The CDF Group at LBNL

- Introduction
- Contributions to the CDF Detector
- Contributions to CDF Physics Analysis
  - Recent Publications
  - Selected Topics:
    - Top Cross Section
    - Top Mass
    - Wbb search
    - Hadronic Moments in Semileptonic Decays
    - Preparations for Bs Mixing
- Future Directions

Marjorie Shapiro

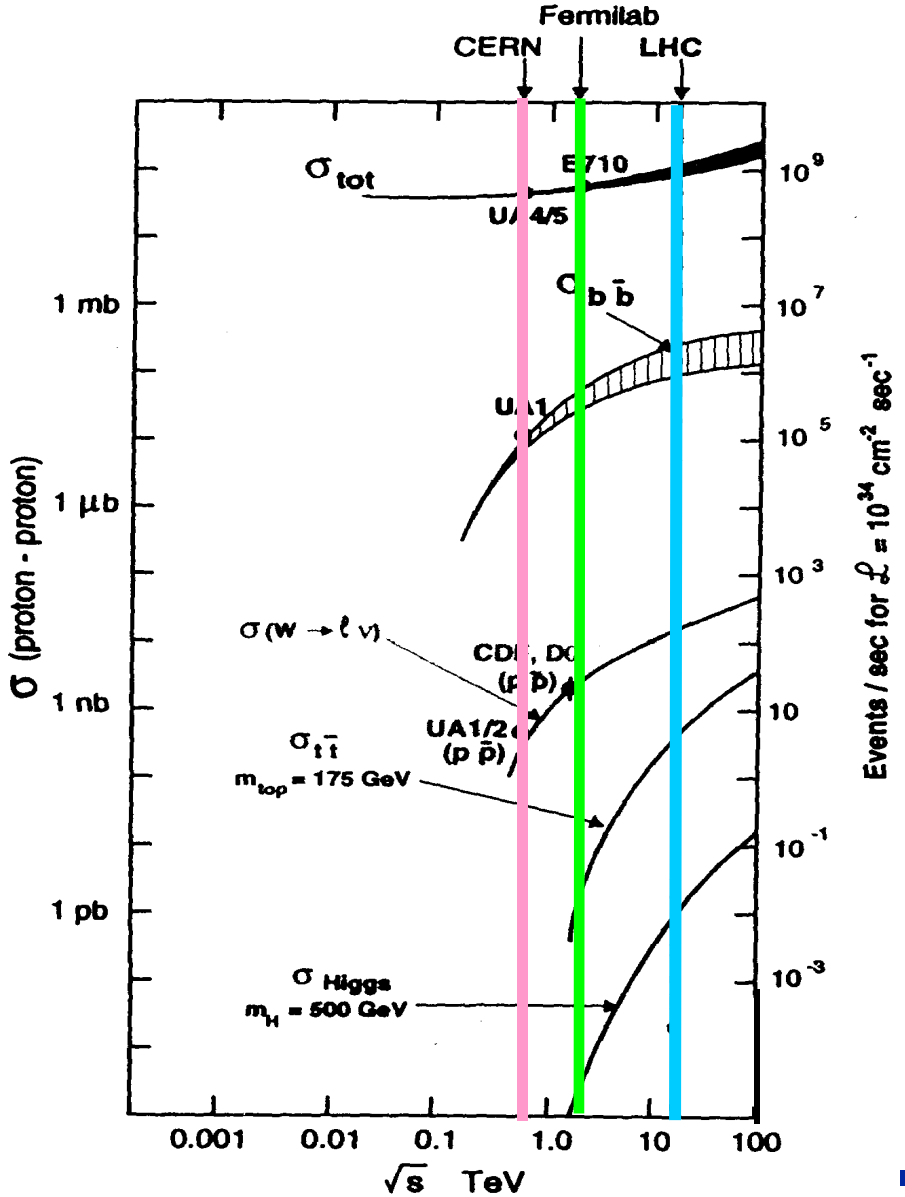
Physics at the High Energy Frontier

- Particle Physics: The search for the fundamental components of matter and their interactions
- Hadron Collider experiments play a unique role:
  - Highest available center-of-mass energy → can *directly* produce new particles (eg top)
  - Large production cross sections → can search for rare phenomena and make high precision measurements
- <u>Collider experiments are intrinsically broadband:</u>
  - Search for a wide variety of phenomena
  - Responsive to changing physics landscape

Physics at Hadron Colliders

- Probes physics at high mass : Production of new particles
  - Top physics
  - Higgs
  - Supersymmetry
- … to intermediate mass : Precision Measurements
  - Electroweak physics (radiative corrections)
- … to low mass: Rare and forbidden processes
  - B and charm physics

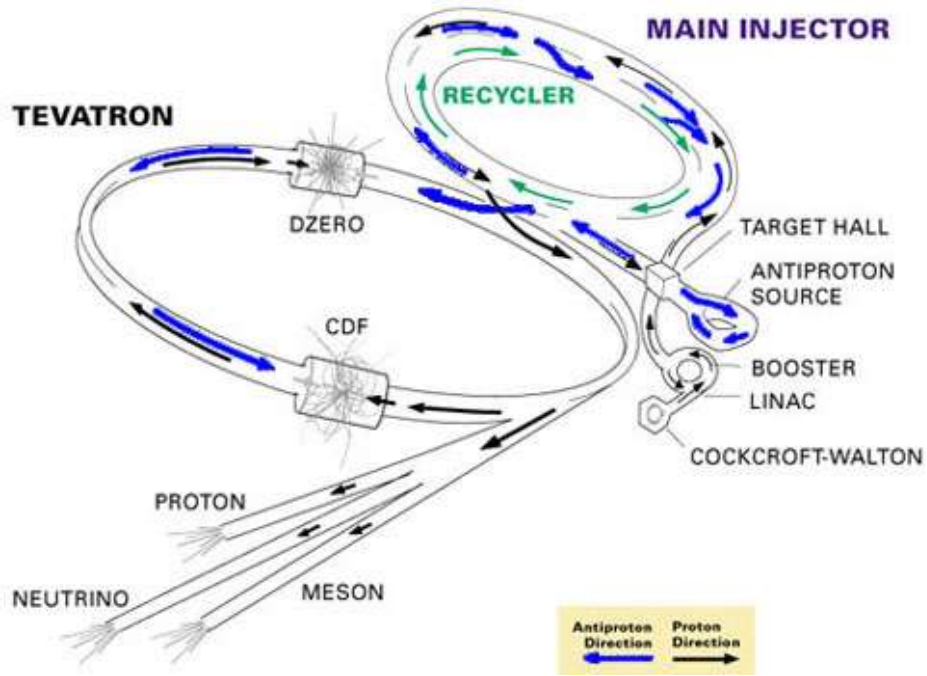
LBNL has contributed in all 3 areas this year

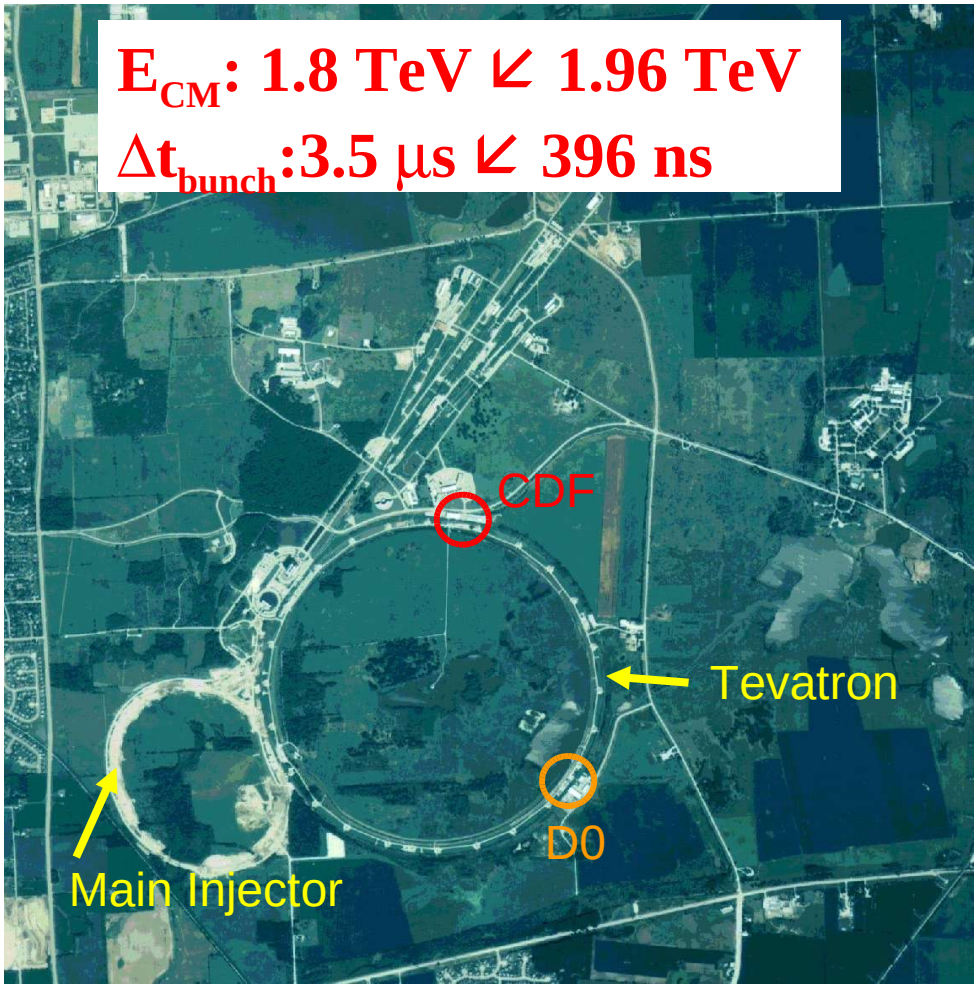


An Integrated Collider Program

- Staying at the energy and intensity frontiers is key
  - The Tevatron until ~2007-2008: CDF and D0
  - LHC after 2007: ATLAS
- Tevatron and LHC share people, technical knowledge and strategy
  - Senior physicists in common
  - Postdocs, students move between Atlas and CDF
  - Engineering and technical staff at cutting edge
- Strategic Plan: Migration from CDF to Atlas
  - Budget constraints: CDF group shrinks faster than planned or desired

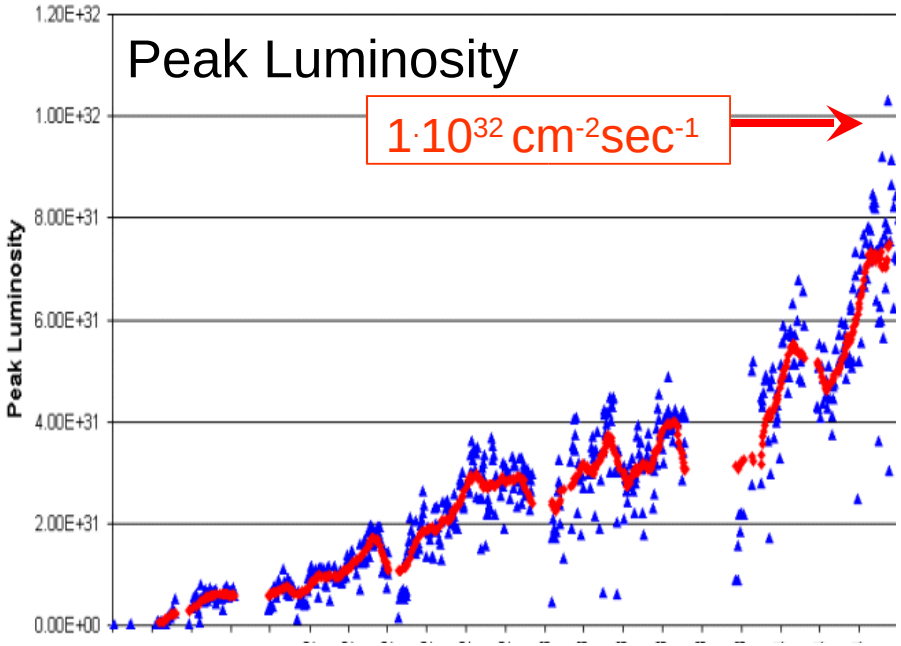
Upgraded Tevatron: Run II





- New Main Injector:
  - Improve p-bar production
- Recycler ring:
  - Improve p-par accumulation

Accelerator Performance



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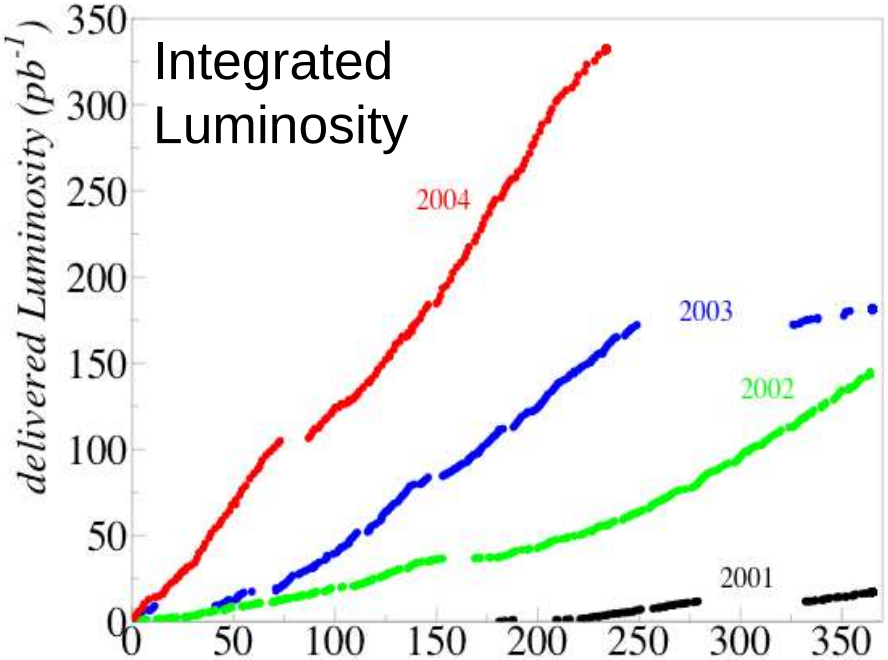
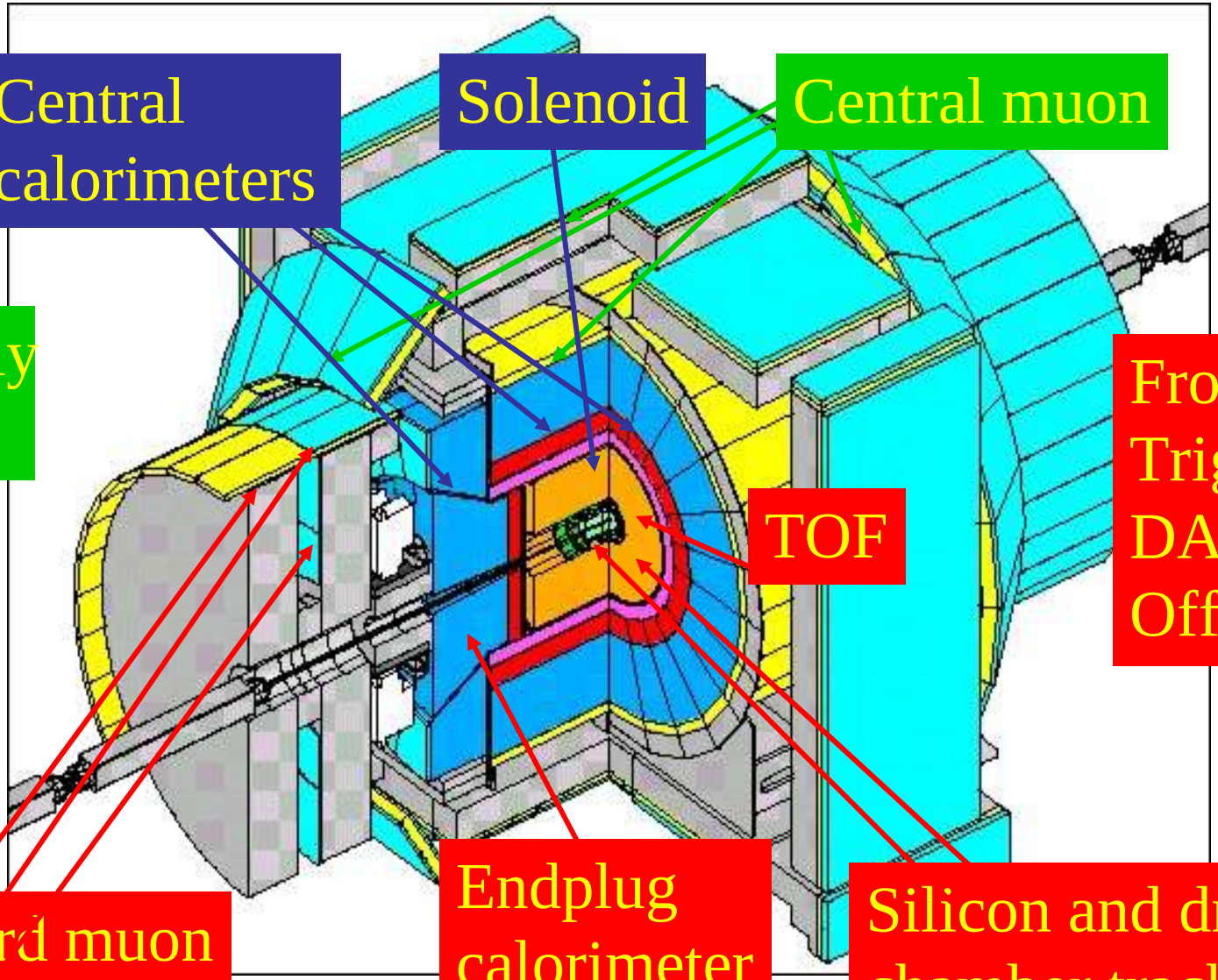


Peak luminosity > 10^{32} cm^{-2} sec^{-1}

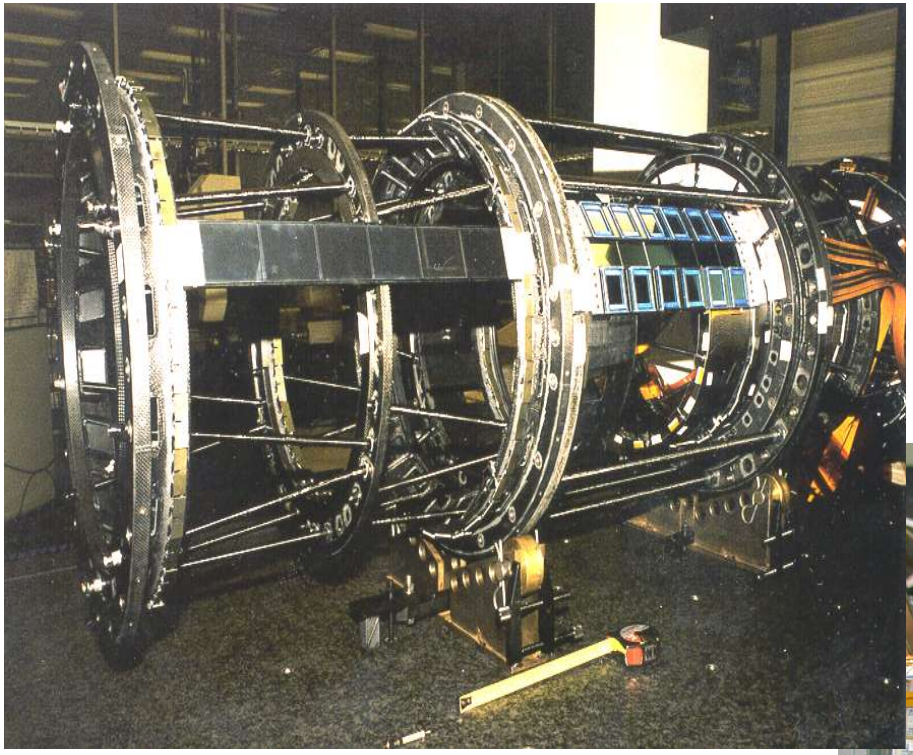
Total ~0.7 fb^{-1} delivered so far, $\geq$4 fb^{-1} by 2008

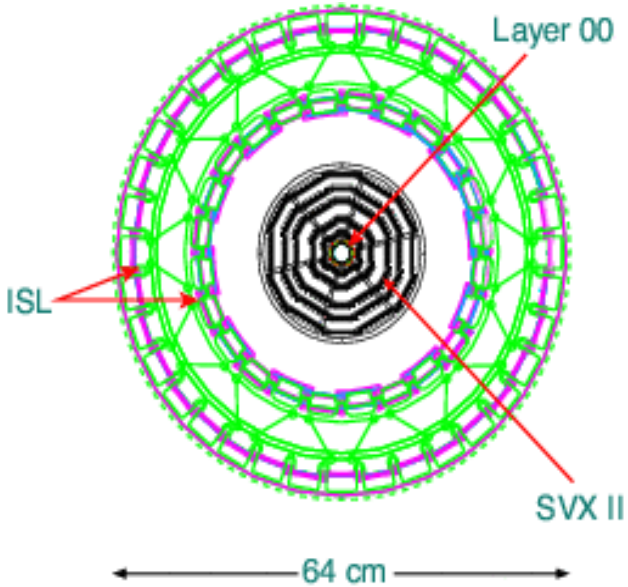
Installing electron cooling during present shutdown
x2 improvement if this works.

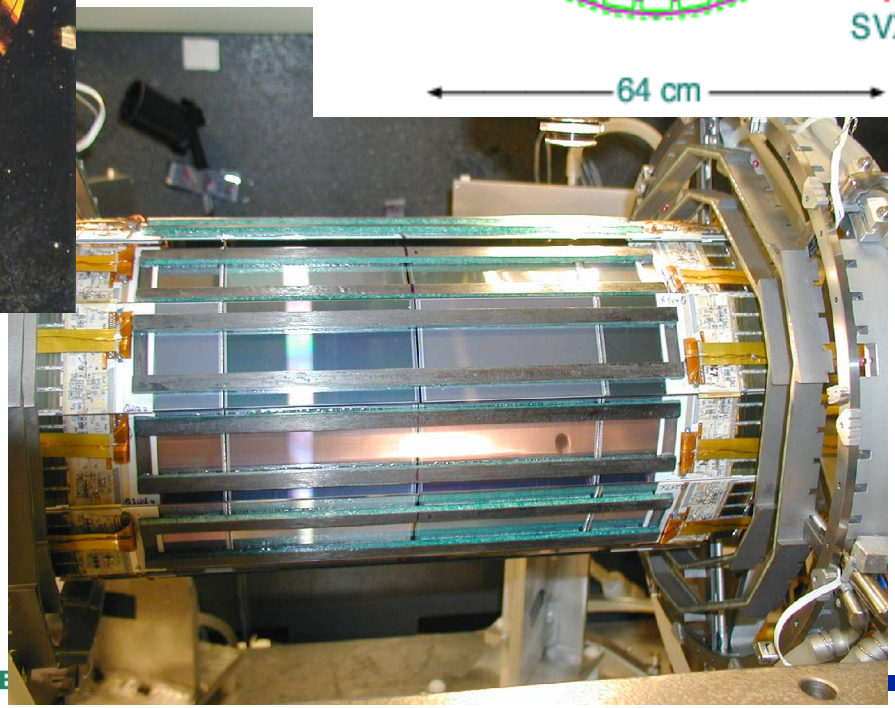
The Upgraded CDF Detector



Silicon Vertex Detectors





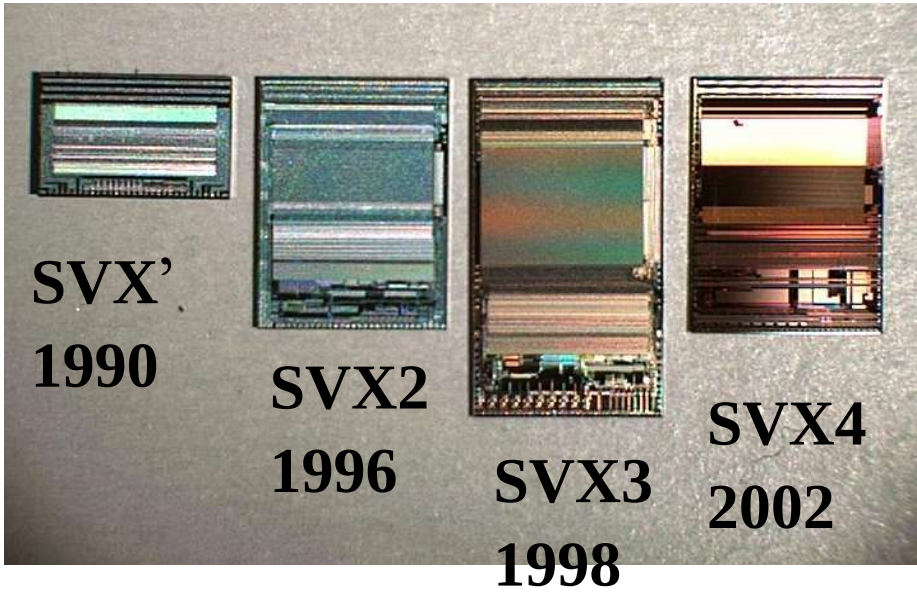


ISL

SVX

LBNL a Major Player in Silicon Vertex Detector Technology

- Silicon detectors transform physics capability of CDF
- Front-end electronics a real challenge
  - Good spatial resolution: can select tracks with large impact parameter
  - Low power, Low noise
  - Radiation Hard
  - Accomodates displaced track trigger
- LBNL contributed to generations of chips
- Essential knowledge for LHC



LBNL Contributions to CDF II

I. Construction

- Silicon detectors (SVX-II)
  - SVX3 chip (co-design with FNAL), test, probe
  - hybrids for L00, SVXII, ISL
  - associated electronics
- Drift Chamber (COT)
  - inner cylinder, field sheets
  - Conceptual design of alignment
  - Time calibration system
- Time of Flight (TOF)
  - Study laser calibration system
  - Install fibers, online monitoring

II. Commissioning

- COT Associated Project Manager
- Commissioning
- Silicon commissioning

III. Operation

- CDF II Operation Manager
- SVT operation

IV. Computing and software

- Project manager
- Codegen for relational data bases
- Data handling software for early tests
- Silicon Code librarian

Run II LBNL Responsibilities on CDF

Detector Operation (MOU)

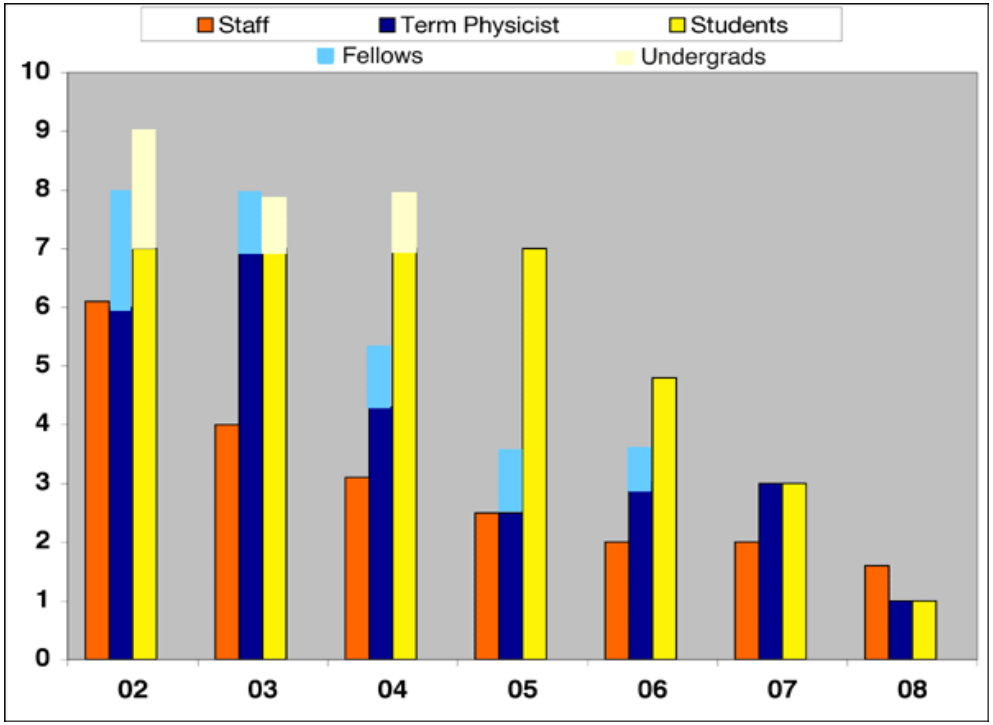
- Online silicon monitoring
- Offline Silicon calibration
- Online data monitoring (YMON)
- COT calibration

Other Responsibilities

- MC generators :
  - ISAJET
  - HERWIG, Wbbgen
  - ZGRAD
- Silicon geometry software
- Silicon Tracking software
- Secondary vertices code
- Passive material description

Things are a'Changing...

- Budget pressure has forced premature contraction of the CDF group



- Have relinquished many CDF responsibilities this year

Time for LBNL to Reap the Rewards from Years of Hard Work

- Group now concentrating on physics analysis
  - Tevatron best window for new physics until LHC turn-on
  - Large data samples being collected now
  - Detector working well
- Many first round analyses at or near completion
- Work on next generation of measurements underway
  - We still have 7 excellent students who will do PhD work on CDF, as well as a 2 outstanding postdocs and 1 fellow

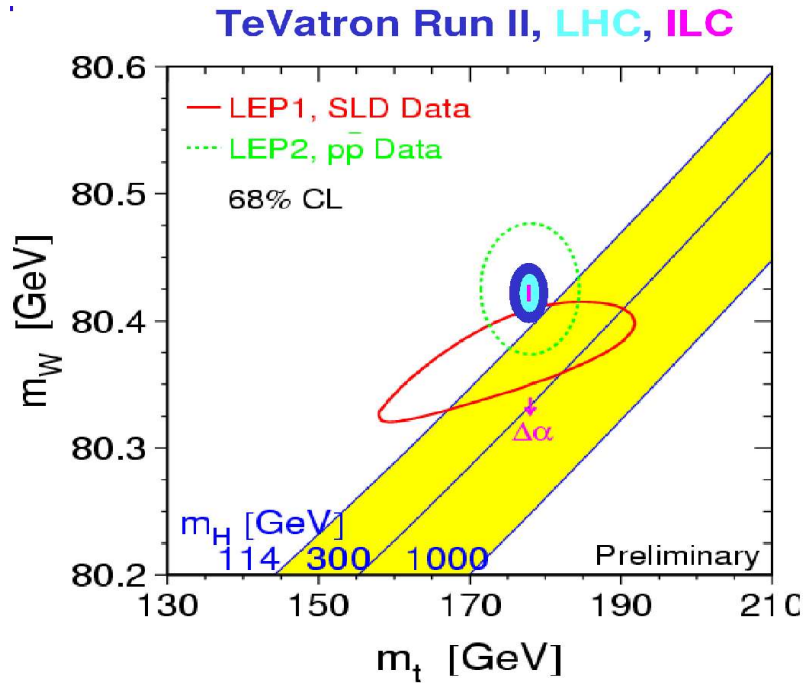
LBNL Physics Contributions

- Papers Submitted or Published
  - ttbar Production Cross Section in with Secondary Vertex b-tagging
  - Partial Widths and Search for Direct CP Violation in D0 Decays to K^+ K^- and $^+$
- Papers with Drafts Circulating in Collaboration
  - Cross Section of pp→ WX and ZX
  - Forward-Backward Charge Asymmetry of e+e- pairs
  - Bs/B0 Branching Fraction Ratio
  - Moments of Hadronic Invariant Mass Distribution in Semileptonic Decays
- Analyses Presented at Summer '04 Conferences
  - Top Mass in Lepton+Jet Channel Using a Multivarient Method
  - Top Mass in Lepton+Jet Channel using a Template Method
  - Search for Particles Decaying into bb with associated W Production

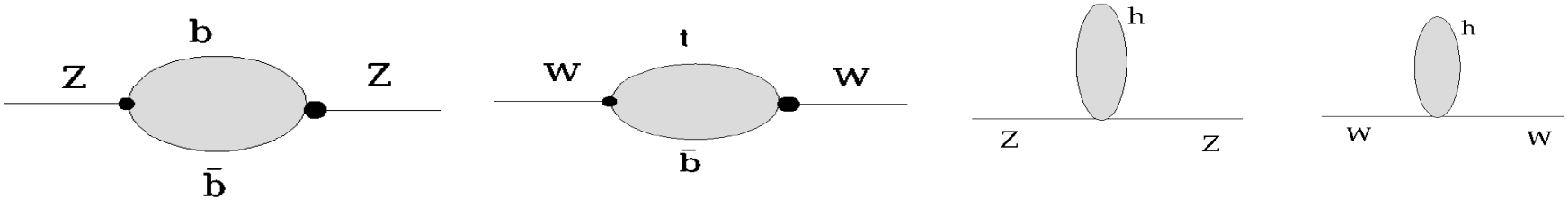
Will highlight only a few of these analyses here

Top Physics: Motivation

- Due to large mass, top plays unique role in EW rad. corrections
  - W mass sensitive to top and Higgs masses
- Does its large mass probe new physics?
  - Comparison of cross section in different decay modes
  - Top mass

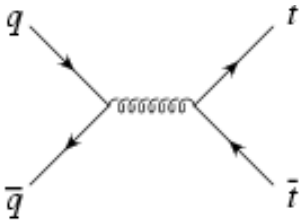


$$\left(\frac{M_W}{M_Z \cos\theta_W}\right)^2 = 1 + 0.0096\left(\frac{m_t}{175GeV}\right)^2 + \alpha ln\left(\frac{m_H^2}{m_W^2}\right)$$

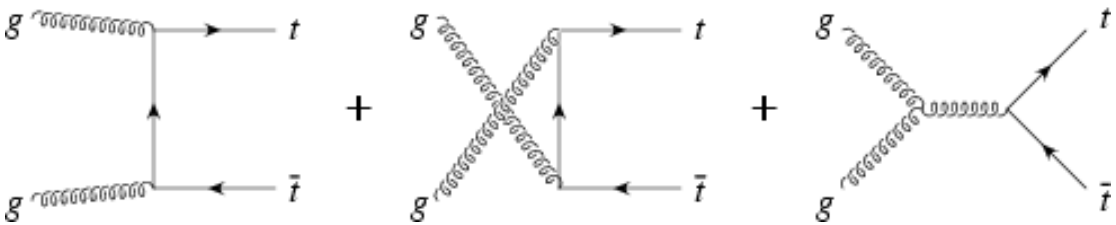


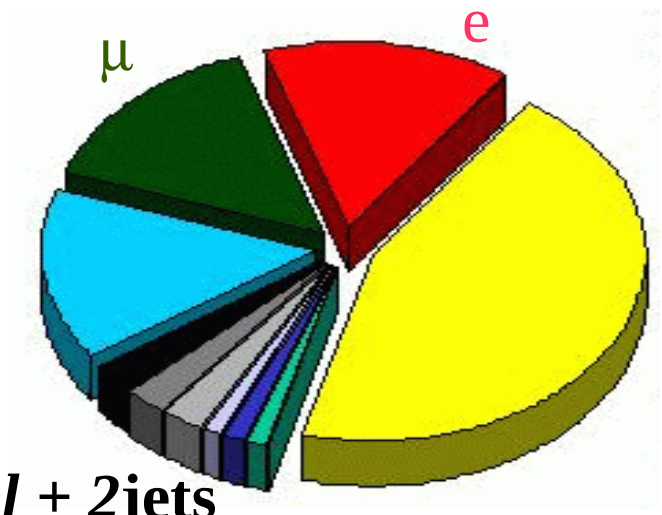
Top Production

- 85% qq annihilation, 15% gluon fusion at Tevatron



- Top Pair production

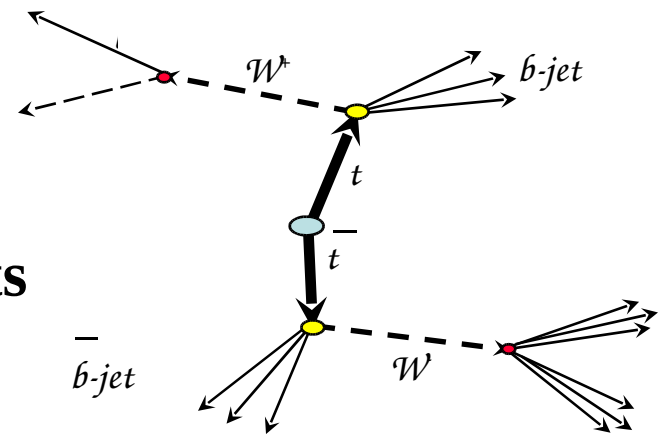




***l* + 4jets**

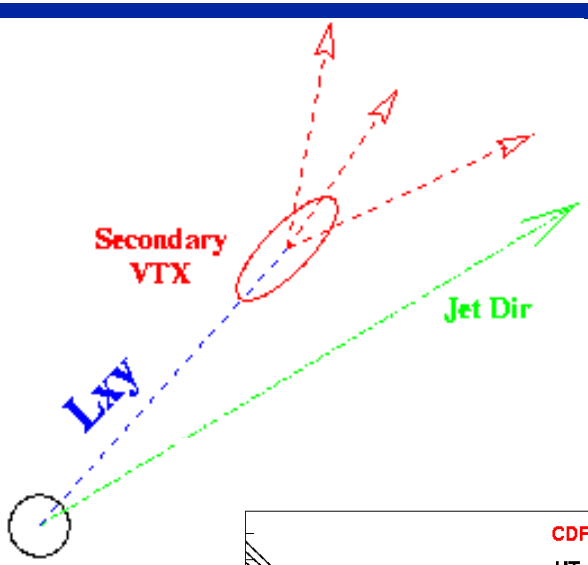
6 jets

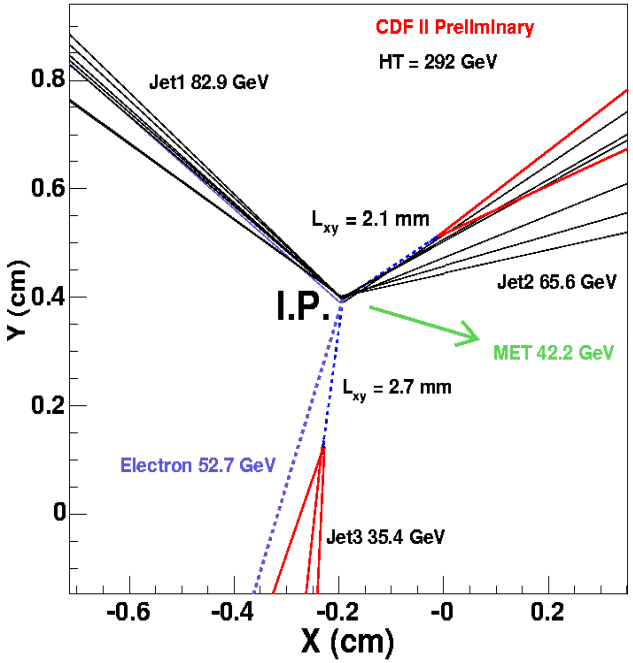
2*l* + 2jets



Top Physics Strategy

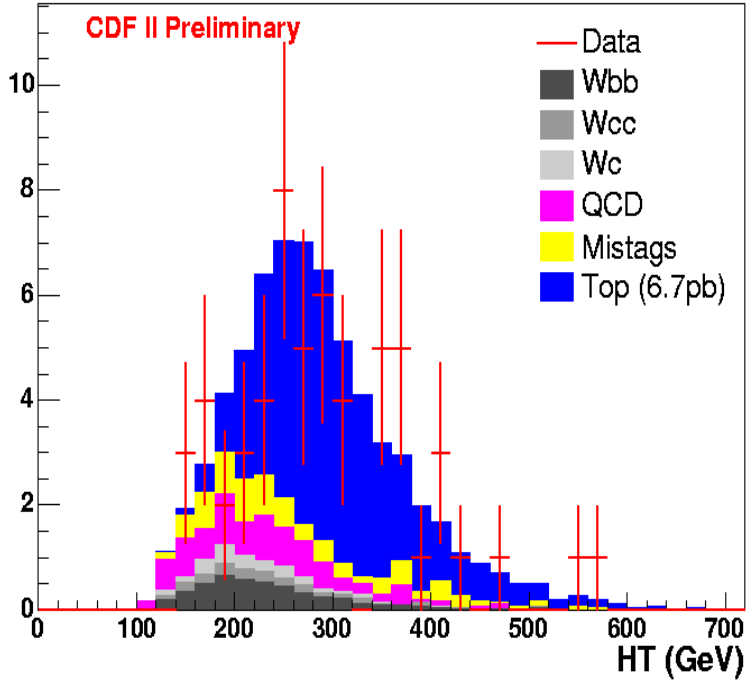
- CDF: measurements in all top decay channels
- LBNL: lepton+Jet mode
- Lepton+Jet Signature:
  - 1 isolated lepton
  - Missing momentum
  - 2 b's (secondary vtx)
  - 2 jets from W→qq
  - Large transverse energy flow (Ht)



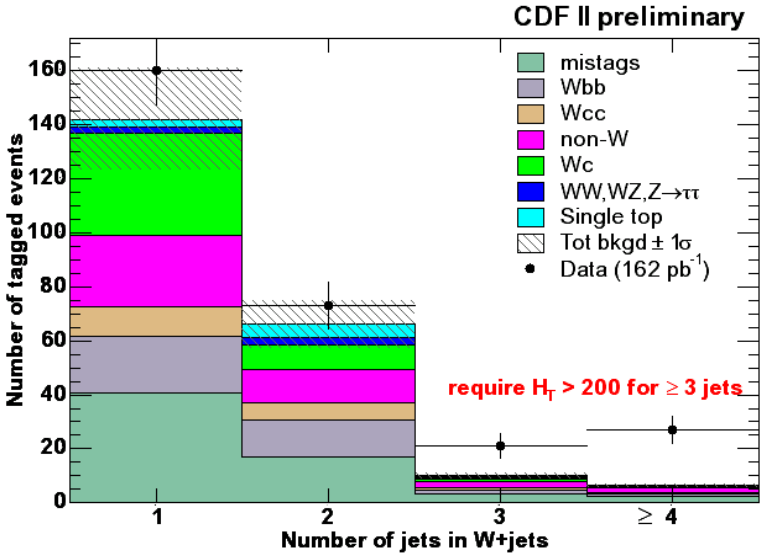


Top Cross Section
(Bachacou, Nielsen, Yao)

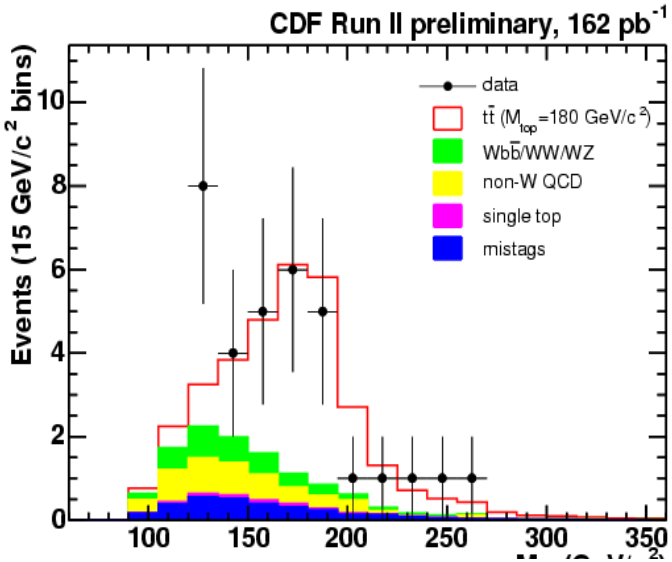
- Sample Selection:
  - Single b-tag
  - Tag efficiency from bb
  - Ht cut to reduce bcknd
- Lepton + Jet Bckgnd:
  - Wbb, Wcc, Wc
  - W+light jets (mistags)
  - QCD multijets

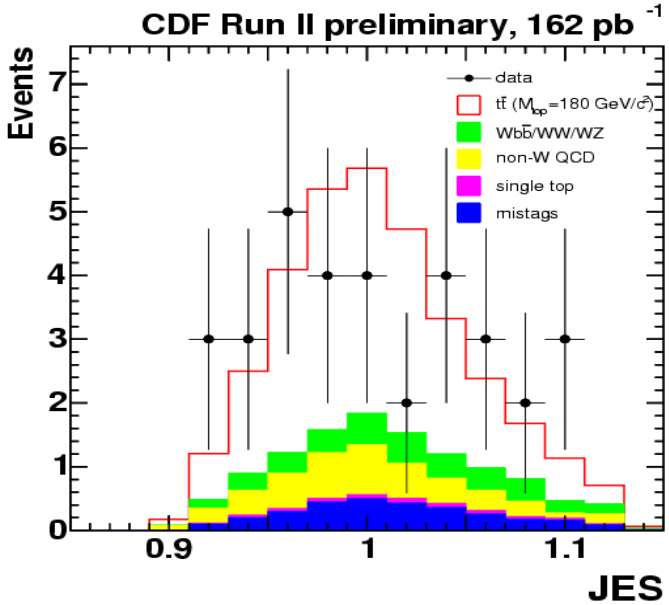


$$\sigma_{t\bar{t}} = 5.6^{+1.2}_{-1.0}(\text{stat.})^{+1.0}_{-0.7}(\text{syst.}) \quad \text{pb}$$



Top Mass



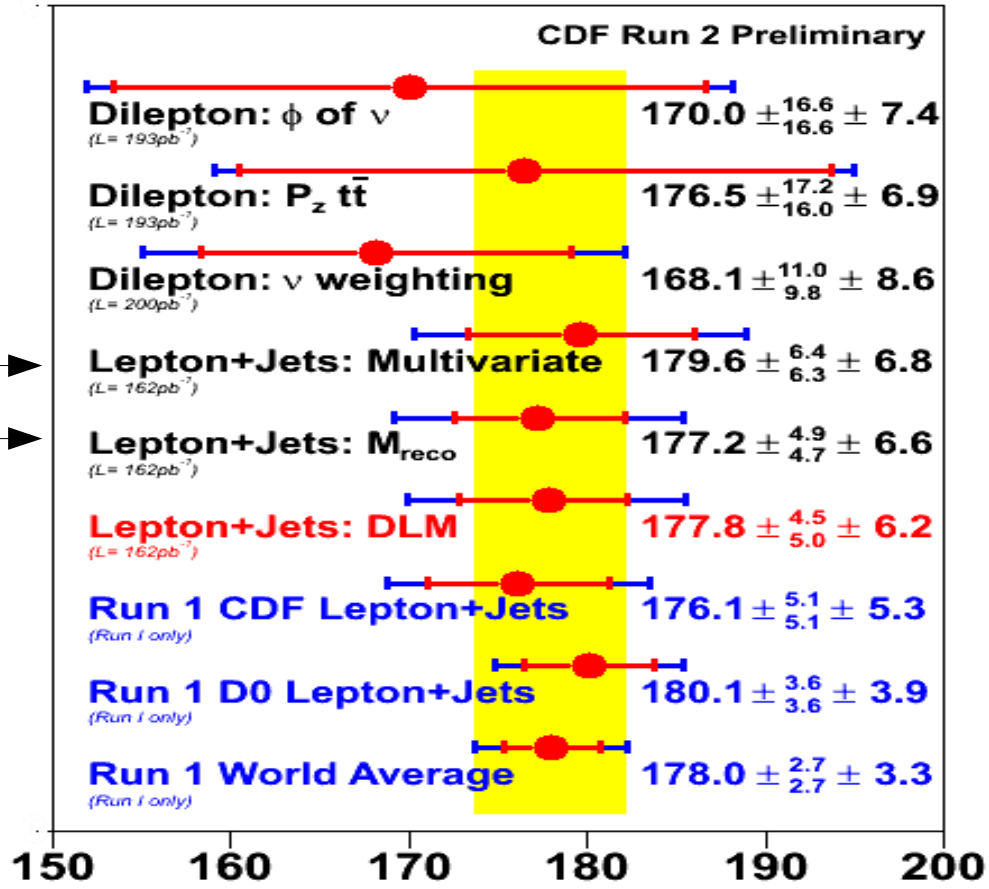


1. <u>Template Method</u>
   (Brubaker, Gibson, Chicago, Toronto)
   - likelihood method using templates for signal and background
   - Chooses best χ^2 soln
2. <u>Multivariant Method</u>
   (Volobouev, Fernandez, Freeman, Galtieri, Lys)
   - Varies Jet energy scale with W mass constraint
   - Uses all possible solns, weighted by probability
   - Multivariable templates

Summary of CDF Top Mass Results

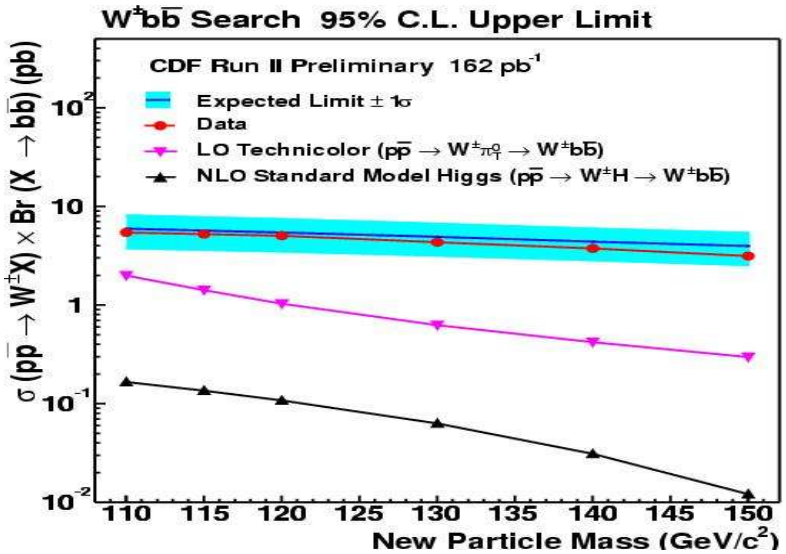
multivariant method

template method



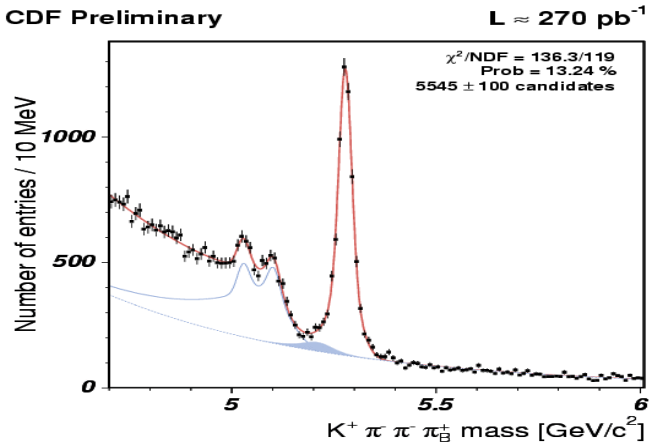
Search for New X→bb with W
(Yao, Tsukuba U.)

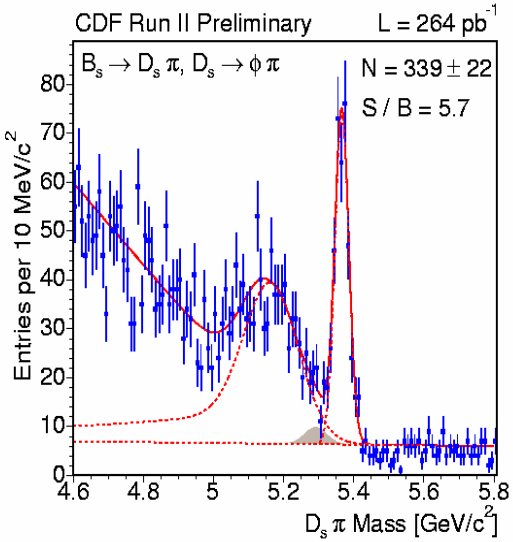
- Techniques developed in Top analyses can be used for other searchs
- Production of new particles in association with W
  - H→bb SM cross section too small for observation in current data
  - Models such as technicolor can predict larger σ

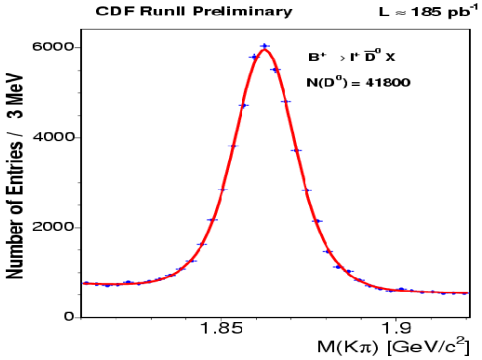


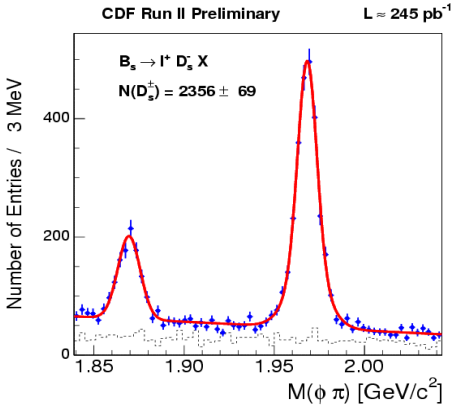
B Physics at CDF

- Babar and Belle producing beautiful results with high precision
- Is there a role for CDF?
  - Very high b production cross section
  - Bs and B baryons
- Concentrate on unique results or those where statistics make CDF competitive



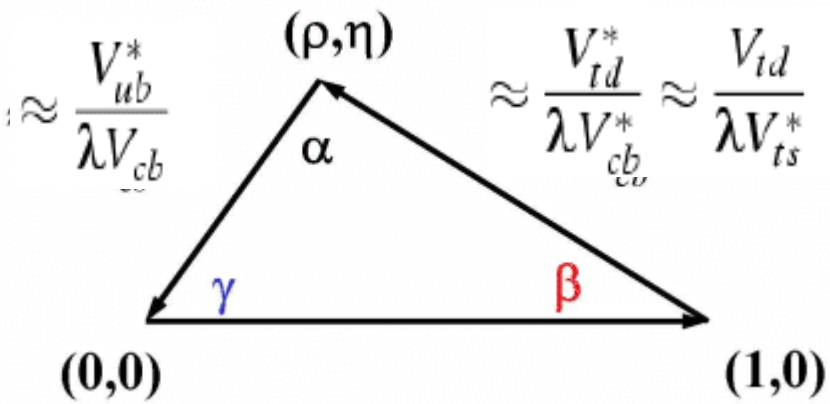






B Physics: Overview

- Quark mixing matrix: unitary if *only* SM decays occur
- Matrix has 3 real, 1 imaginary parameter
  - The source of CPV in SM
- Is the matrix unitary?
  - Measure sides and angles of triangle
- LBNL focus on 2 sides:
  - V_{cb}
  - $\frac{V_{td}}{V_{ts}}$



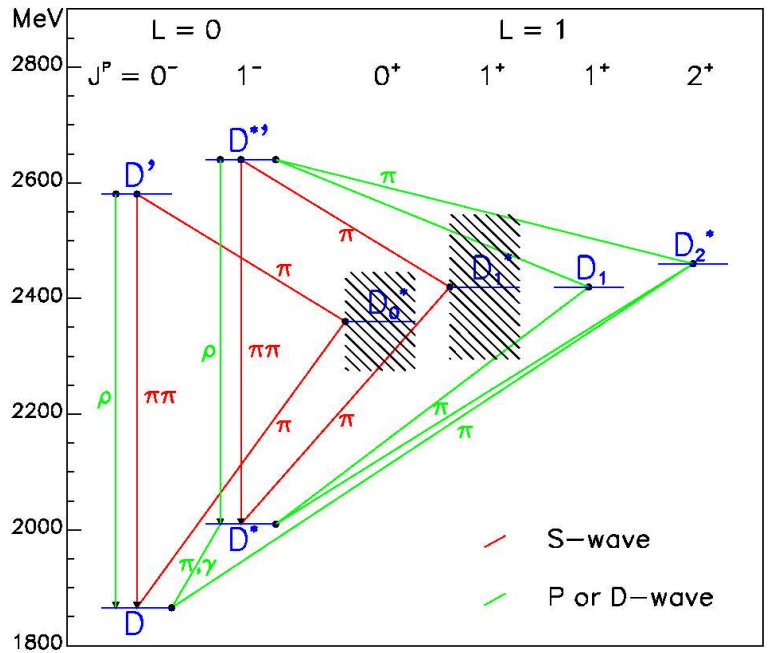
$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

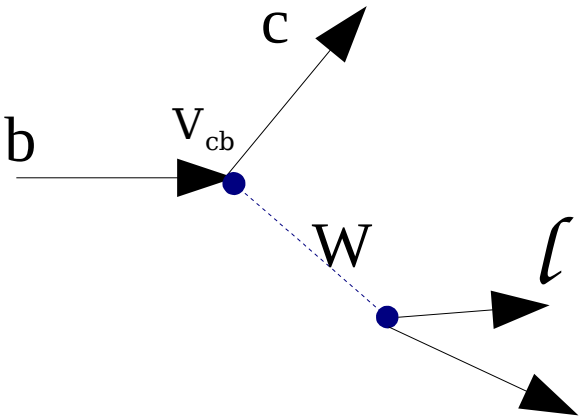
$$\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} + 1 + \frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*} = 0$$

$$V_{cd} = \lambda, \quad V_{ud} \approx V_{tb} \approx 1$$

Hadronic Moments in Semileptonic Decays: Motivation

- b→c transitions measure coupling Vcb
- Binding of b inside hadron affects decay rate
- Can parameterize QCD corrections as perturbative expansion: *measure* the coefficients from inclusive distributions (eq moments of hadronic recoil mass)

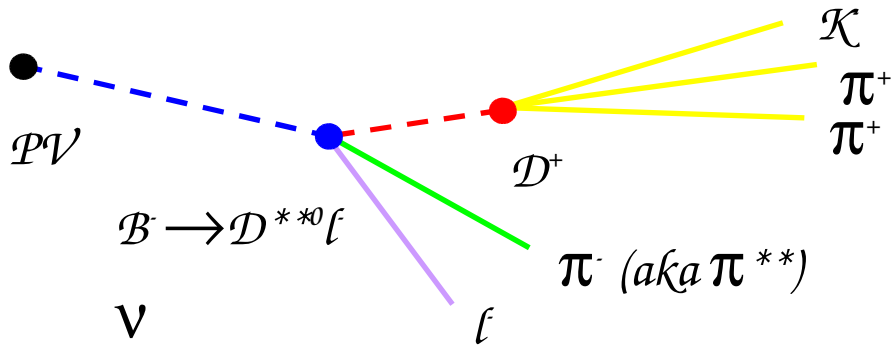


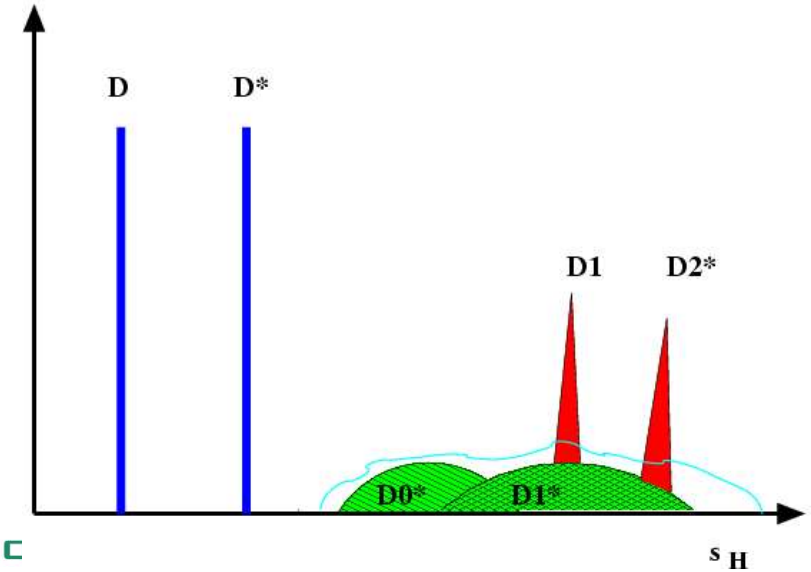


Moments Analysis Strategy

- Want to know full charm recoil spectrum (D, D*, D**)
- D and D* components already well measured
- This work: Measure shape of D** contribution (add π** to D* and D+)

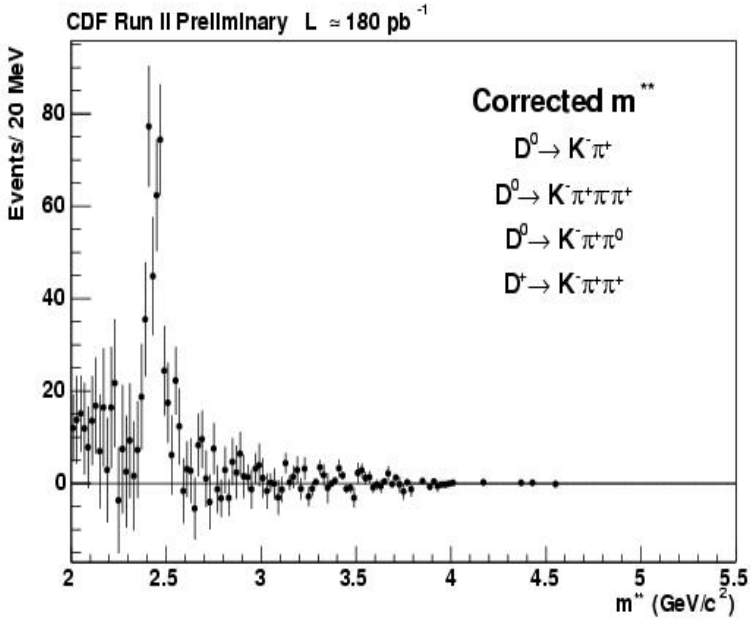
$$\frac{1}{\Gamma_{SL}}\frac{d\Gamma_{SL}}{ds_H} = \frac{\Gamma_D}{\Gamma_{SL}}\delta\left(s_H - m_D^2\right) + \frac{\Gamma_{D^*}}{\Gamma_{SL}}\delta\left(s_H - m_{D^*}^2\right) + \left(1 - \frac{\Gamma_D}{\Gamma_{SL}} - \frac{\Gamma_{D^*}}{\Gamma_{SL}}\right) f^{**}(s_H)$$

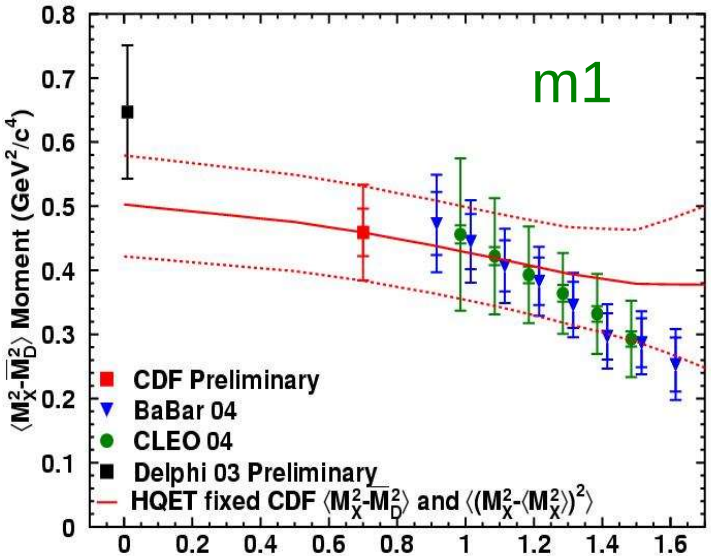


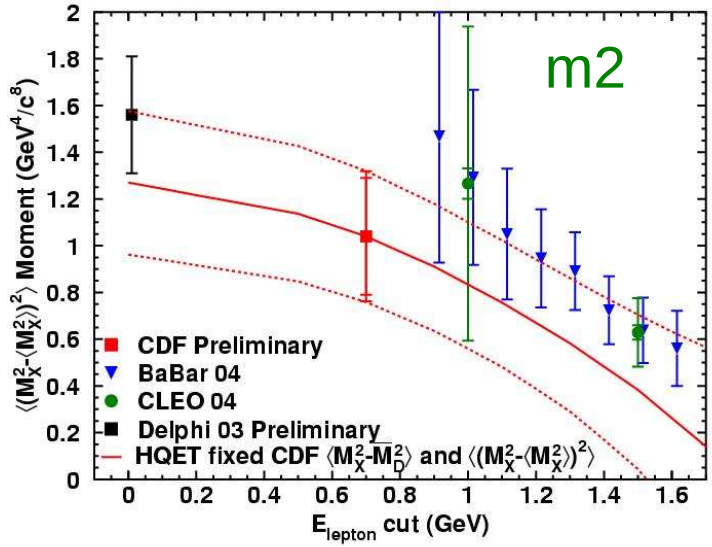


Moments Analysis Results
(Cerri, Fang, Miquel, Shapiro, Vacavant)

- Correct M** distribution to fixed lepton p*



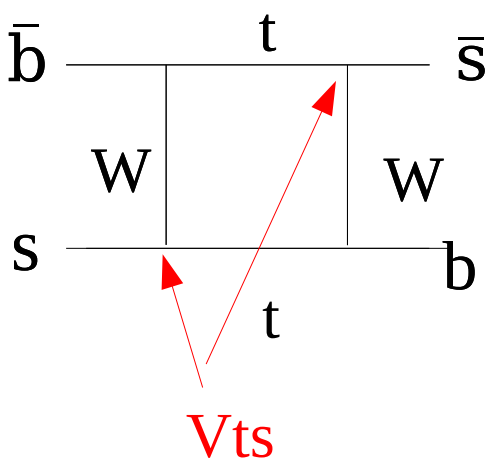


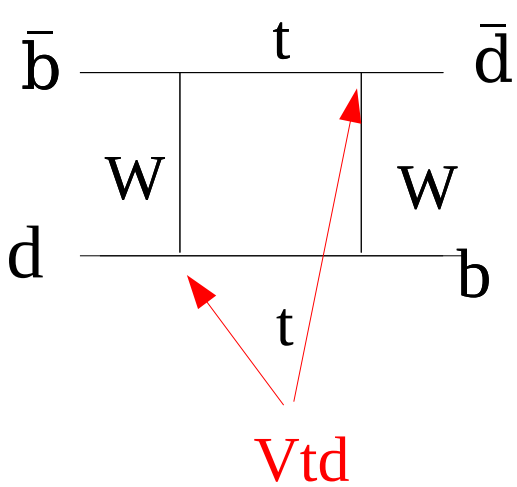


- Combine with D and D*
- Extract QCD parameters λ, λ1
- Theory predicts evolution with p*

Bs Mixing: Motivation

- Bs mixing: flagship for CDF B Program
- Bd and Bs mixing together allow determination of $\frac{V_{td}}{V_{ts}}$
- This is a <u>hard</u> measurement
  - Low statistics for Bs reconstruction
  - Need to ``tag'' flavor at production
  - Must measure time dependent oscillation





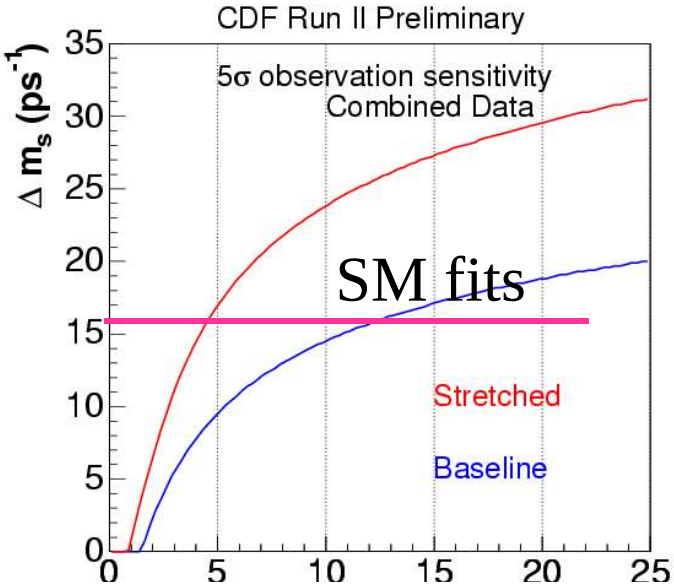
Bs Mixing Strategy

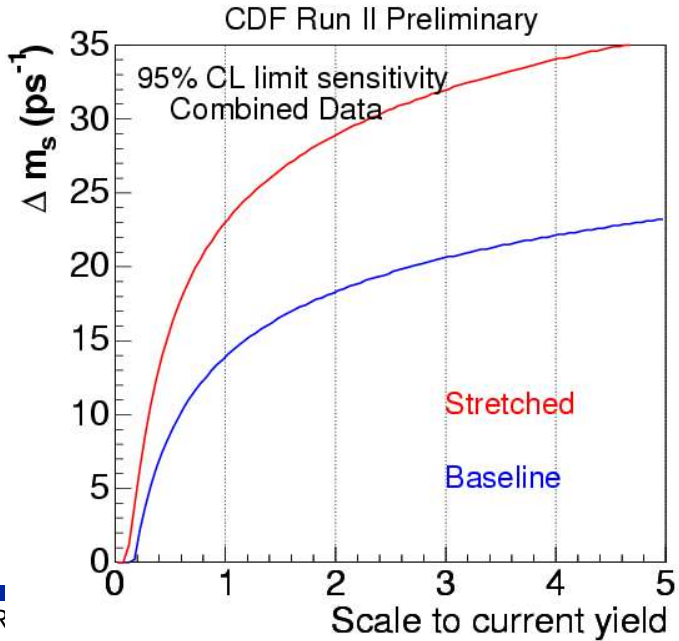
- Optimize yield of Bs
  - Use many modes
  - Cuts to give best signal significance
  - Improvements in trigger
- Optimize vertex resolution
  - Primary Vertex determined event-by-event
  - Best possible silicon tracking
- Optimize Tagging
  - Combine many tags

LBNL activities in areas marked in red

(Beringer, Cerri, Deisher, Muelmenstaedt, Shapiro)

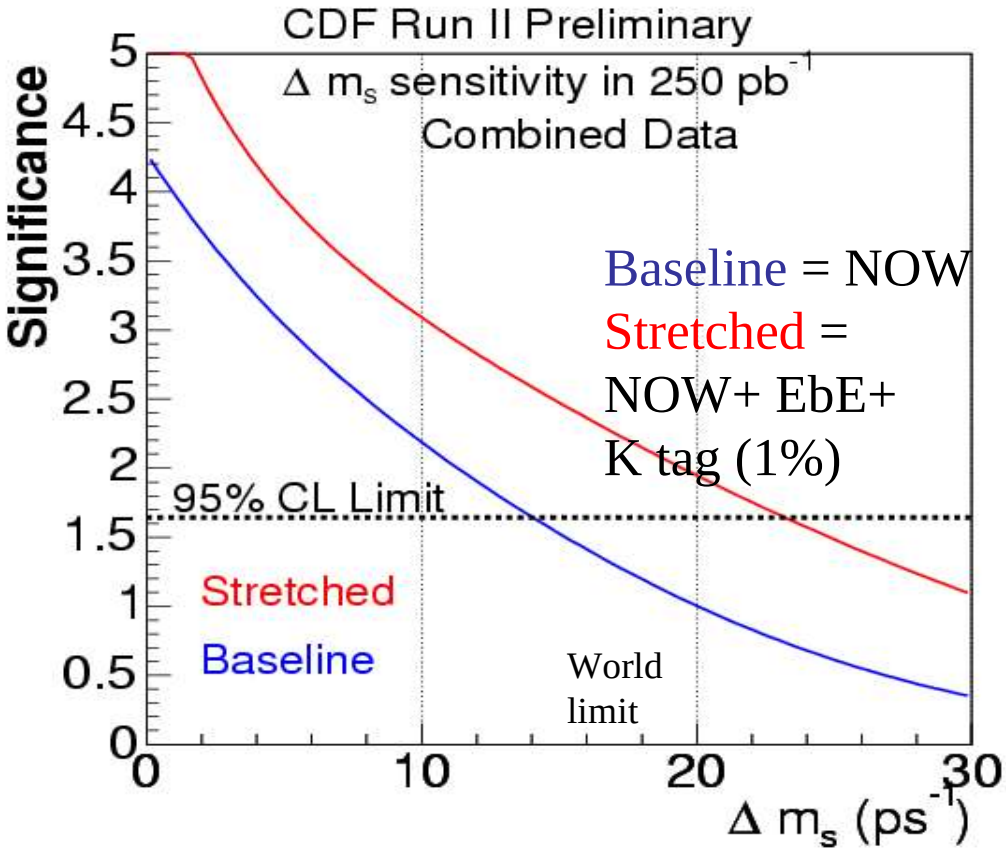
Bs Mixing Projections





World limit:
$\Delta m_s > 14.4\ ps^{-1}$

SM pred. (99% prob.):
$15 < \Delta m_s < 27\ ps^{-1}$



Conclusions

- LBNL made major contributions to CDF
  - Silicon Vertex Technologies
  - Construction, Commissioning, Operations
  - Scientific Leadership
- Current focus on analysis of data
  - Electroweak production
  - Top cross section and mass
  - Search for new particles
  - CKM matrix measurements from B decays
  - 9 papers published or in preparation this year
- Tevatron performance is improving: will mine the data until LHC turn-on

Backup Slides

People

Physicists-Staff

A. Galtieri
J. Beringer**
R. Ely*(retired)
M. Garcia-Sciveres*
C. Haber*
Y.K. Kim (now Chicago)
J. Lys *(retired)
R. Miquel** (now SNAP)
M. Shapiro*
J. Siegrist*
W. Yao**

Fellows

M. Weber (now Rutherford)
P. M. Fernandez

Physicists-Term

A. Cerri
A. Dominguez (now Nebraska)
J. Nielsen
B. Orejudos (now industry)
L. Vacavant* (now IN2P3)
I. Volobouev (now SLAC)

Grad. Students

G. Veramendi (now Illinois)
H.C. Fang
E. Brubaker (now Chicago)
H. Bachacou
A. Gibson
J. Freeman
J. Muelmenstaedt
A. Deisher
P. Lujan

Undergrad. Students

L. Tompkins
E. Feng (to ATLAS)
M. McFarlane

Visitors

F. Zetti
M. Tavi (Finland)

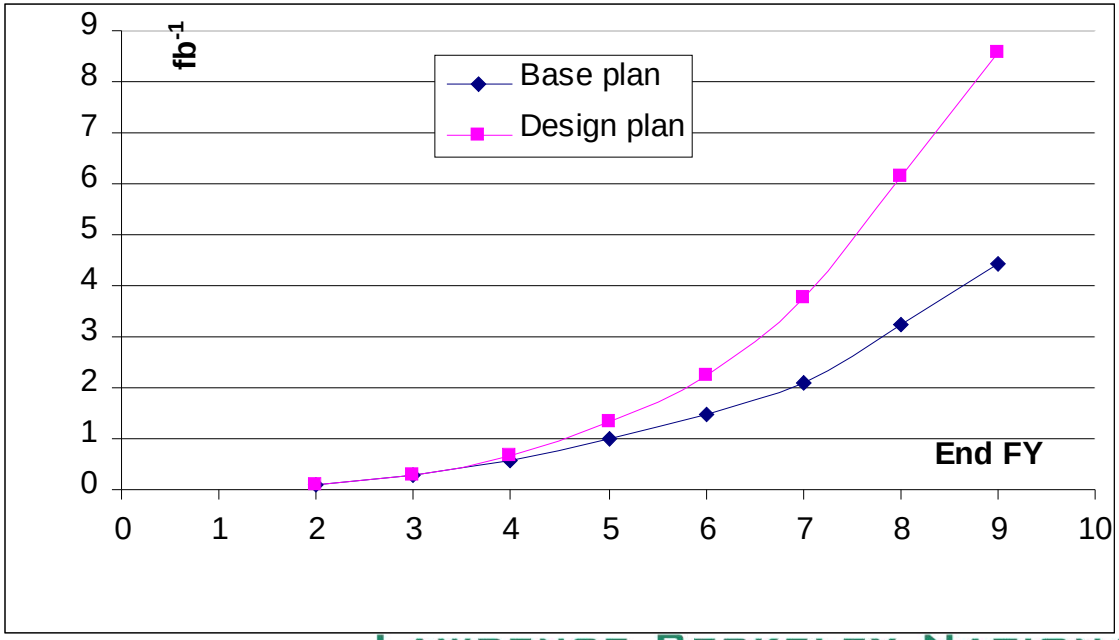
* Atlas
** PDG

green=left CDF this year

Extended TeV goals

$\mathcal{L}_{max}$ = 2-3 x 10^{32}

- Luminosity plan 2002
- Goals 2002 - 04 accomplished
- Goals 2004 ~ 310 - 380 pb^{-1}
  - Tevatron is performing very well



Year	Base plan luminosity/yr (fb^{-1})	Design plan Luminosity/yr (fb^{-1})
FY02	0.08	0.08
FY03	0.20	0.22
FY04	0.31	0.38
FY05	0.39	0.67
FY06	0.50	0.89
FY07	0.63	1.53
FY08	1.14	2.37
FY09	1.16	2.42
Total	4.41	8.56