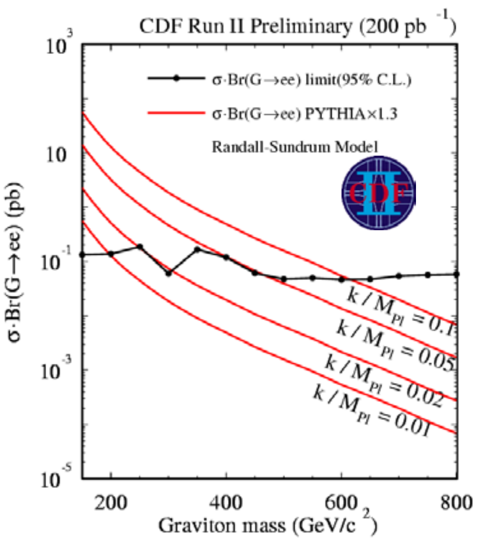


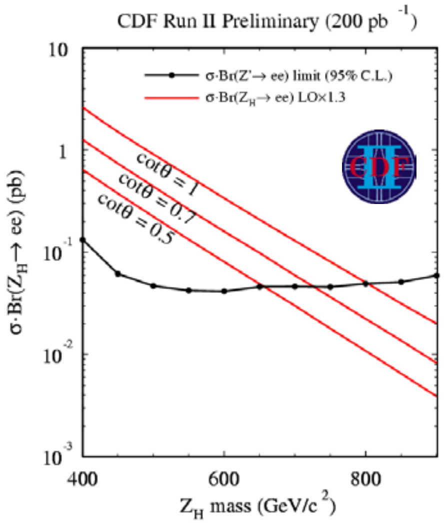
Limits from e^+e^- events

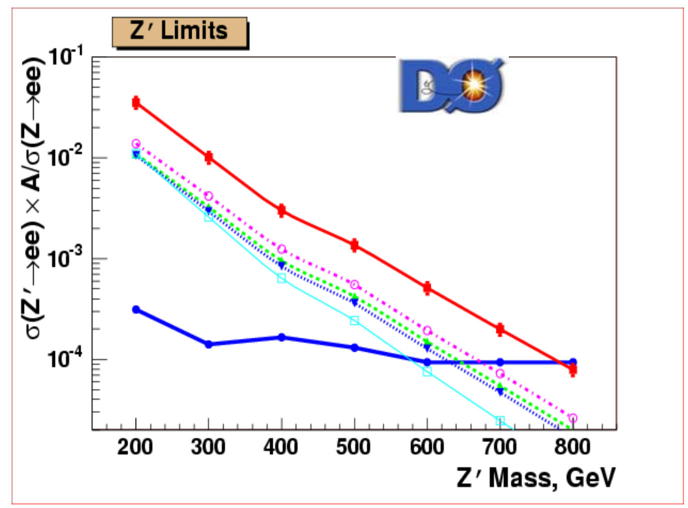




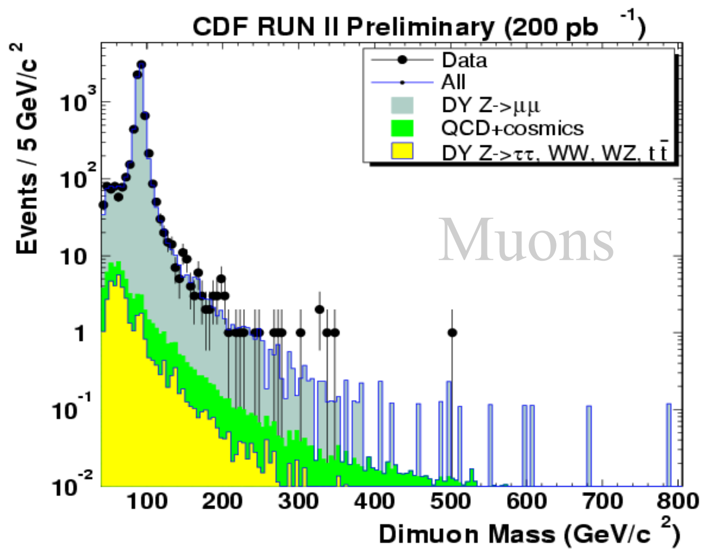


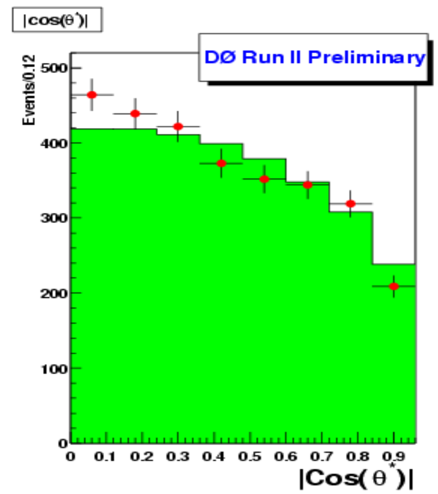


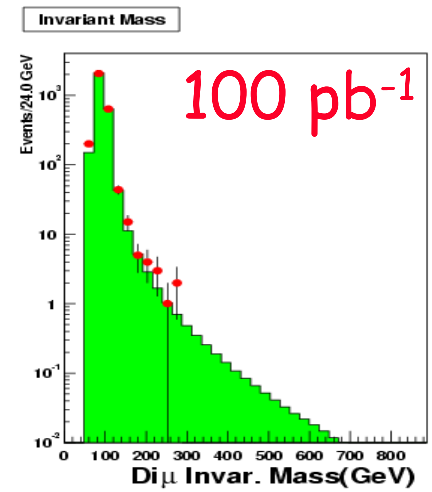


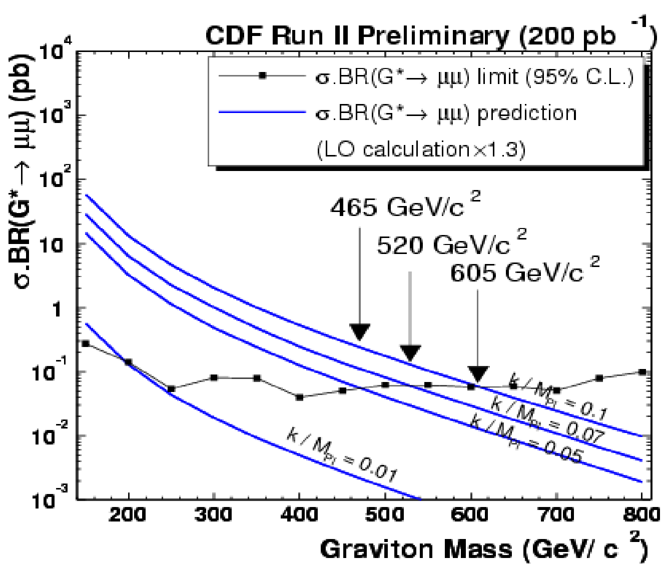


Di-muons









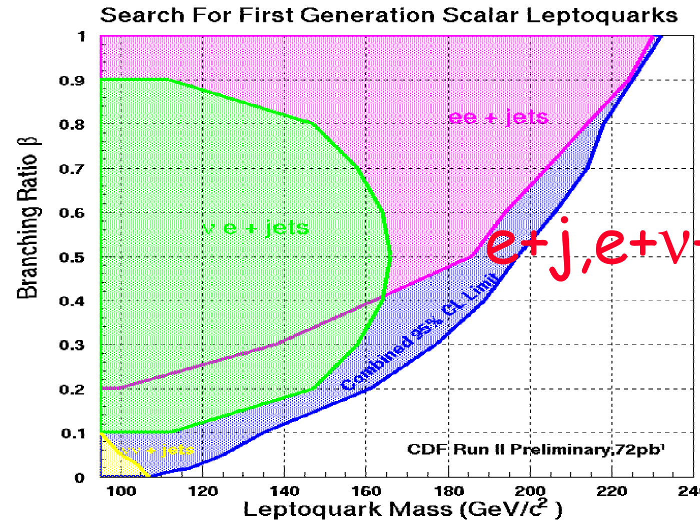
Z' gauge bosons: SM-Like Z' boson limit $M_{Z'} > 680 GeV/c^2$

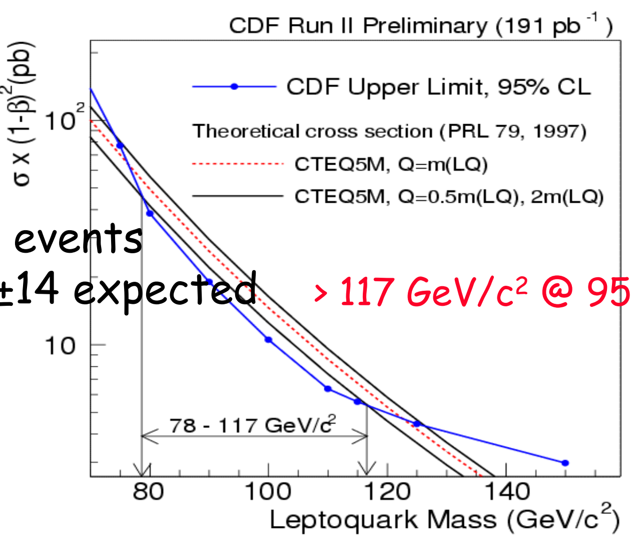
RS Graviton of extra dimensions: $M_G > 605 GeV/c^2$

LeptoQuarks

At Hadron Collider LQ are pair-produced. Signature:

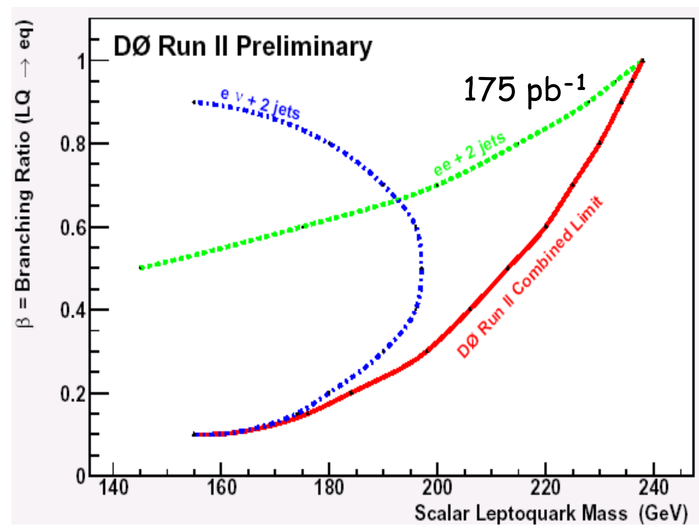
- Jet pairs + dilepton pairs
  - ⇨ 2jets+(ee,eν,νν,μμ)
- Decay controlled by β (BF(LQ→e(μ)q)), measure
  - ⇨ $\sigma \times \beta^2, \sigma \times (1-\beta)^2, \sigma \times (1-\beta) \times \beta$
- In first generation both CDF and D0 combines eejj, eνjj channels





124 events
118±14 expected

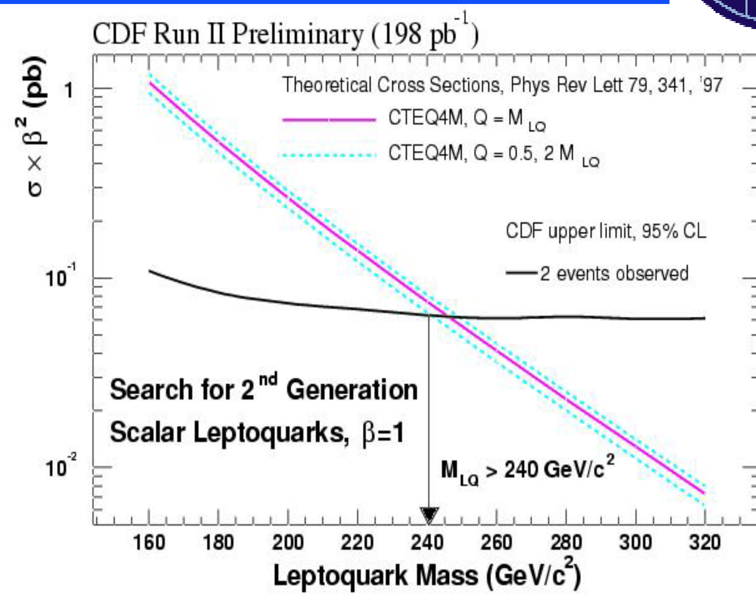
> 117 GeV/c² @ 95 % C.L.

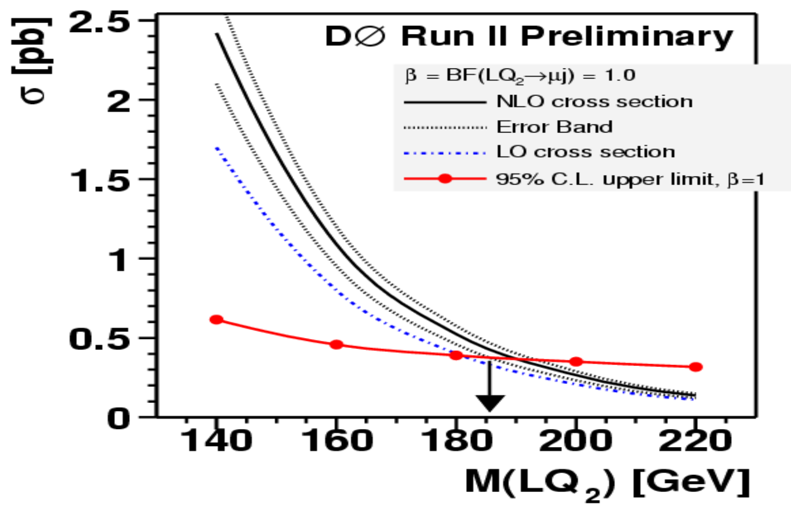


Leptoquarks- II generation

2^{nd} generation searched in $\mu\mu jj$ events

- Signature: 2 muons and 2 jets
- Background:top, Z+2 jets,QCD fakes
  - ⇨CDF Requires a tight and a loose muon
    - →2 events,
    - →Background: 3.15±2.17 events
  - ⇨D0 (104 pb-1)
    - →1 event
    - →Background: 1.59±0.47 events





Extra Dimensions

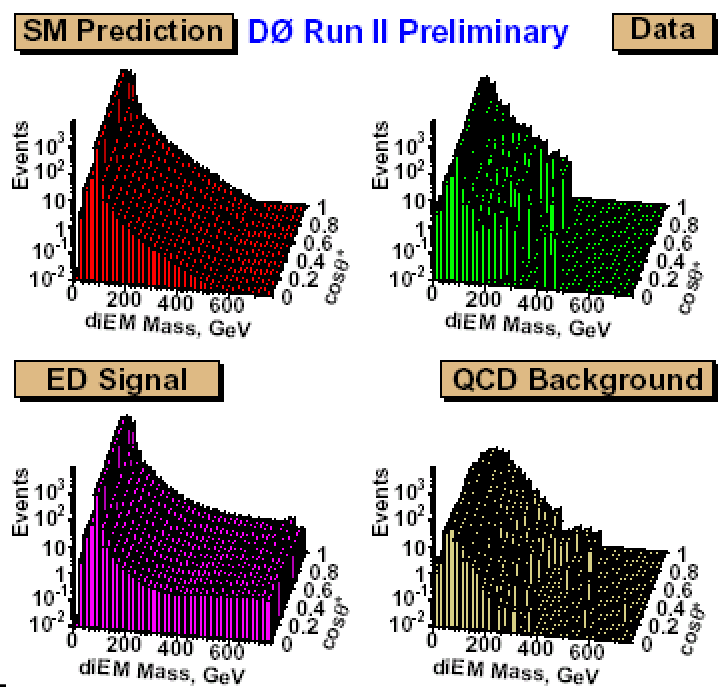
Limits set using: $\eta_G^{95} = F/M_S^4$

Run 2 from pp→ee,γγ

- M_s(GRW)> TeV(e,γ)
- M_s(GRW)> TeV(μμ)
  - ⇨ Run 1+2: 1.43 TeV (e,γ)

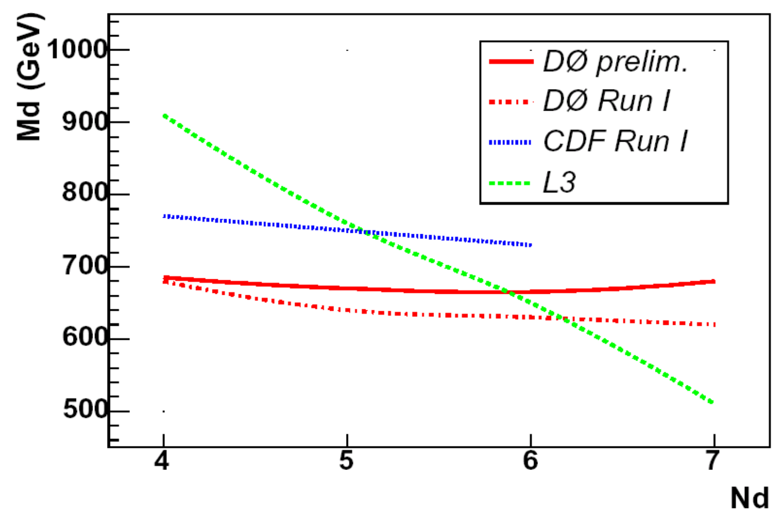
Plot M_{ee} vs $\cos(\theta^*)$

GRW [4]	HLZ [5]						Hewett [6]
	n=2	n=3	n=4	n=5	n=6	n=7	λ = +1
1.43	1.67	1.70	1.43	1.29	1.20	1.14	1.28



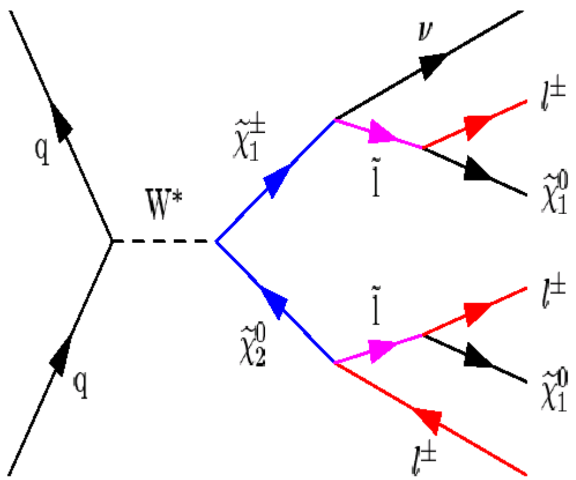
Search for graviton recoiling against a jet (*q* or *g*). Monojets are back...

- Data (85 pb^{-1}) are consistent with background (mainly Z→νν +jets)



Trilepton

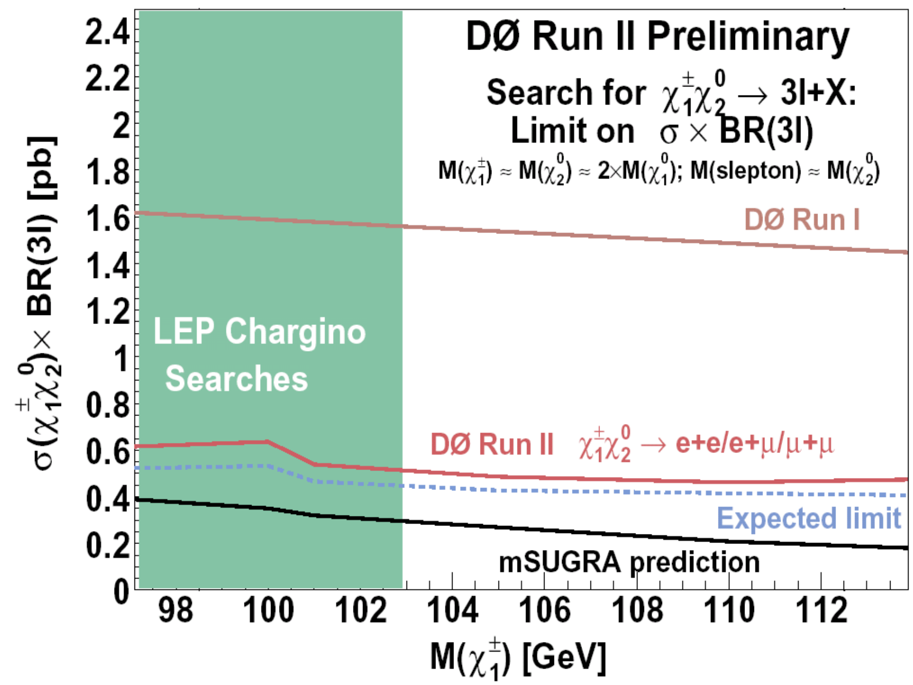
Di- and tri-lepton events are a clean signature:



strategy:

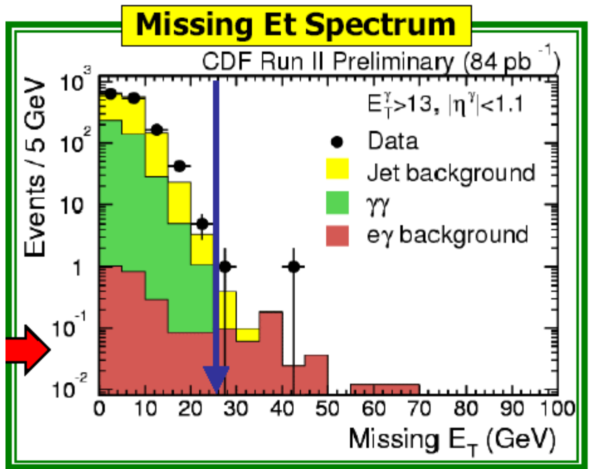
- Combine ee(l),μμ(l),$\mu^+\mu^+$
- Dataset: 175,158,158 pb^{-1},
- Compare to MSUGRA…

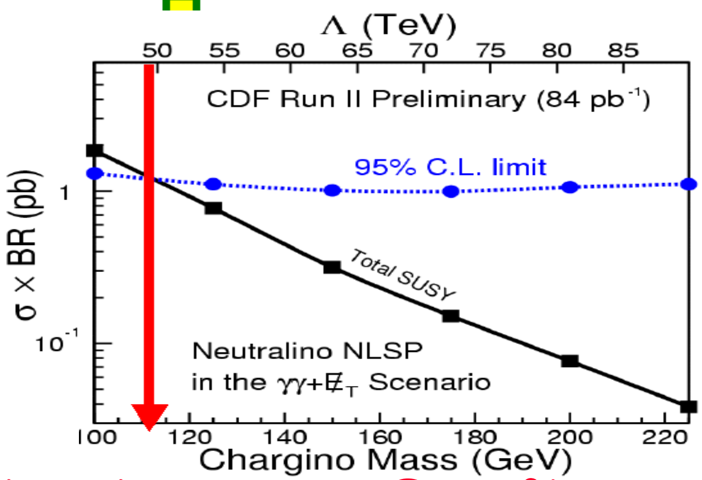
D0 succeeds in using all channels together



GMSB: NLSP = $\chi^0_1 \rightarrow \gamma$

CDF searches for γγMET

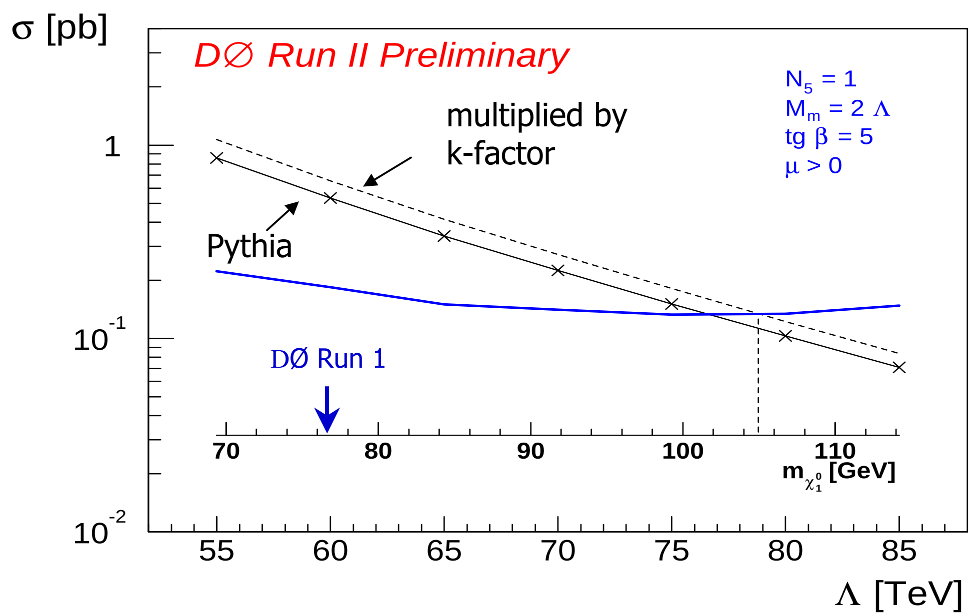




$M(\chi^+_1)$>113GeV@95%CL

D0 looks for γγMET in 185 pb-1…

- End of selection 1 events where 2.5 are expected



$M(\chi^0_1)$>105GeV@95%CL

$M(\chi^+_1)$>180GeV@95% CL

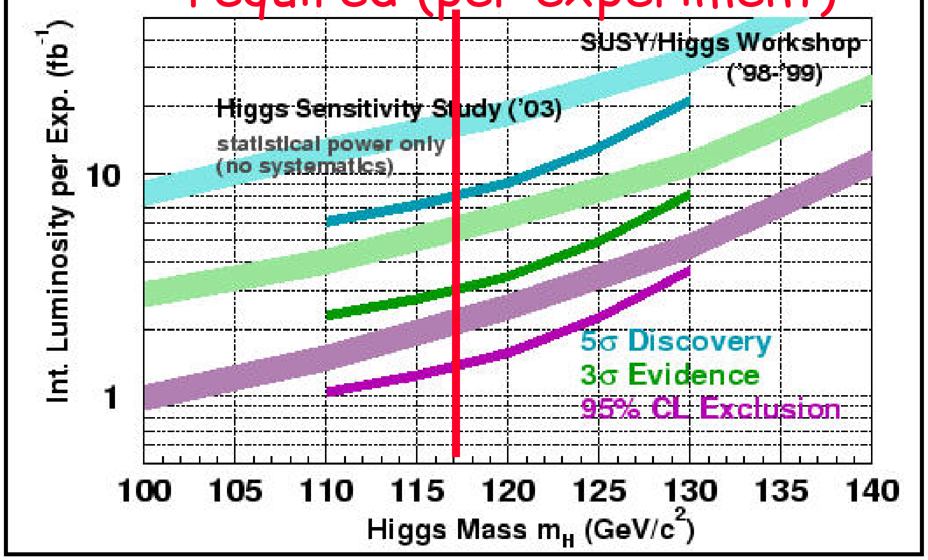
Higgs Hunting

Challenge is: what about SM Higgs?

Critical re-assessment of SUSY-Higgs Working Group (thanks to DOE)

- CDF looks at WH, $H \rightarrow bb$
- D0 looks at ZH, $Z \rightarrow \nu\nu$
  - Run II in progress
  - WG not too optimistic…but
    - Systematics not included…

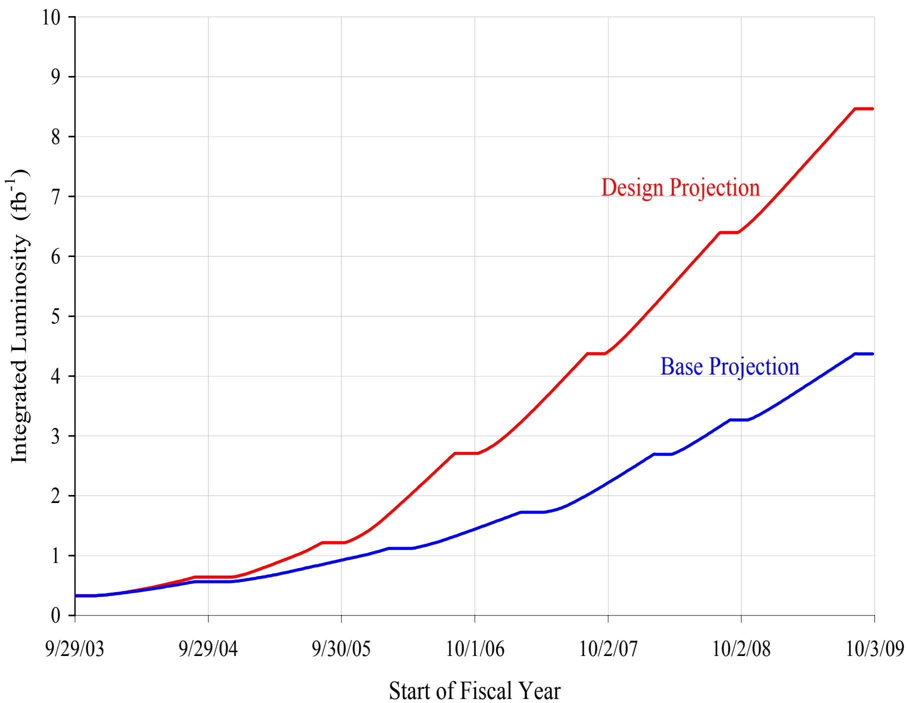
SM Higgs reach, luminosity required (per experiment)



Future

Machine is performing…in the future:

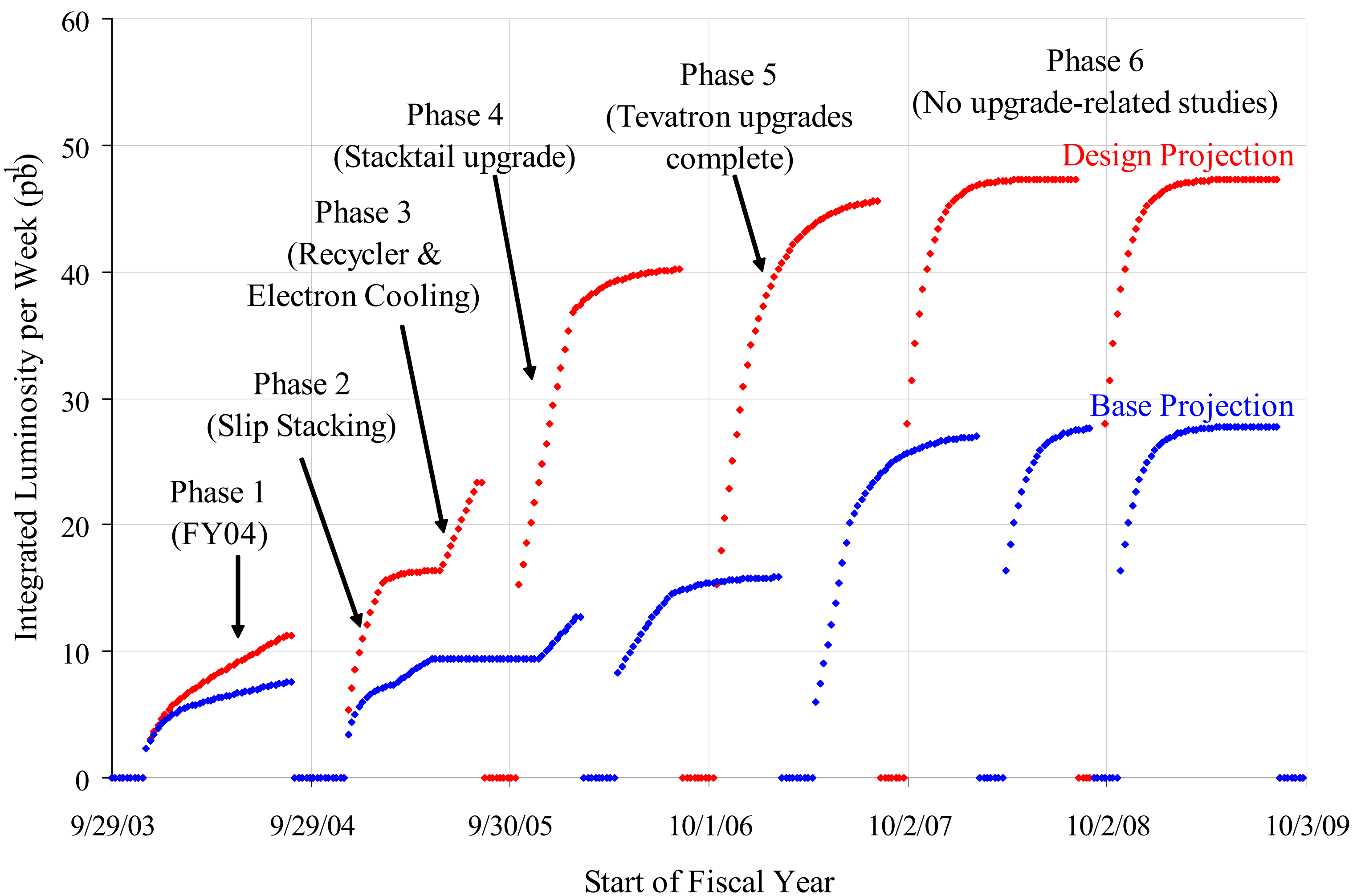
- CDF &D0, designed for 132 ns
  - will have to work at 396 and ~2.7×10^{32} $cm^{-2}s^{-1}$



Fiscal Year	Design (fb^{-1})	Base (fb^{-1})
FY03	0.33	0.33
FY04	0.64	0.56
FY05	1.2	0.93
FY06	2.7	1.4
FY07	4.4	2.2
FY08	6.4	3.3
FY09	8.5	4.4

Machine R&D

A number of technical challenges..



Conclusion I

CDF and D0 are taking (and analyzing) data

- Tevatron is performing well
- Both experiments are coping well with current instantaneous luminosity
- CDF is experiencing some problems with COT unexpected aging (http://www-cdf.fnal.gov/upgrades/cot/aging_committee.html)

Tevatron is undergoing a complex process towards higher luminosity

- Goal is to collect between 2 and 4 fb^{-1} by mid 2007
- Detectors should be able to survive the challenge

Conclusion II

Physics results do not come in batches…

- Continuos flow of results from both CDF and D0
- Basic physics objects understood
  - Learning curve was slow
  - Most results are still "basics" (EWK and top x-sections)
    - Follow analysis "a la Run I"
  - Already some results based on new techniques/detectors
    - More on its way, stay tuned (M_W in summer with 200 pb^{-1}, Mtop…)
  - Impact on Higgs searches (if luminosity projections hold)

Grazie a tutto il comitato organizzatore ed ai colleghi di Torino per la splendida accoglienza