The CDF Group at LBNL

Angela Galtieri

LBNL Director Review, November 8-9, 2005

Outline

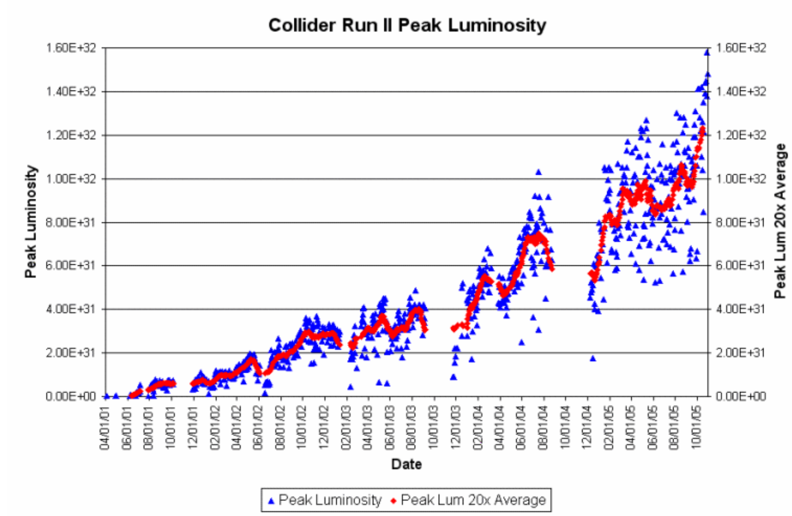
- Status of the Tevatron
- LBNL Group
- CDFII Detector
- Contributions to CDFII
  - Hardware
  - Operation
- Recent Contributions to Analysis Tools
- Physics Program
  - B physics
  - Top Physics
  - New Phenomena
- Summary and Conclusions

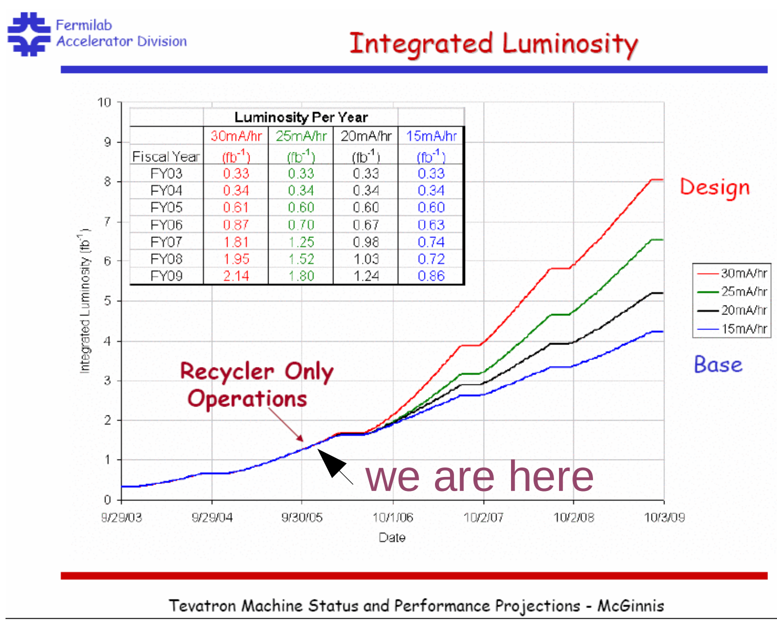
Tevatron Status and Plans

Tevatron has been doing very well. It is on the Design curve.

Record luminosity: 1.64×10^{32}

Needs to improve pbarstacking rate to 30 mA/hr to stay on the Design curve

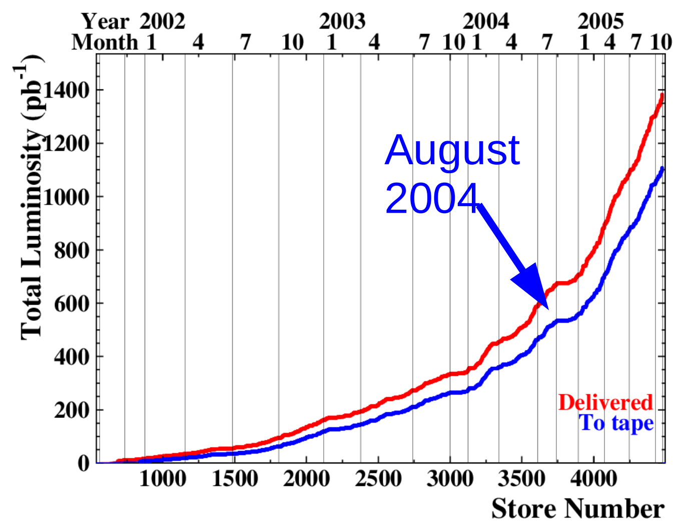




Luminosity Per Year

Fiscal Year	30mA/hr (fb^{-1})	25mA/hr (fb^{-1})	20mA/hr (fb^{-1})	15mA/hr (fb^{-1})
FY03	0.33	0.33	0.33	0.33
FY04	0.34	0.34	0.34	0.34
FY05	0.61	0.60	0.60	0.60
FY06	0.87	0.70	0.67	0.63
FY07	1.81	1.25	0.98	0.74
FY08	1.95	1.52	1.03	0.72
FY09	2.14	1.80	1.24	0.86

Presently have 850 pb^{-1} with Silicon, mostly processed. Expect ~ 1 fb^{-1} by 3/1



Members of the LBNL Group

Physicists-Staff (2.7 FTE)
A. Galtieri
J. Beringer**
C. Haber*
J. Lys *
R. Miquel** (now SNAP)
M. Shapiro* (UC Berkeley)
J. Siegrist* (UC Berkeley)
W. Yao**

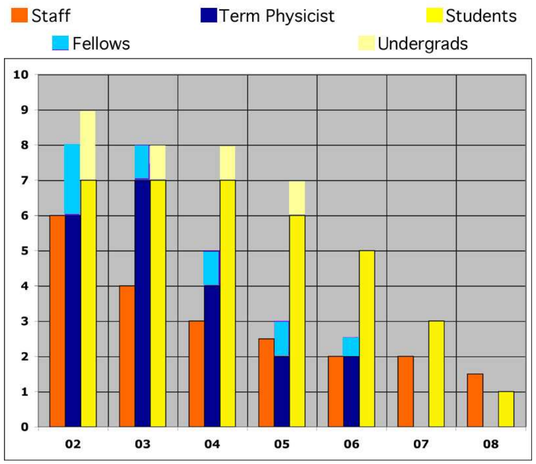
Physicists-Term (2 FTE)
A. Cerri
J. Nielsen

Fellows (1 FTE)
P. M. Fernandez

Grad. Students(6.5FTE)
H. Bachacou (now Orsay)
H. C. Fang
A. Gibson (PHD end '05)
J. Freeman
A. Deisher
J. Muelmenstaedt
P. Lujan

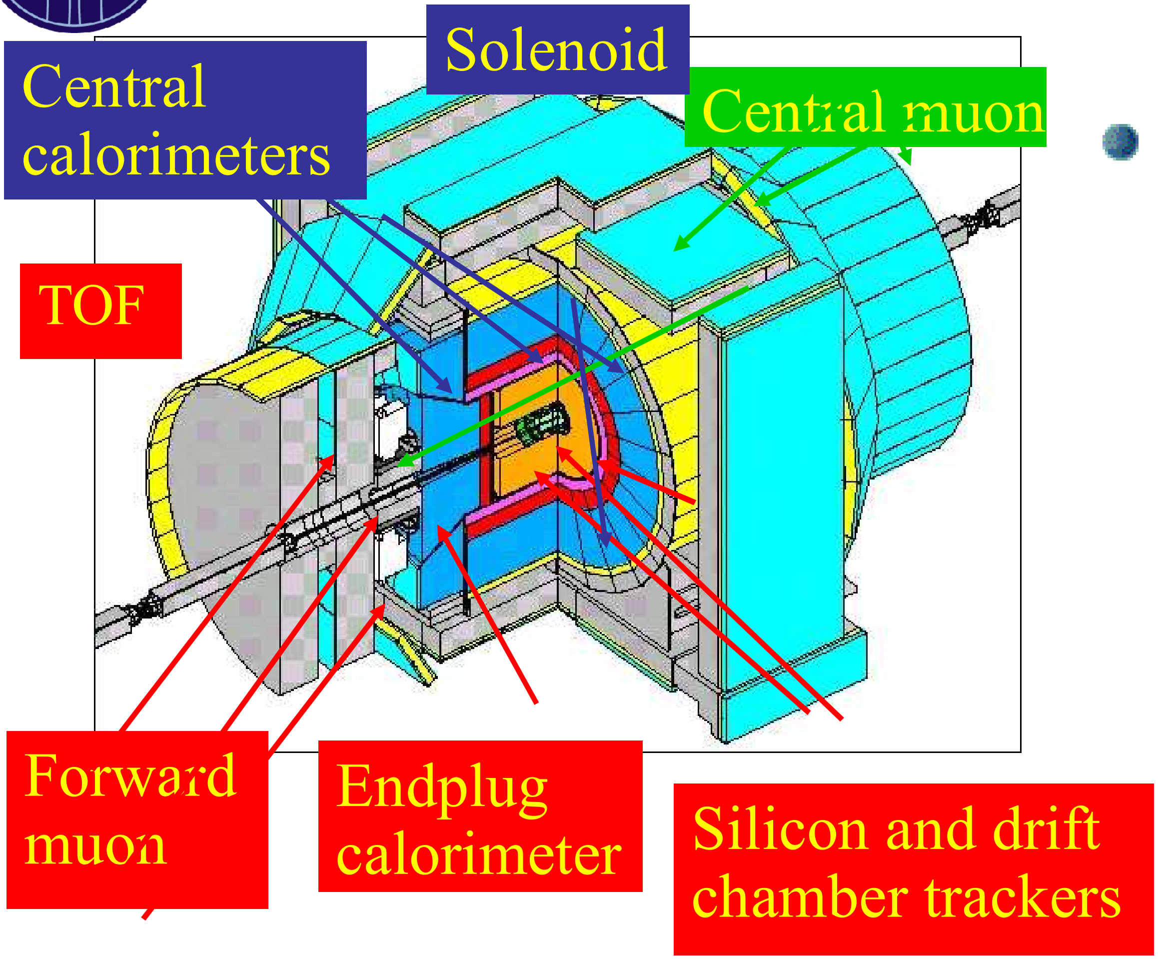
Undergrad. Students (1FTE)
M. McFarlane

Guest
I. Volobouev



***ATLAS,** ** PDG
FTE refer to FY05

CDFII Detector



- CDF recent upgrades
  - Improved photon detection
    - EM calorimeter: timing readout added
    - Central preshower: wire chambers replaced with scintillation tiles
  - DAQ upgrade
    - To match the trigger: 20MB/sec -> 60 MB/sec
  - Trigger Upgrade
    30KHz(L1), 1KHz(L2) 100Hz(L3)

LBNL Contributions : Silicon detectors, COT, TOF

Commissioning, Operation, Software

Silicon Detectors: LBNL contributions

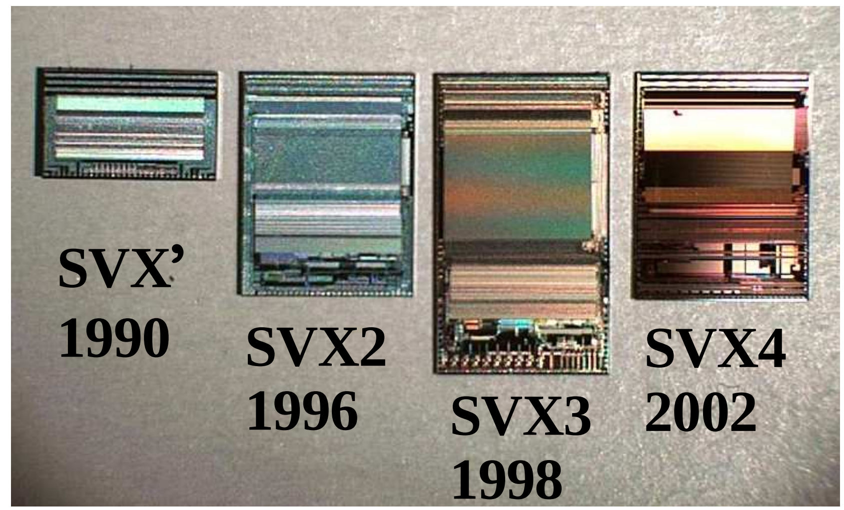
Silicon detectors transformed physics capabilities of CDF since early '90. LBNL is a major player in Vertex Detector technology. Long standing tradition, now applied to LHC.

- LBNL designed SVX, SVX'.
- Joint designs with FNAL since.
- SVX3 used in CDFII

RUN 2b R&D and prototyping

- SVX4: developed for Run 2b
  Project canceled due to budget cut.
  Chip used by D0, Phenix at BNL
- Conversion to .25 micron CMOS technology proposed by LBNL. Later used by ATLAS pixel chip
- Hybrids and "stave" (new detector concept : integrated electrical, mechanical and cooling unit) being evaluated by ATLAS

Rad hard chips for Silicon Detectors



SVT, displaced vertex trigger
Extended B physics capability

LBNL Contributions to CDF II

I. Construction

- Silicon detectors
  - 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
- TOF
  - Study laser calibration system
  - Install fibers, online monitoring

II. Commissioning

- COT Associate Project Manager
- COT Commissioning
- Silicon commissioning

III. Operation

- CDF II Operation Manager
- SVT operation
- Silicon Operation (ongoing, see later)

IV. Computing and software

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

LBNL Contributions to CDFII

Detector Operation (MOU)

- Silicon calibration (Nielsen)
- Silicon good run list (P. Lujan)
- SVT online monitoring checks, SVT hardware support, upgrade code consultant (A. Cerri)
- DAQ shifts (3 months service) (FY04-05: 3 students, one fellow)
- SCI-Co or CO shifts (everybody)

moved to other groups

- Online silicon monitoring (to John's Hopkins)
- Online data monitoring (YMON) (to Rochester))
- COT calibration (to FNAL)
- SVT data taking: pager (to Pisa)

Software Responsibilities (MOU)

- MC: EVTGEN, B decays generator (Juerg Beringer)
- GFLASH tuning (P. Fernandez)
- SVT simulation (A. Cerri)

moved to other groups

- MC generators : ISAJET (Galtieri), HERWIG, Wbbgen (Lys), ZGRAD (Gibson)
- Silicon geometry (A. Dominguez)
- Passive material (L. Vacavant)
- Silicon Tracking (W. Yao)
- Secondary vertices code (W. Yao, A. Dominguez)

Contributions to Analysis Tools in 2005

Exploit group expertise to optimize data taking and detector performance.
Develop reliable tools to perform physics analysis.
Essential for precision measurements.

- EVTGEN: improved B decays simulation (Beringer)
- Trigger efficiency for electrons (for all High P_T physics groups)
- Improved offline code, Gen5, and validation for top group analysis. Validate Gen6 using W cross section data (Freeman,Nielsen)
- Improved Scale Factor (data/MC) for electron ID (McFarlane, Yao)

- Trigger studies for B physics (improve B_s mixing measurement)
- Silicon b tagging high P_T (efficiency, scale factor, NN)
- Jet corrections and systematics (smaller systematics on top mass)
- Improved impact parameter resolution (better B_s mixing sensitivity)

Trigger studies for B physics

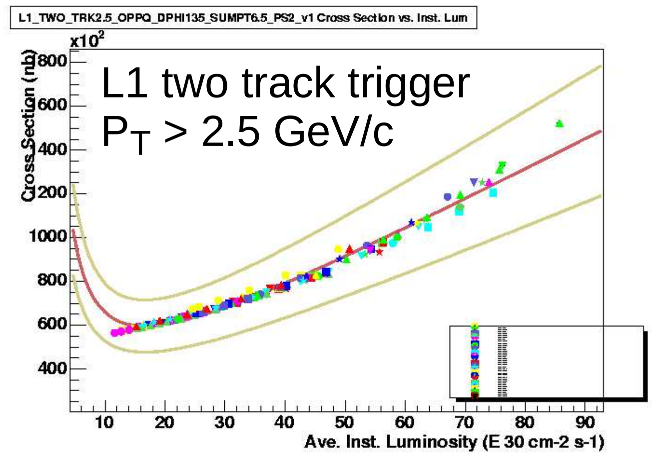
Deisher, Muelmenstaed, Beringer, Cerri, Shapiro

Trigger Upgrade: 30KHz(L1), 1KHz(L2) 100Hz(L3)

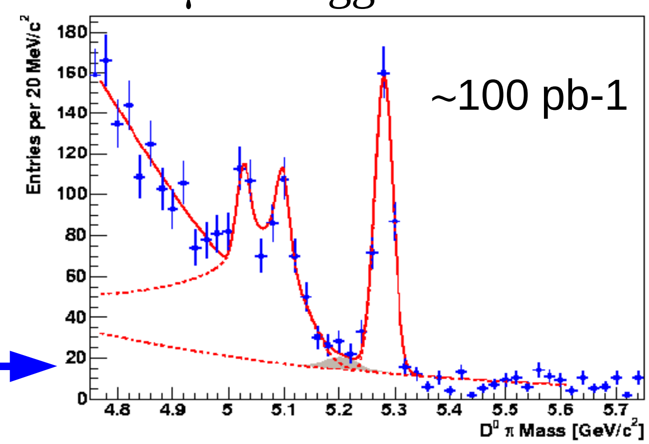
- B cross section is very large
- The "trigger cross section" increases with luminosity as $\mathcal{L}^2$
- Need new trigger strategies to keep collecting hadron B decays (essential for B_S mixing) at high luminosity
- Reduce event rate without rejecting taggable candidates

Solution:

- Require b tag at trigger level, i.e, require a muon trigger with the 2 tracks at L1.
- Keep the SVT cut of 120 μm for the impact parameter at L2
- This will give us b events enriched in b-tags (the muon).

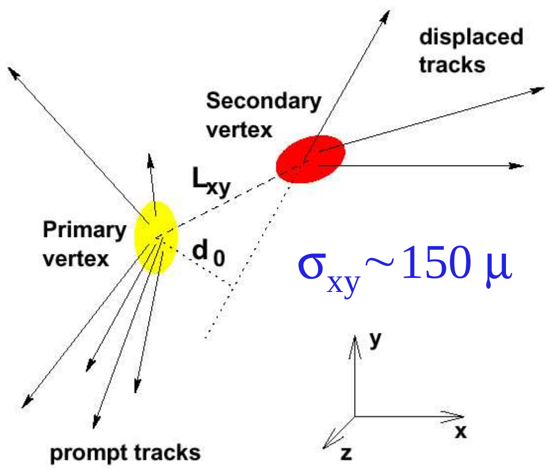


μTT trigger test



Displaced vertex b-tagging (SECVTX)

H. Bachacou, P. Lujan, M. McFarlane, J. Nielsen, W-M Yao



Displaced vertex algorithm allows detection of b quarks, important for B physics, top, and Higgs

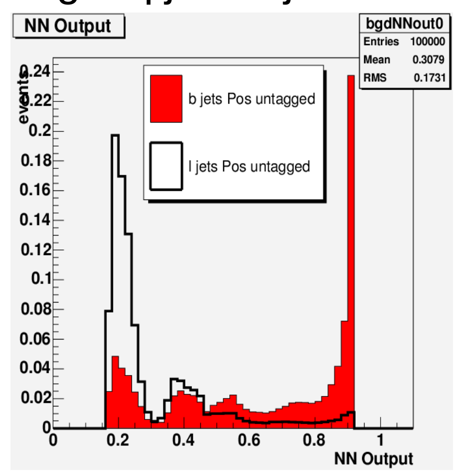
- tt event efficiency =(55±5)%, **now (60±3)%**
- Efficiency for a second tag in top events (24.0±1.7)% , **now (25±2)%**
- Efficiency ratio between data and MC (86 ± 7)%, **now (91± 6)%**

NN improve tagging efficiency.

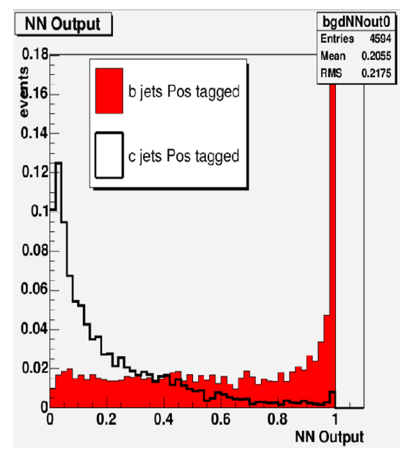
Combine SECVTX (reconstructed secondary vertices) with JetProb (single displaced tracks).

- Improved efficiency by ~25%
- Reduced backgrounds from c and light quark jets by ~fac. 2

light q jets-b jets



charm jets-b jets



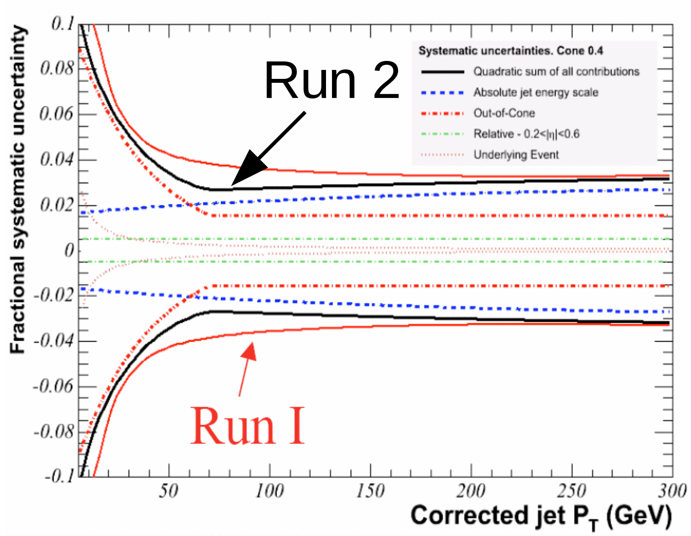
Jet Corrections and systematics

Pedro Fernandez, L. Galtieri, A. Gibson, P. Lujan

- Long standing expertise on jets in LBNL group (since 1986).
- Run2 systematic uncertainties now smaller than Run1

Improved ΔM_{top} syst.. by factor ~2

Systematics on jet P_T

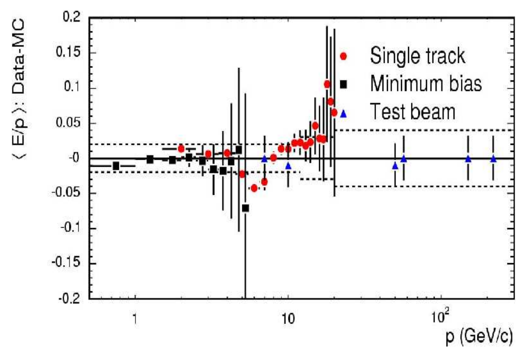


Paper submit. to NIM (10/'05)

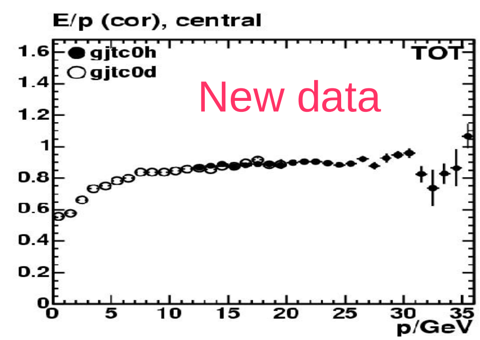
Work in progress

- Large sample of isolated tracks
- Tuning of GFLASH can be extended to 35 GeV (from 5 GeV)
- Lateral tuning of GFLASH will help reduce Out-of-Cone syst.

Present syst. on E/P



E/p for isolated tracks



Publications 2004-2005

Papers published or submitted for publication

- ttbar Cross Section with Secondary Vertex b-tagging (Bachacou PHD)
- Moments of Hadronic Inv. Mass Distribution in Semileptonic Decays
- F-B Charge Asymmetry in e+e- pairs (Veramendi PHD Thesis)
- Combined limit for Higgs Production (Run I)
- b-bbar correlations (A. Affolder PHD thesis, Run I)
- Partial Widths and Search for Direct CPV in D0 Decays to $K^+ K^-$ and $\pi^+\pi^-$
- Inclusive cross sections of $p\bar{p}$ --> W and Z
- SM Higgs, H/A into tau-tau (A. Connolly PHD thesis, Run I)
- B_s/B^0 Ratio of Branching Fractions
- Top Mass in Lepton+Jet Channel using a Template Method (Brubaker PHD thesis)

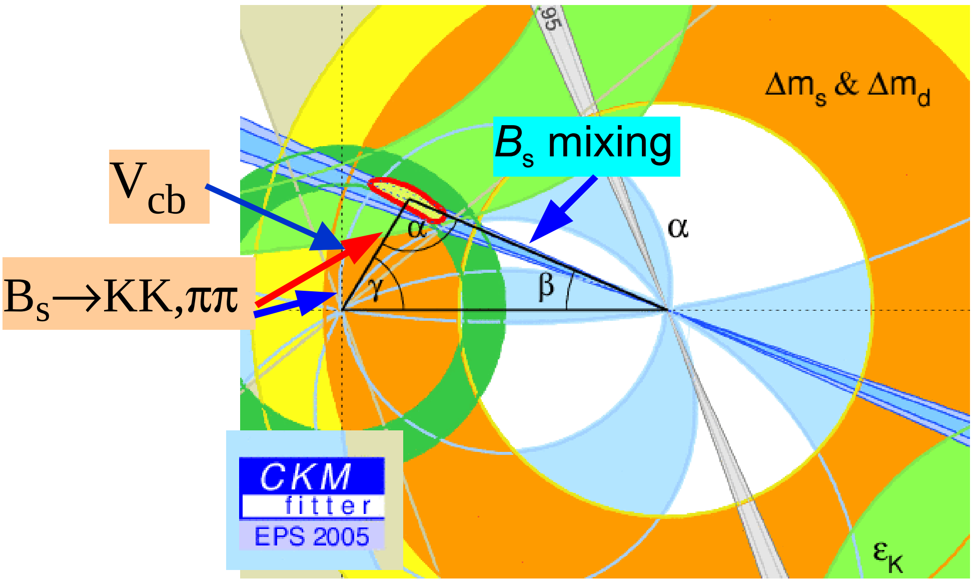
Papers with Drafts Circulating in Collaboration

Search for Particles Decaying into $b\bar{b}$ with associated W Production

Will highlight only a few of these analyses here

B Physics: where are we?

CP violation in the B system constrains the unitary triangle.
SM requires $\alpha+\beta+\gamma=\pi$, **Sin2β well** measured at the B factories.



CP violation in $B_s \to J/\psi\phi$ is new physics

- B_s physics can only be done at the Tevatron
- SVT (Silicon Vertex trigger) allows study of the hadronic decays
  $B \to hh$ and $B_s \to D_s \pi$
- It opens whole new window that can lead to new physics

- B_s mixing requires fully reconstructed decays to reach high values of x_s and eventually will lead to measurements of the angle γ
- Initially B_s semileptonic decays , high statistics, can be used
- LBNL Group working on B_s mixing. Published work on V_{cb}.

Cabibbo suppressed $B^- \rightarrow D^o K^-$

H-C. Fong (PHD thesis), M. Shapiro, others

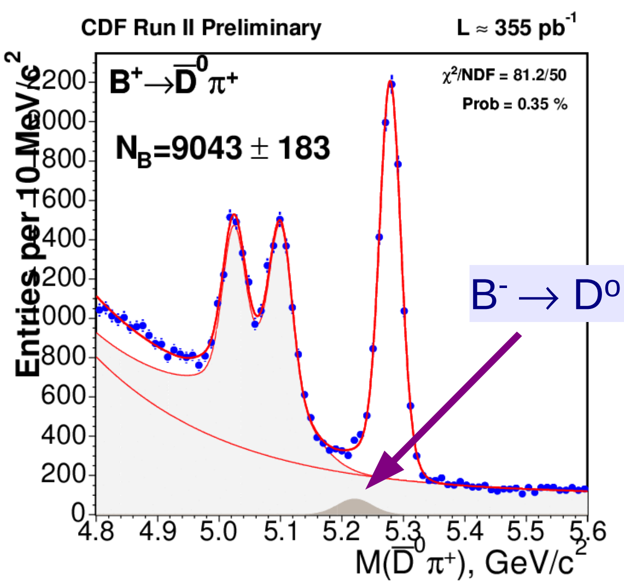
Motivations: measure $BR(B^- \rightarrow D^o K^-)/BR(B^- \rightarrow D^o \pi^-)$

Direct CP-violation in $B \rightarrow D_{CP\pm} K$ (M. Gronau, PRD 58, 037301)

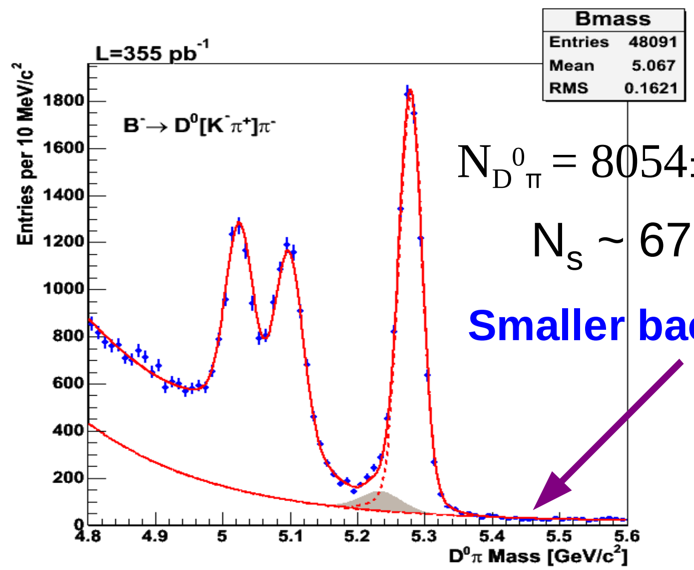
gives $BR(B^- \rightarrow D^o_{CP\pm} K^-) \neq BR(B^+ \rightarrow D^o_{CP\pm} K^+)$

Using these three branching ratios it is possible to measure the angle **γ.**

Standard event selection

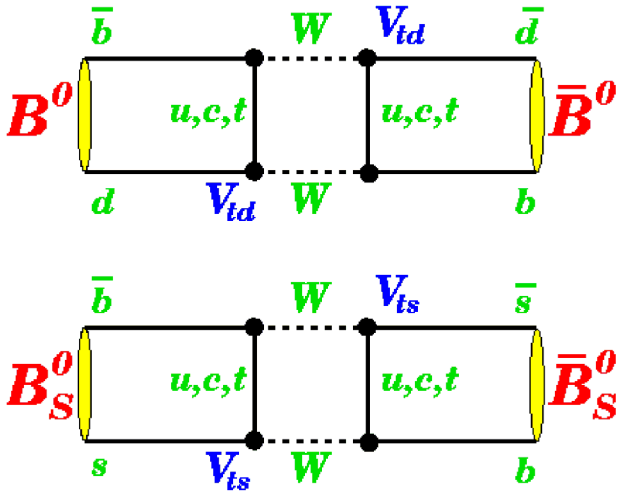


Selection optimized for $B^- \rightarrow D^o K^-$



Right:: new fit to templates for known processes + using Particle ID

B_s Mixing at CDF



$$\frac{|V_{td}|}{|V_{ts}|} = 1.01\xi\sqrt{\frac{\Delta m_d}{\Delta m_s}}$$

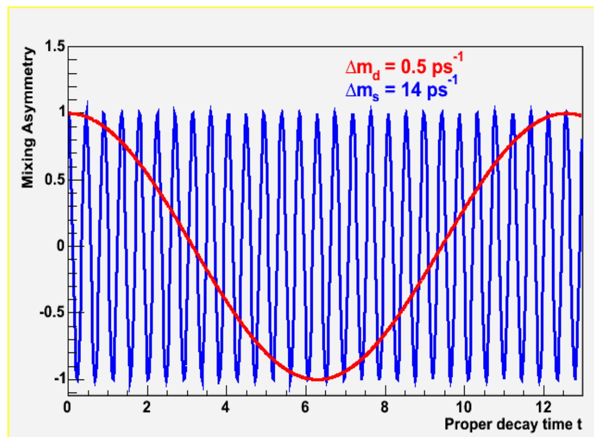
from LATTICE

ξ accurate at ~ 5%

SM Fit: $\Delta m_s = 18.3 \pm 1.6\ ps^{-1}$

- To measure CPV in the B_S system we need to measure Δm_s from B_S-$\bar{B}_S$ oscillations.

  $A_{mix} \sim D*\cos(\Delta m_S t)$
- Δm_s expected to be large due to coupling to top quark
- B_S fully mixes in < 0.15 lifetimes !!



- B mixing World Average @95 C.L. Uses data from LEP and SLD

  $\Delta m_S \geq 14.5\ ps^{-1}$

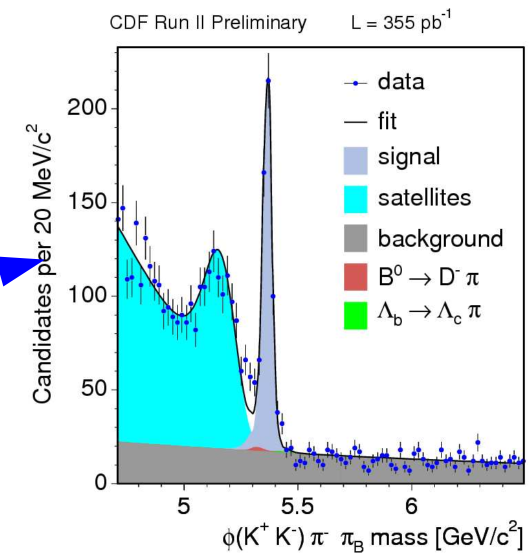
B_s : fully hadronic modes

- B_s mixing signals in 355 pb^{-1}:
  - $B_s \rightarrow D_s\,\pi$, $D_s\,3\pi$
  - $D_s \rightarrow \phi\pi$, KK; 3π
  - Highest ct resolution. 1118 fully reconstructed events.
  - $\varepsilon D^2 = (1.55 \pm 0.16 \pm 0.05)\%$
- Preliminary limit:

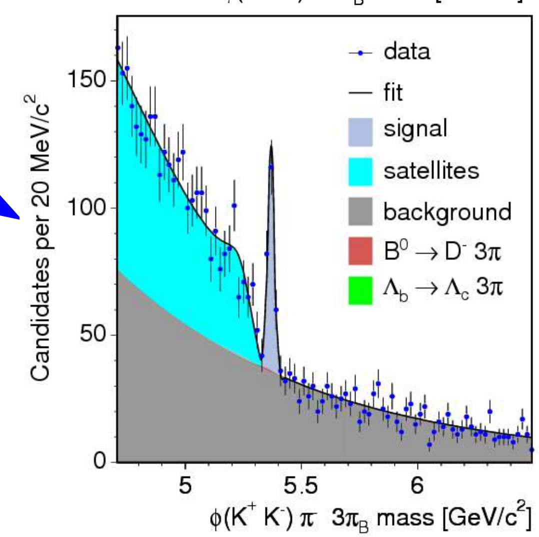
  $\Delta m_s > 0.0\ ps^{-1}$ @95% C.L.

  Sensitivity = 9.8 ps^{-1}

$B_s \rightarrow D_s\pi$
$D_s \rightarrow \phi\pi$



$B_s \rightarrow D_s\,3\pi$



$D_s^- \rightarrow \phi\pi^-$

$N = 158 \pm 17$

Semileptonic: Lower resolution than hadronic.... but very large statistics: ~8K events $\varepsilon D^2 = (1.55 \pm .09)\%$

Basic: $B_s \rightarrow l\nu D_s$ Sens.=10.6

$D_s \rightarrow \phi\,\pi$, K^* K, 3π

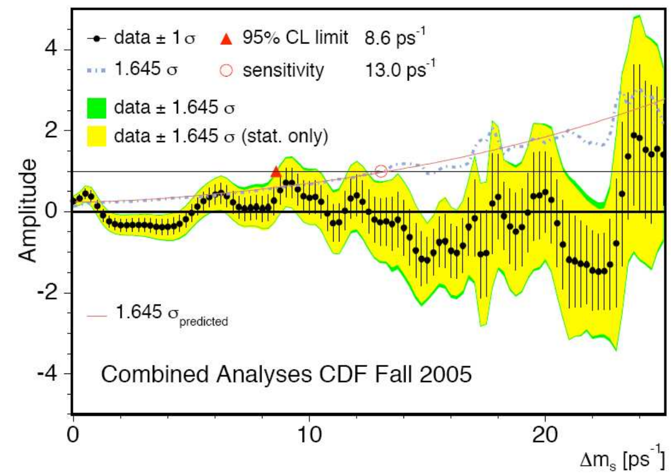
$\Delta m_s > 6.8\ ps^{-1}$ @95% C.L.

CDF B_s Mixing Results

Tevatron Results are now improving World Average

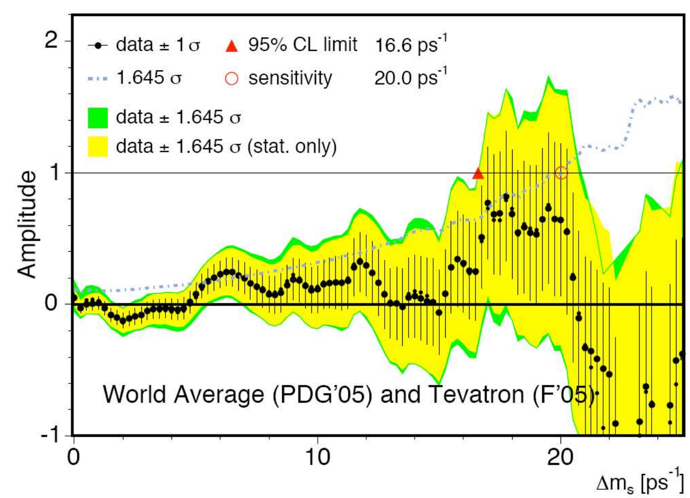
$\mathcal{L} \sim [1 \pm AD\cos(\Delta m_s t)]/2$

- New combined CDF Results: semileptonic+ hadronic modes (compared with Winter '05)
- Limit : 7.9 ->8.6 ps^{-1} @95% CL
- Sensitivity: 8.4 ->13.0 ps^{-1}



➤ Effect on World Average:

- Limit 14.5 -> 16.6 ps^{-1}
- Sensitivity: 18.5 -> 20.0 ps^{-1}



SM Fit: $\Delta m_s = 18.3 \pm 1.6\ ps^{-1}$

LBNL Contributions to B_s Mixing

Beringer, Cerri, Deisher, Muelmenstaedt, Shapiro

$$\text{Signif.} = \sqrt{\frac{S\varepsilon D^2}{2}}\; e^{-\frac{(x_s \sigma_t/\tau)^2}{2}} \sqrt{\frac{S}{S+B}}$$

Working on hadronic modes

- Optimize yield of B_s
  - Use many modes
  - Cuts to give best signal significance
  - Improvements in trigger (see earlier)
- Optimize vertex resolution (σ_t)
  - Primary Vertex determined event-by-event
  - Best possible silicon tracking
- Optimize Tagging (efficiency(ε), and Dilution(D))
  - Combine many tag

LBNL activities in areas marked in red completed, green are in progress

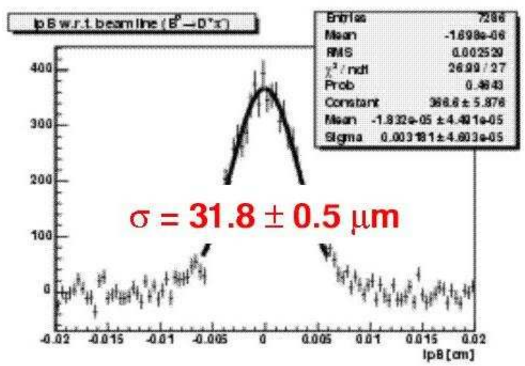
ct Resolution improvement

Cerri, Shapiro, Deisher, Muelmenstaedt, Beringer,

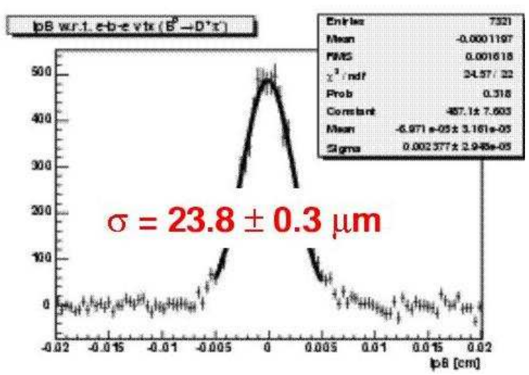
Use L00 of the silicon system and perform event by event primary vertex reconstruction to improve the ct resolution in B_S mixing studies

σ_d in $B^{\pm} \to D^0 \pi^{\pm} \to [K\pi]\pi^{\pm}$ sample

Uses the Beamline

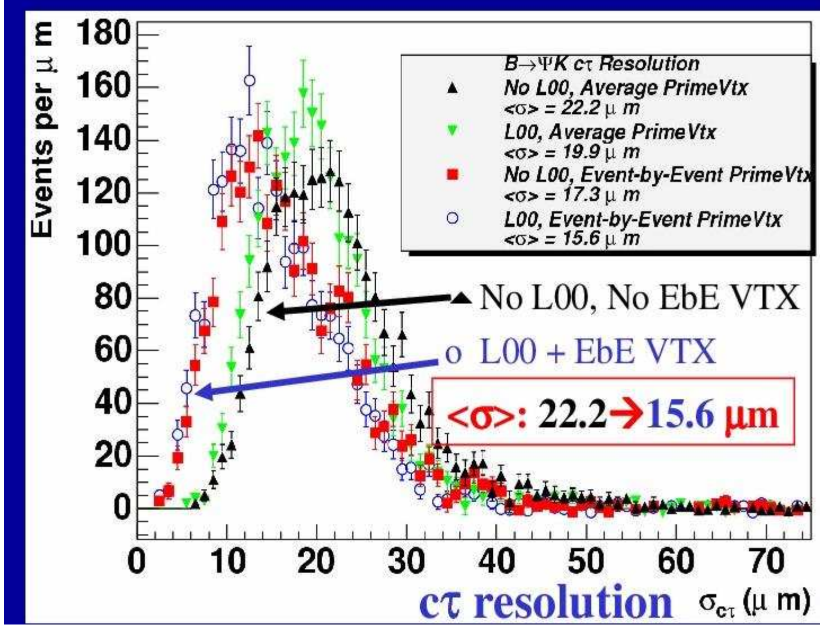


uses the event by event PV



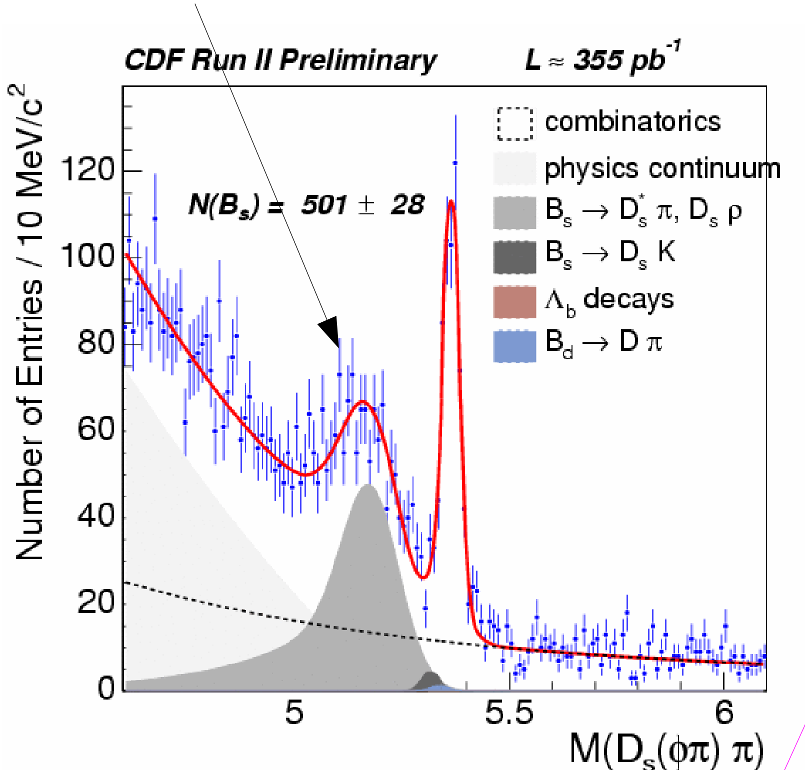
d/σ_d

$$Signif = \sqrt{\frac{N\varepsilon D^2}{2} e^{-\frac{(x_s \sigma_t / \tau)^2}{2}}} \sqrt{\frac{S}{S+B}}$$



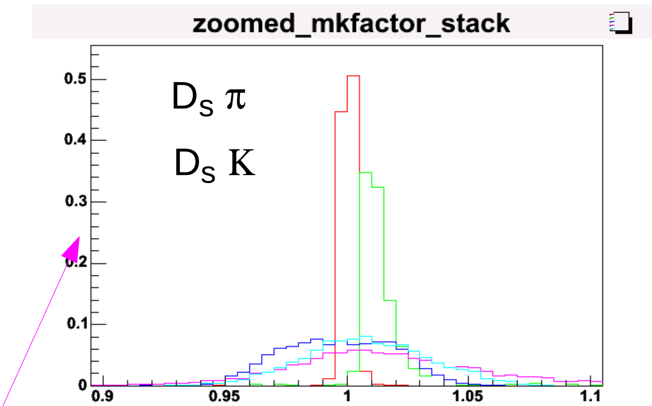
Work in Progress: Increasing B_s Yield

Use partially reconstructed modes:

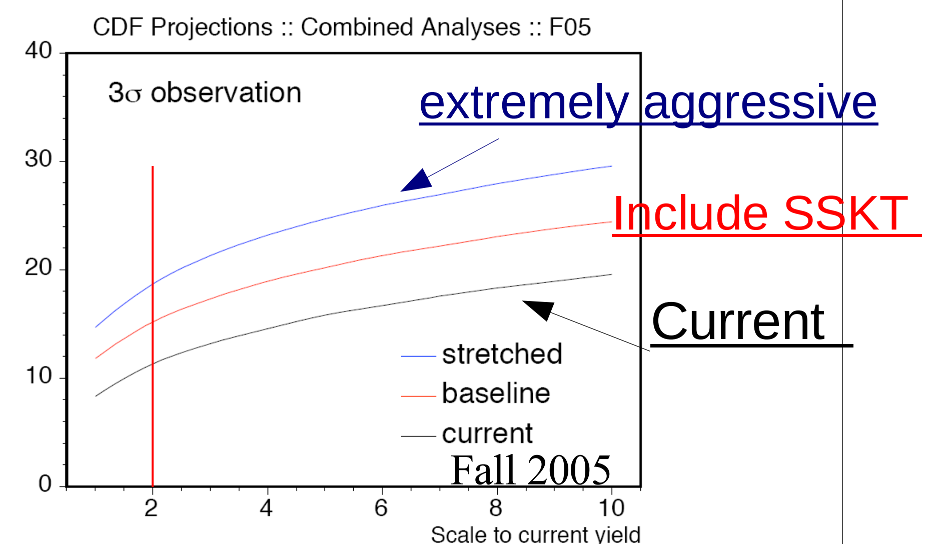


- Increase Yield by Factor of 2-3
- Some loss in $c\tau$ resolution wrt fully reconstructed modes
- Requires careful modeling

$\beta\gamma$ Correction Factor



More then x2 data on tape



Prospects for High P_T physics at CDF

Measure top quark properties

Mass to 3 GeV, Top cross section to 10%

Verify SM decay properties

Any non SM processes hide in top events?

Higgs production

SM Higgs: it is a big challenge, but try

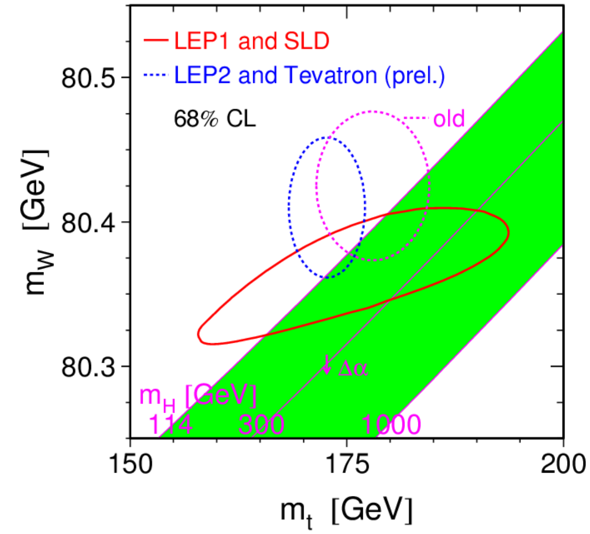
SUSY: tanβ=50 5σ discovery possible of H/A with M=175 GeV (5 fb^{-1})

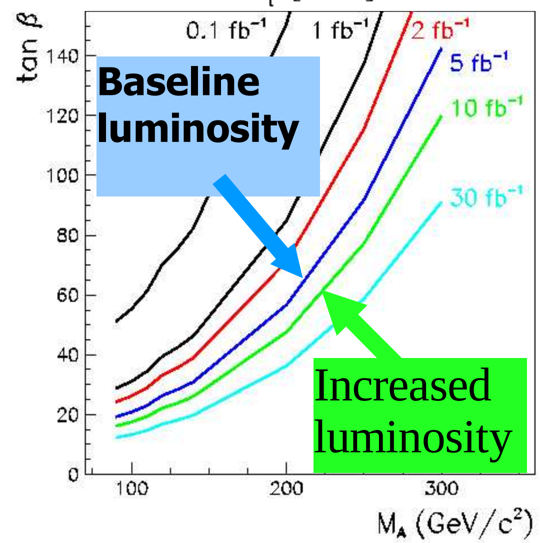
SUSY:

Some of the parameter space for squarks and gluinos can be explored.
Long lived stable particles , trileptons, etc.
Many ways to search

Many other searches: W'. Z', leptoquarks , technicolor, extra dimensions etc.

Electroweak Precision Measurements





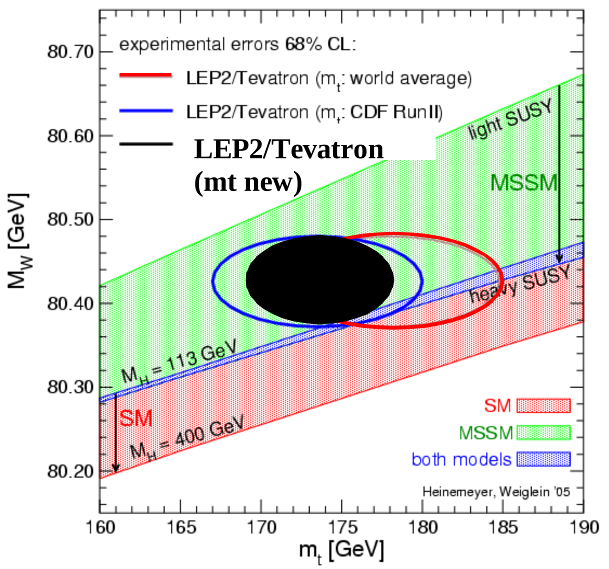
Top Quark Property Measurements

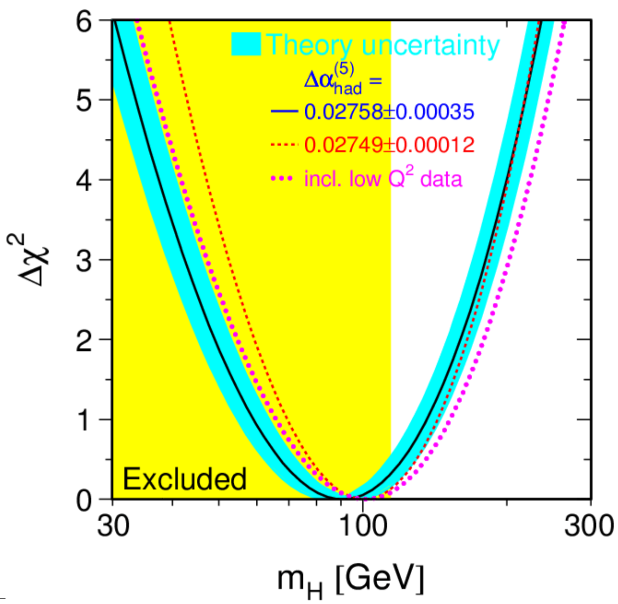
Fernandez, Freeman, Galtieri, Gibson, Lujan, Lys, McFarlane, Nielsen, Yao

- The Standard Model predicts the Higgs mass, once the W and Top mass are measured with high precision.
- Loop corrections to M_W proportional to M_t^2 and M_H

M(top) = 172.7 ± 2.9 GeV (CDF+D0 Run I+II)
M(top) = 178.0 ± 4.3 GeV (CDF+D0 Run I)

Summer '05 fits with M=173.5 ± 4.1 GeV





July 2005 best Fit

$$M_H = 91\,^{+45}_{-32}\ GeV$$

old:

$$M_H = 126\,^{+73}_{-48}\ GeV$$

now

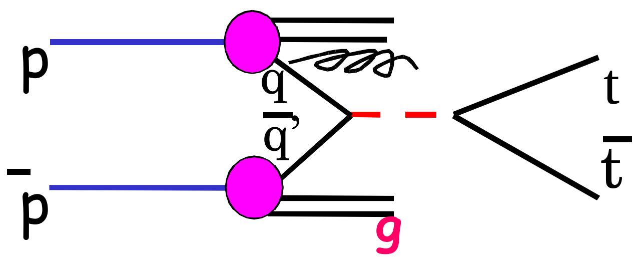
$M_H < 186$ GeV at 95% CL

Direct limit:

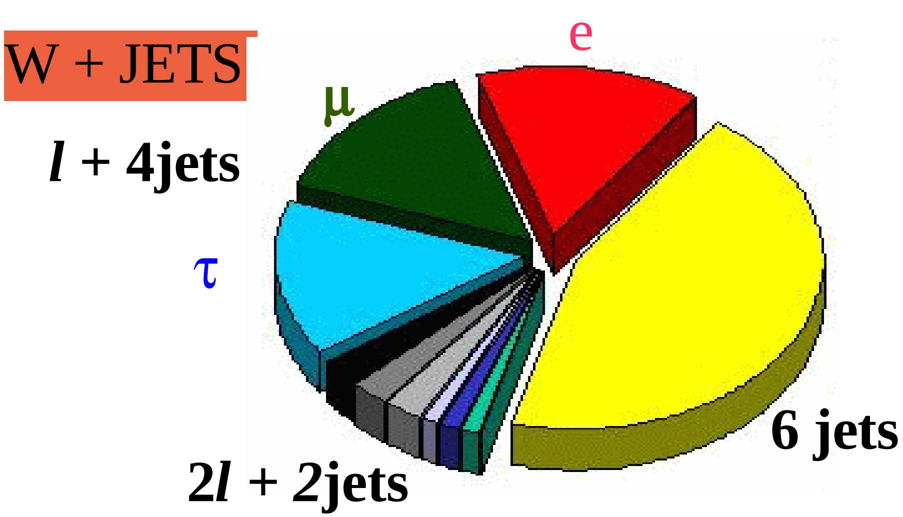
$M_H > 114$ GeV at 95% CL

Top Physics Studies

t t Production at the TeV:



$t\,\bar{t} \rightarrow W^{+}\,b\,W^{-}\,\bar{b}$



Top events preferentially W+≥ 3 jets

Top quark is heavy: decays very fast!

Γ(t -> Wb) ~ 1.5 GeV, t=4x10^{-25}sec

Λ_{QCD} = 100 Mev, $\Lambda^{-1} = 10^{-23}$ sec

No hadronization: no top mesons or baryons

LBNL group strategy:

- Understand the top candidate sample: b-tagging, backgrounds, agreement between data and Monte Carlo etc.
- Optimize tools for above measurements
- Look for deviations from SM

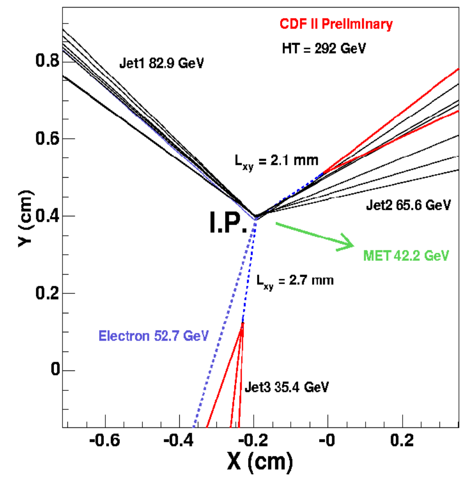
Top Cross Section Measurement

Bachacou(PHD), Lujan, McFarlane, Nielsen, Yao+ others

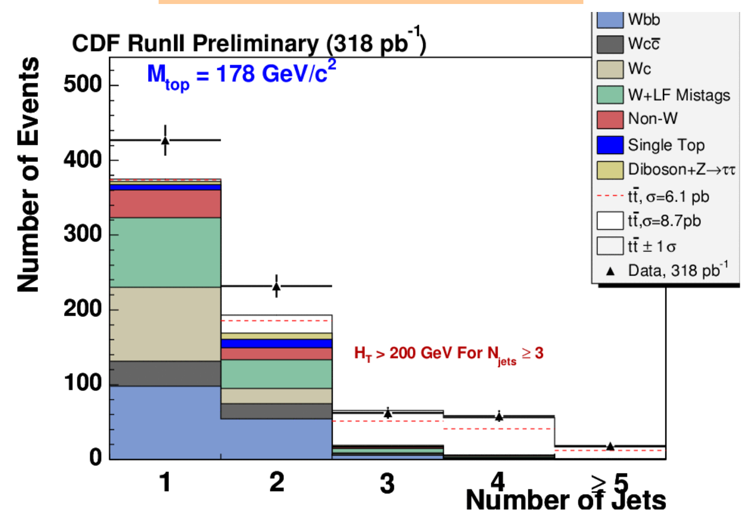
- Understanding top candidates sample, to be used for all other top studies
- LBNL: use lepton+jets channel, b-tagging to reduce background.
- Sample selection:
  - Isolated lepton, $P_T > 20$ GeV
  - MET > 20 GeV (neutrino)
  - N (jets) ≥ 3 jets $P_T > 15$ GeV/c
  - 1 b-tag by the SVX algorithm

- Background : use N(jet) = 1,2 to check background calculations
  - Mistag
  - non-W QCD
  - Physics background: Wbb, Wcc
  - Single top, WW, WZ etc.

Double tagged top event



Summer '05, 318 pb-1



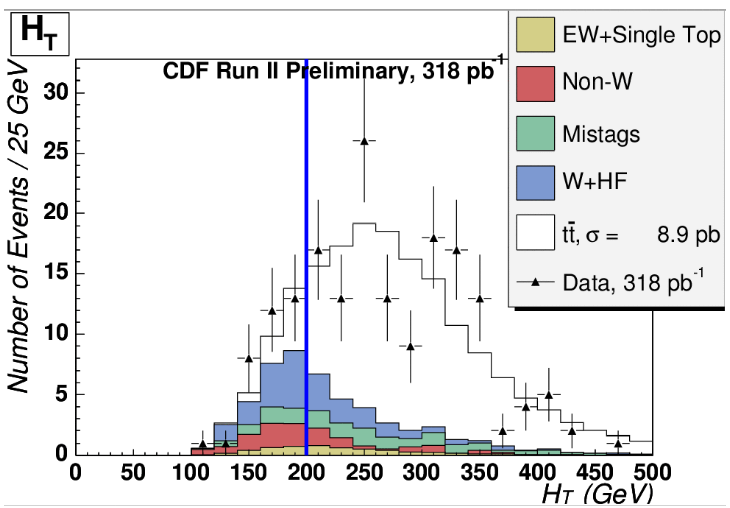
Top Cross Section (cont.)

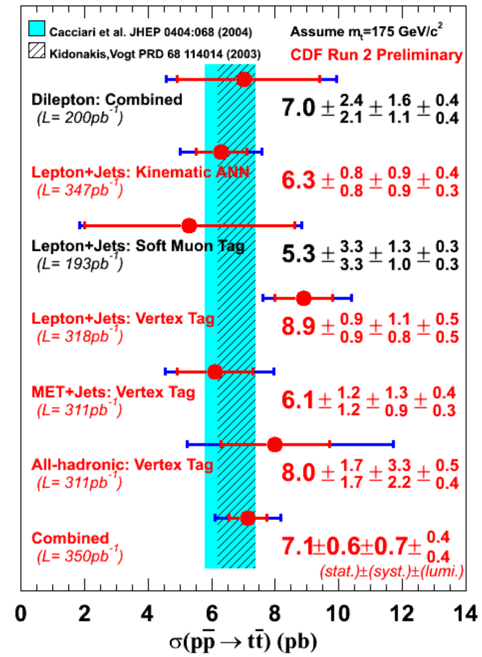
Require, H_T (total transverse energy) > 200 GeV to reduce background

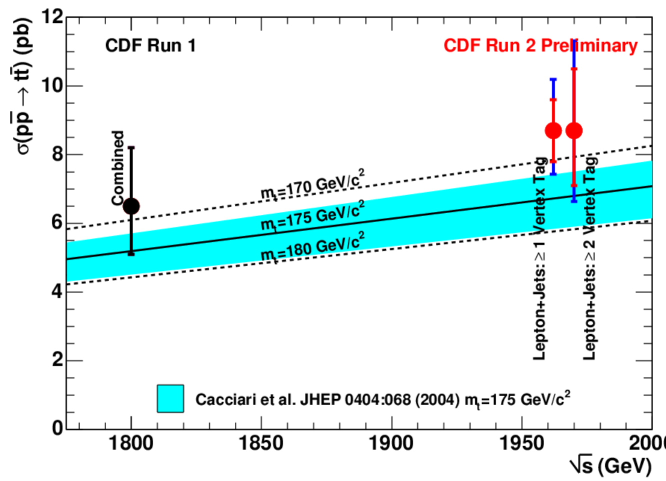
$$\sigma_{t\bar{t}} = \frac{N_{\rm obs} - N_{\rm bkg}}{\epsilon_{t\bar{t}} \times \mathcal{L}}$$

$$\sigma_{t\bar{t}} = 8.9\ ^{+0.9}_{-0.9}(stat)\ ^{+1.2}_{-0.9}(syst)\ pb$$

Summer '05, 318 pb^{-1} to be Published





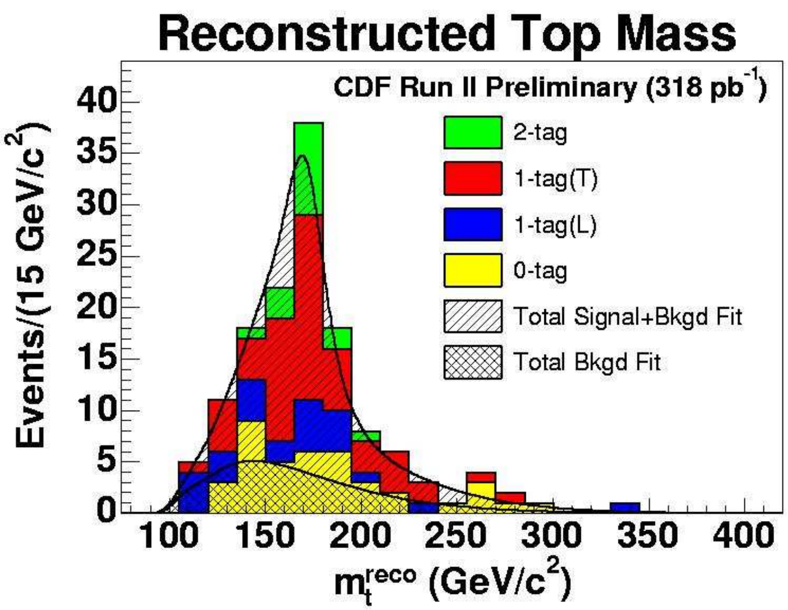


Top Mass Measurements

The LBNL group has been involved in the measurement of the top mass since 1993. Recent work in CDF has involved CDF students and staff. E. Brubaker (PHD thesis) as well as J-F Arguin (Toronto, now Chamberlain Fellow at LBNL) have contributed .

Analysis follows run I methodology. New: 2D fit, mass and JES (jet energy scale parameter)

- 121 Lepton+jets, b-tagged events
- 26.6±3.0 estimated background
- Include 40 untagged events (15 are background)
- Kinematic constraints (χ^2)
- Compare reconstructed mass to Monte Carlo Top +background templates in a lilelihood.



$$M = 173.5^{+3.7}_{-3.6}(stat) \pm 1.3(syst)\ GeV$$

Addition of JES jet energy scale parameter) to the fit has reduced the systematic error. Submitted to PRL

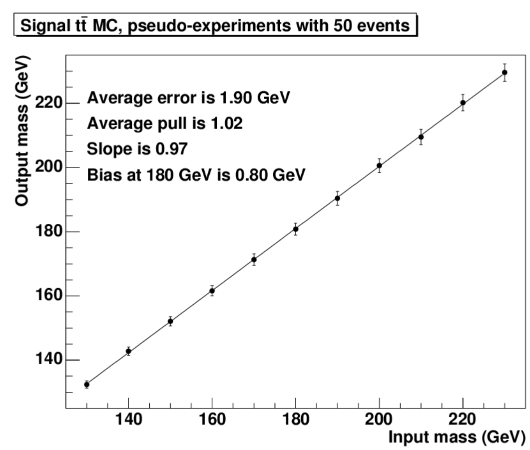
Top Mass: new LBNL method

Fernandez, Freeman (thesis), Galtieri, Lujan, Lys, Nielsen, Volobouev

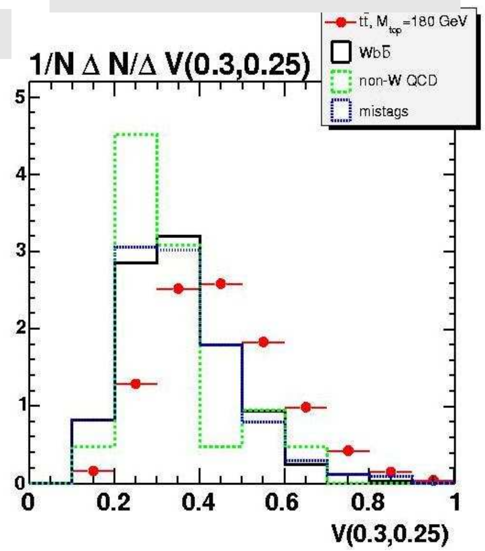
- Major systematic uncertainty in top mass measurement comes from jet energy uncertainty. We use jet transfer functions to improve resolution and the JES parameter to transfer systematic to statistical uncertainties.
- We integrate over phase space and Matrix Element for top production and decay, after a transformation into measured variables (similar to the method D0 has used for recent Run I result).
- See Kondo (JPhys. Soc. 57,1988), Dalitz&Goldstein(Proc. R. Soc. Lond., A445,1999).

- Integration being done over 7 variables + jet energy scale (JES). W mass constraint not imposed (2C fit, 4d).
- Use multivariate method for background separation: kinematic discriminant.
- Present data has 63 tagged events. Will have x2.5 soon

Uses TF and ME integration



kinematic discriminant



Other Top mass measurements

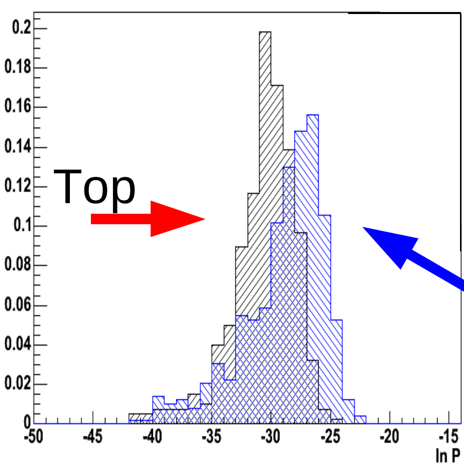
A. Gibson(PHD thesis), and others

- Another variation of the ME approach to top mass measurement. Uses transfer functions for jets.
- Uses matrix elements for top production and decay in likelihood. Integrates over 3 variables. Narrow width approximation for the W's.

M = 172.0±2.6(stat)±3.3(syst) GeV

CDF average top mass
M = 172.3±2.3(stat)±3.1(syst) GeV

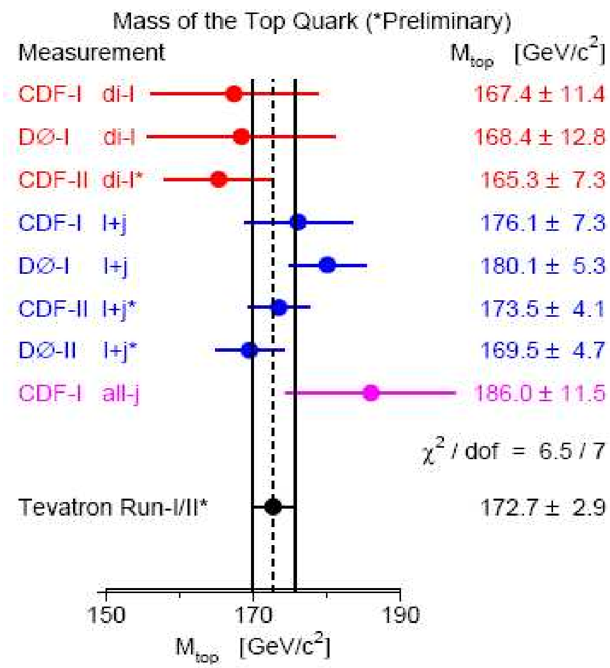
HERWIG, VECBOS MC



Uses matrix element for background as well

Background (after detector simulation)

CDF and D0 average October 05



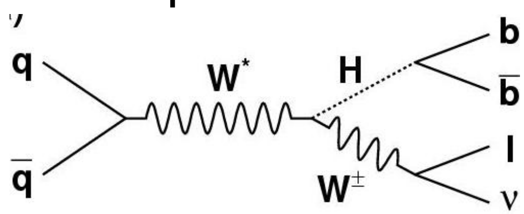
$$M_{top} = 172.7 \pm 1.7(stat.) \pm 2.4(syst.)\,GeV/c^2$$

Search for new signals in W $b\bar{b}$ events

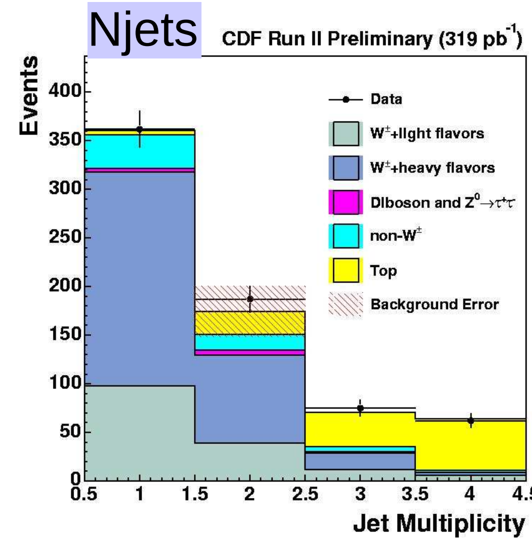
J. Nielsen,W-M Yao, Y. Ishizawa (Tsukuba)

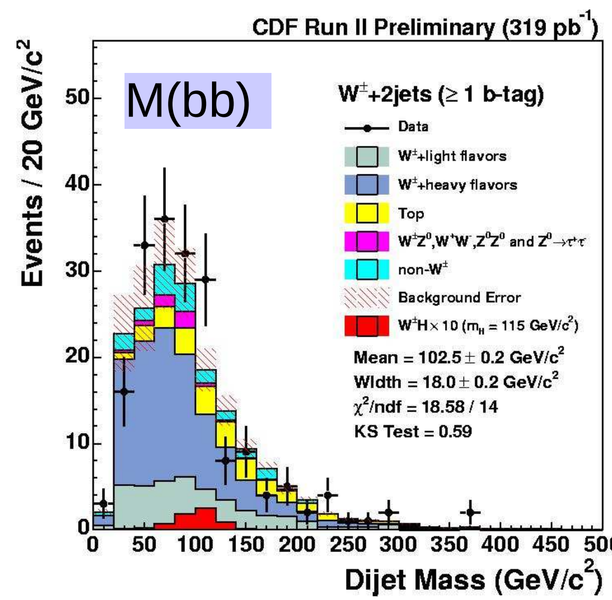
Techniques developed in Top analyses can be used for other searches, for example:

$p\bar{p} \rightarrow W X$ with $X \rightarrow b\bar{b}$



- Higgs $\rightarrow b\bar{b}$, SM cross section too small for observation in current data
- Models such as technicolor predict larger σ



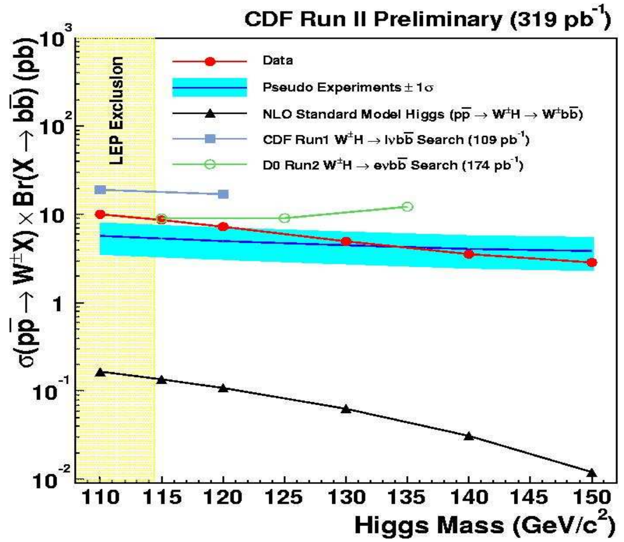


Even so, a search for SM Higgs helps with understanding of backgrounds, and needed improvements.

- Use top sample events with a W and 2 jets (at least one tagged jet).
- In 319 pb^{-1}, observe 187 events, with an expected background of 175±26 events

Particle searches at CDF

- Limit for SM Higgs $\to b\bar{b}$ from this analysis
  For M_H =115 GeV: 8.6 pb at 95% CL
  poor observed limit due to ~1σ excess
  (paper reviewed by collaboration is in 2th draft stage)



Expected limit: 5.4 pb
SM prediction: 0.14 pb
We are about a factor 40 off!

- Combine with other channels (factor ~2)
- Need improvements in the analysis
- More statistics ($\sqrt{\mathcal{L}}$= 3-5 fb^{-1} , 3 σ evidence)
- Need more work on background estimate

Anticipated Improvement	WH→lνbb
Mass resolution	1.7
Continuous b-tag (NN)	1.5
Forward b-tag	1.1
Forward leptons	1.3
Track-only leptons	1.4
NN Selection	1.75
Product of above	8.9
CDF+DØ combination	2.0
All combined	17.8

- Cross sections for technirho production
  $\rho_T \to W\pi_T$, $\pi_T \to b\bar{b}$
  are an order of magnitude larger.

Summary and Conclusions

- Large contributions to hardware and physics over the last 23 years
  Contributed 13 PHD thesis, 18 postdocs.
  20 of these have faculty or lab staff positions.

- Contributed to top discovery, precision top and W mass measurements, particle searches, properties of B mesons, B_s mixing

- LBNL still contributing to Run II CDF physics results:

  - CKM Parameters, B_s Mixing
  - Top Physics
  - New particle searches

- Enthusiastic about pursuing this physics for the next few years.
- Better statistics, improved analysis tools.
- Data sample expected to be ~ 40 times the Run I data by end FY07.
- Window of opportunity for high P_T physics before the LHC.
- Great way to prepare for the challenges of LHC physics.

Backup Slides

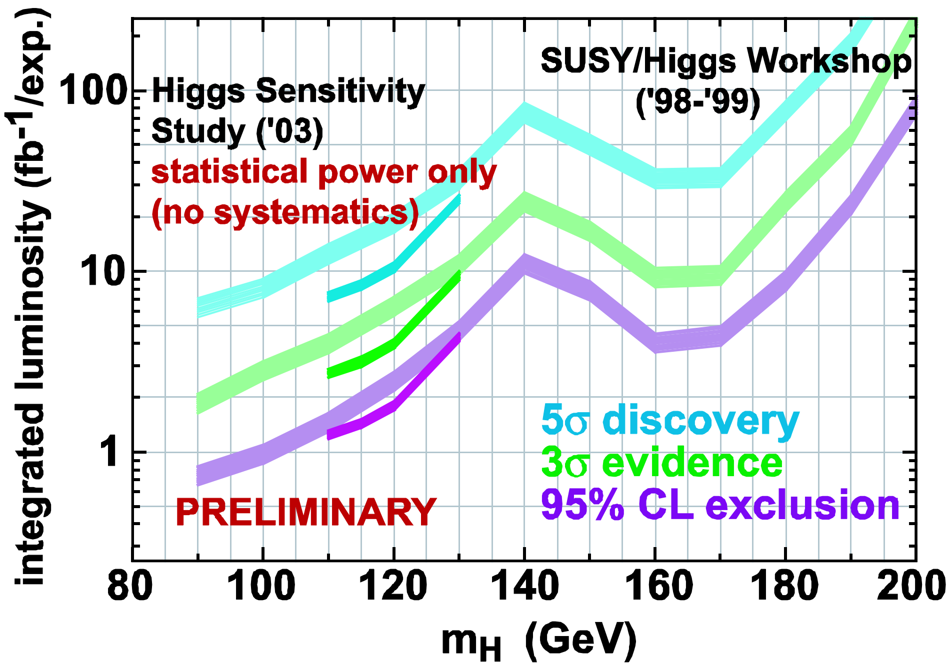
Technical Publications in 2004-05

"The CDF Central Open Tracker (COT)", NIM A526, 249 (2004)
"Silicon Vertex Tracker (SVT)" , NIM A518,532 (2004)
"CDF Run 2B Silicon Detector: Stave Design and Testing",
IEEE Trans. Nucl. Science, 51, 2209 (2004)
"SVX4: A new Deep Submicron Readout IC for the Tevatron Collider",
IEEE Trans. Nucl. Science, 51, 1968 (2004)
"The CDF Run 2B Silicon Detector: Design, ComponentsTesting",
NIM A518, 270 (2004)
"Shielding and Electrical Performance of Silicon Detector Supermodules",
submitted to IEEE Trans. Nucl. Science (10/04)
"Determination of the jet energy scale at the Collider Detector at FNAL"
submitted to NIM A, October (2005).
"The CDF RunIIb Silicon detector: Design, Preproduction and performance" , submitted to NIM A, October (2005).

Standard Higgs Expectation

Standard Model Higgs needs large integrated luminosity

SUSY Higgs can have a large cross section for large values of tanβ.
Study the A/H → ττ, bb channels



LEP m_H>114.4 GeV @95% CL