Particle physics at the "energy frontier": Recent Results from CDF

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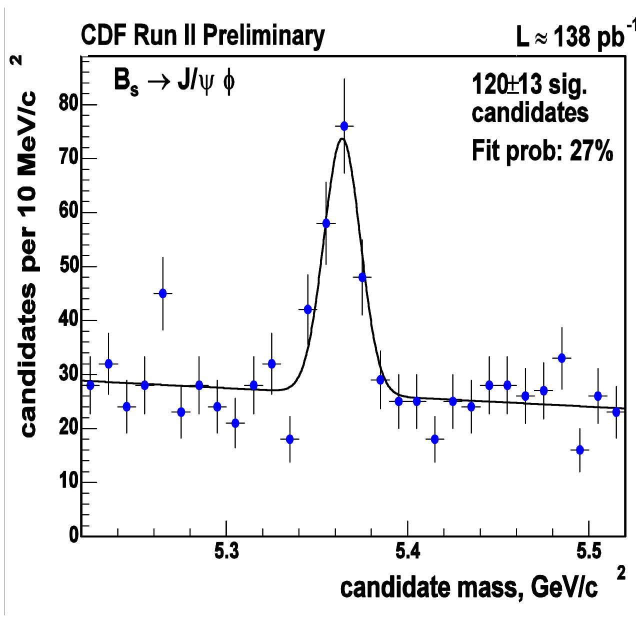
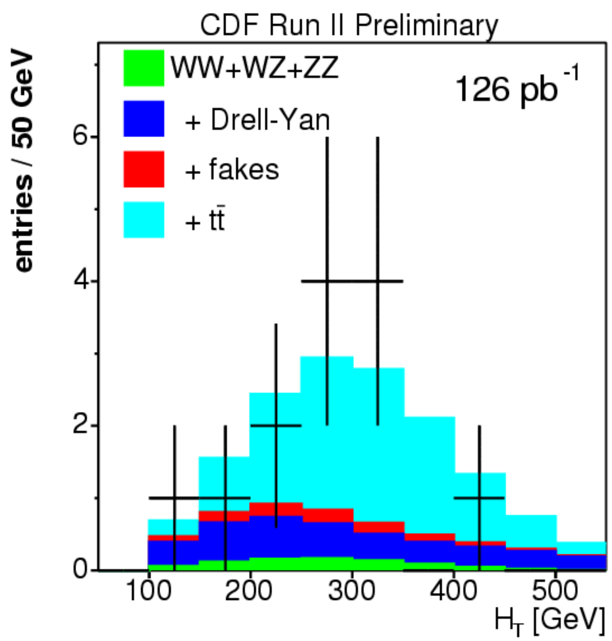
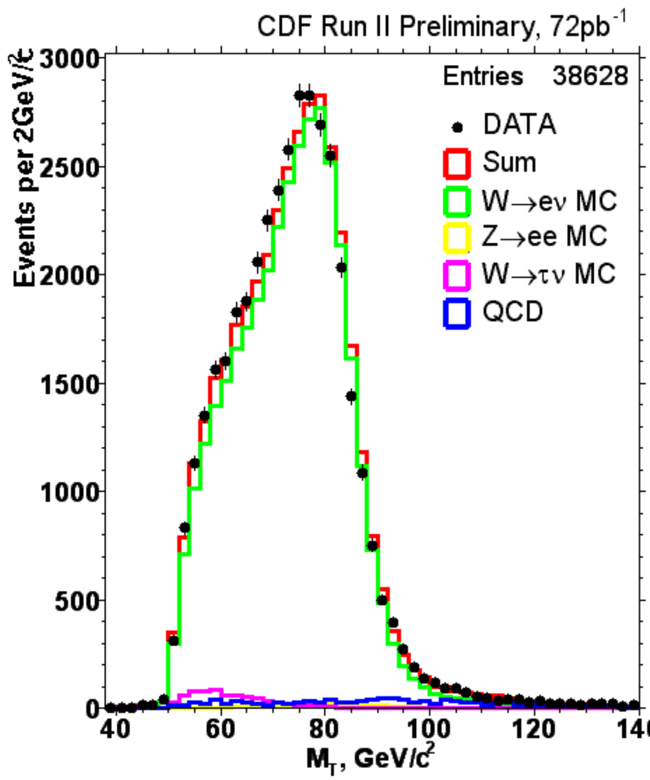
B$_s$? J/? F



top dilepton events



W ® en

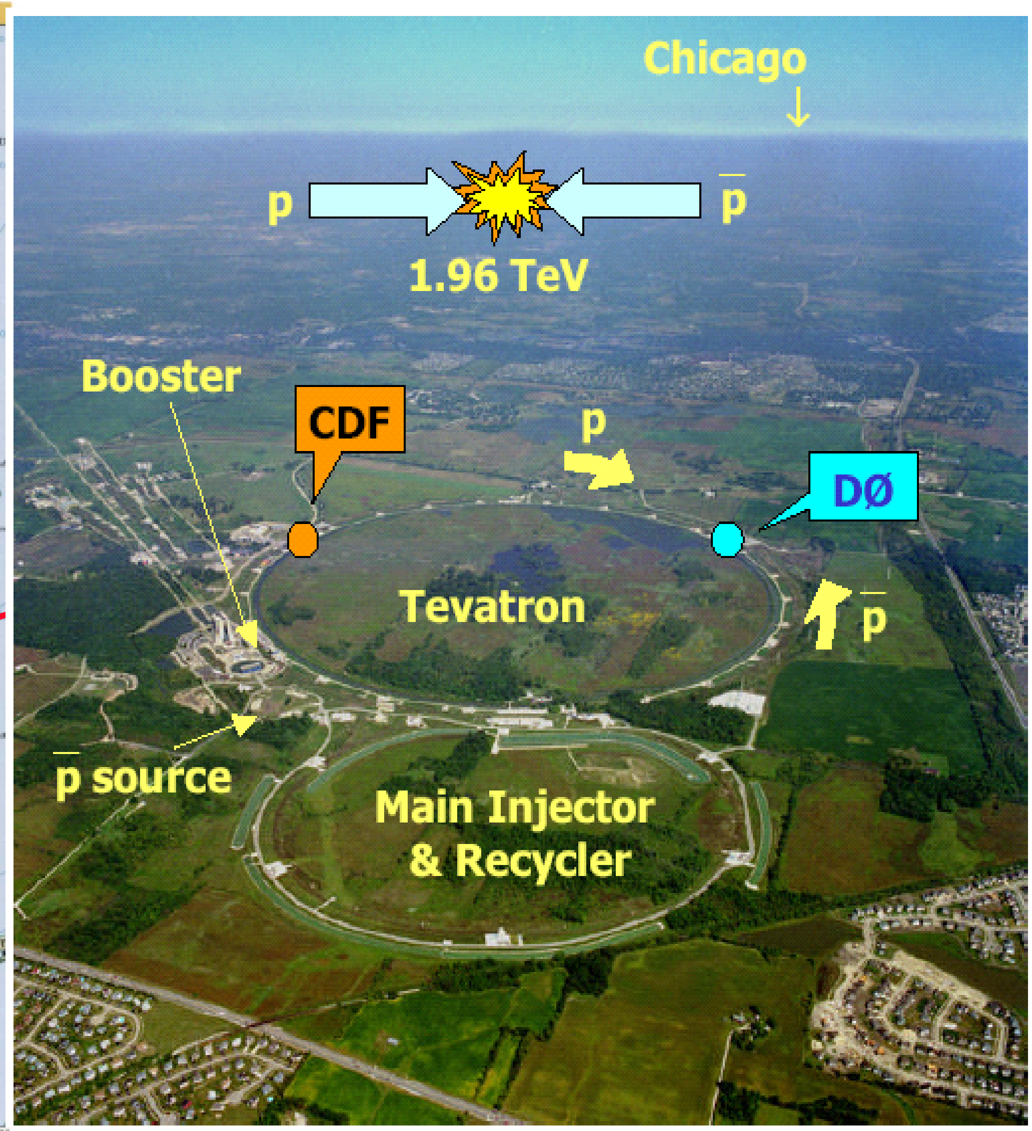


Fermilab

Tevatron (+ Main Injector/Recycler)

Chicago, USA

proton antiproton at ~2 TeV !



Improvements for Run II

1992-96: **Run Ib** => discovery of the top quark
since April 2001: **Run II**

massive upgrade of accelerator complex

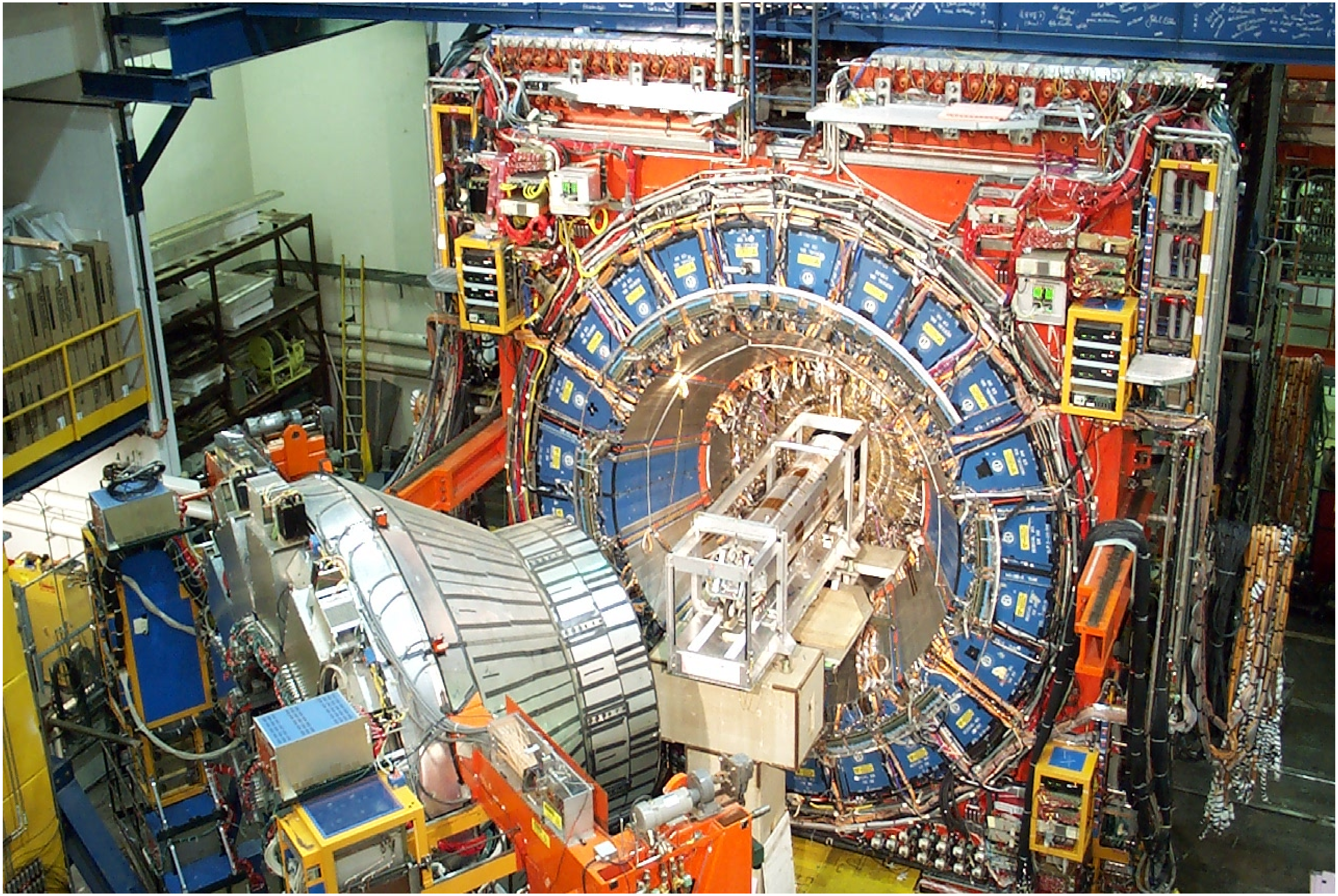
(construction of main injector/recycler)

- increased beam energy: **980** instead of **900 GeV**
  (=> ~35% increase of top quark X-section)
- proton collisions every **396 ns** instead of **3.5 ms**
- more antiprotons (and protons) per bunch

massive detector upgrade (CDF and D0)

- **faster** (132 ns); **bigger** (acceptance); **better** (resolution, trigger …)

CDF II: Collider Detector at Fermilab

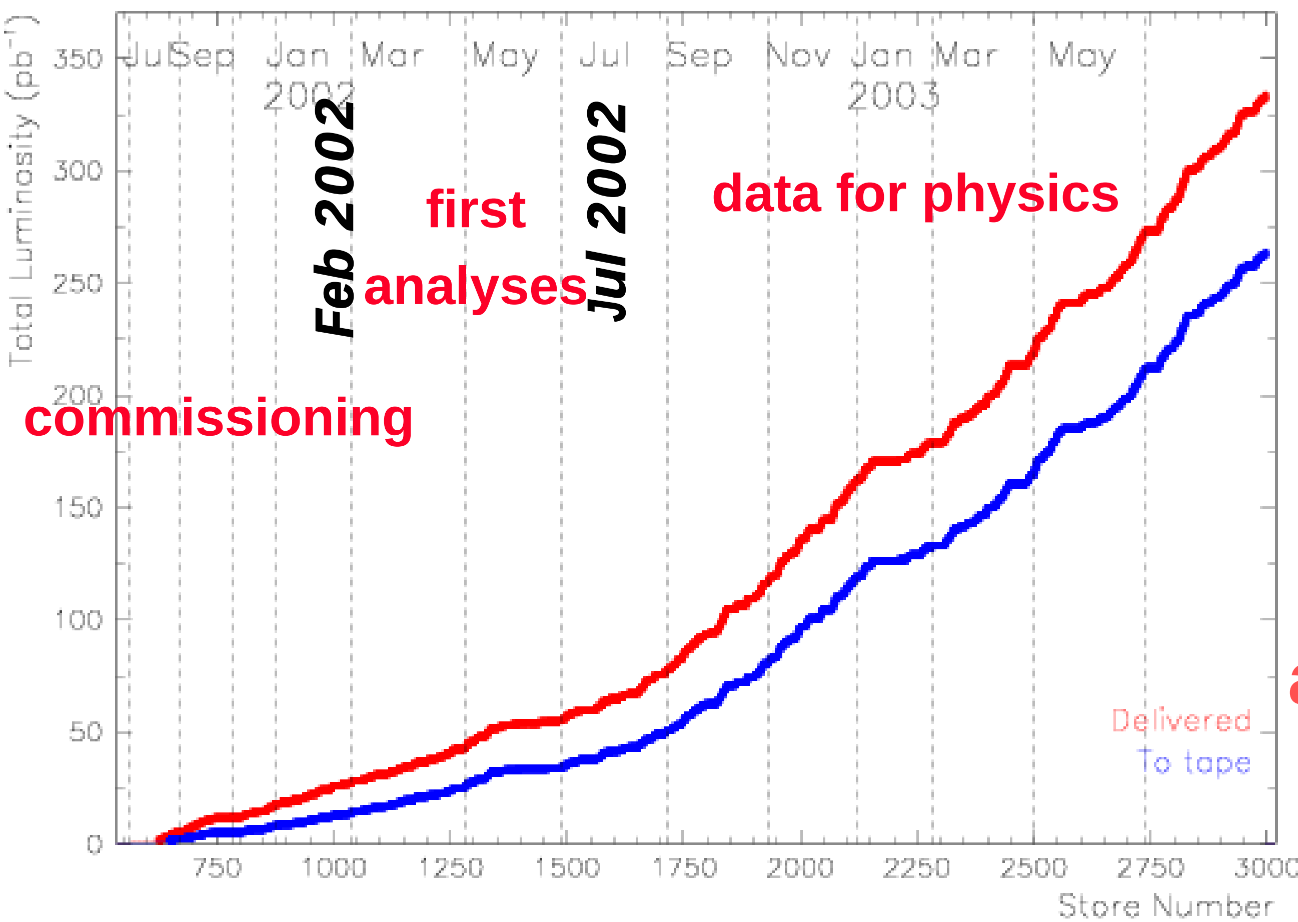


Luminosity

Run I: ~110 pb-1

Run II: **~260 pb-1** on tape; peak luminosity: **$\sim 4.5 \times 10^{31}$** s^{-1} cm^{-2}

Integrated luminosity



330 pb^{-1} "Tevatron"

260 pb^{-1} CDF "on tape"

Goal for 2004:

add >300 pb^{-1}

Luminosity

- initial Luminosity expectations: **~15 fb-1 until 2007**
- have become more pessimistic/realistic over last 3 years

=> disappointment; criticism; reorganization of beam division; cancellation of Run IIb Silicon upgrade project …

but: good data coming in daily; exceeded Run I data; much better detector; great physics potential

Recent shutdown activities

- **Tevatron** dipole magnet alignment; better alignment tools
- **Recycler** vacuum bake out (3 x smaller emittance), commissioning
- **Booster** improvements (new large aperture magnets; new collimation system)

Tevatron Luminosity Projections

Integrated Luminosity (fb^{-1})				
	Design Projection		**Base Projection**	
	per year	Accum-ulated	per year	Accum-ulated
FY03	0.22	0.30	0.20	0.28
FY04	0.38	0.68	0.31	0.59
FY05	0.67	1.36	0.39	0.98
FY06	0.89	2.24	0.50	1.48
FY07	1.53	3.78	0.63	2.11
FY08	2.37	6.15	1.14	3.25
FY09	2.42	8.57	1.16	4.41

FY06–FY09: With recycler and electron cooling

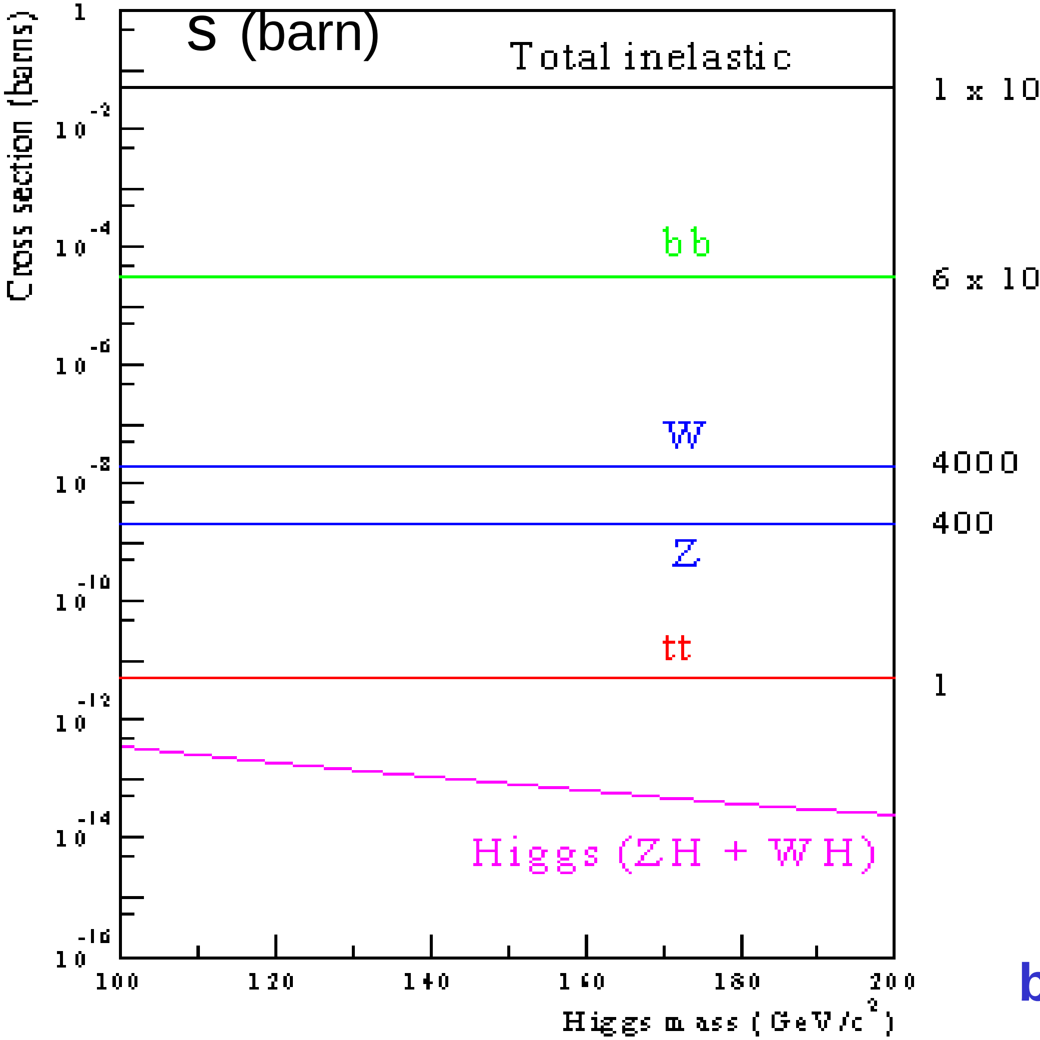
(Electron cooling is challenging)

Should reach: ~1 fb^{-1} in 2 years (~10 x Run I !)

Total data may be: 4.4 to 8.6 fb^{-1} (> 50 x Run I)

Hadron collider: challenges …

Particle menu



Flood of data:

2 Terabyte/day on tape

high **radiation field:**

MRad doses near beam pipe

Proton structure:

need PDFs; many subprocesses for a given final state; proton remnants, initial state radiation; etc.

Huge **variation of X sections:**

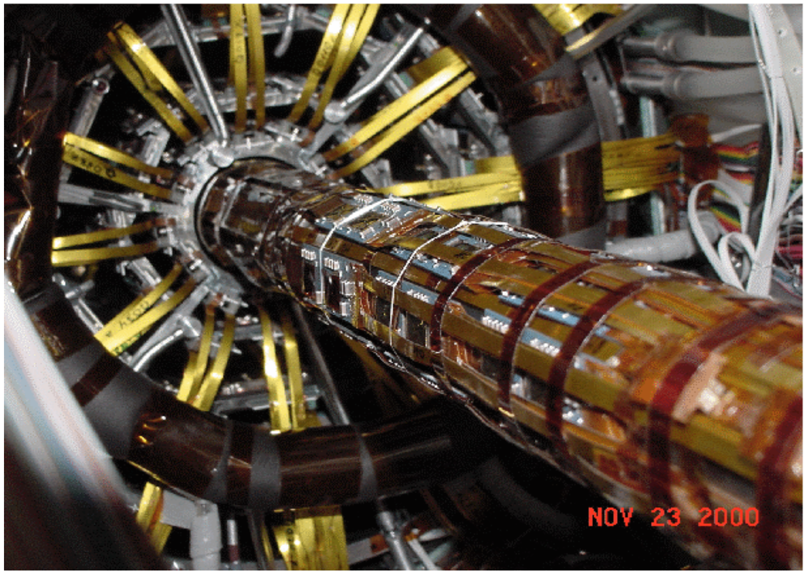
~5 μb of "reconstructable" BBs

(~150 Hz at $4\times10^{31}cm^{-2}s^{-1}$, too much !)

but need to record 10^{10} events to get 1 top quark pair …

CDF II – Silicon tracker

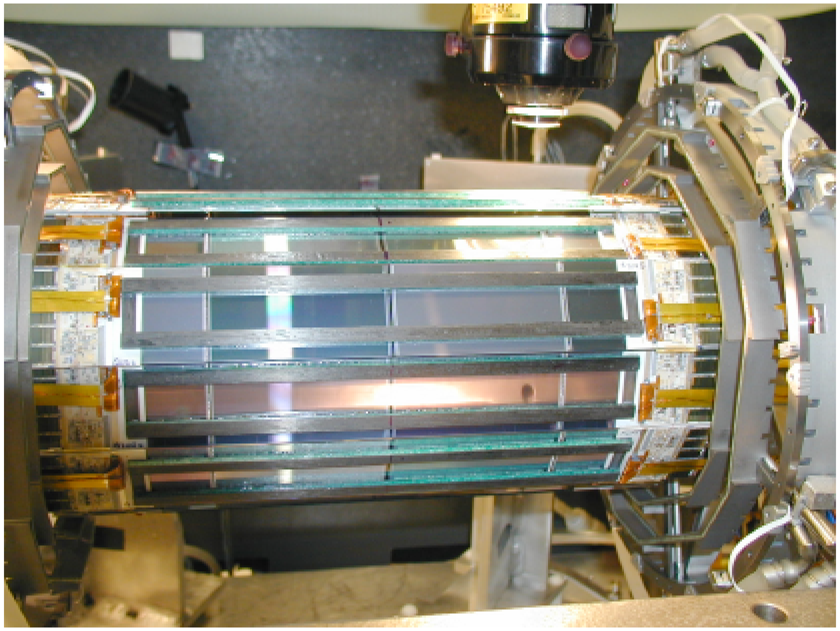
L00: innovative; light weight; radiation hard; only ~1.5 cm from beam line, key to best tracking performance



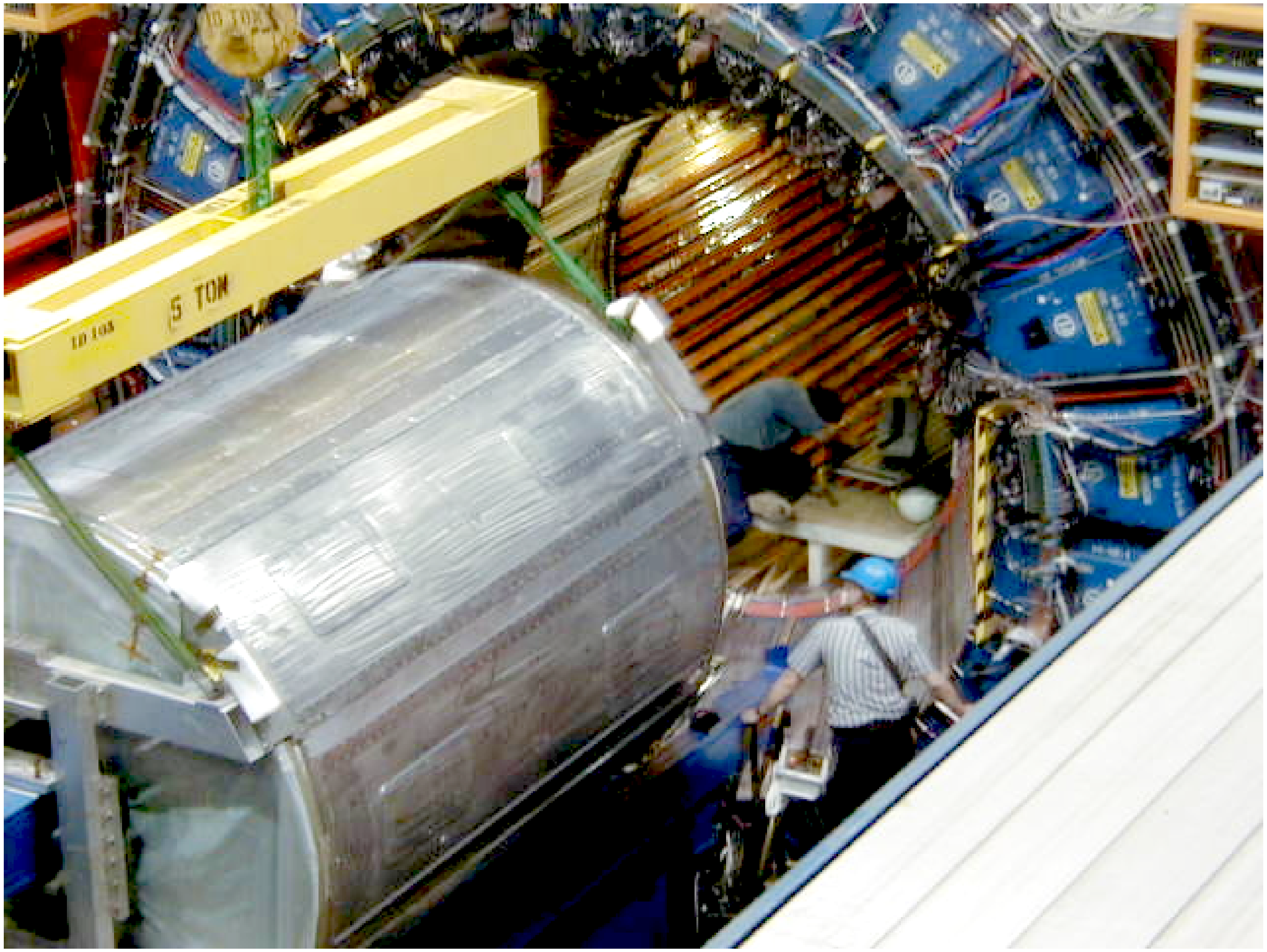
Installation of L00 into SVXII

ISL: links SVXII with COT

SVXII: 5 double-sided layers



CDF II – Drift chamber COT and TOF

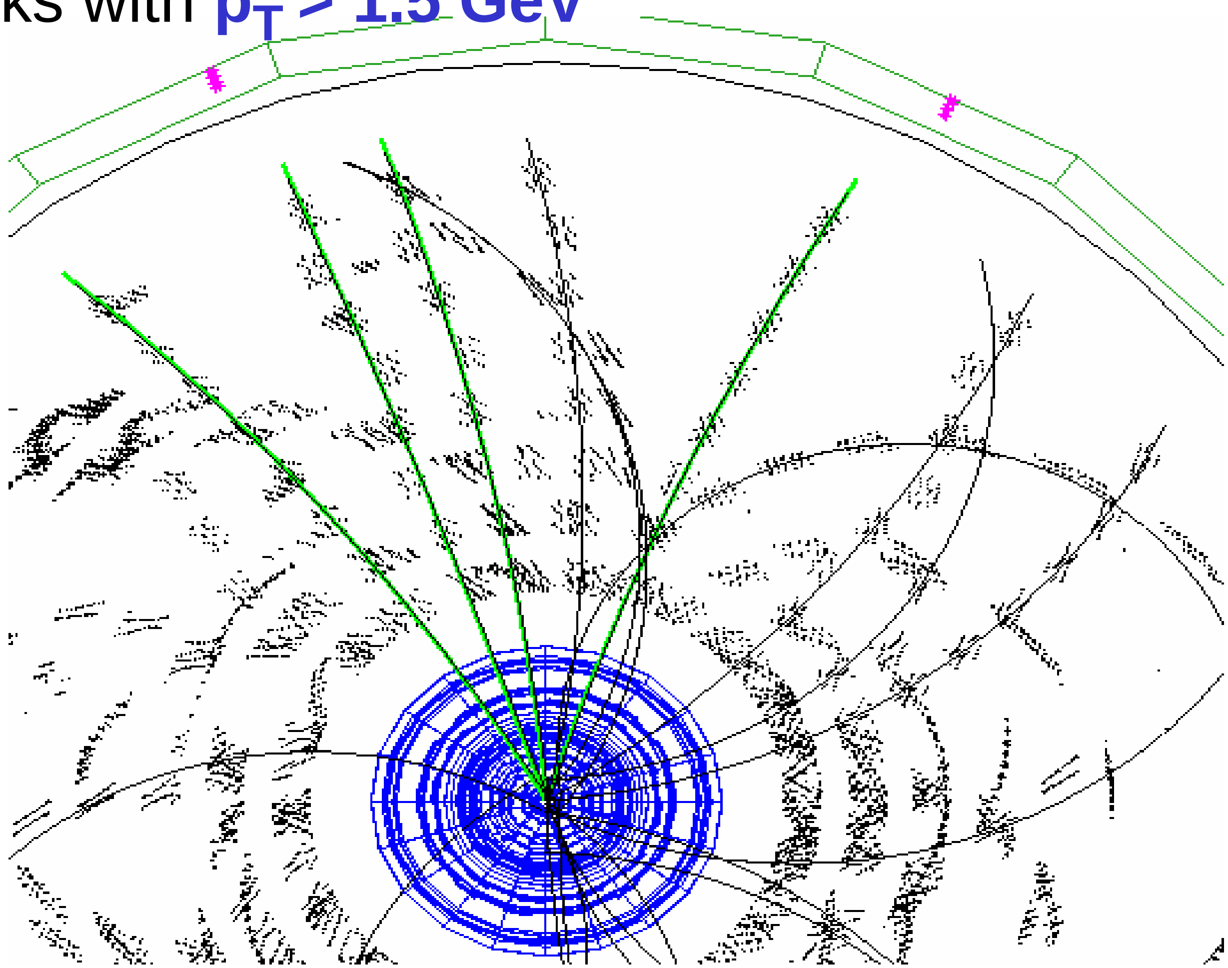


48 axial and 48 stereo layers, drift time < 100 ns, dE/dx,

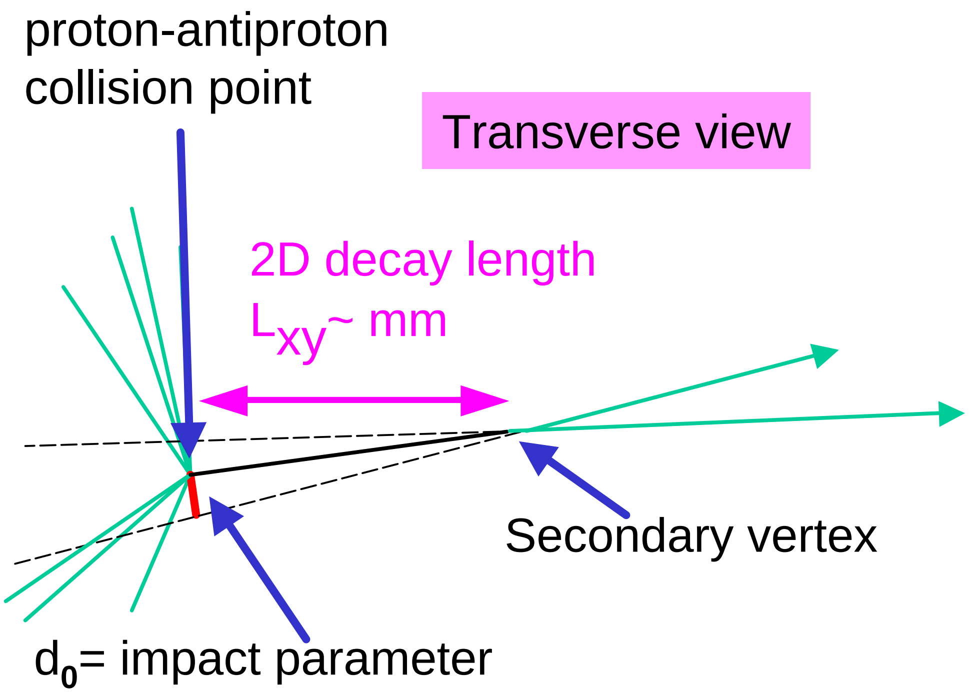
DpT/pT < 0.1% pT

Drift Chamber – Track Trigger

- **L1** COT track trigger **XFT** (1. trigger level)
- decision within **5 ms** (no deadtime)
- 96% efficiency for tracks with **p_T > 1.5 GeV**
- **s(pT)/pT < 1.8% pT**
- **s(j) = 5 mrad**



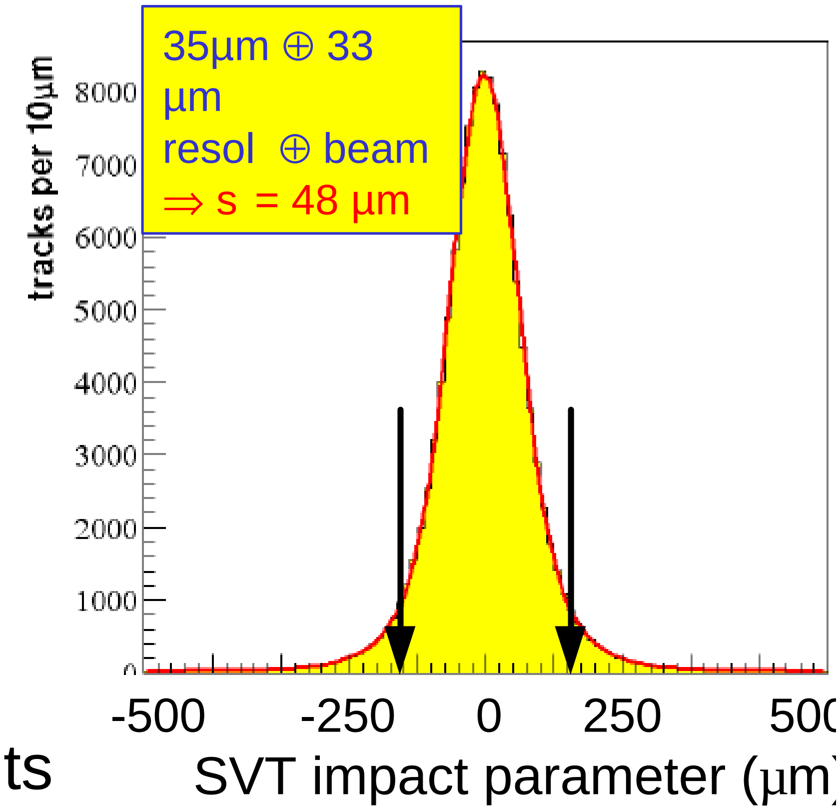
Silicon – Secondary Vertex Trigger



SVT d_0 - resolution:

35 mm ⊕ 33 mm = 48 mm !

(intrinsic ⊕ beam)



- **L2** secondary vertex trigger **SVT**

  (2. trigger level)

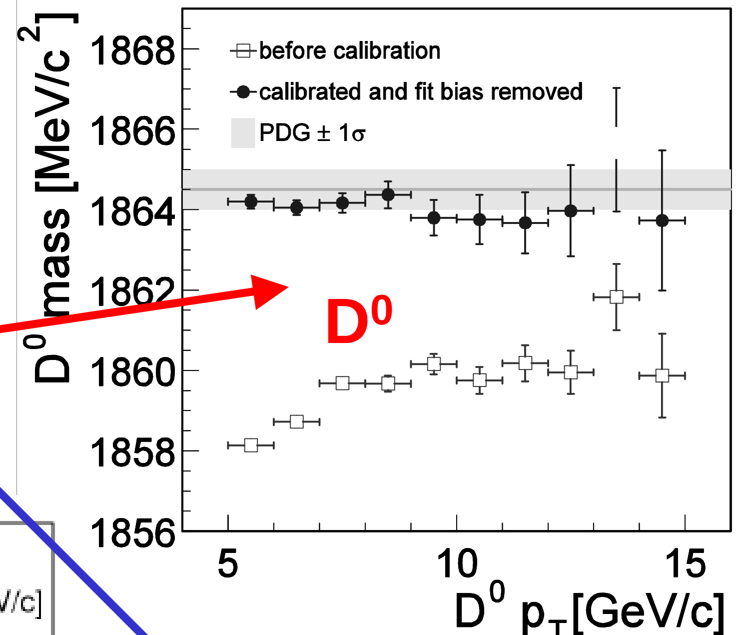
- decision within **20 ms**
- combines XFT tracks and silicon hits

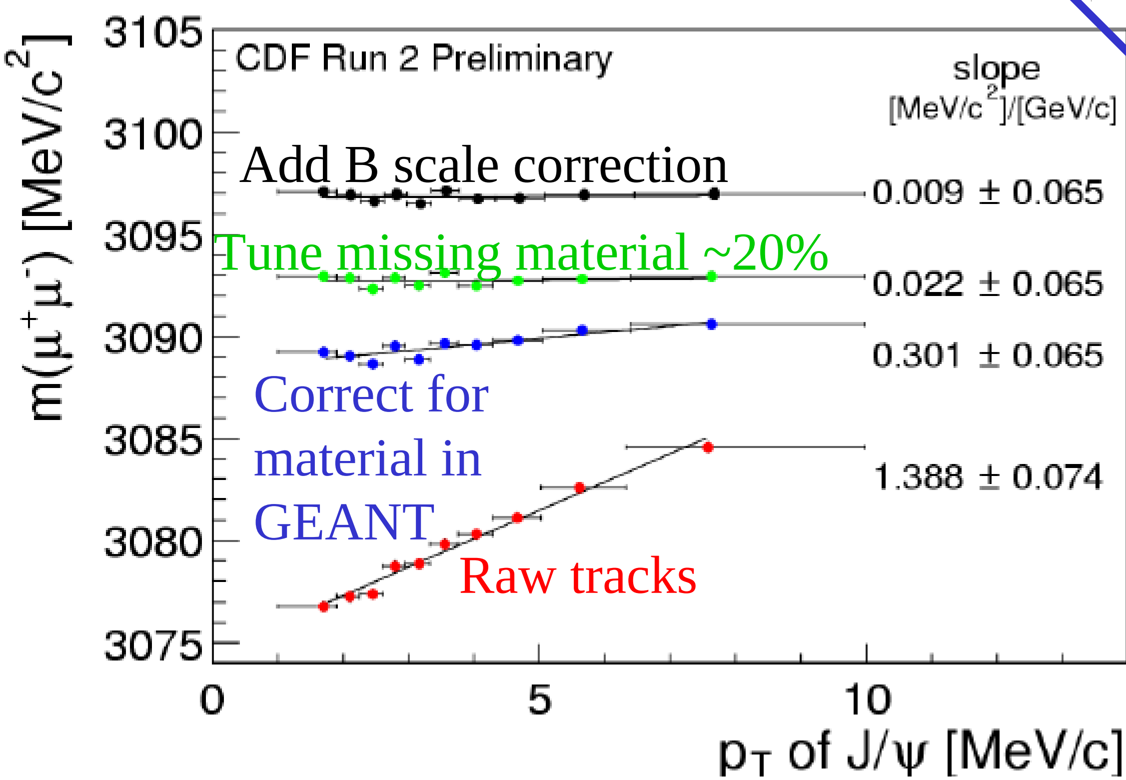
new era for B physics at hadron colliders!

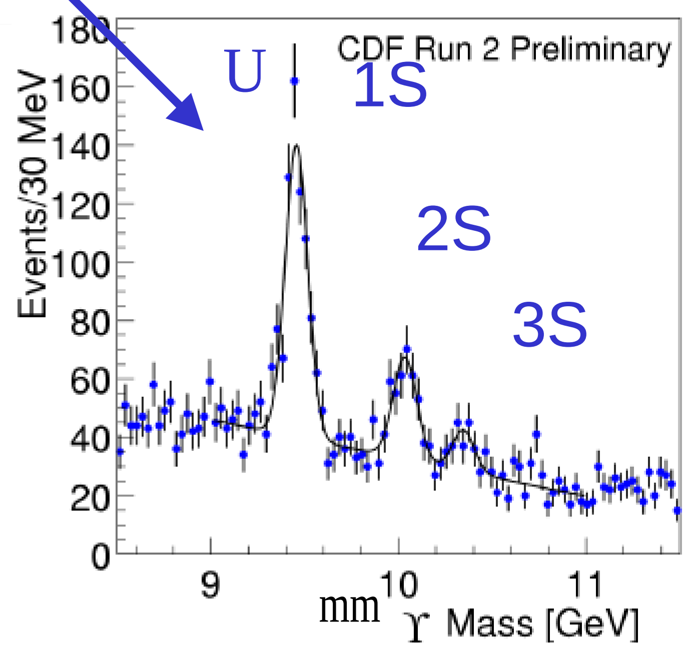
Momentum scale calibration with J/? -> $\mu^+ \mu^-$

- “raw mass” momentum dependent !
- => understand/tune detector material (energy loss)
- correct magnetic field
- cross check with other resonances

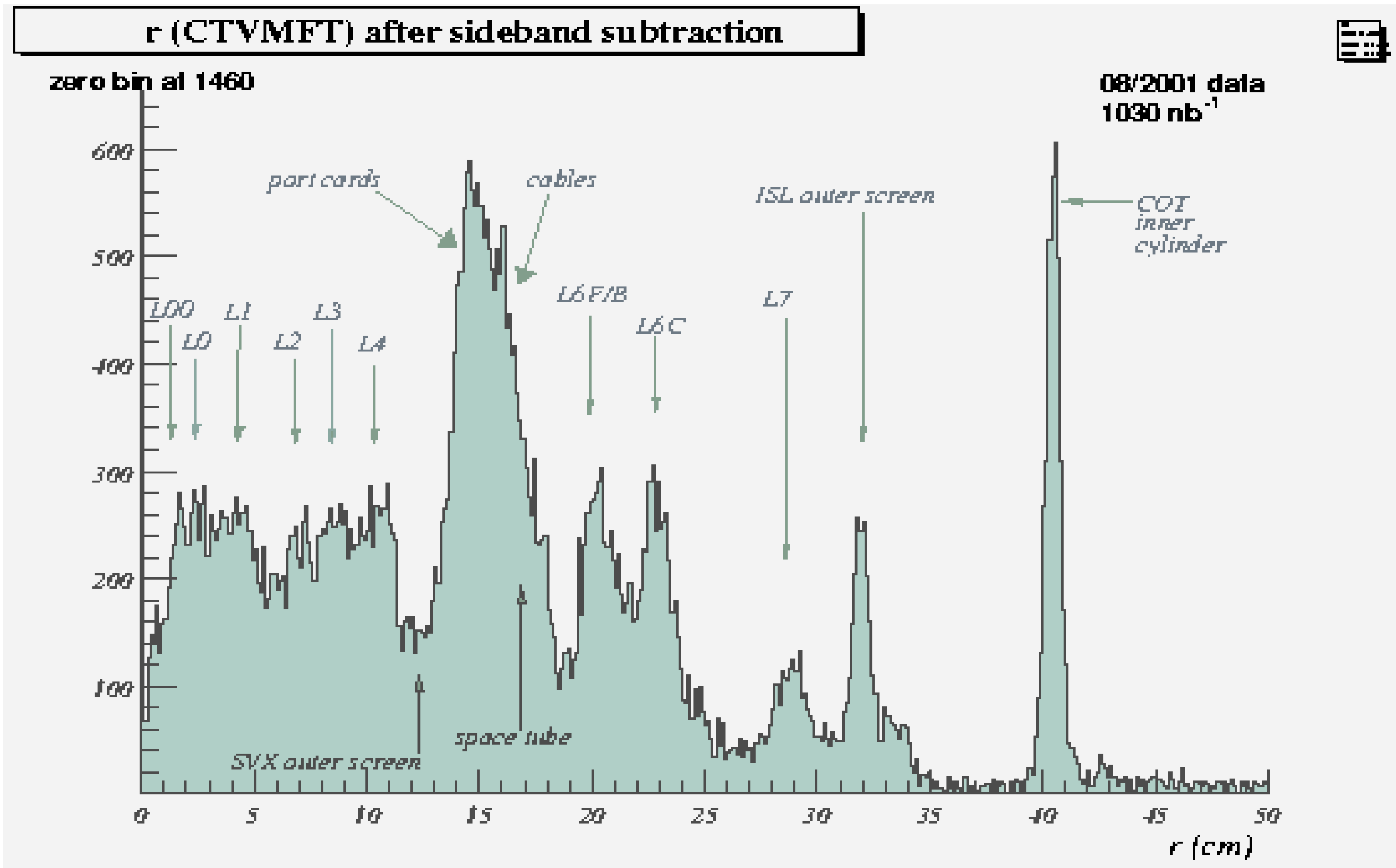
reach MeV precision !







X ray detector with ? conversions



? -> e^+e^-

=> alternative estimate of detector material; tuning of simulation

Outline

Introduction: Basics, Accelerator, Detector

Heavy flavor: **Charm, Bottom, Top**

Heavy bosons: **W, Z**

QCD at highest energies: **jets**

Diffraction

Searches: **Higgs,** exotics

Run IIb: Silicon upgrade project

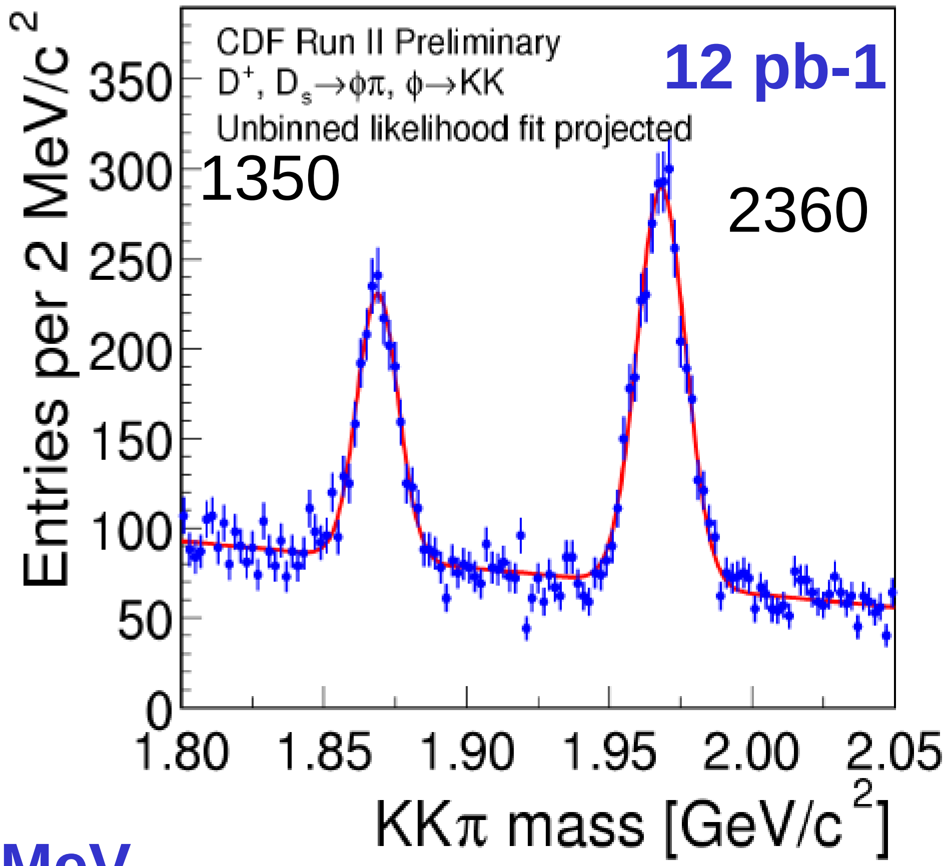
D_s^+ - D^+ Mass Difference

First Run II publication PRL .....

Compare D_s^+ - D^+ and B_s^0 – B^0 mass difference

=> Test of lattice QCD, HQET

- common final state, nearly identical kinematics => cancelation of uncertainties
- clean peaks even without TOF and dE/dx
- only small fraction of available data



$m(D_s^{\pm})$- $m(D^{\pm})$:

99.41 ± 0.38 (stat.) ± 0.21 (syst.) MeV

World average (2002): **99.2 ± 0.5 MeV**; BaBar (2002): **98.4 ± 0.1 ± 0.3 MeV**

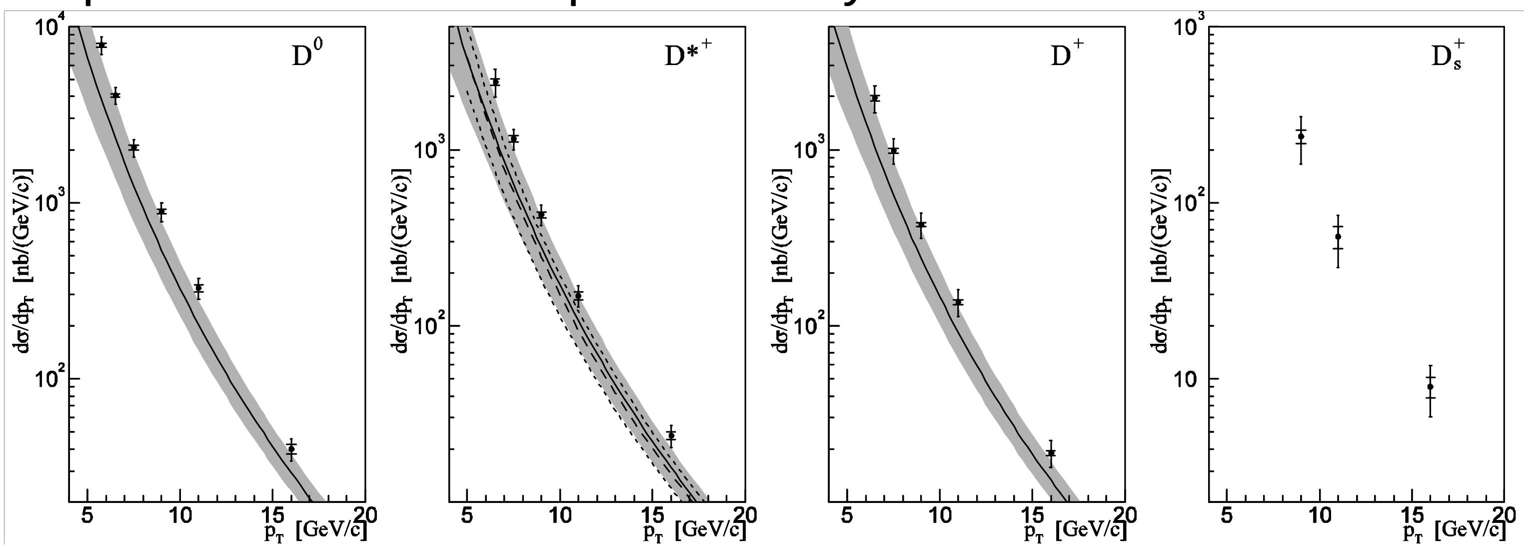
Early competitive measurements thanks to SVT

Prompt Charm Production

B meson production at hadron colliders and HERA underestimated by theory

Do we understand Charm production ?

- CDF measurement based on 5.8 pb-1, |rapidity| < 1   (hep-ex/0307080)
- direct charm fraction estimated using impact parameter measurement
- comparison with FONLL prediction by M. Cacciari and P. Nason



$s(D^0, p_T > 5.5\,GeV) = 13.3 \pm 0.2 \pm 1.5\ mb$

$s(D^{*+}, p_T > 6.0\,GeV) = 5.2 \pm 0.1 \pm 0.8\ mb$

$s(D^+, p_T > 6.0\,GeV) = 4.3 \pm 0.1 \pm 0.7\ mb$

$s(D_s^+, p_T > 8.0\,GeV) = 0.75 \pm 0.05 \pm 0.22\ mb$

Familiar picture: data exceeds prediction by factor 1.5 – 2

Consistent (barely) within systematic errors

Rare D decays (FCNC) : $D^0 \rightarrow m^+m^-$

- SM expectation: $BR(D^0 \rightarrow m^+m^-) \sim 3 \times 10^{-13}$
- but 3-4 x 10^{-6} in R-parity violating SUSY

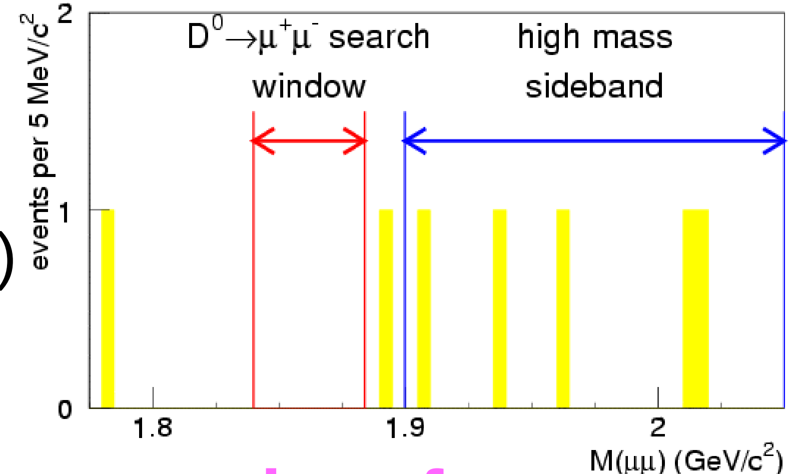
- **experimental techniques:**

use $D^* \rightarrow D^0 \pi$ only for background suppression;

normalize to $D^0 \rightarrow \pi^+\pi^-$ mode (~1400 $D^0 \rightarrow \pi^+\pi^-$ in 69 pb-1)

- limit on BR$(D^0 \rightarrow \mu^+\mu^-)$:

  $< 2.4 \times 10^{-6}$ (90 % C.L.)
- PDG: BR $< 4.1 \times 10^{-6}$ (90 % C.L.)



Limits may further improve by one order of magnitude during Run II

Physics with Charm Quarks

- soon **world largest data sets** due to Secondary Vertex Trigger and large production cross sections

- have some world best or competitive measurements:

  mass difference: $D_s^{\pm} - D^{\pm}$

  decay rates: $\Gamma(D^0 \to K^+K^-) / \Gamma(D^0 \to K\pi)$ and

  $\Gamma(D^0 \to \pi^+\pi^-) / \Gamma(D^0 \to K\pi)$

- **production cross sections**

- **Quarkonia …**

CDF became a charm factory !

many interesting measurements; test of QCD – models; limits

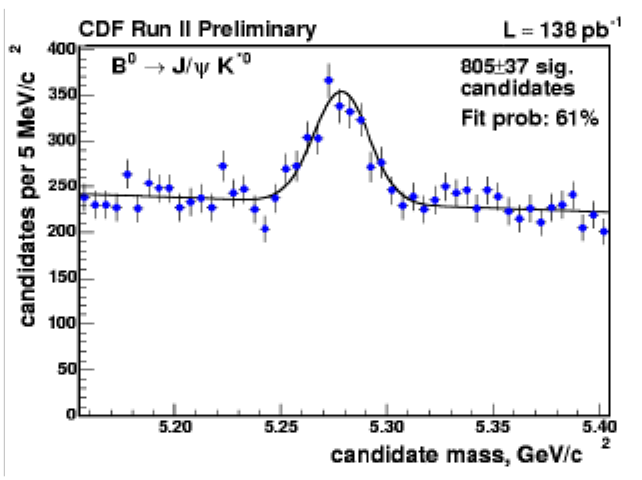
full potential of charm physics still to be explored

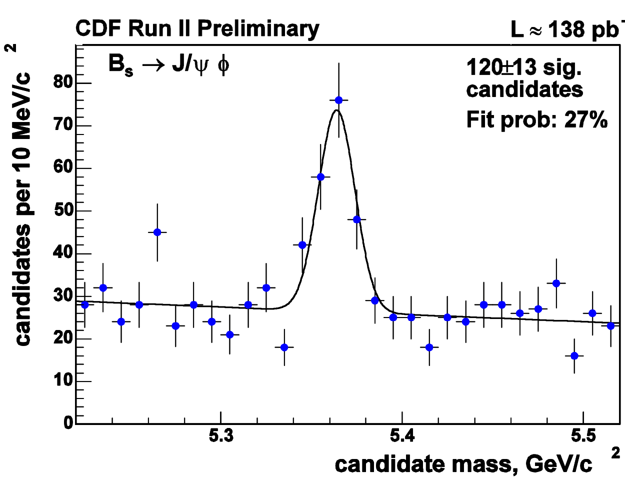
b Hadron Masses

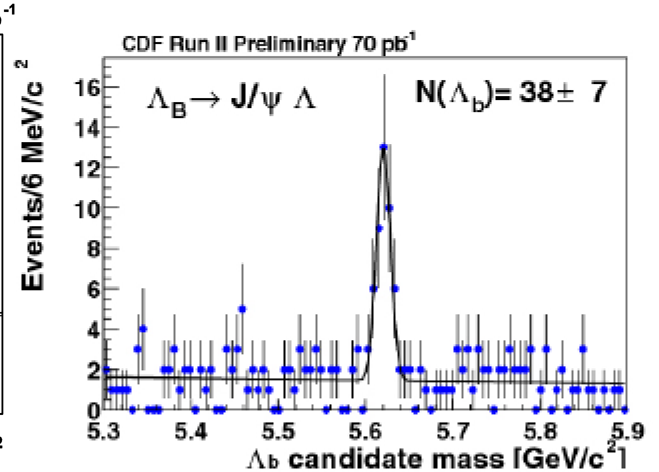
- best mass resolution from fully reconstructed decays: b hadron → J/? X

  e.g. **?$_b$? J/? ?** and **B$_s$? J/? F** with J/? ? $\mu^+\mu^-$,? ? pp and F ? K^+K^-
- need excellent understanding of absolute track momentum scale
- B^+ and B^0 serve as control sample; **B$_s$** and **?$_b$** **world best measurements**

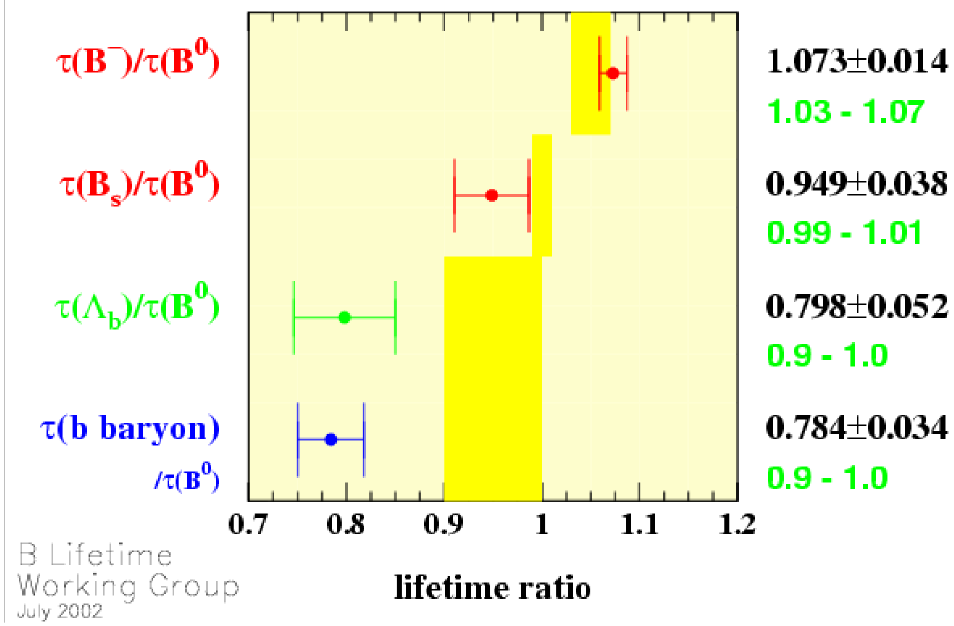
	CDF mass	PDG mass
B^+:	**5279.32 ± 0.68 ± 0.94 MeV**	**5279.0 ± 0.5 MeV**
B^0:	**5280.30 ± 0.92 ± 0.96 MeV**	**5279.4 ± 0.5 MeV**
B_s:	**5365.50 ± 1.29 ± 0.94 MeV**	**5369.6 ± 2.4 MeV**
?$_b$:	**5620.4 ± 1.6 ± 1.2 MeV**	**5624 ± 9 MeV**







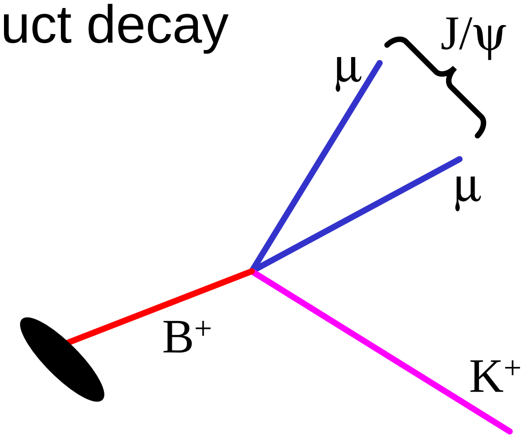
B hadron lifetimes



- lifetime most basic property
- All lifetimes equal in spectator model
  differences come from interference and other non-spectator effects
- precise predictions from theory (HQET):
  $t(B^+) > t(B^0) \sim t(B_s) > t(\Lambda_b) >> t(B_c)$
- CDF will be competitive in B_s, B_c, and Λ_b

Principle of measurement

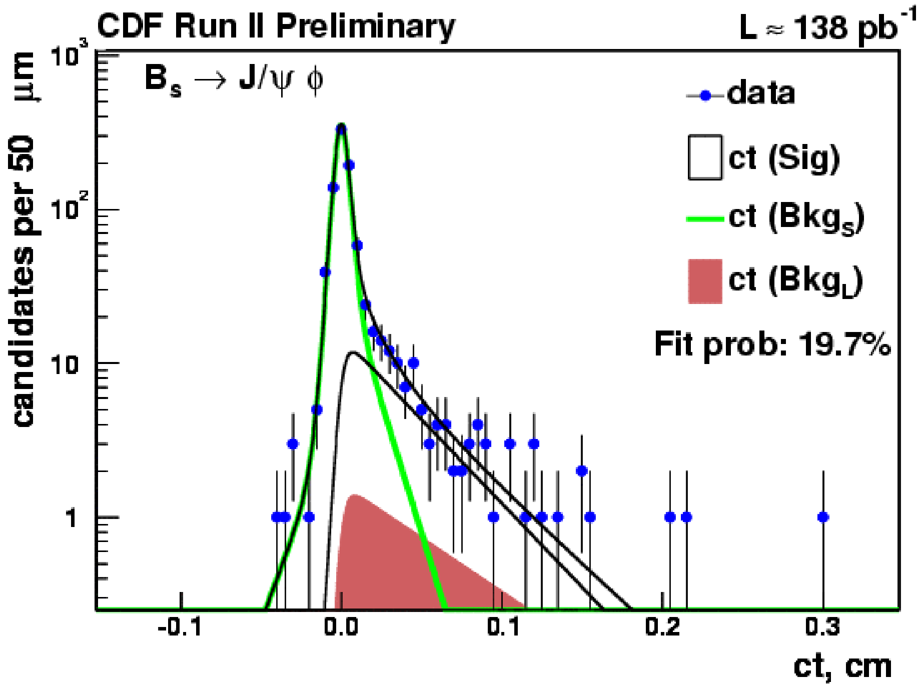
- reconstruct decay

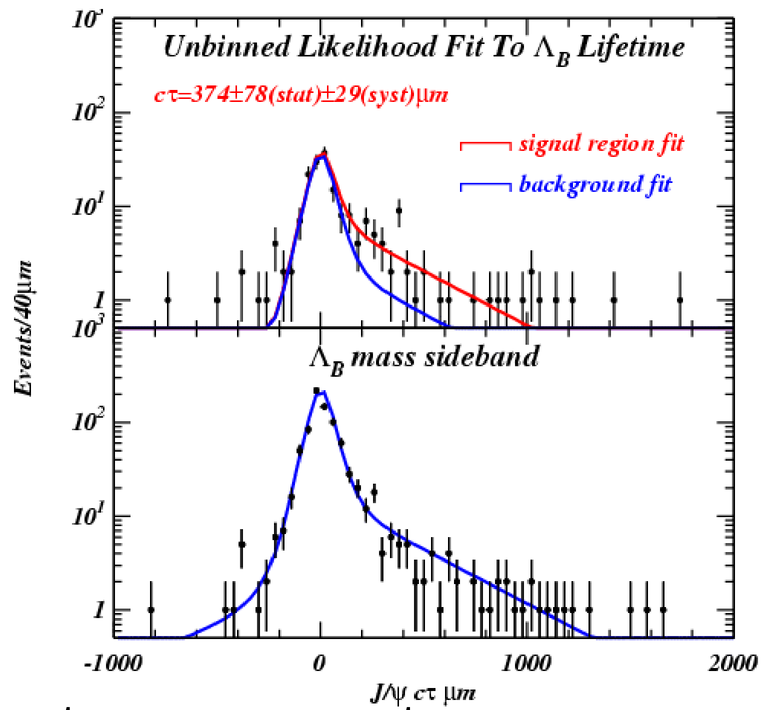


- measure p_T
- measure decay length
- plot/fit ct with

$$ct = \frac{L_{xy}}{b\,g} = \frac{L_{xy}\, m(B)}{P_T(B)}$$

B hadron lifetimes (b hadron ® J/? X)



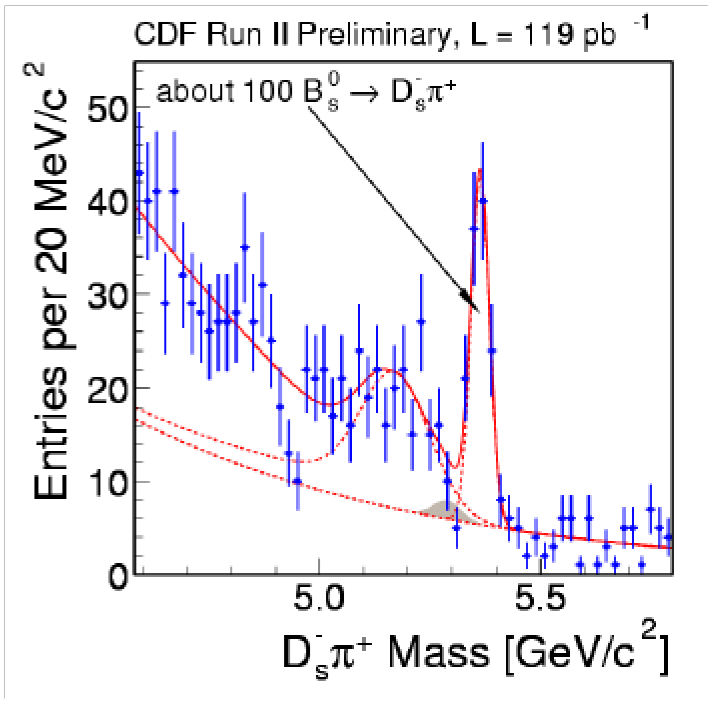


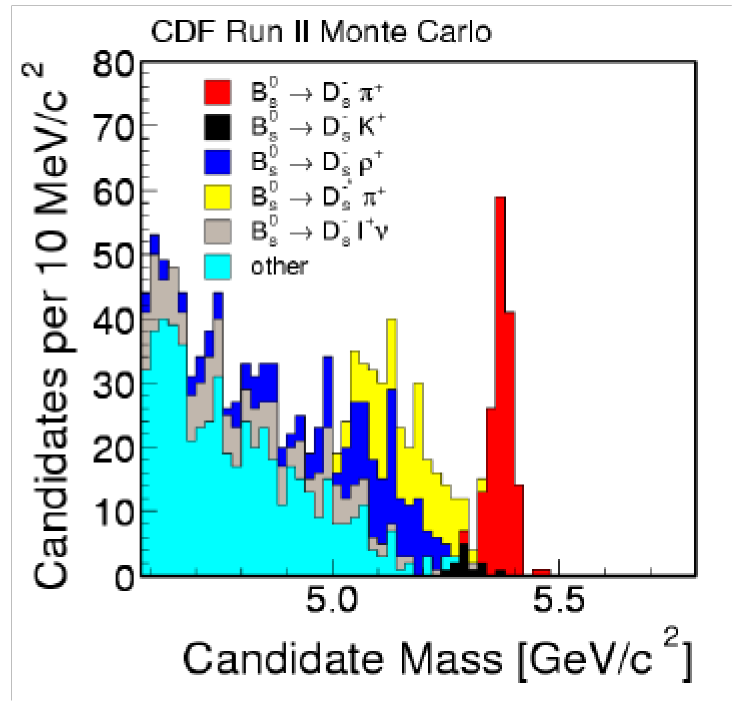
- competitive with LEP, but not world best measurements
- here exclusive modes: smallest systematics but less statistics
- will much improve with statistics; have also semileptonic channels

	CDF lifetime	PDG lifetime
B^+:	1.63 ± 0.05 ± 0.04 ps	1.674 ± 0.018 ps
B^0:	1.51 ± 0.06 ± 0.02 ps	1.542 ± 0.016 ps
B_S:	1.33 ± 0.14 ± 0.02 ps	1.461 ± 0.057 ps
$?_b$:	1.25 ± 0.26 ± 0.10 ps	1.229 ± 0.080 ps

Decay: B_s? D_sp ("golden mode")

- purely hadronic, fully reconstructed decay !
- important for best measurement of B_s decay vertex and oscillation





B^0_s®D^-_sp$^+$ *with* D^-_s ® fp$^-$ *and* f ®K^-K^+

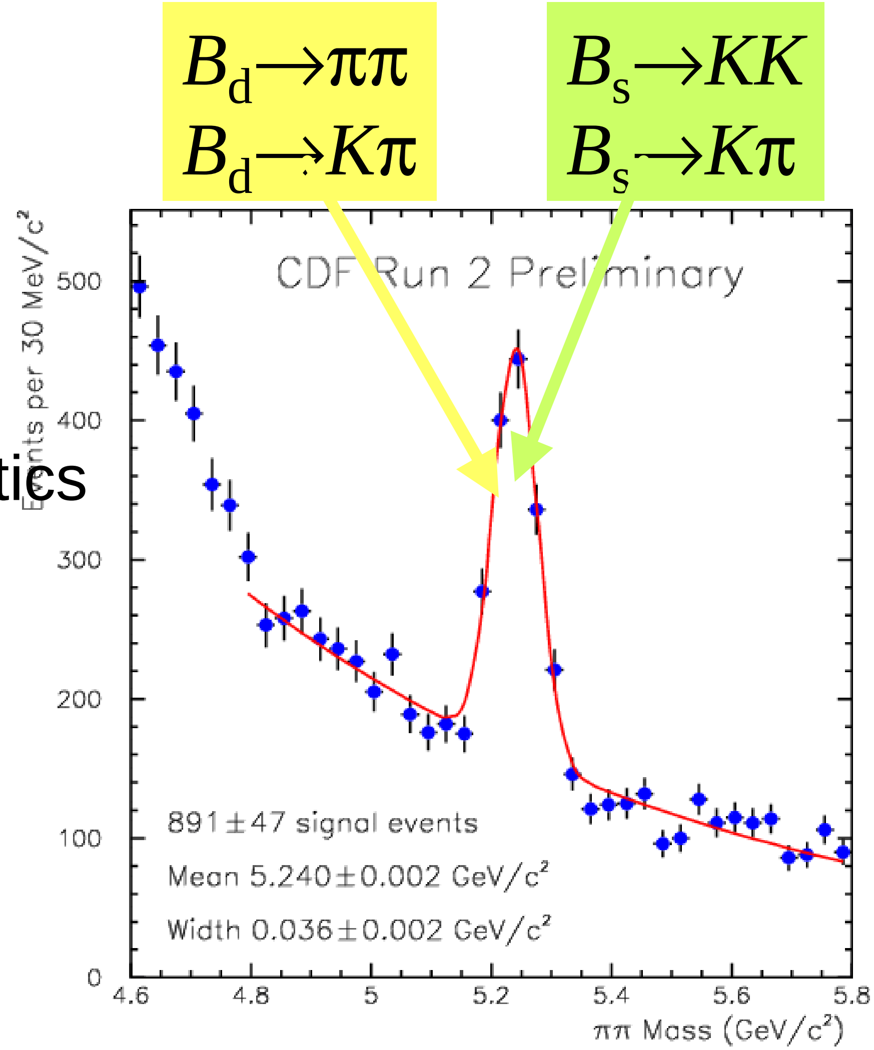
$$\frac{f_s\, BR(B_s^0 \to D_s^- p^+)}{f_d\, BR(B^0 \to D^- p^+)} = 0.35 \pm 0.05(stat) \pm 0.03(syst) \pm 0.09(BR)$$

First observation of this decay !

Charmless hadronic B decays B®h$^+$h$^{'-}$

- **these are rare decays;**
  BR ~10^{-5} or less!
- $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$ modes
  sensitive to CP angle g
- superposition of four decays, but statistically separated by kinematics and particle identification (dE/dx)
- BR($B_d \rightarrow \pi\pi$)/BR($B_d \rightarrow K\pi$) =
  0.26 ± 0.11 ± 0.055
  (PDG: 0.25 ± 0.125 ± 0.015)

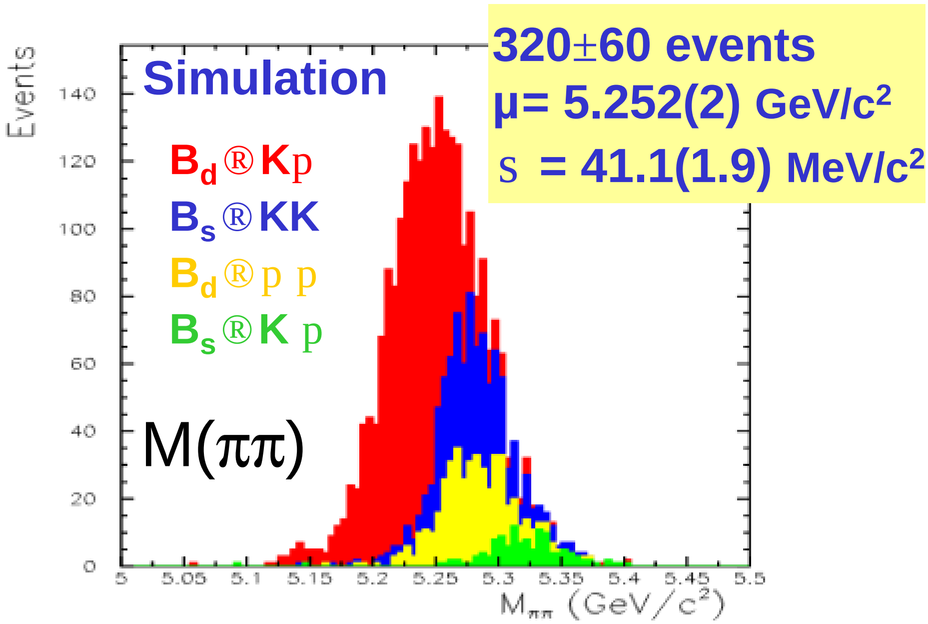
- **first observation of decay: B_s®K^+K^-**



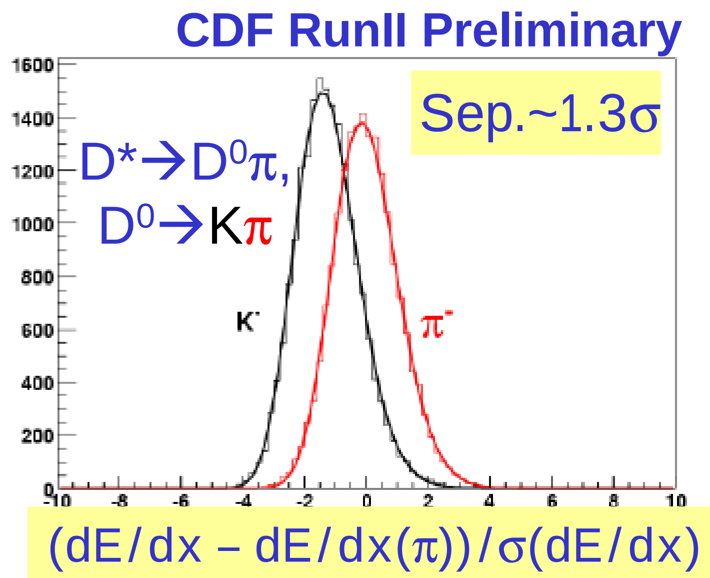
M(pp)

Disentangling the modes

kinematics



dE/dx

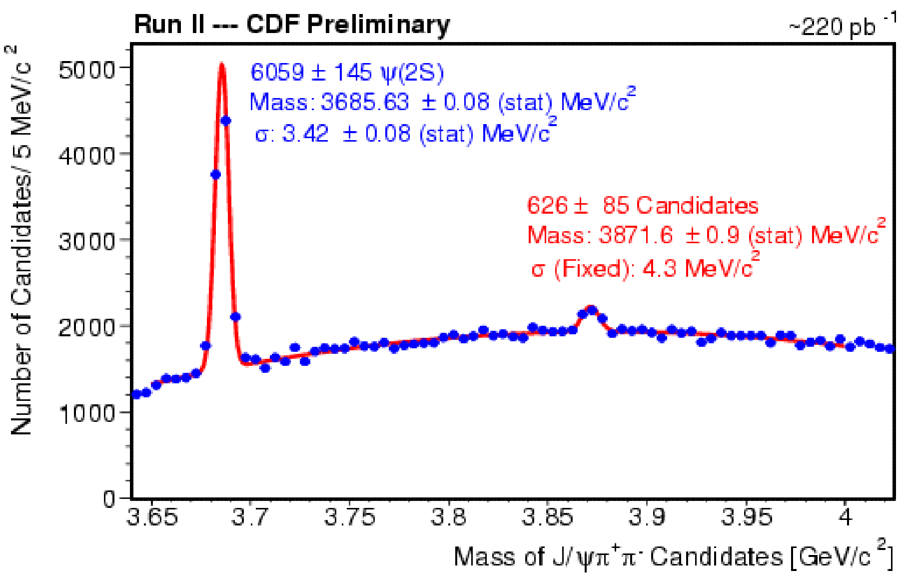


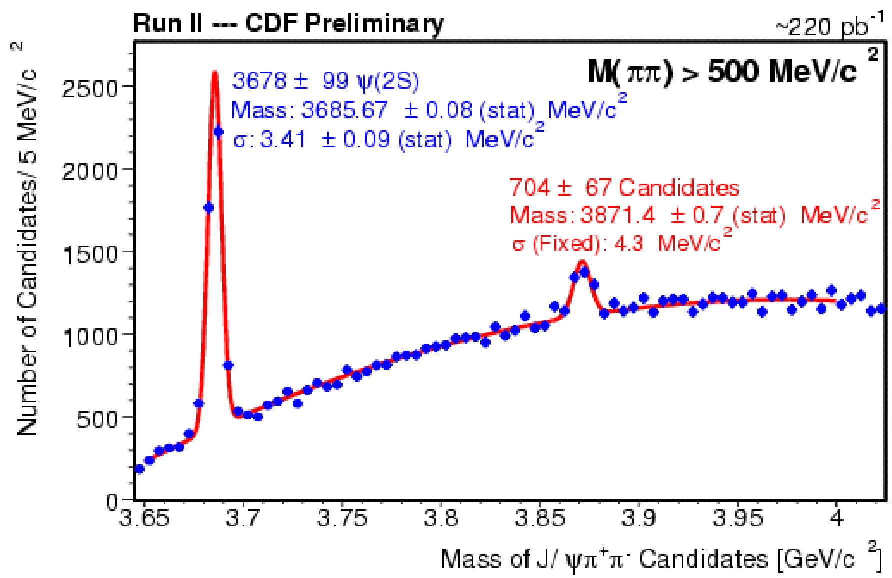
Fit results

mode	yield (from 65 pb^{-1})
B^0 ® Kp	148 ± 17(stat.) ± 17(syst.)
B^0 ® pp	39 ±14 (stat.) ± 17 (syst.)
B_s ® KK	90 ± 17 (stat.) ± 17(syst.)
B_s ® Kp	3 ± 11 (stat.) ± 17(syst.)

Surprises: X(3872) ? J/? $p^+ p^-$

- new state observed by Belle
- **What is it ?** New charmonium state at unexpected mass; D D* “molecule”, or ccbar gluon hybrid ?
- **Does CDF see it too ?** **Yes !**





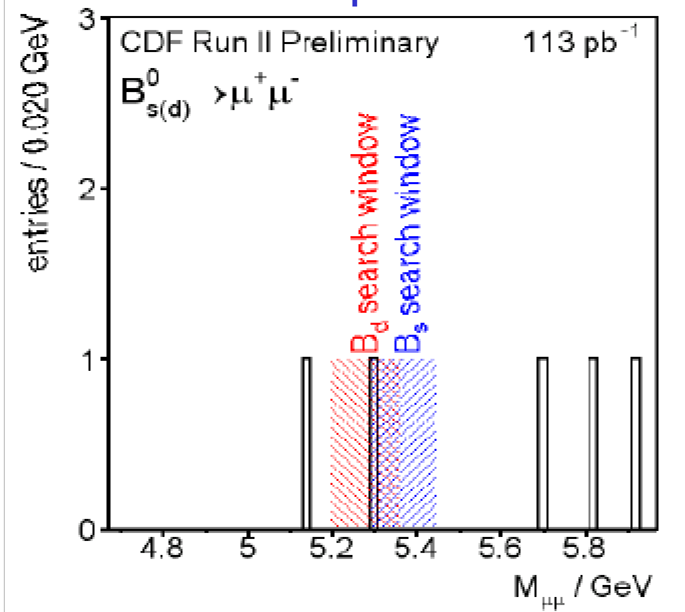
>10 s signal; same mass as Belle; large production X section

Cuts: Dimuon and X(3872) vertex, proper J/? mass, p_T(J/?) > 4 GeV, p_T(p)>0.4 GeV, p cone cut

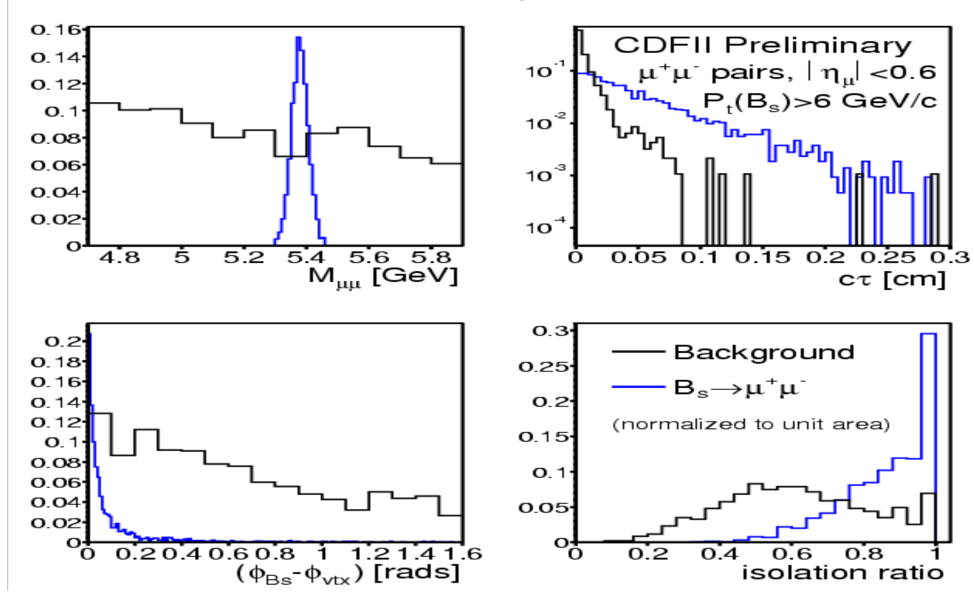
Rare B decays (FCNC) : B $_{s(d)}$→m^+m^-

- SM expectation tiny: BR(B$_s$→ m^+m^-) = (3.8 +/- 1.0) 10^{-9}
- but enhancement by 10-1000 in various SUSY models !

Massenspektrum



Discriminating variables

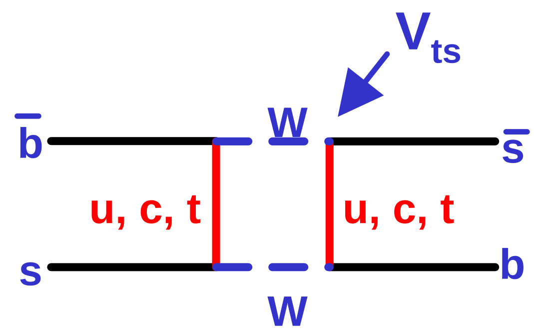


- world best limit on BR(**B$_s$**→m^+m^-): < 1.2 x 10^{-6} (95% C.L.)
- competitive limit on BR(**B$_d$**→m^+m^-): < 3.1x 10^{-7} (95% C.L.)

Touching interesting range; limits may improve substantially during Run II

B_s mixing: prospects

- measures one side of unitarity triangle with small theoretical uncertainty (Dm_s / Dm_d)
- Babar/Belle can not do it
- may turn out to be one of the most important Run II results



It's difficult:

current limit is $\Delta m_s > 14.4 ps^{-1}$ @95%CL

=> oscillations are fast: full mixing in < 0.15 x B_s lifetime

Requirements:

good initial B_s **flavour tagging** (efficiency e, dilution D); **many B_s** (signal S); little **background** (B) ; good **time (vertex) resolution** (s_t)

$$Significance = \sqrt{\frac{S e D^2}{2}} e^{-\frac{(\Delta m_s s_t)^2}{2}} \sqrt{\frac{S}{S+B}}$$

CDF B_s Sensitivity Estimate

with current performance:

- S = 1600 reconstructed events/ fb-1; S/B = 2/1
- εD^2 = 4%
- σ_t = 67 fs

$$Significance = \sqrt{\frac{S e D^2}{2}} e^{-\frac{(\Delta m_s s_t)^2}{2}} \sqrt{\frac{S}{S+B}}$$

=> 2s sensitivity for Dm_s =15 ps^{-1} with ~0.5 fb^{-1}

with modest improvements

- S = 2000 events/ fb-1 (better trigger, more modes) ;S/B = 2/1
- εD^2 = 5% (include Kaon tagging)
- σ_t = 50 fs (event-by-event vertex, L00)

=> 5s sensitivity for Dm_s =18 ps^{-1} with ~1.7 fb^{-1}

=> 5s sensitivity for Dm_s = 24 ps^{-1} with ~3.2 fb^{-1}

CDF will provide this measurement, but not tomorrow

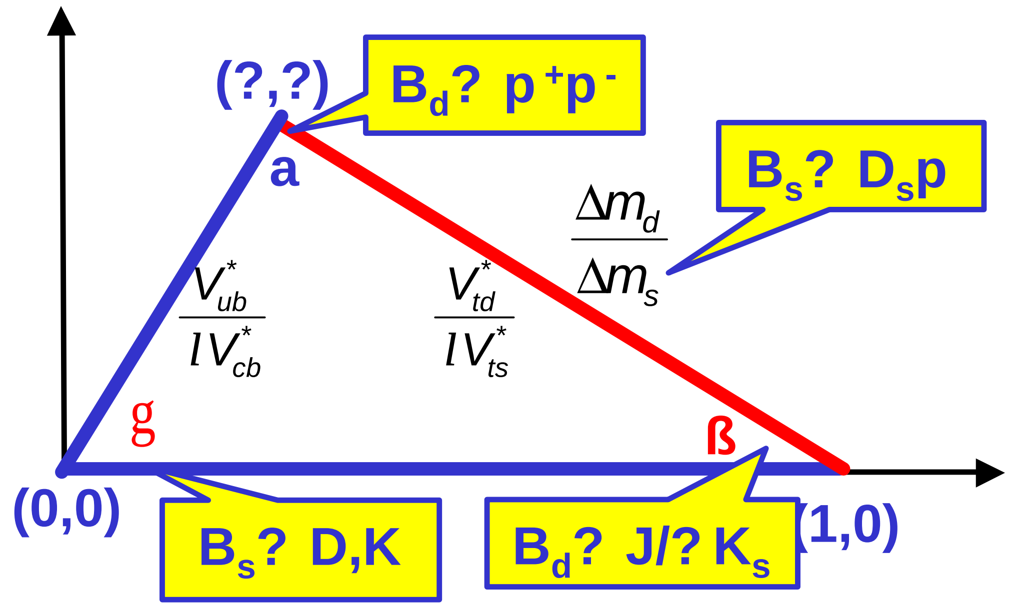
B physics

Broad spectrum of interesting measurements

- **masses, life times, decays** of b hadrons

  no competition in **B_s** , **$?_b$** and other heavy b hadrons

- **production cross sections**
- **B_s mixing**
- contributions to **CP violation** measurements
- **rare decays**



Tevatron is b factory,

SVT has started a new era

W Boson

- 1983: discovery in proton-antiproton collisions at CERN
- in Run I ~ 40,000 W bosons
- most important measurement M_W = 80.452 GeV ± 0.08 % ! (CDF + D0)

Why are $W^{\pm}$ and Z^0 so heavy ??

consistency check of SM:

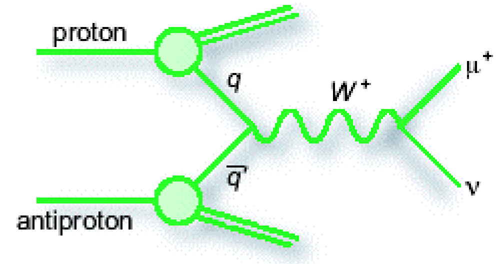
$$m_W^2 = \frac{p}{\sqrt{2}} \frac{a}{G_F \bullet \sin^2 q_W}$$

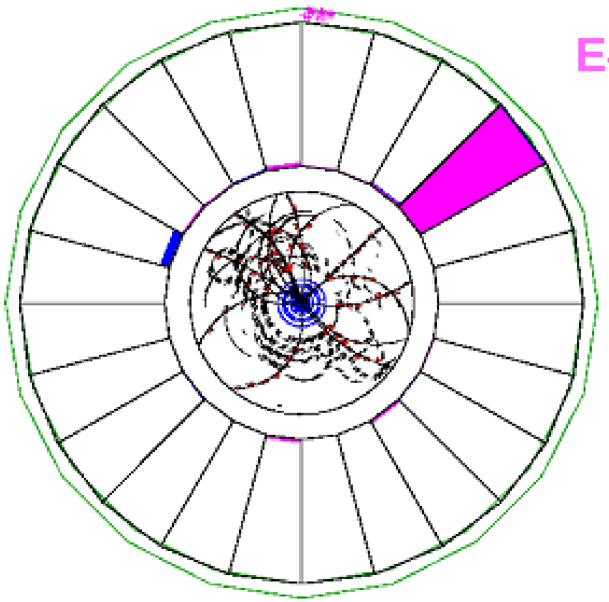
given top and W masses => Higgs mass

plus: W production cross section, width,

WW, WZ, Wg, Charge asymmetry ...

$W^{\pm}$ production





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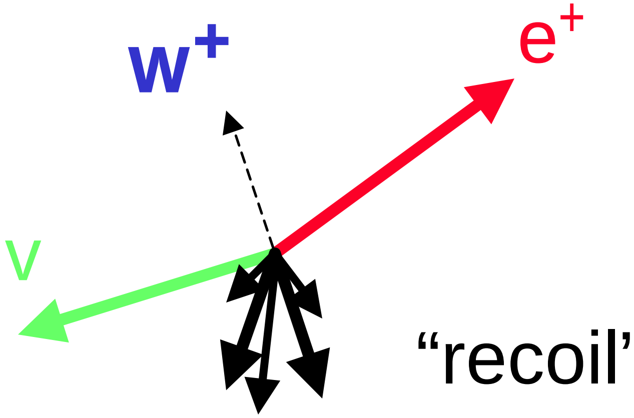
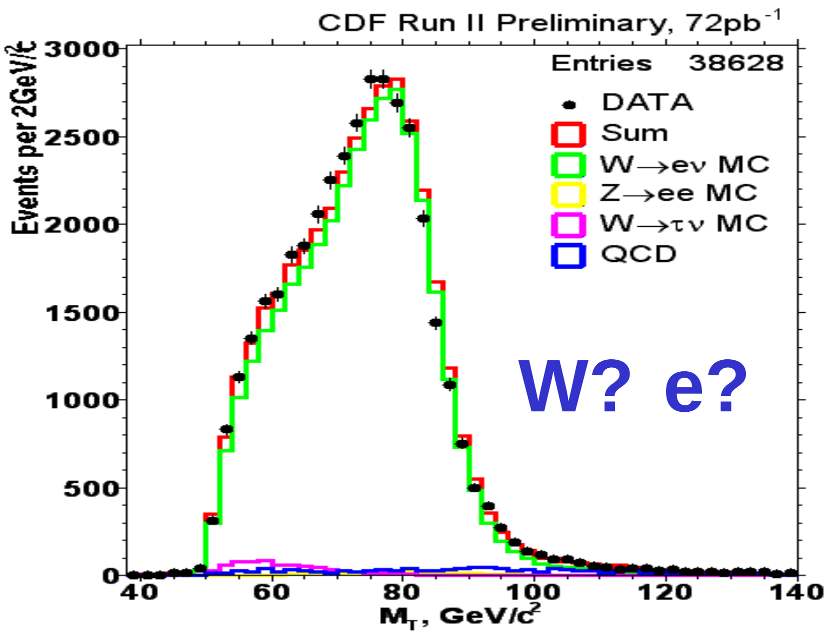


- **electron** well-measured: track and cluster, high p_{Te} ,isolated **but**
- **neutrino** invisible: "missing energy", **"recoil":** poorly measured
- momenta of incoming quarks unknown

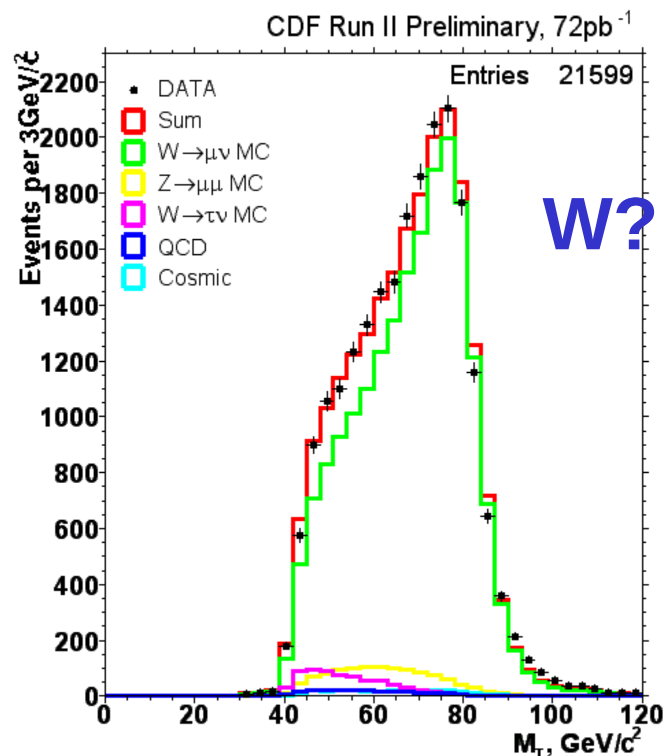
Define "transverse mass": $M^2_{TW} = 2\, p_{Te}\, p_{Tv}\, (1-\cos f_{ev})$

s (W) x BR(W? l ?)

E_T>25GeV, MET>25 GeV, |?|<1.0



p_T>20GeV, MET>20 GeV, |?|<0.6



W? μ?

	events	s (W) x BR(W? l ?) (nb)
e:	38,625	2.64 ± 0.01 ± 0.09 ± 0.16
μ :	21,599	2.64 ± 0.02 ± 0.12 ± 0.16
t :	2,346	2.62 ± 0.07 ± 0.21 ± 0.16
		± stat. ± sys. ± lumi.

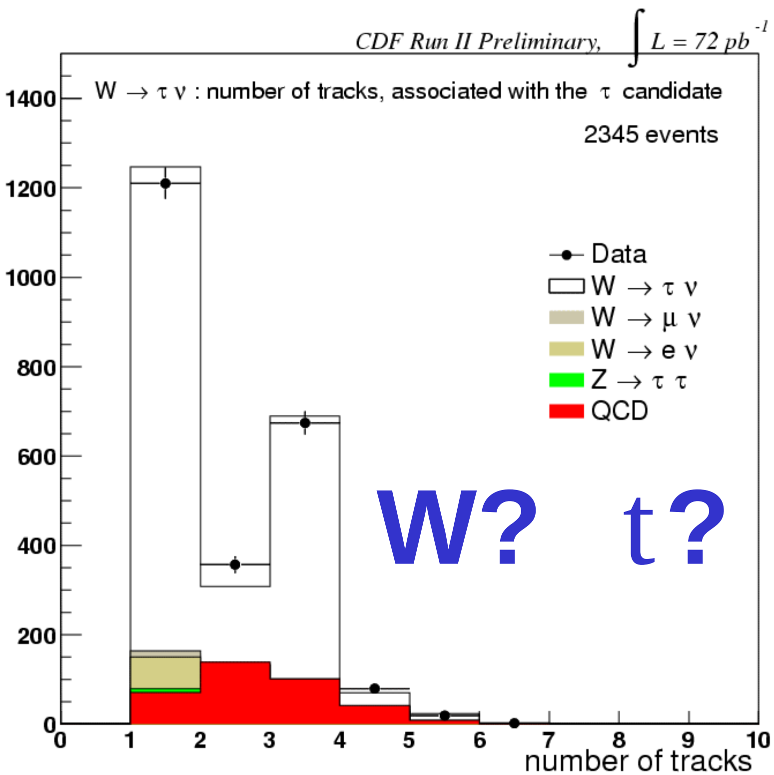
Theory: 2.731 ± 0.002 nb in NNLO
Stirling et al., Phys Lett B531 (2002)

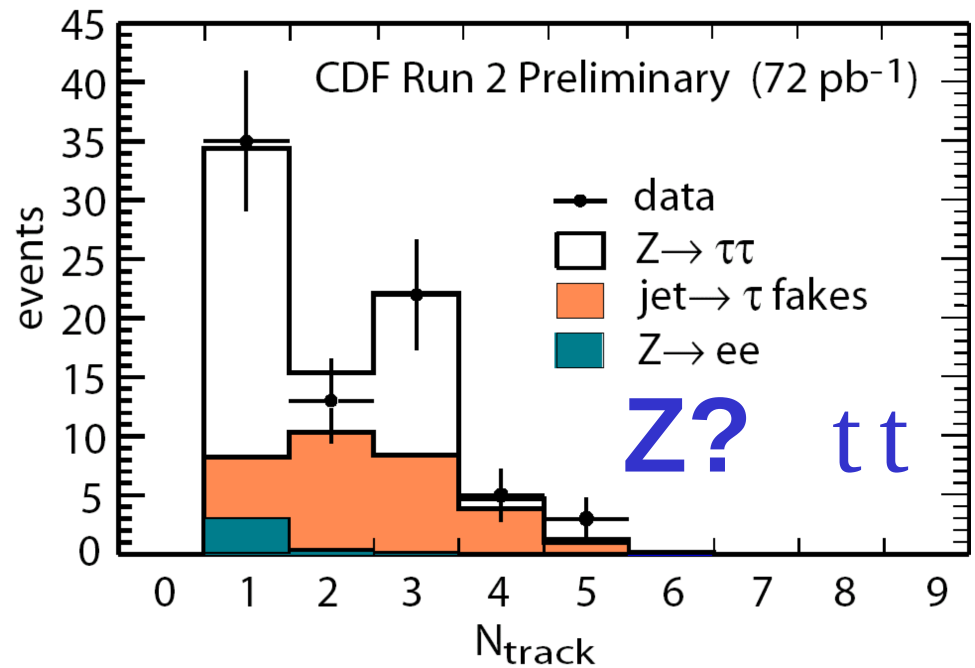
- many W bosons in fraction of data; little background; good MC description
- luminosity error dominant
- also t channel measured !
- lepton universality

CDF: W? t n and Z? t t

Tau modes are challenging ! Important for searches and supersymmetry !

E_T>25GeV, MET>25 GeV, |?|<1.0



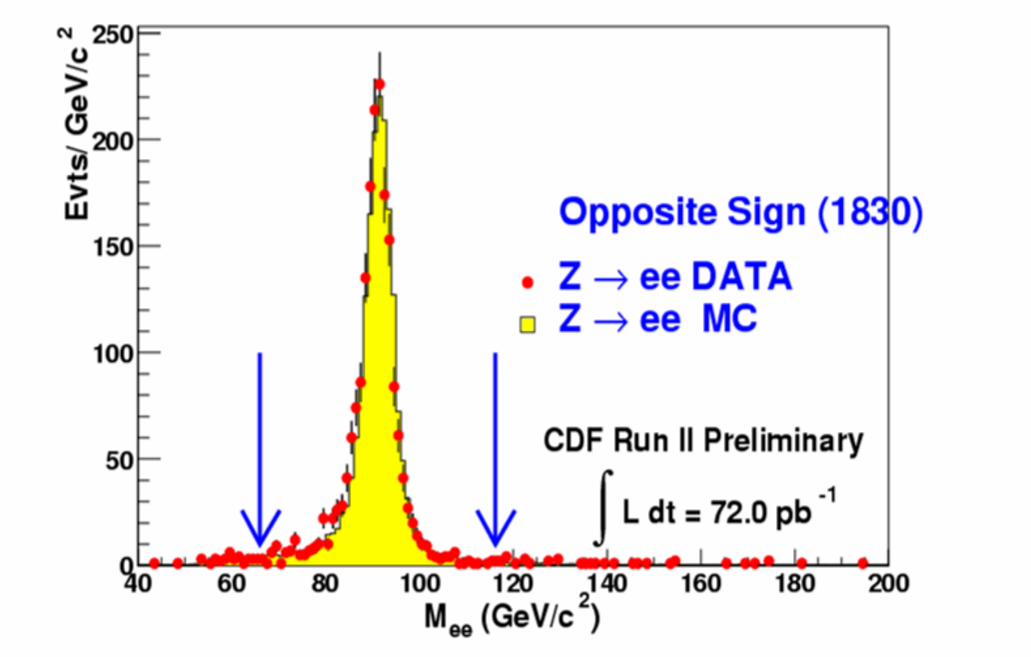


- search for isolated, high p_T e or μ
- opposite narrow hadronic jet

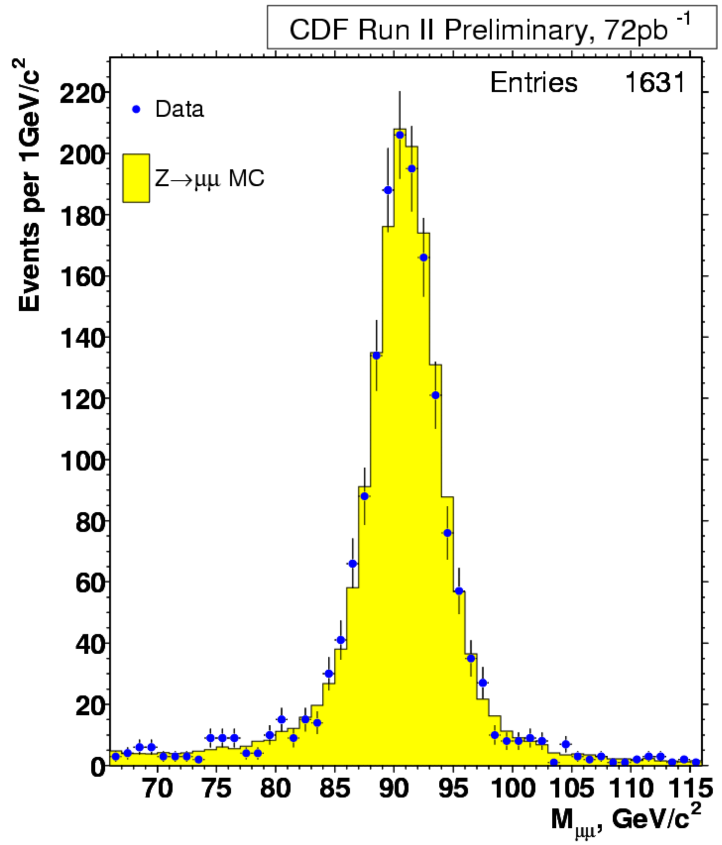
- search for hadronic jet within narrow 10 degree cone,
- Isolated within wider 30 degree cone

s (Z) x BR(Z? l ?)

E_T>25GeV, |?|<1



p_T>20GeV, |?$_1$|<0.6, |?|<1.0,

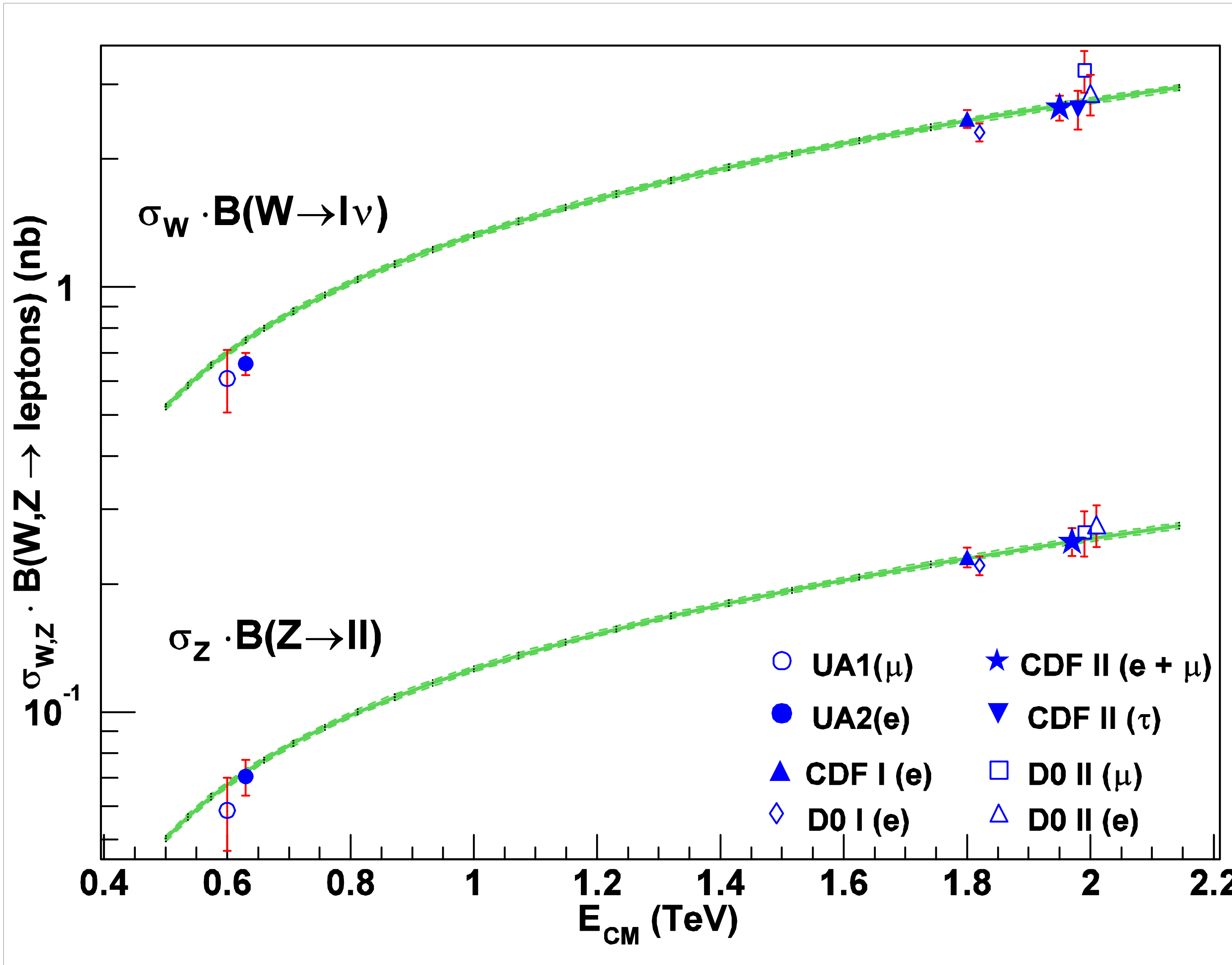


events	s (W) x BR(W? l ?) (pb)		
e: 1830	267 ± 6.3	± 15.2	± 16
μ: 1631	246 ± 6	± 12	± 15
	± stat.	± sys.	± lumi.

Theory: 252 ± 9 pb in NNLO
Stirling et al., Phys. Lett. B531 (2002)

- recall: 10 x less Zs than Ws
- very little background
- luminosity error dominant

W and Z cross section vs E_{CM}



Theory: R. Hamberg,
WL van Neerven, and T. Matsuura,
Nucl. Phys. B359 (1991) 343, CTEQ4M PDF

Small change of cross section between Run I and Run II; measurement agrees with expectation

Indirect measurement of W Width

Calculate ratio R:

s (W) x BR(W? l ?)/s (Z) x BR(Z? l l)

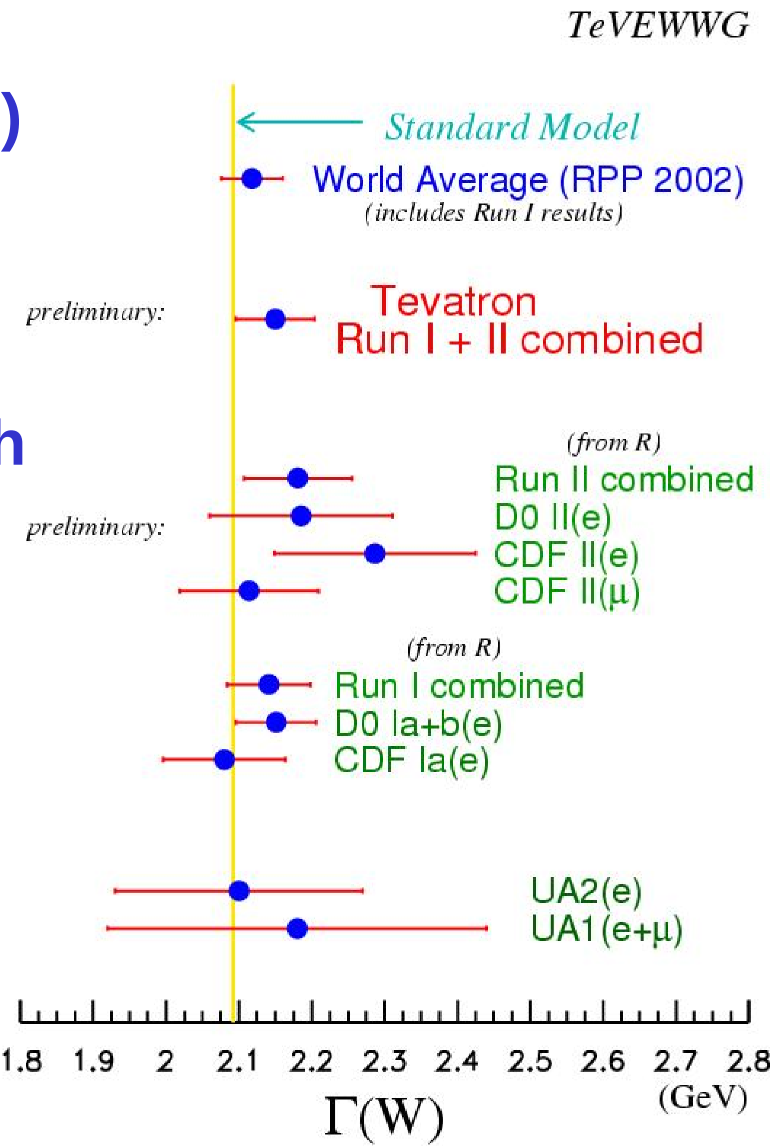
- luminosity uncertainty cancels !
- PDF, lepton efficiencies, etc. partially cancel !

=> indirect measurement of W width

Theory

$$R = \frac{s(p\bar{p} \to W)}{s(p\bar{p} \to Z)} \frac{\Gamma(Z)}{\Gamma(Z \to ③③)} \frac{\Gamma(W \to ③n)}{\Gamma(W)}$$

LEP



Expect much increased precision with 2 fb^{-1}:

- **O(10^6)** W? l? evts per channel per exp.
- **O(10^5)** Z? ll evts per channel per exp.

LEP II: **O(10^3)** W? l? decays per channel per exp.

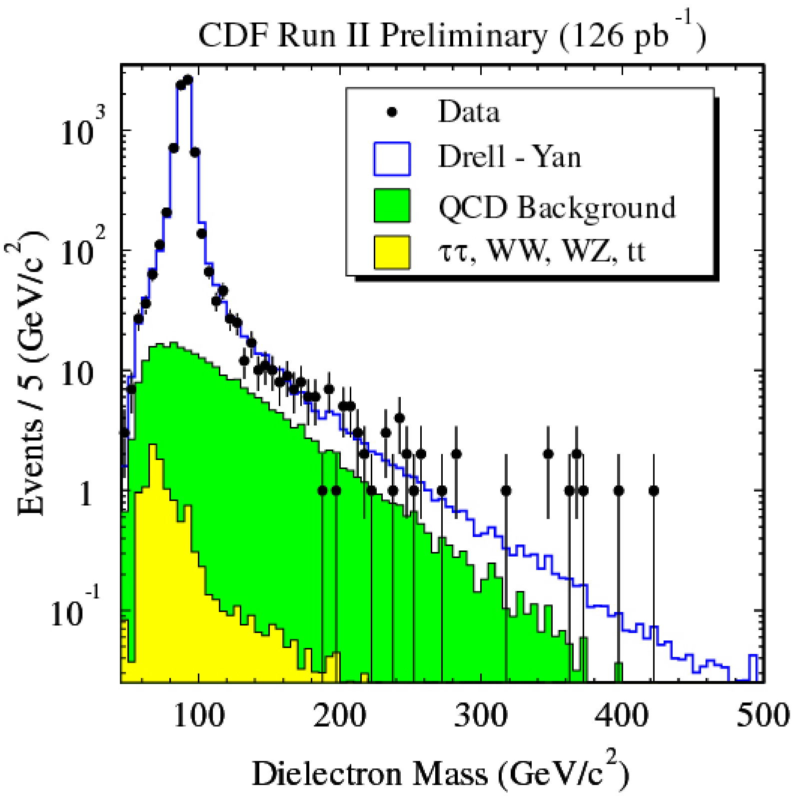
Indirect measurement of W Width

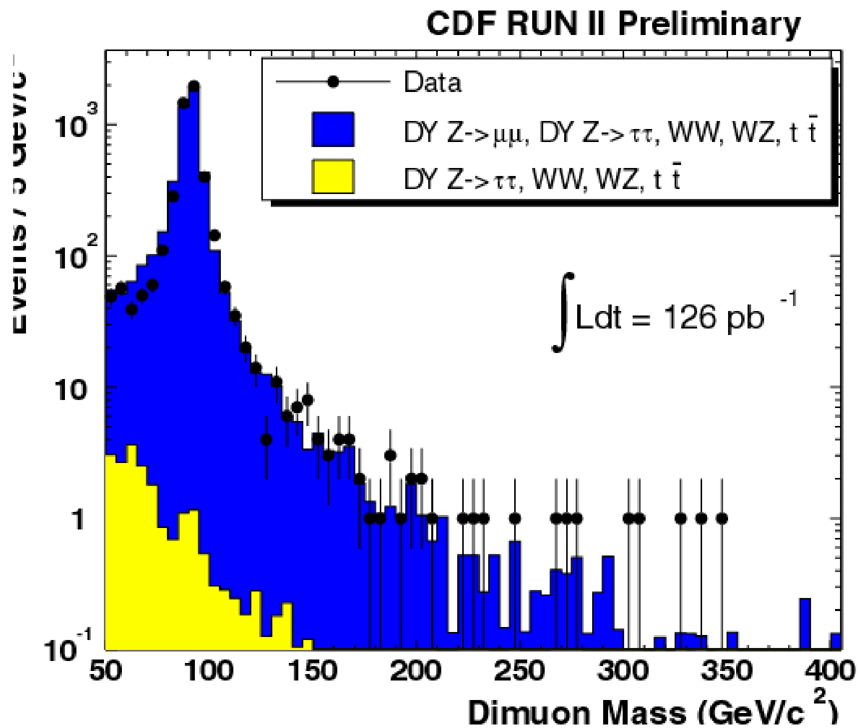
- Results from 72 pb-1

	R
CDF e	9.88 ± 0.24 ± 0.44
CDF μ	10.69 ± 0.28 ± 0.31
D0 e	10.34 ± 0.35 ± 0.49
Combined	10.36 ± 0.16 ± 0.27

G(W) – PDG 2.118 ± 0.042 GeV
Run II 2.181 ± 0.074 GeV

Search for Z's and RS Gravitons



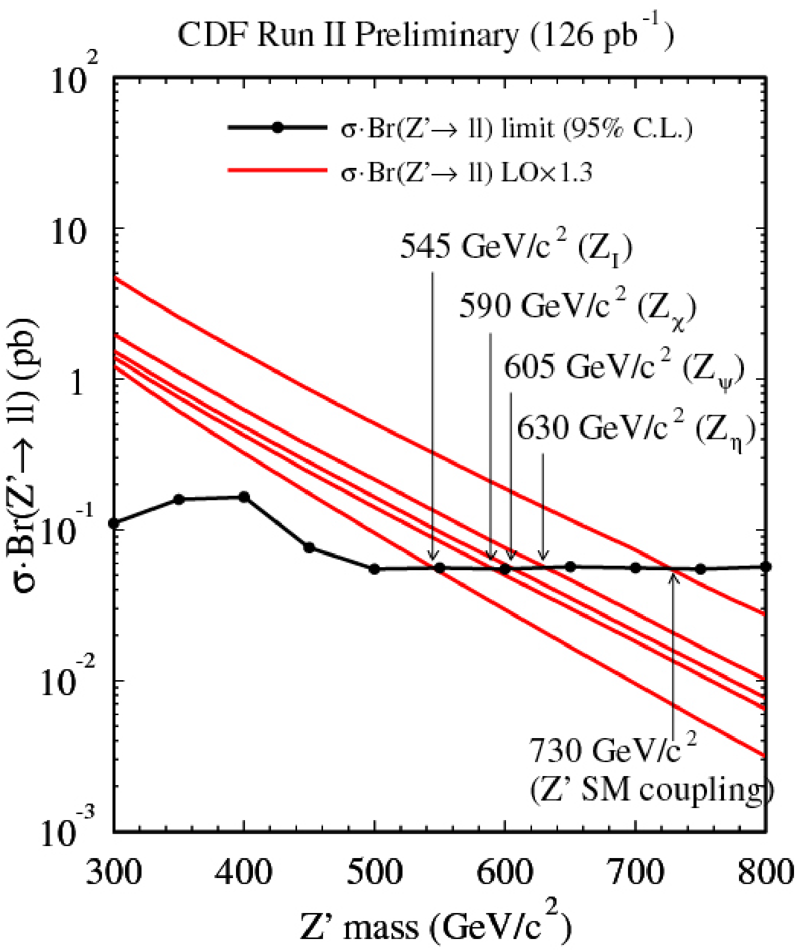


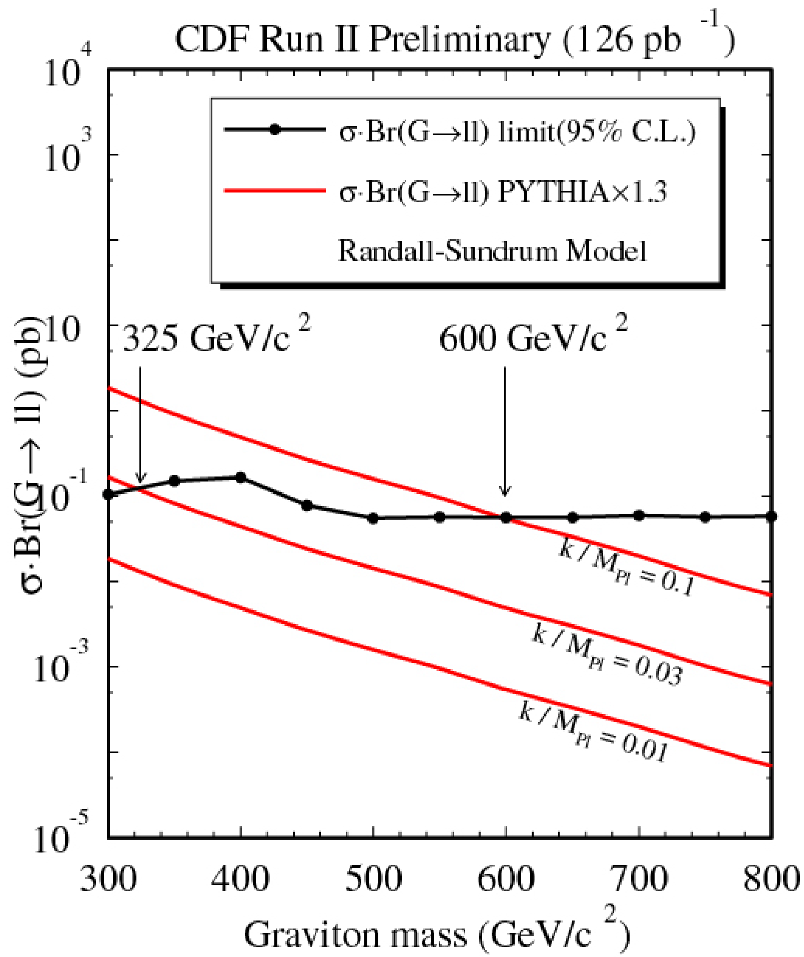
- search for high mass opposite sign dilepton pairs
- assume **narrow** resonance

No surprises

mode	mass (GeV)	SM	found
ee:	250+/-20	13.9	15
μ μ:	>250	5.35	8

Z' and RS Graviton Mass Limits





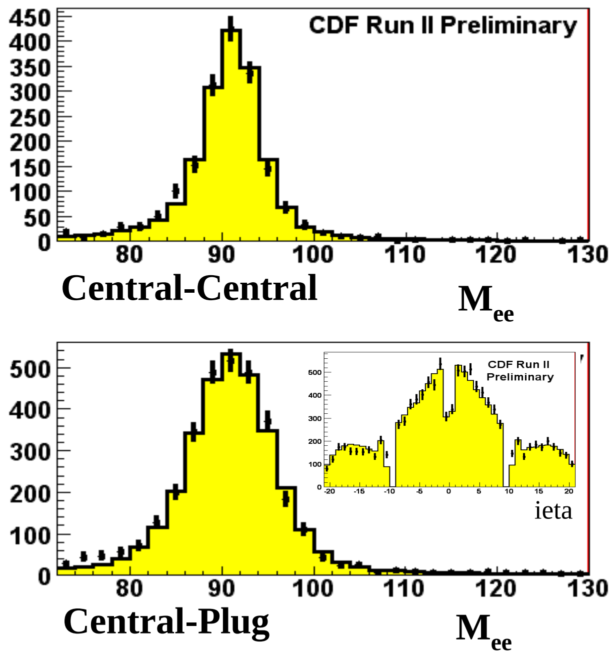
limits are in the 0.1 pb^{-1} range

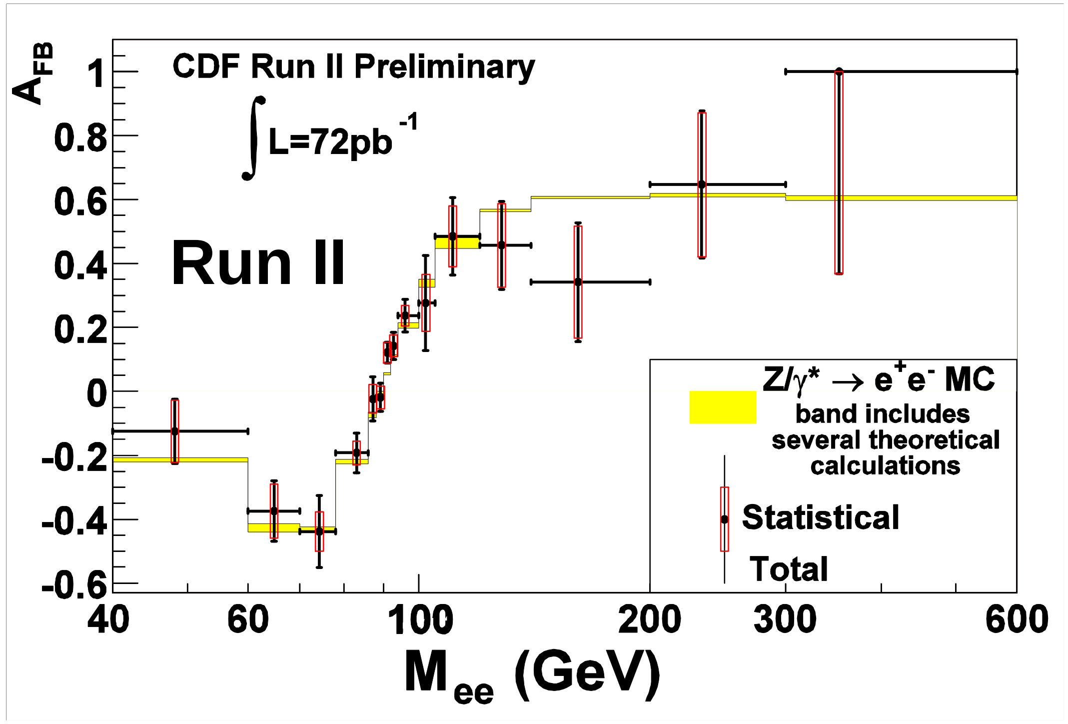
CDF m(Z')> 730 GeV @ 95% C.L (assuming SM coupling)

will reach up to 1 TeV with 2 fb^{-1}

Electroweak physics with Z bosons

- don't have LEP I statistics and precision but have high energy !

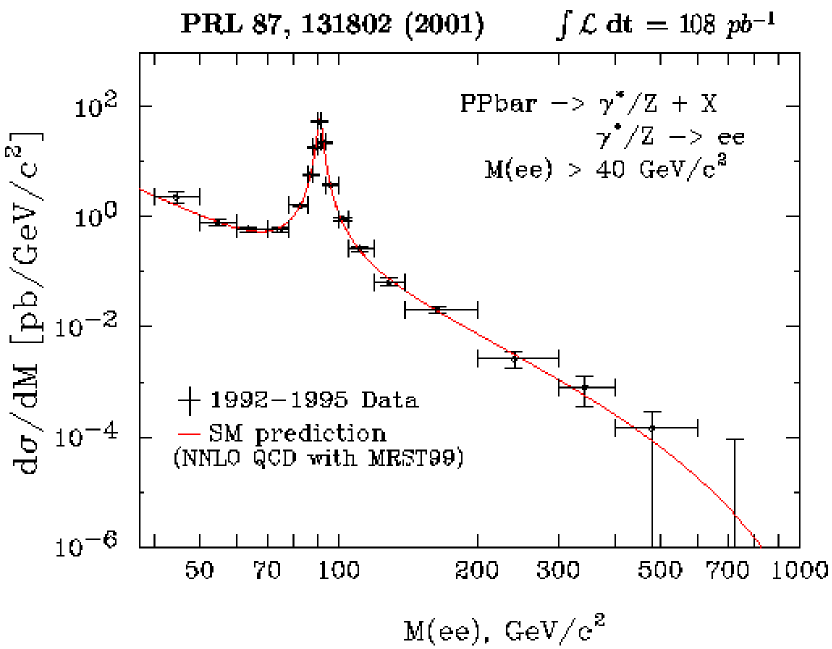


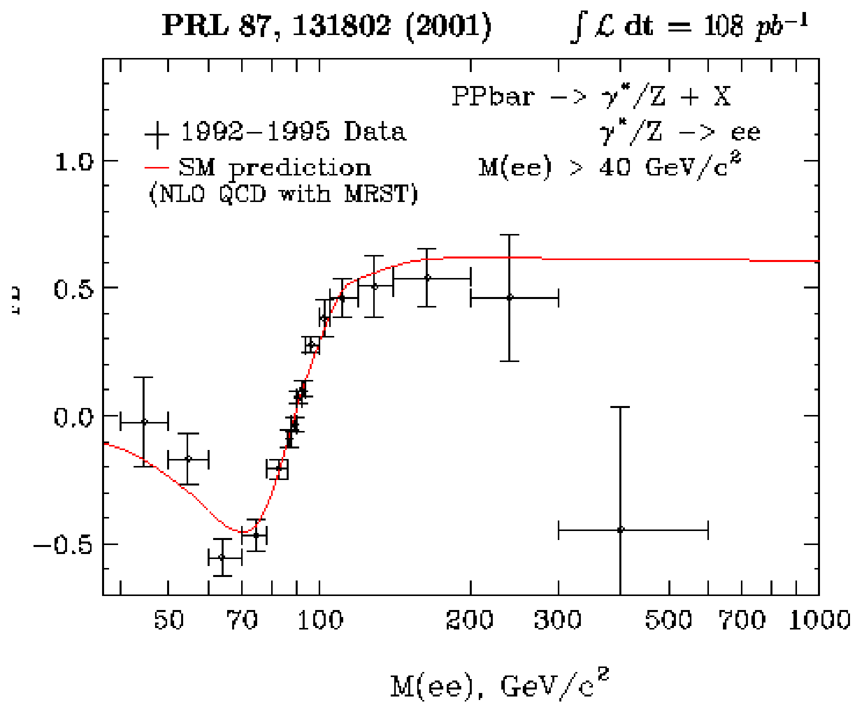


- **asymmetry complements direct Z' searches**
- also sensitive to leptoquarks, Susy …
- new plug calorimter extends until **|?|<3**

so far everything fits nicely with SM expectation

Compare with Run I
Forward- Backward-Asymmetry





- statistical fluctuation in high mass bin not present in Run II !
- new plug calorimeter and silicon stand alone tracking

  in forward/backward regions of Run II detector

  => more Zs/Luminosity

Top physics

- 1995: top quark discovery at Tevatron **in Run I**
- only ~100 reconstructed top events
- precision mass measurement: M_{Top} = 174.3 GeV ± 2.9 %

top is a funny beast !

- most **massive elementary particle**
  nearly as heavy as gold atom, heavier than W / Z bosons
- decays faster (10^{-25} s) than it hadronizes => no top hadrons

What does this tell us ??

verify top properties experimentally

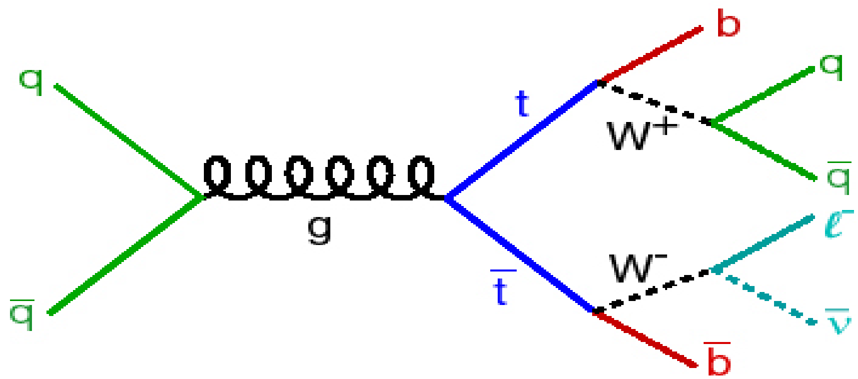
production cross section /kinematics, branching ratios, mass, top resonances, rare decays, W helicity,

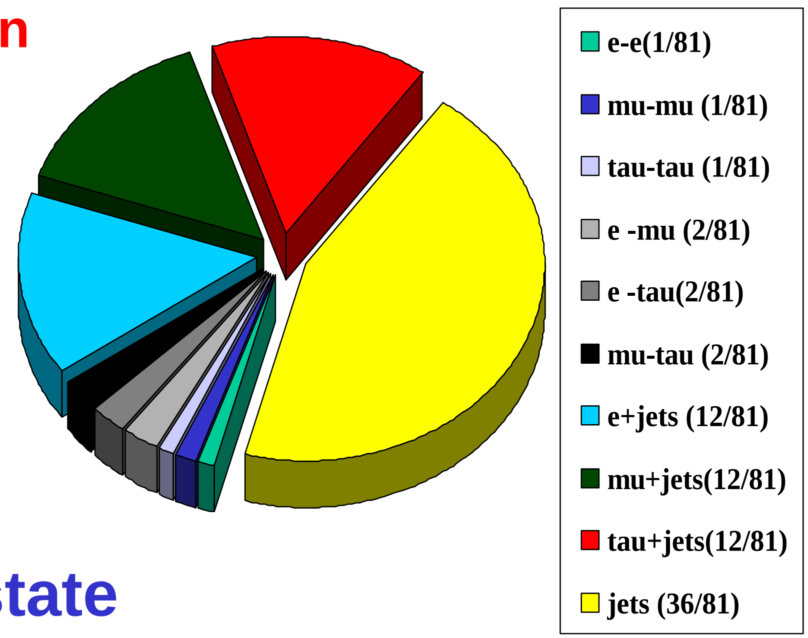
non-SM decay: t? H^{+}b

Top production and decay

Top pair production by strong interaction

85% quark annihilation, 15% gluon fusion





WW decays characterize final state

Dilepton (ee, μμ, eμ): BR = 5%; pure but small signal

2 high-p_T charged leptons, 2 b-jets, MET

Lepton + jets: BR = 30%; less clean but best for mass measurement

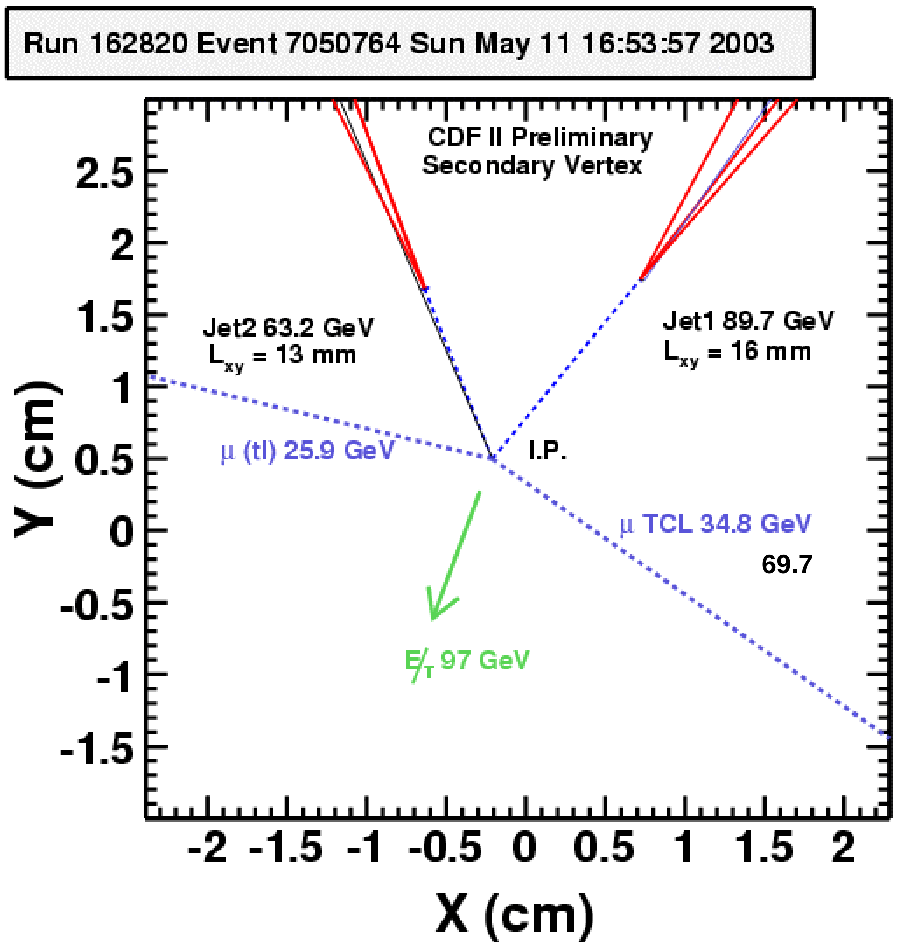
1 charged lepton + 4 jets (2 b-jets), MET

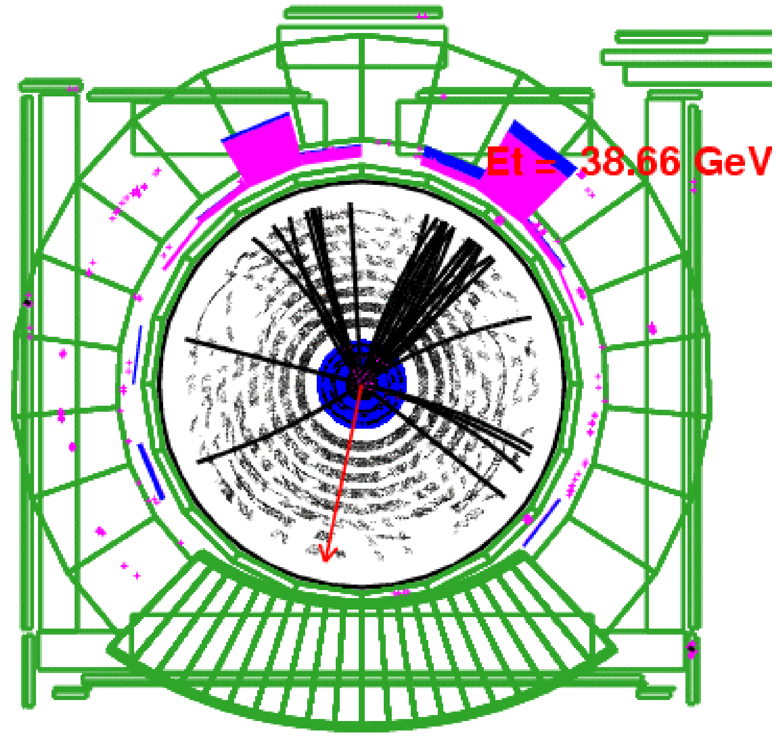
All hadronic: BR = 44%; huge QCD background; need 2 b-tags

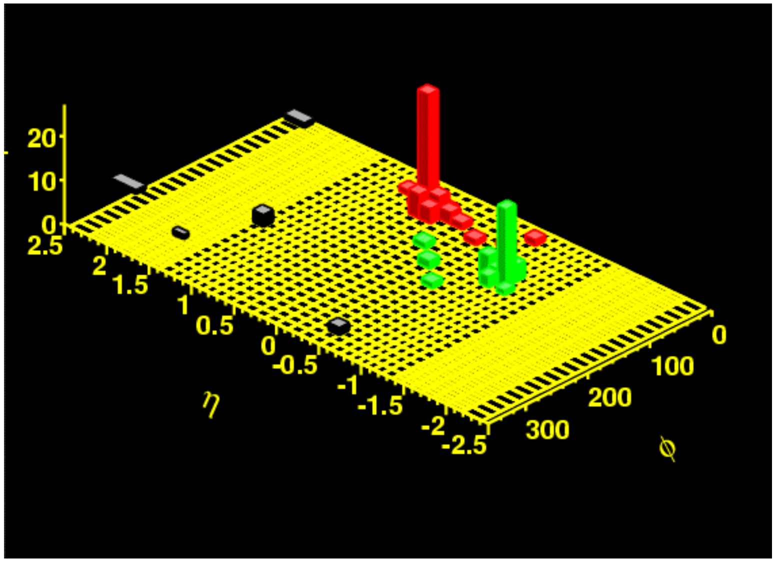
6 jets (2 b-jets), no MET

t_{had} +X: BR = 23%

Dilepton top event







both b-jets tagged by silicon vertex detector !

Run II top signals

Dilepton

2 high p_T leptons (e,μ,τ,iso track)

2 central jets

Large Missing E_T

Lepton + jet

1 high p_T lepton(e,μ)

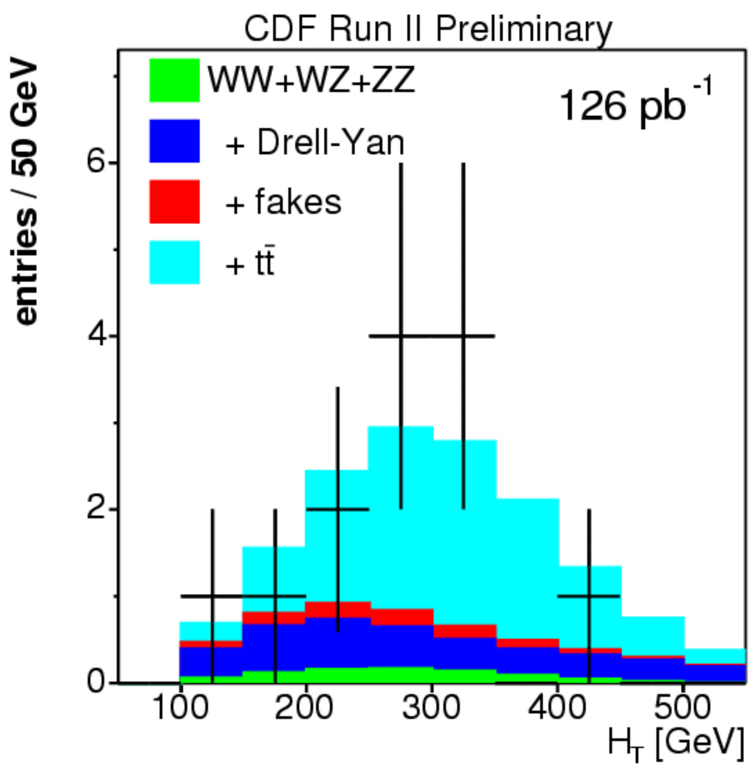
>3 central jets

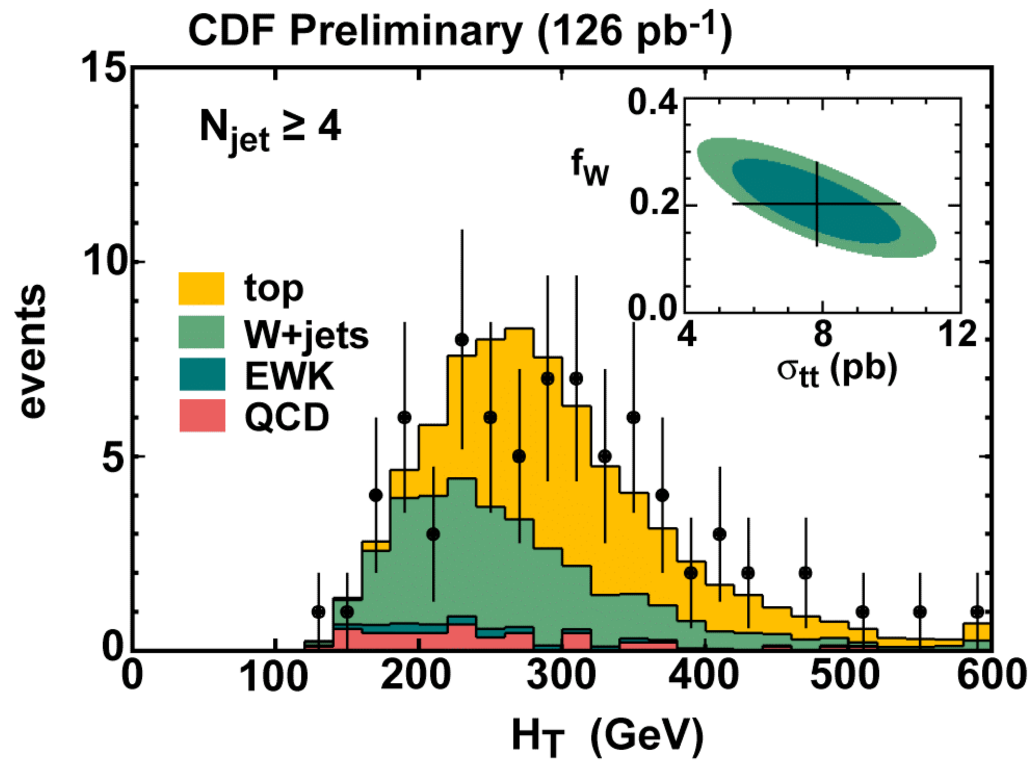
Clean signal

Poor statistics (13 candidates)

W+jet background

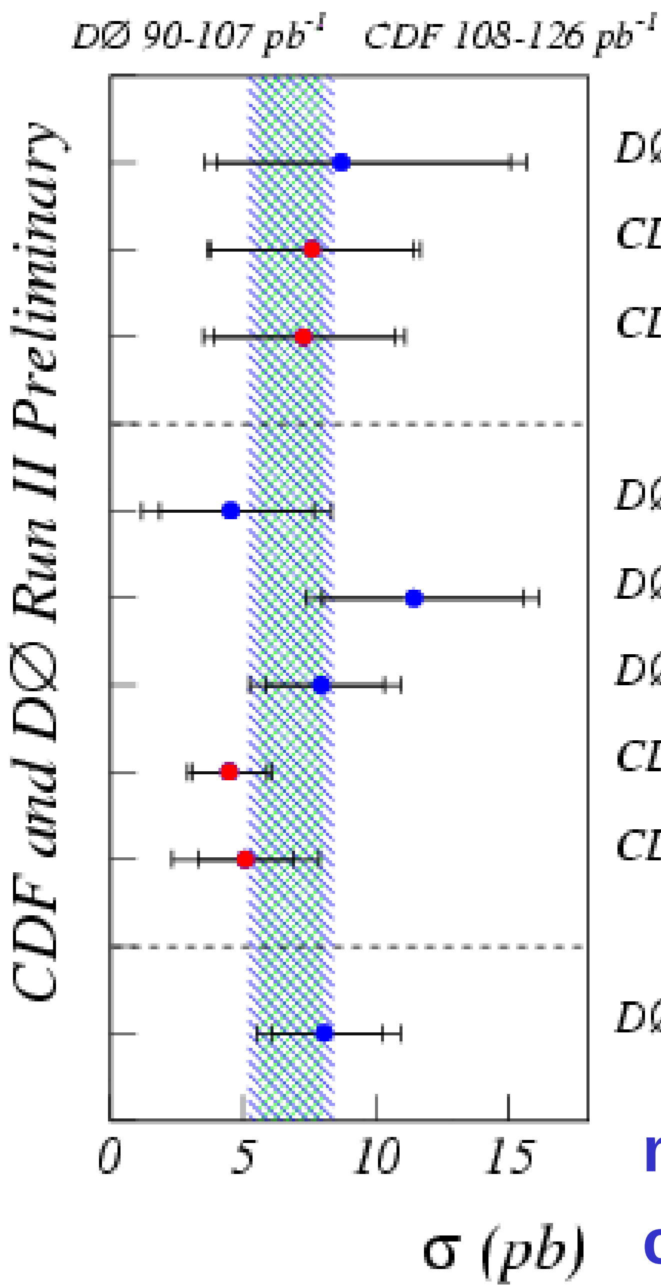
good statistics





H_T: scalar sum of all leptons' and jets' E_T

Top cross section overview (Run II)

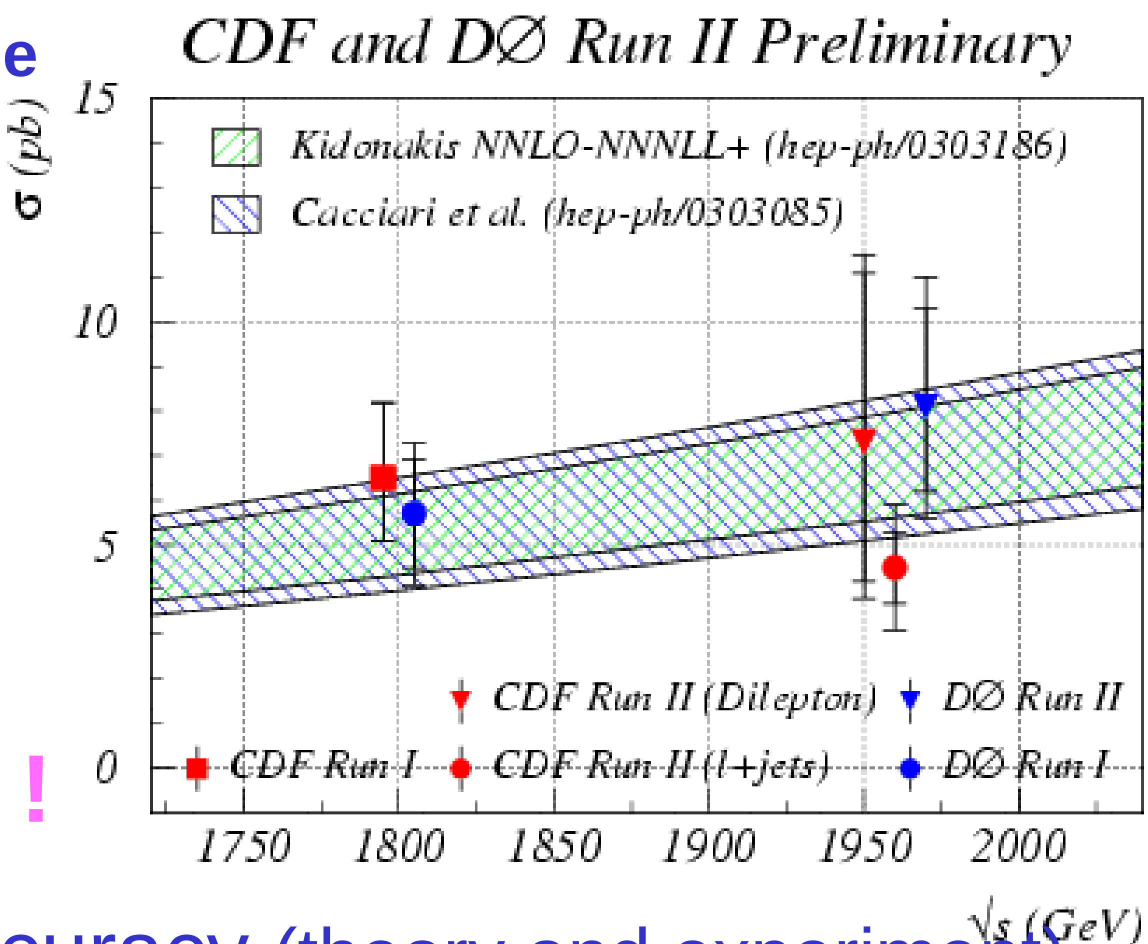


DØ Dileptons	$8.7^{+6.4}_{-4.7}(\text{stat})^{+2.7}_{-2.0}(\text{syst}) \pm 0.9(\text{lum})$
CDF Dileptons	$7.6^{+3.8}_{-3.1}(\text{stat})^{+1.5}_{-1.9}(\text{syst})$
CDF Lepton+Track	$7.3 \pm 3.4(\text{stat}) \pm 1.7(\text{syst})$
DØ Lepton+jets/topo	$4.6^{+3.1}_{-2.7}(\text{stat})^{+2.1}_{-2.0}(\text{syst}) \pm 0.5(\text{lum})$
DØ Lepton+jets/SMT	$11.4^{+4.1}_{-3.5}(\text{stat})^{+2.0}_{-1.8}(\text{syst}) \pm 1.1(\text{lum})$
DØ Lepton+jets combined	$8.0^{+2.4}_{-2.1}(\text{stat})^{+1.7}_{-1.5}(\text{syst}) \pm 0.8(\text{lum})$
CDF Lepton+jets/SVX	$5.3 \pm 1.9(\text{stat}) \pm 0.9(\text{syst})$
CDF Lepton+jets/HT	$5.1 \pm 1.8(\text{stat}) \pm 2.1(\text{syst})$
DØ Combined	$8.1^{+2.2}_{-2.0}(\text{stat})^{+1.6}_{-1.4}(\text{syst}) \pm 0.8(\text{lum})$

many measurements, using ~½ of current data set => errors will decrease

Does top production occur as expected ?? Compare with theory

Deviation could come from new physics !



No surprises !

Want higher accuracy (theory and experiment)

Goal for $2fb^{-1}$ is 10% exp. uncertainty

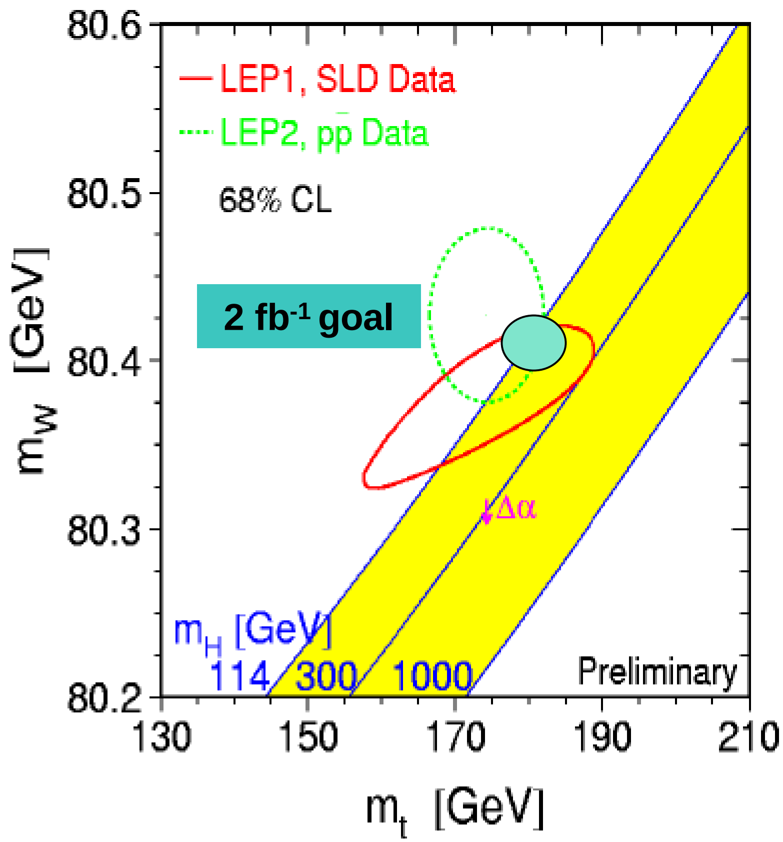
Why care for top and W masses ?

Higgs mass linked to W and top masses via

radiative corrections

- now: indirect prediction of SM Higgs mass
- if Higgs found: direct consistency check of SM
- measurement of W and Top mass hard in LHC environment

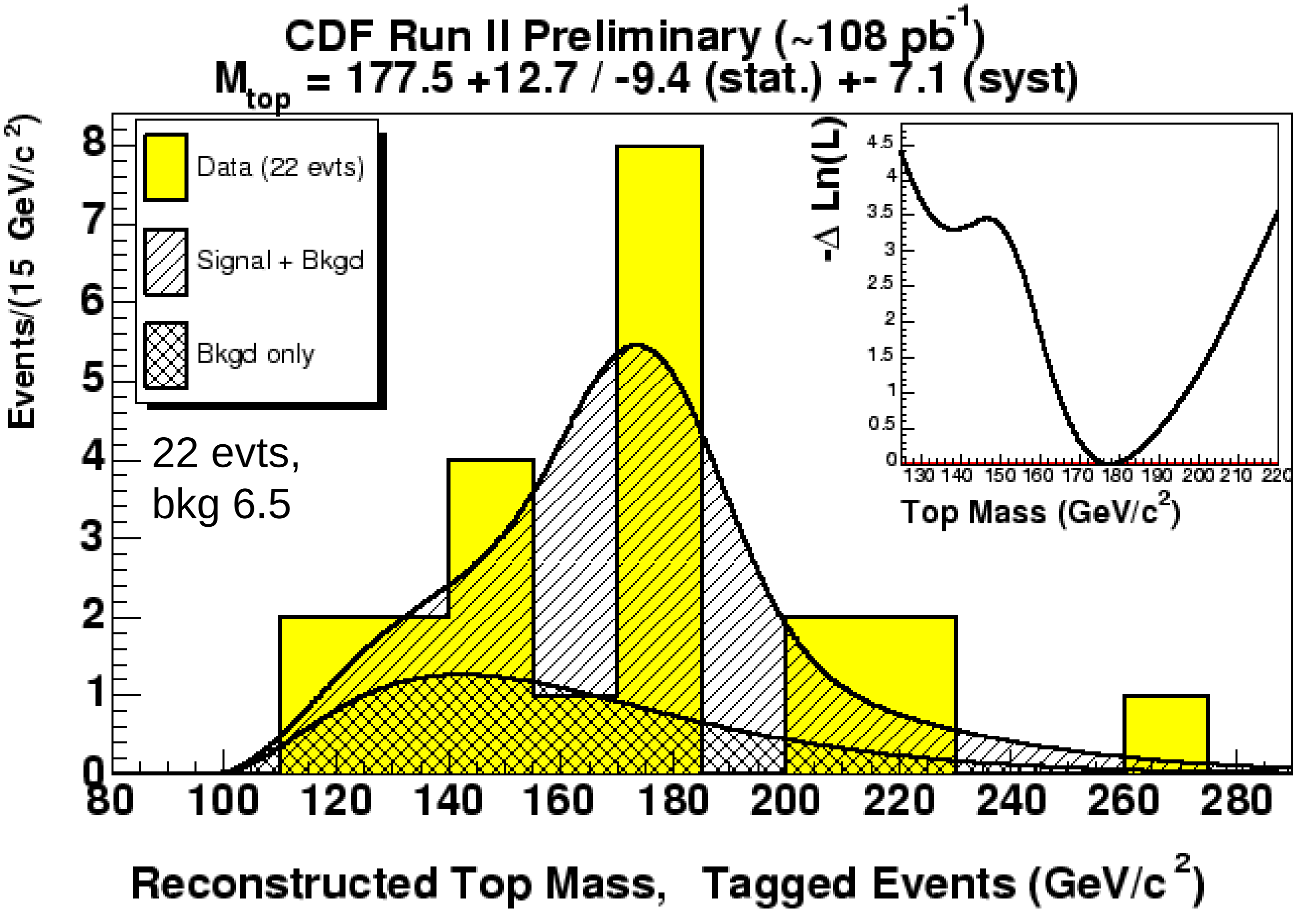
=> will take time and not be much better than Tevatron



Measure W and Top now at Tevatron !

Lepton + jet channel mass (Run II)

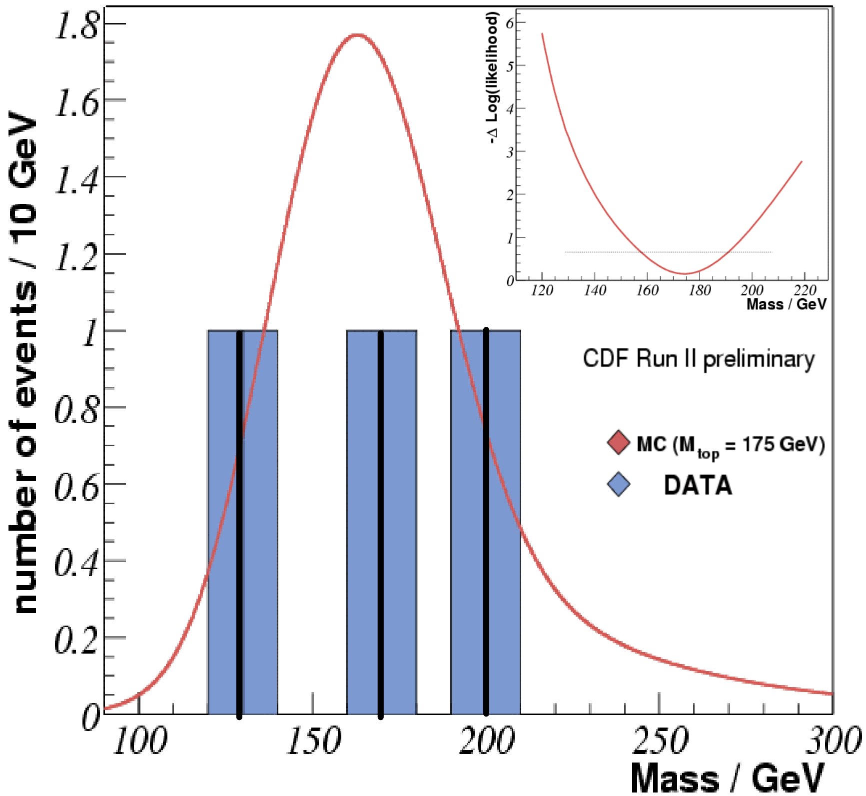
1 high p_T lepton, high MET, =3 jets, 1 b-tag, 4^{th} jet E_T>8 GeV



Source	error (GeV/c²)
Statistical	+ 12.7 - 9.4
Jet scale	6.2
FSR	2.2
PDFs	2.0
ISR	1.3
Other MC	1.0
Generator	0.6
Backgrounds	0.5
b-tagging	0.1
Total sys.	+/- 7.1

- many constraints (only 1 neutrino)
- reasonable statistics; manageable background, require 1 b-tagged jet
- biggest challenge: hadronic energy scale
- mass compatible with Run I

Mass in dilepton channel



CDF RunII preliminary, 126 pb^{-1}

6 events

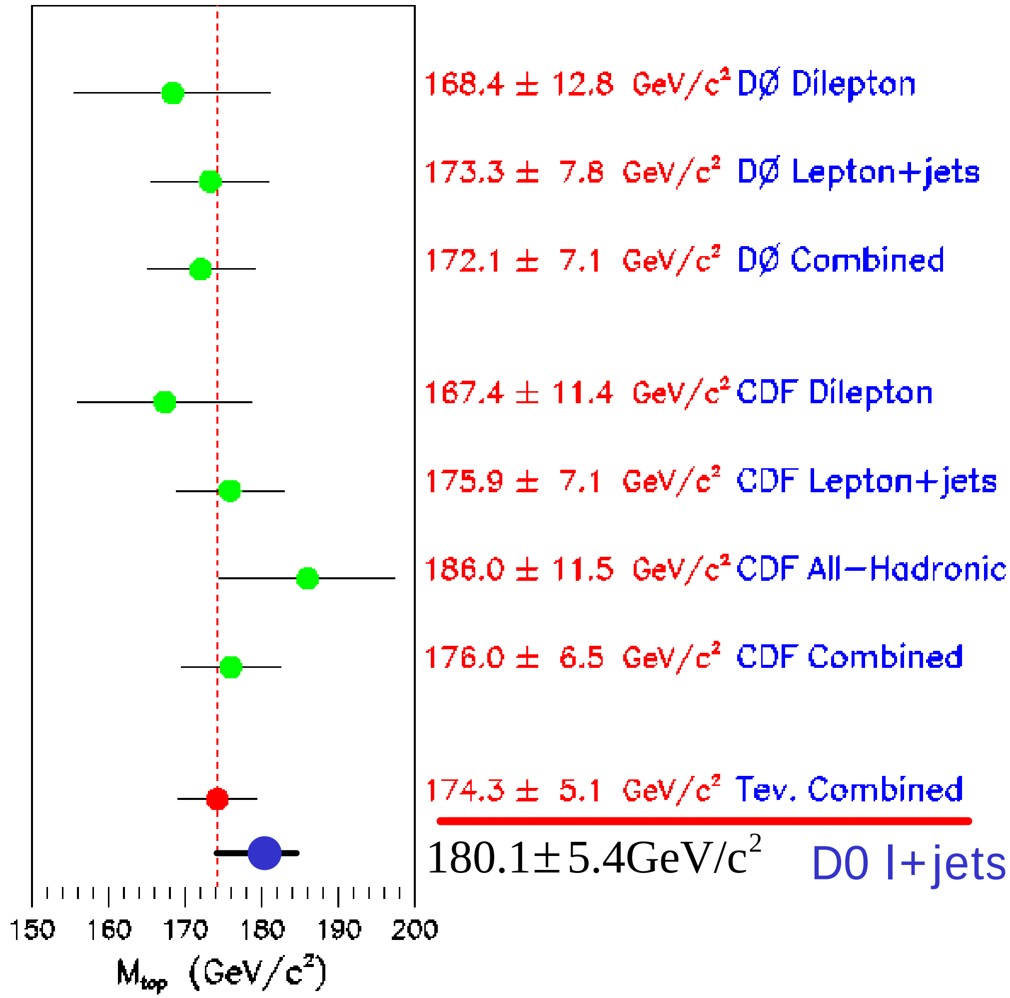
Mass in dilepton channel

$$175.0^{+17.4}_{-16.9}\,(\text{stat}) \pm 7.9\,(\text{syst})\ \text{GeV}/c^2$$

- underconstraint system (2 neutrinos)
- channel with best S/B but only BR only 5%
- => mass measurements difficult and statistics limited
- mass compatible with Run I

Run I masses overview

- fitting methods matter !
  (see Run I D0 result)
- refining methods for Run II
- also lots of work on detector calibration and
- understanding of QCD models

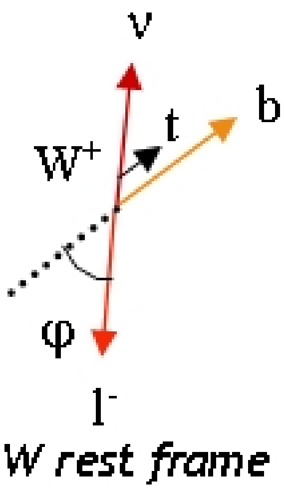


Top masses have not “changed”

W helicity

angular dependence of the semileptonic decay in the W rest frame:

$$w(\cos j_{l^-\bar{b}}) = F_- \cdot \frac{3}{8}(1-\cos j_{l^- b})^2 + F_0 \cdot \frac{3}{8}(1-\cos^2 j_{l^- b}) + F_+ \cdot \frac{3}{8}(1+\cos j_{l^- b})^2$$

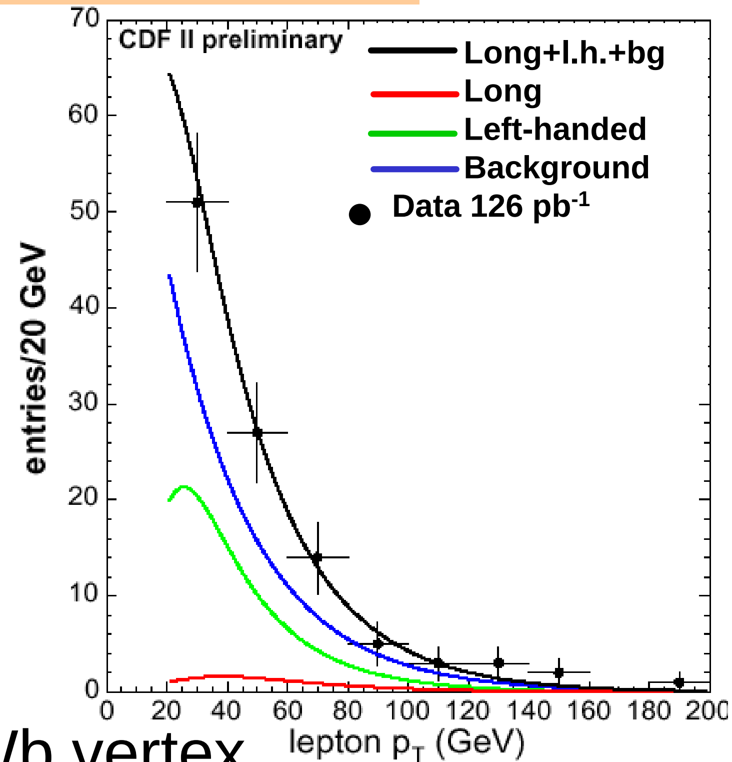


expect:

$F_- = 30\%$,

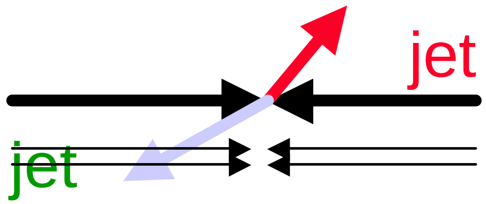
$F_0 = 70\%$,

$F_+ = 0\%$



- helicity of W depends on ratio of top and W masses and V-A structure of tWb vertex
- helicity structure affects lepton p_T in lab frame
- **unique opportunity to test weak interaction of "free quark"**
- several Run I analyses; early Run II analyses in progress

Run II Dijet event: most energetic man produced jets ever seen !



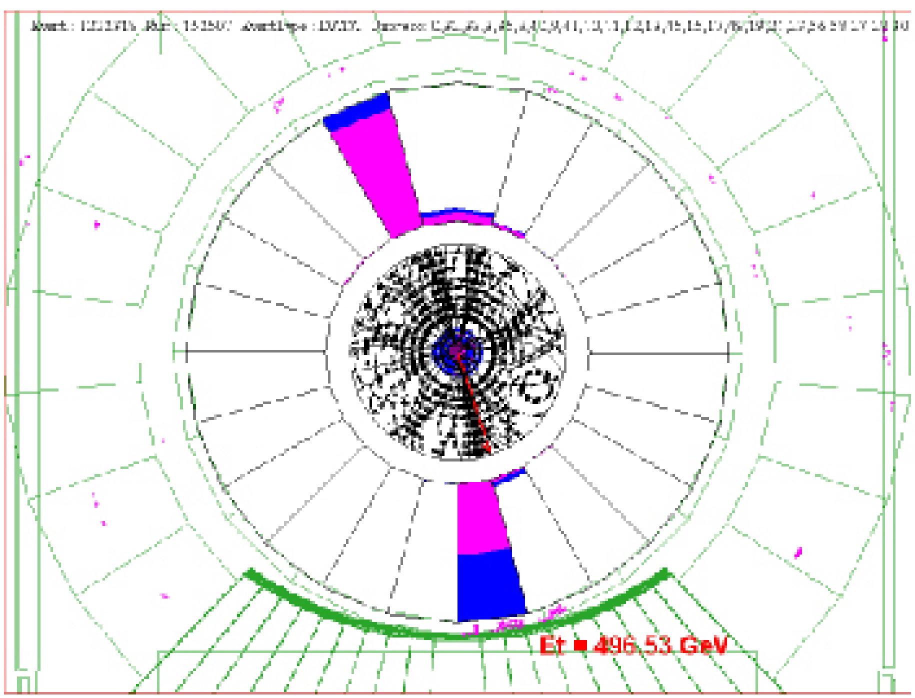
beautiful jets; high jet energies and dijet mass

Run 152507 event 1222318

Dijet Mass = 1364 GeV (corr)

cos θ^* = 0.30

z vertex = -25 cm

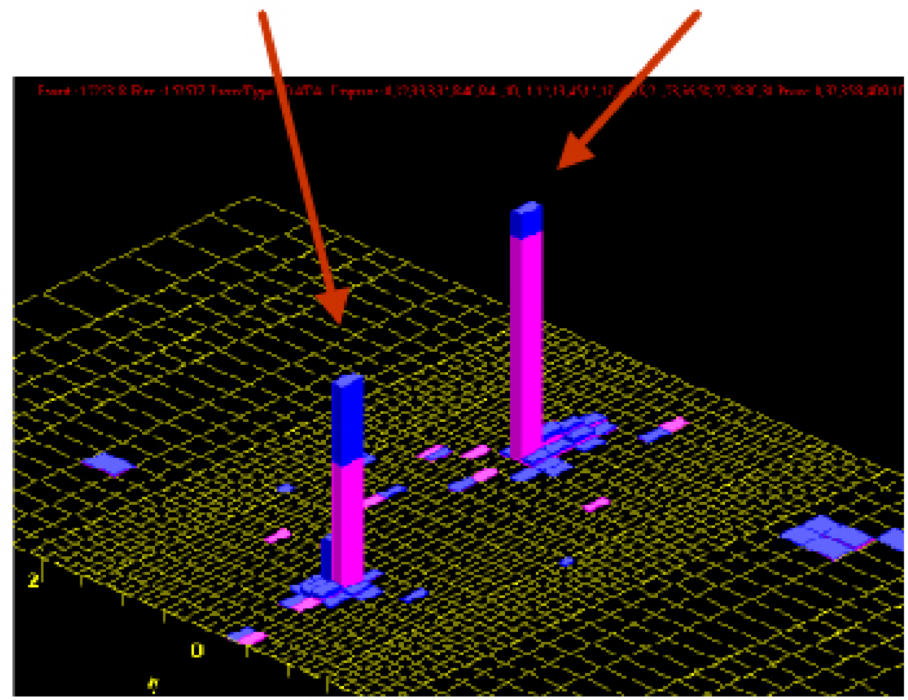


J2 E_T = 633 GeV (corr)
546 GeV (raw)

J2 η = -0.30 (detector)
= -0.19 (correct z)

J1 E_T = 666 GeV (corr)
583 GeV (raw)

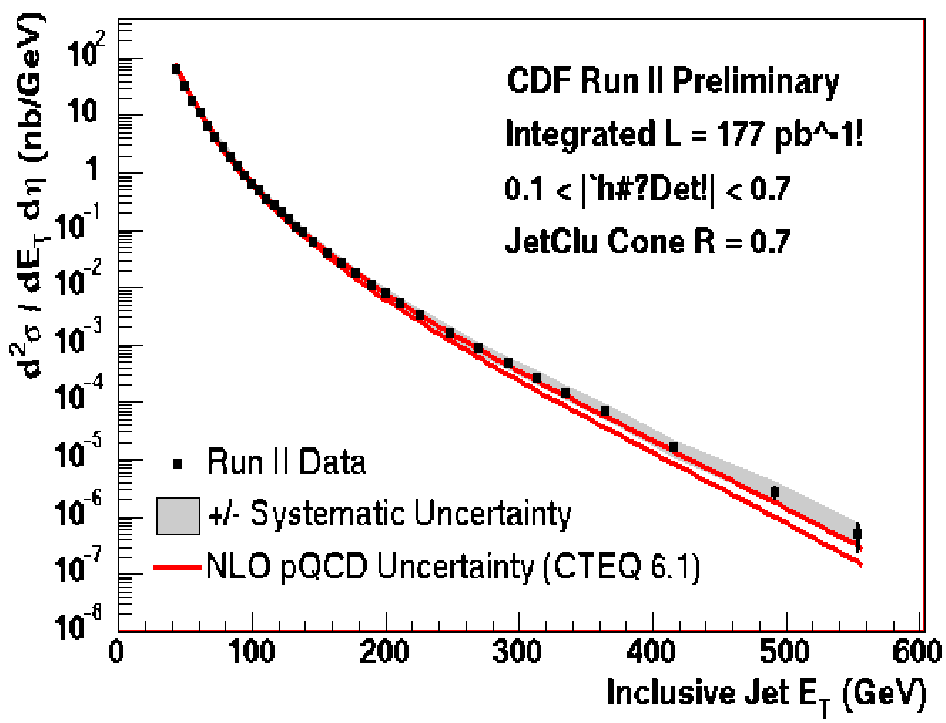
J1 η = 0.31 (detector)
= 0.43 (correct z)

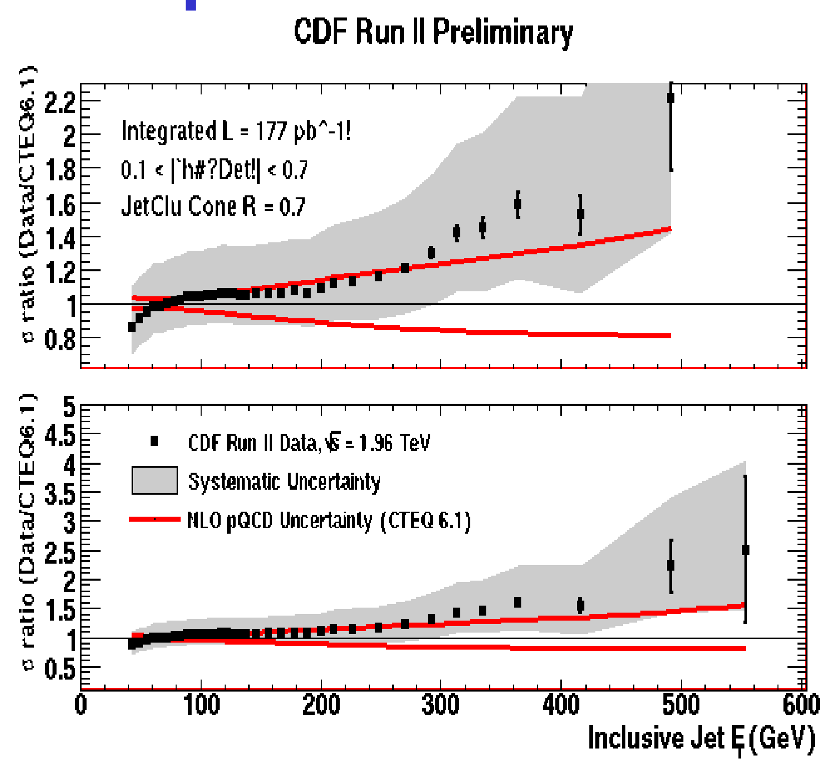


CDF Run 2 Preliminary

Inclusive jet transverse energy

- Important test of strong interaction
- sensitive to **quark structure** and **parton densities**





- Cross section varies over 8 orders of magnitude !
- have already extended Run I E_T range by ~ 150 GeV
- Good energy measurement important and difficult

Agrees with expectation (NLO QCD + CTEQ 6.1)

QCD tests

- huge potential due to high beam energies and cross sections
- alas there is also much other interesting stuff to do …

Jets

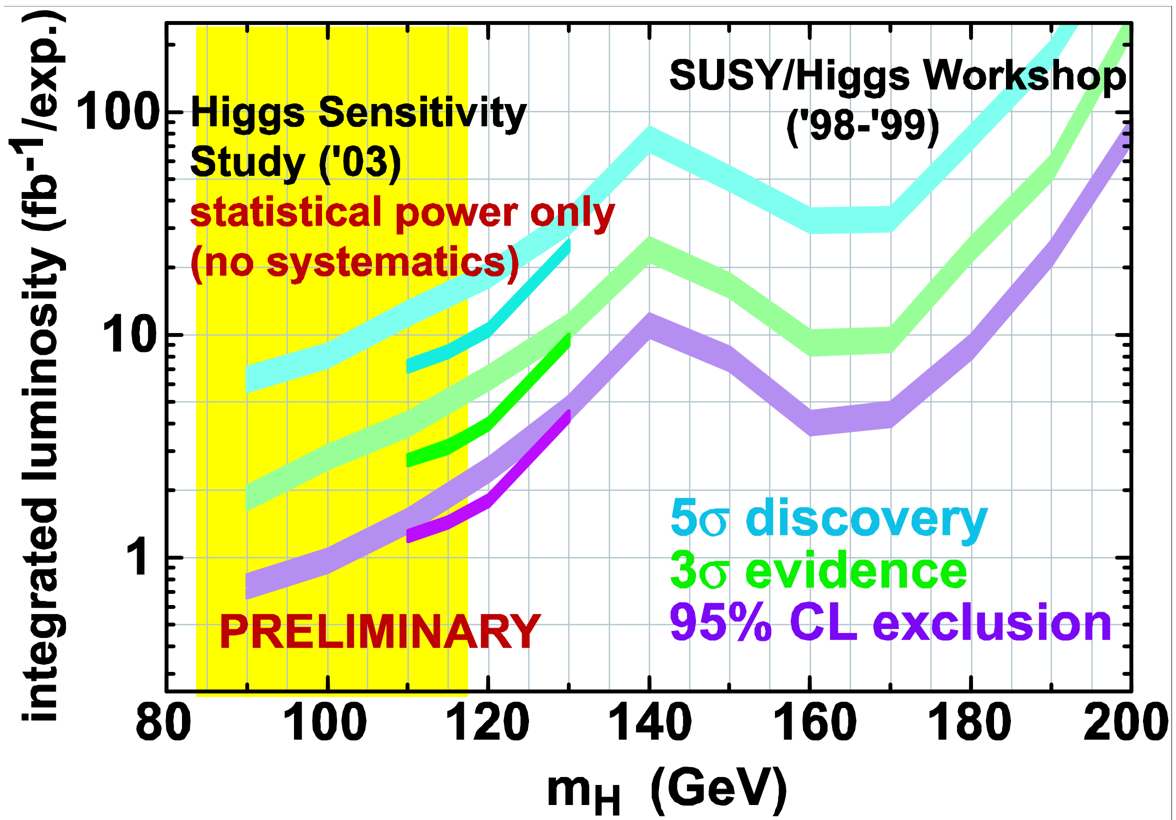
- test of strong interaction at very small distances
- strong coupling, gluon density at high x, quark sub structure
- also results on fragmentation (multiplicities, quark/gluon differences)

What should be emphasized in my view ?

- flavor-tagged jets, 4-gluon vertex, multi-jet topologies
- would like CDF to have H1 LAr calorimeter
- CDF still working hard on calibration

Sensitivity for SM Higgs Boson

- sensitivity study was redone using Run II data/simulation
- => more reliable estimate and confirmation of older study
- **window for discovery limited by luminosity**
- **with 4 fb-1 some chances for light Higgs remain !**
- also MSSM Higgses may be much easier to find (at large tan^{2}b)



Light Higgs decays into in bbar

(unlike LHC cannot afford H->??)

Efficient b-tagging and mass resolution are crucial !

Run IIb silicon project

- **radiation hard** replacement of CDF silicon, needed for **luminosities > ~6 pb-1** (20 MRad, >10^14 protons/ cm^2)
- challenging project, interesting R&D, most positive technical evaluations
- **under budget, ahead of schedule**

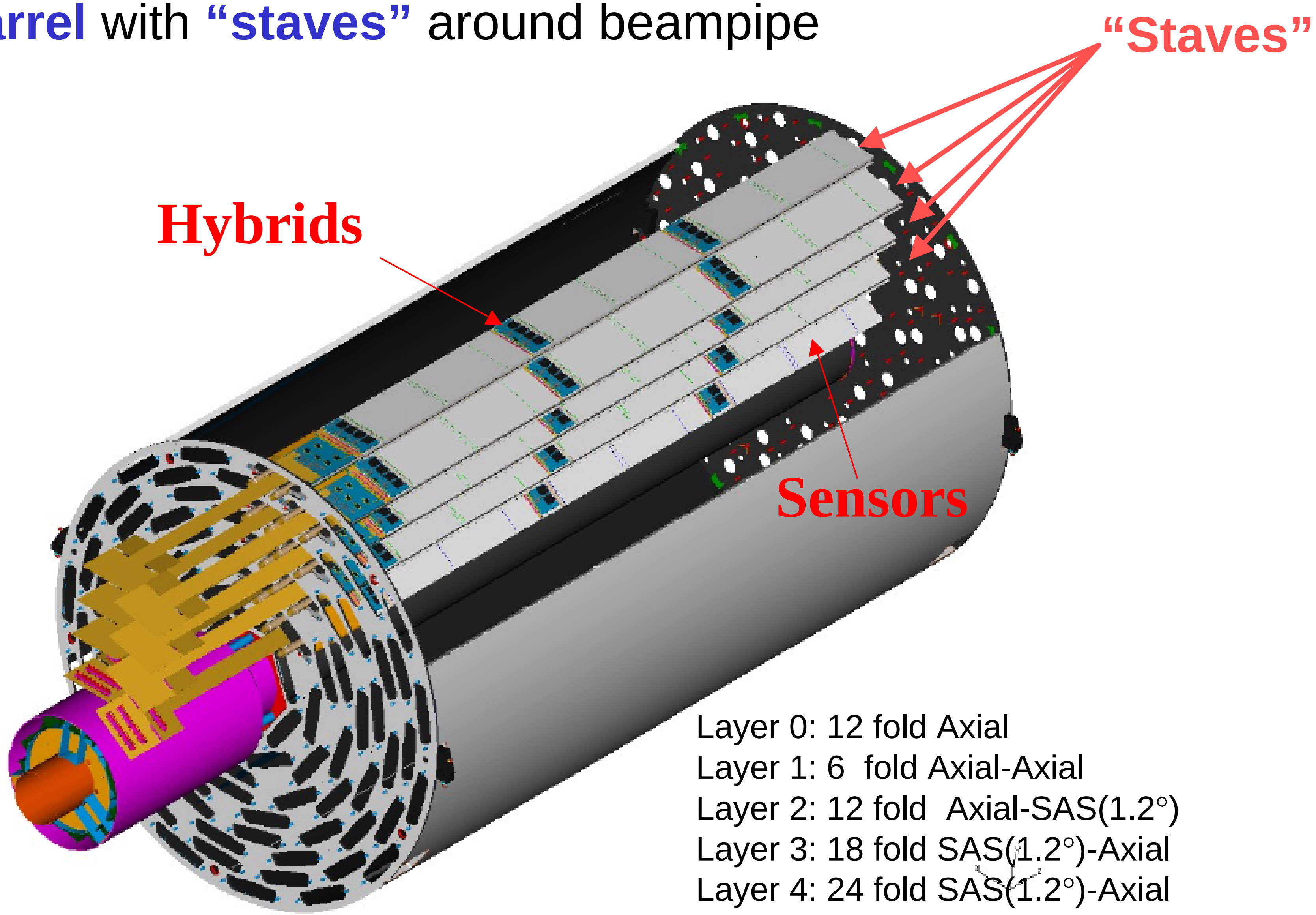
But **canceled** in September 2003 due to pessimistic luminosity expectations and FNAL budget constraints

What remains ?

- Interesting/novel **detector arrangement**
- **SVX4 silicon readout chip/** beryllia hybrids
- **“stave concept”:** very compact packaging of silicon modules

Collider Geometry

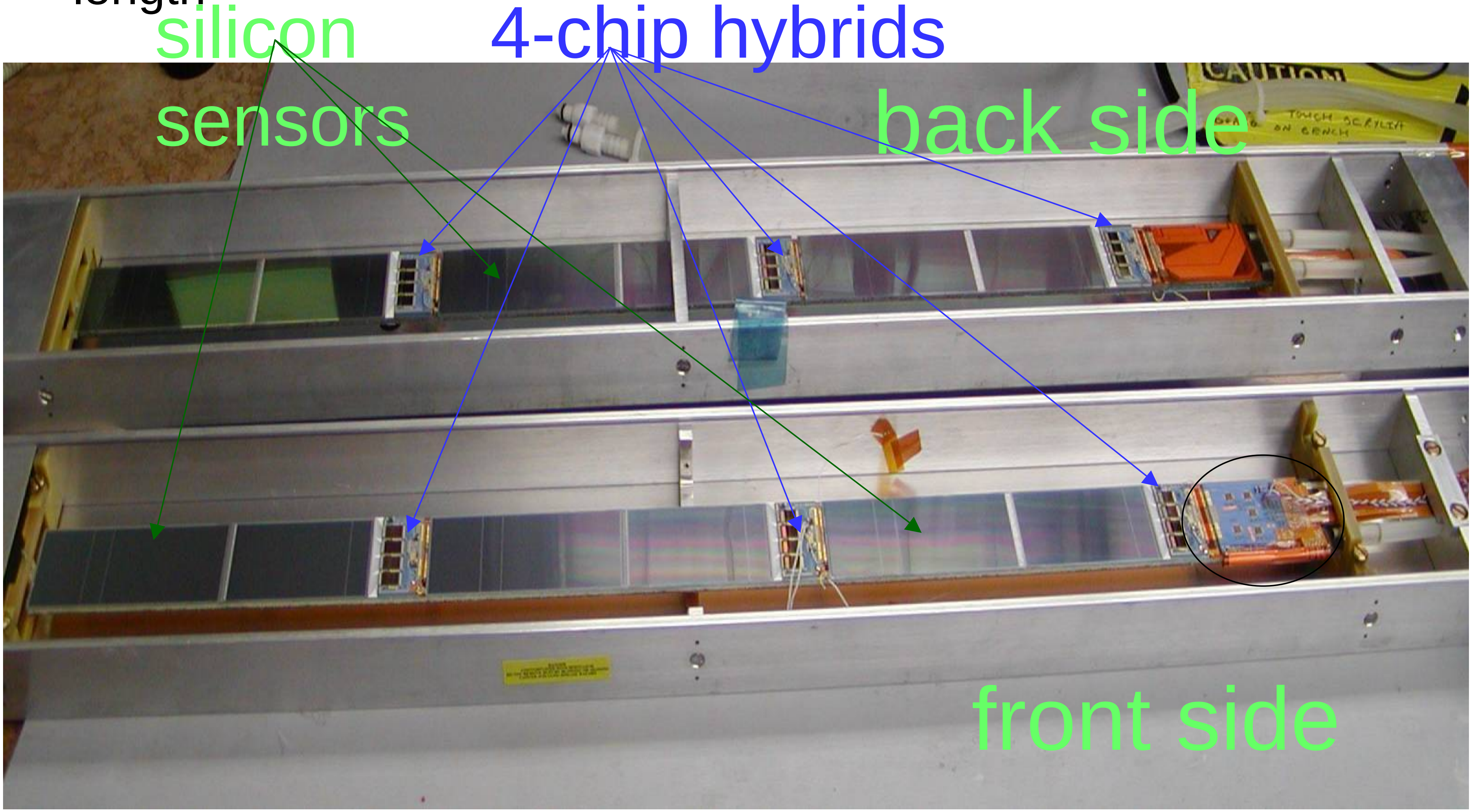
Barrel with **"staves"** around beampipe



Layer 0: 12 fold Axial
Layer 1: 6 fold Axial-Axial
Layer 2: 12 fold Axial-SAS(1.2°)
Layer 3: 18 fold SAS(1.2°)-Axial
Layer 4: 24 fold SAS(1.2°)-Axial
Layer 5: 30 fold Axial-Axial

What is a stave, why is it cool ?

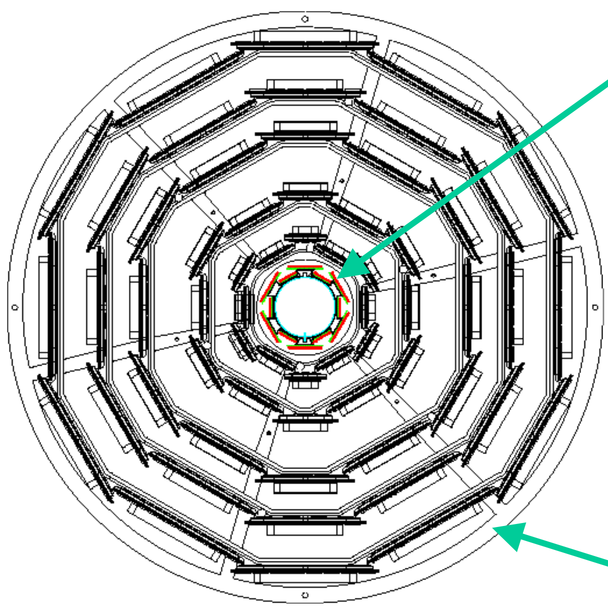
highly integrated mechanical, electrical and thermal structure;
66 cm long; 3072 channels; low mass: 124 g; 1.8% of a radiation length



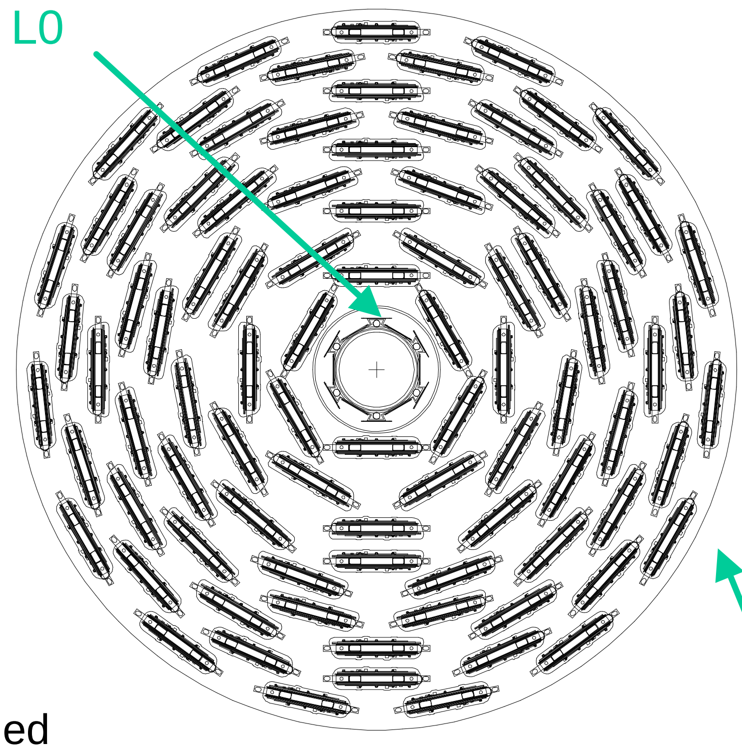
Overall Layout: Run IIa vs. Run IIb

both have 5 outer layers and “beam pipe” layer within ISL barrel

Run IIa: symmetric but **complicated**



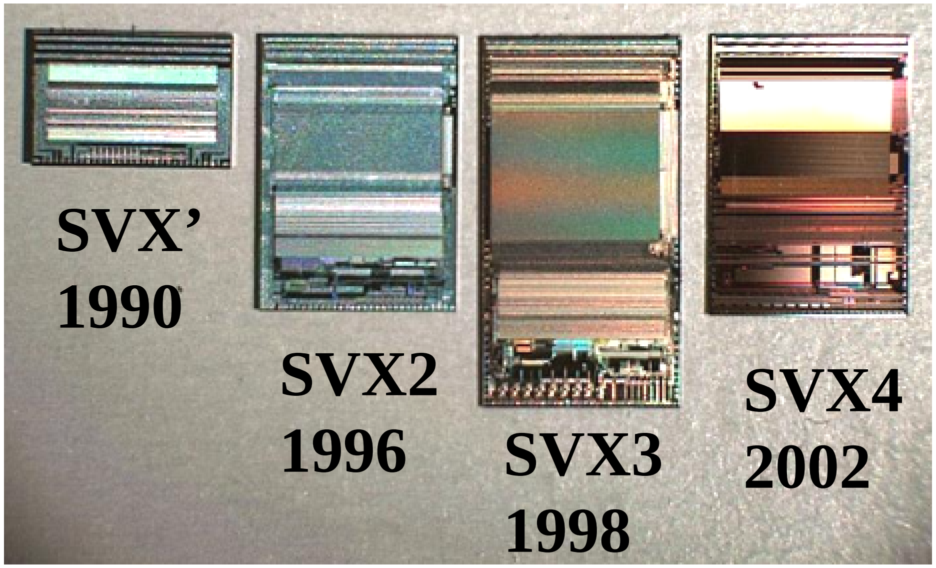
Run IIb: “ugly” but **simple**



extreme simplifications for Run IIb =>

huge practical advantages; similar performance !

SVX4 readout chip



This is a complex chip !

- **ASIC in 0.25 μm CMOS technology**
- preamplifier; analog pipeline; ADC; readout unit
- 50 MHz; low noise; low power
- 300K transistors

Many special features like

- deadtime-less operation
- real-time pedestal subtraction
- data sparsification

Very successful project; completed

- fast design/layout of about 2 years
- 2. submission yielded final chip
- radiation hard to > 20 MRad; performance better than SVX3
- good die yield very high (~ 90%)
- several experiments interested in using SVX4

Hybrids

- Design, procurement, test, mass production by LBNL
- chose **BeO** ceramic substrate: “best” but challenging

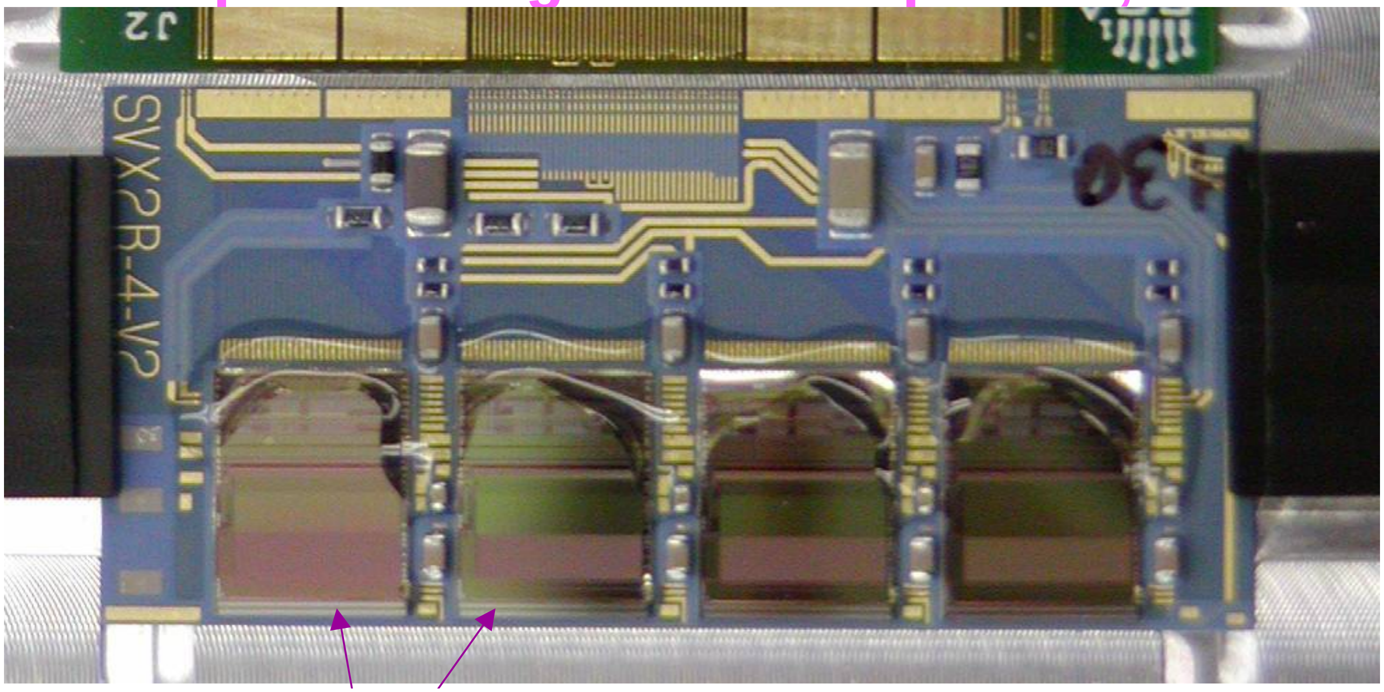
(low Z material and small size to minimize multiple scattering; good heat conduction)

- **fine-pitch thick film technology**: 100/100 mm traces/spaces and

125 mm vias => **conservative, cheaper and safe**

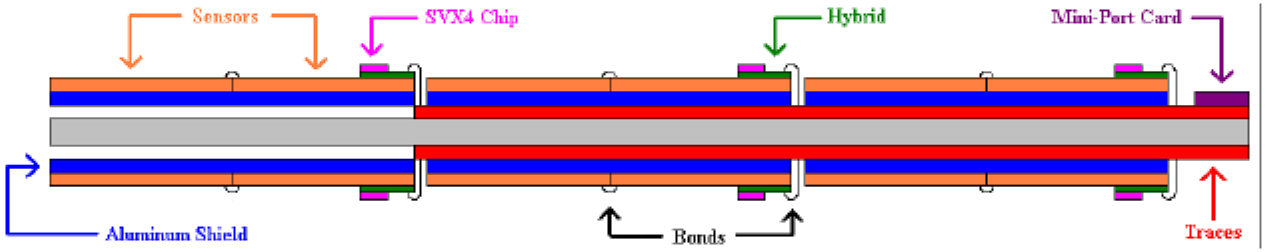
- first version fully satisfactory, only cosmetic changes

Hybrid is critical and expensive high tech component; very few companies work successfully on BeO !



Size: 38 mm x 20 mm

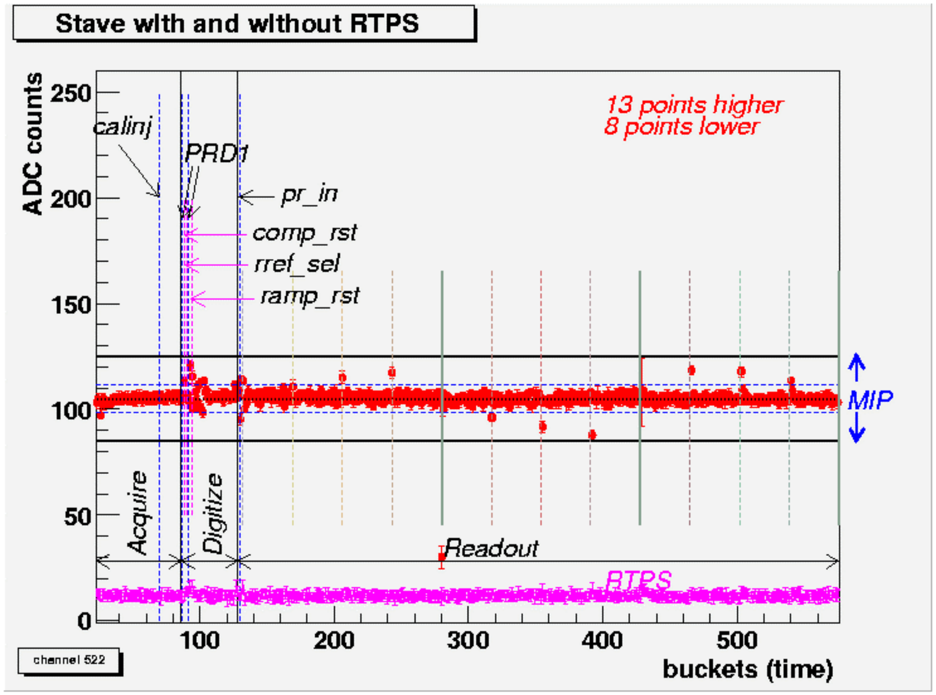
Stave: compact, "massless"



- dense packaging makes electrical properties more challenging
- **sensors in proximity of bus cable** can cause **systematic pedestal shifts** which may lead to **"fake hits" …**
- CDF runs in **deadtime-less mode** (data acquisition during "noisy" digitize and readout) to increase trigger bandwidth

- plot shows arbitrary channel as a function of time/ chip mode:

  every channel with "signal" above average pedestal by "2-3" x noise will be read out and be used in tracking algorithms



Excellent performance !

Summary/Outlook

- experiments at high energy hadron colliders have been most successful
- **broad** physics program combined with **spectacular highlights**

- flood of interesting “early” Run II results due to much improved **innovative detectors**
- 50 times **more data** to come

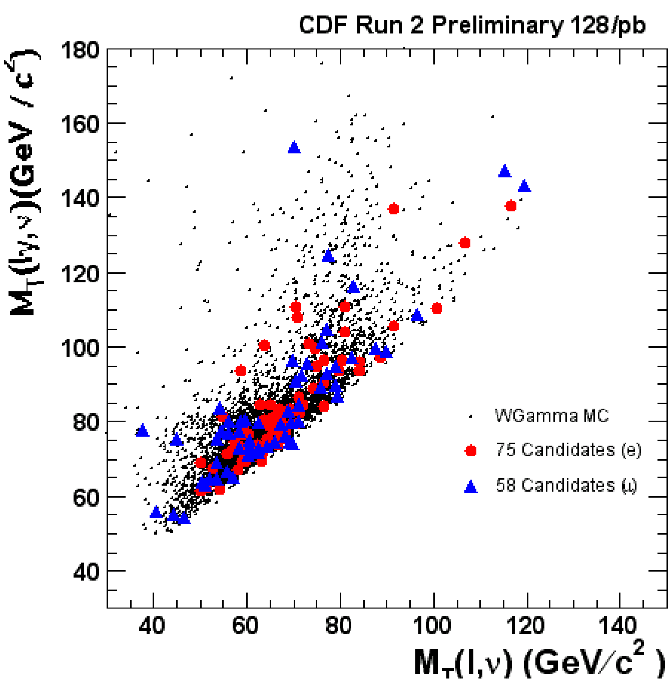
Will this yield another major Tevatron discovery ?

If not at Tevatron, then at LHC !!

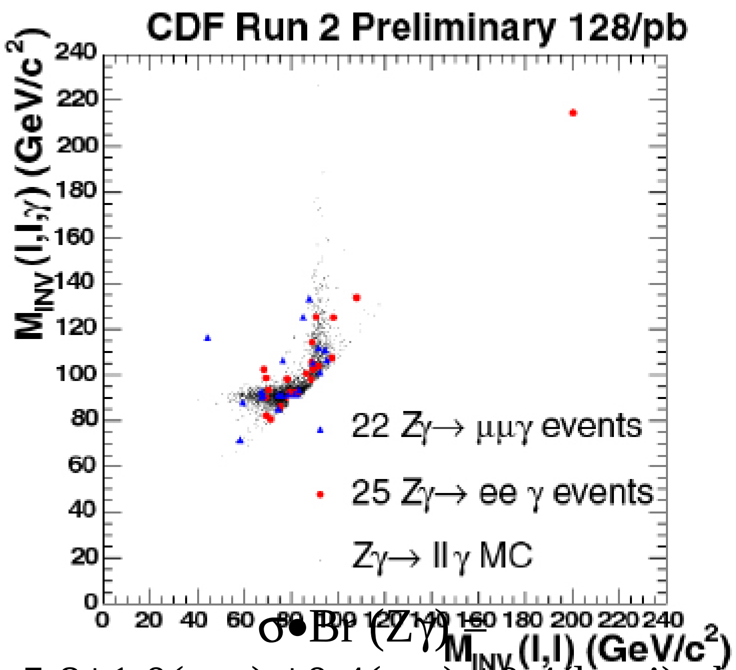
VVV Coupling: Wγ and Zγ Production

133 seen
141 expected

- μ and e modes
- Central γ, E_T (γ) > 7 GeV
- ΔR(lepton, γ) > 0.7



σ•Br (Wγ) =
17.2±2.2(stat) ±2.0(sys) ±1.1(lumi) pb



σ•Br (Zγ) =
5.8±1.0(stat) ±0.4(sys) ±0.4(lumi) pb

Agreement with SM