CDF Status and Prospects

Physics Advisory Committee

March 30th, 2007

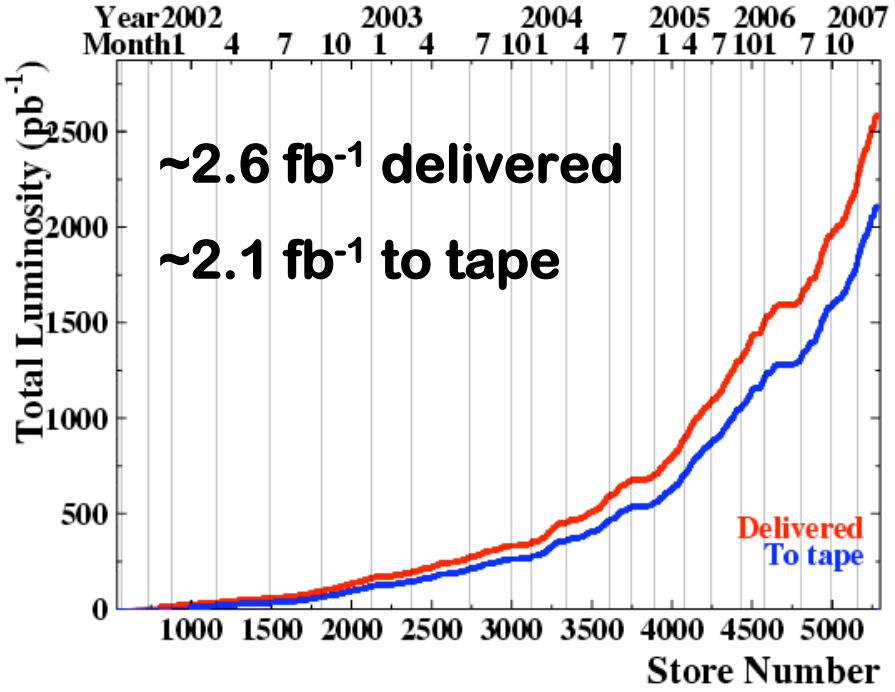
Rob Roser & Jaco Konigsberg

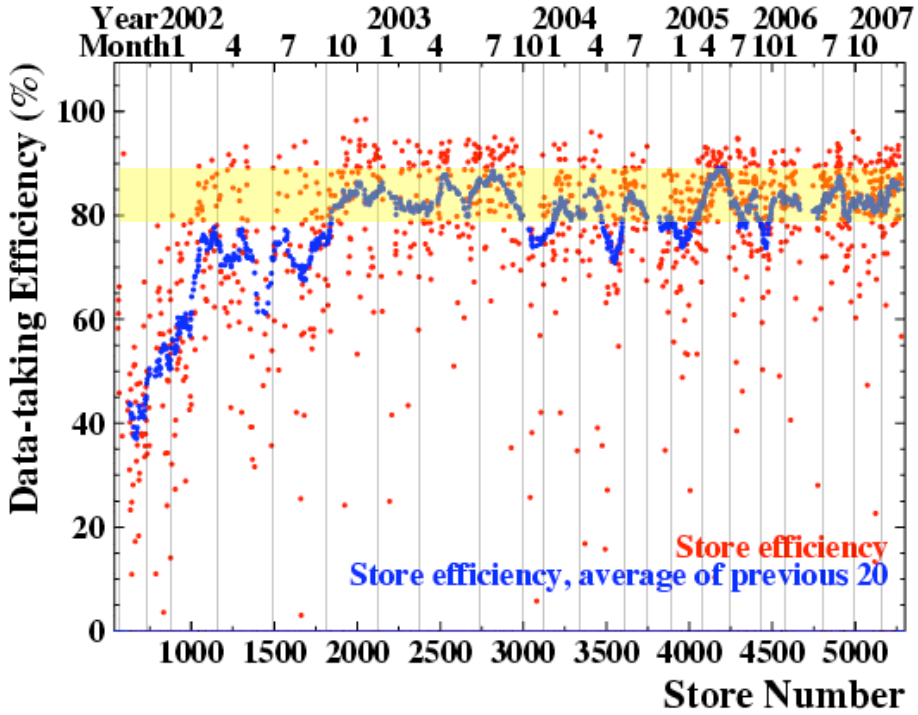
Outline

- Perspective
  - Detector operations
  - High Luminosity running
  - Data processing
  - Publications
- Physics Highlights
  - Overall and since last PAC
- Prospects
  - Summer'07
  - People resources
  - The road to discoveries/Higgs
- Conclusions

Perspective

Collecting data - happily…





- Luminosity records:
  - Highest initial inst. lum
    - ~2.92e32
  - Integrated lum/week
    - 43 pb^{-1}
  - Integrated lum/month
    - 165 pb^{-1}
  - Stacking rate
    - 23.1 mA/hr

Great success

- Sources of inefficiency include:
  - Trigger dead time and readout ~ 5%
    - Intentional - to maximize physics to tape
  - Start and end of stores ~5%
  - Problems (detector, DAQ) ~5%

Stable

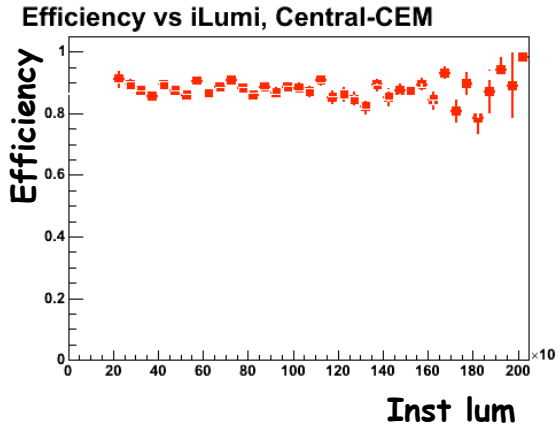
Detector Status - big picture

- **Silicon longevity**
  - Expect silicon detector to last through 2009
- **Tracking chamber (COT)**
  - Aging not a problem, will be ok through 2009
- **High Luminosity running**
  - Trigger
    - Requires constant attention
    - Upgrades on tracking and calorimetry fronts
  - DAQ
    - Built more bandwidth
  - Physics
    - No significant effect up to 3e32

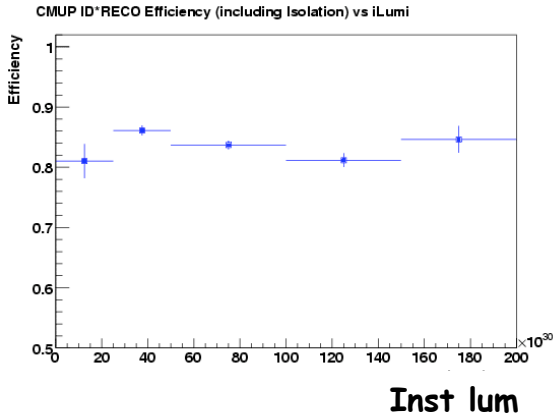
No showstopper foreseen through FY09

Physics at High Luminosity

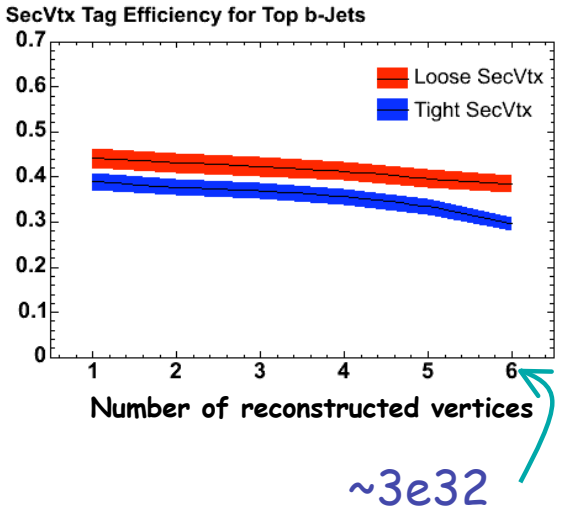
Electron ID efficiency

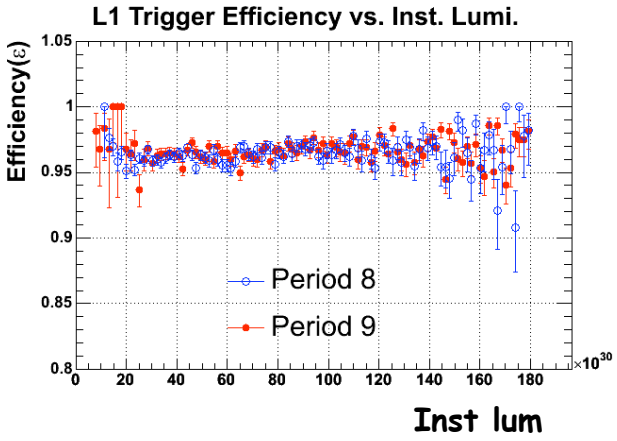


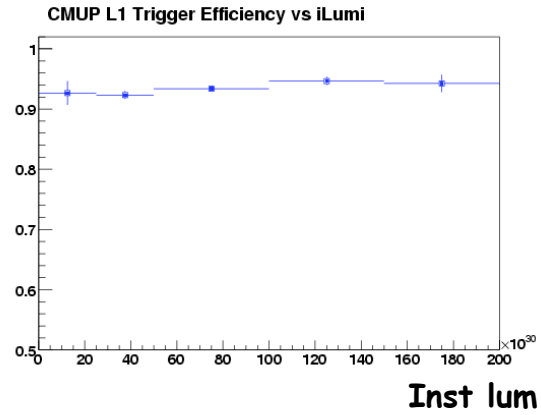
Muon ID efficiency



b-tagging efficiency







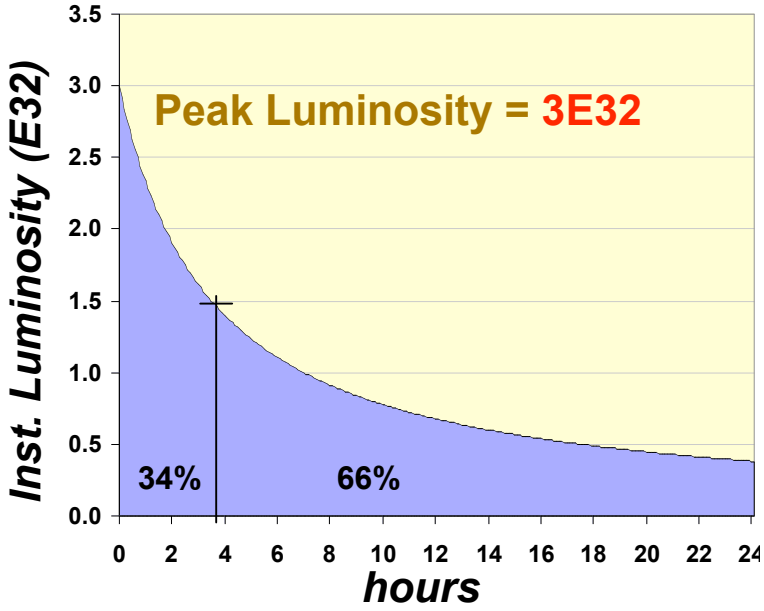
Electron L1 trigger eff.

Muon L1 trigger eff.

Physics at high luminosity is under control

Trigger @ High Luminosity

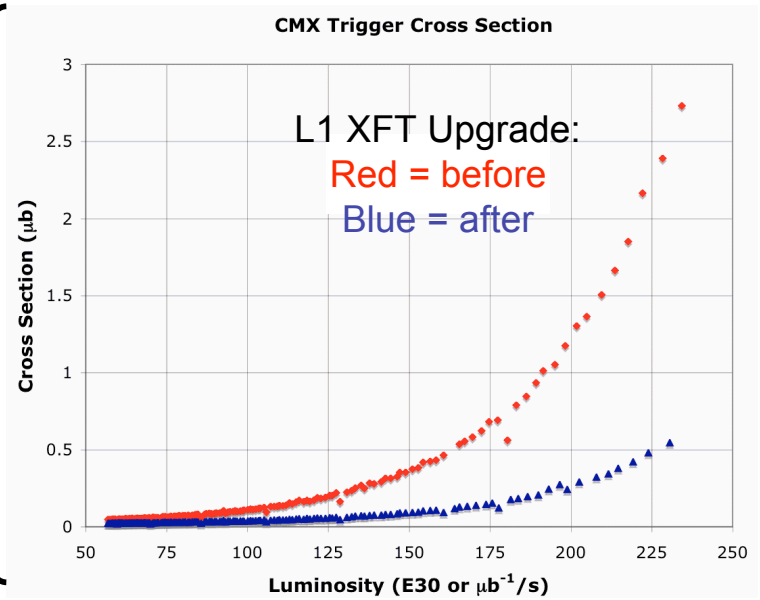
- **Experience with luminosity at ~3e32**
  - Bulk of triggers [for Higgs] are fully functional to at least 3e32
  - Identified a few triggers with unacceptable rates
    - XFT and Cal upgrades to help deal with these
  - Using "dynamic prescaling" to optimize physics and bandwidth
    - High rate triggers have large prescale at high lum
    - Prescales relaxed as banwidth becomes available at low lum
  - Most of the time is spent at below ~1.5e32



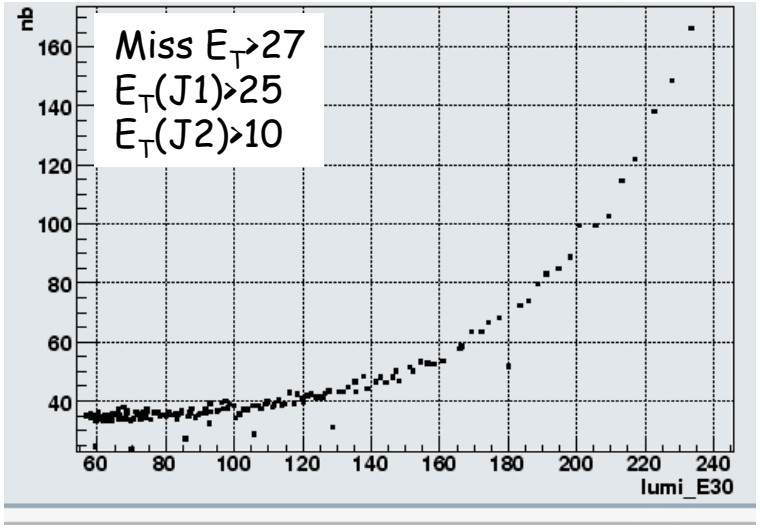
No serious issue but continuous watch is needed

Ex: dealing with runaway triggers

- High P_T muons - CMX
  - L1 XFT upgrade - completed in Fall'06
    - Add COT stereo layers
    - Rate reduced x4-5 with
    - ~2% loss of efficiency
  - Spring 2007:
    - Expect another factor of 2-3
      - L2 XFT: matching in Z with full stereo tracks
      - Tighten r-ϕ match



- Missing E_T + jets
  - Upgrade L2 cluster finder
    - Switch to Cone based jets like offline
    - Better resolution Missing E_T calculation
    - Deploy additional Pulsar boards and new decision software
    - Other algorithms possible
  - Install and commission in Spring 2007
    - 14 postdocs and students !



Data processing

- Computing will always require attention
  - Dealing with continually larger data sets, faster acquisition of data, and evolving technology
- Recent successes include
  - Detector calibrations automated
  - Standard Ntuples now made in an automated fashion
  - Automated string of high-level modules to do jet-E-scale, ID and trigger efficiencies on leptons, b-tagging efficiency, data-to-MC scale factors
  - All MC production done off-site
  - Enhanced GRID computing capabilities
  - Everything needed to include new data in any physics analysis with a lag time of <12 weeks
- We are elaborating a ~5-year plan in conjunction with CD and Lab
  - Detailed CDF staffing needs per operation, per year
  - Continue streamlining ops
  - Transition to CD jobs that match their personnel's skills

CDF Run 2 Publications

Calendar Year	Publications
2003	4
2004	17
2005	44
2006	55
2007	11
Total to date	131*

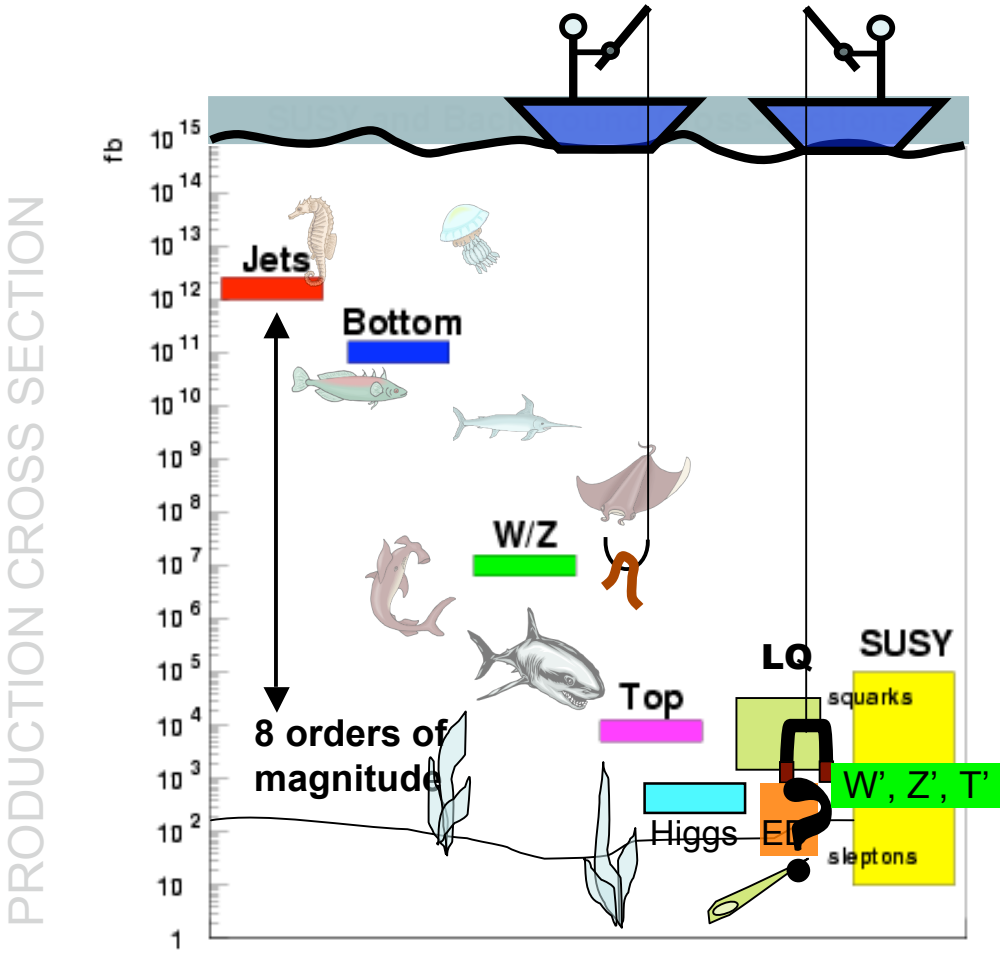
* Include submitted+accepted+published

- We also have >50 additional papers under internal review !

We are publishing our results as we go

Physics Program

Broad and deep program



Highlights @ October'06 PAC

- Observation of Bs-mixing
  - Δm_s = 17.77 +- 0.10 (stat) +- 0.07(sys)
- Observation of new baryon states: Sigma_b
- Improved Top mass precision
  - Mtop_cdf = 170.9 +- 1.4(stat) +- (1.9) syst
  - Mtop_world = 171.4 +- 1.2 (stat) +- 1.8 (syst) -dominated by CDF
- Improved Higgs sensitivity and limits

New Physics Highlights

- ✓ WZ discovery (6-sigma)
  - Measured cross section 5.0 (1.7) pb
- ✓ ZZ evidence (3-sigma)
- ✓ Single top expected sensitivity at 1 fb^{-1} = 2.6 sigma
- ✓ Precision W mass measurement
  - Mw_cdf = 80.413 GeV (48 MeV)
- ✓ Improved Top mass precision
  - Mtop_cdf = 170.5 (2.2) GeV
- ✓ W-width measurement
- ✓ B==>hh states

✓ == World's best results

Will briefly illustrate some of these here

New results shown at 07 Winter Conferences

Just for the record

- **QCD**
  - b-bbar dijet production cross section (260 pb^{-1})
  - Z+jets cross section measurement (1.1 fb^{-1})
  - Z ==> b-bbar
  - Dijet production cross section measurement (1.13 fb^{-1})
- **B-physics**
  - Lifetime measurements:
    - B+, B0, Bs and Lambda_b (1fb^{-1})
  - Rare decay searches:
    - B+ ==>mu+ mu- K+, B0 ==>mu+ mu- K*, Bs ==>mu+ mu- phi (1fb^{-1})
    - B==>hh
- **EWK**
  - Observation of WZ production
  - Evidence for ZZ production
  - W mass
  - W width

New results shown at 07 Winter Conferences

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

- **New Phenomena**
  - Search for New Particles Coupling to Z+jets (b'->Z+b) in 1.1/fb
  - Search for CHAMPS - 1/fb
  - SUSY trilepton combined limit - 0.7 to 1/fb
  - High-mass dielectron (Z' search) - 1.3/fb
  - Search for LED in the monojet signature - 1/fb

- **Higgs (1/fb)**
  - H==>tau,tau SUSY Higgs
  - H==>WW ME-based analysis
  - ZH==>llbb 2D-NN and MET fitter analysis

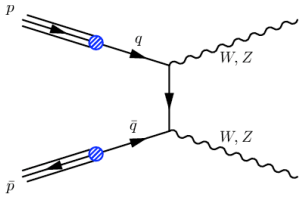
A rich menu !

CDF Wine and Cheese Talks

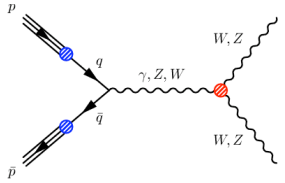
- Just since last September:
  - Sept 22: B_s Mixing observation
  - October 20: Σb observation
  - October 25: WZ observation
  - October 27: B ==>hh observation
  - November 10: All-hadronic Top
  - December 1: Status of Single Top
  - January 5: W mass measurement
  - February 2: h==>tau,tau
  - March 23: Heavy long-lived particle searches
  - March 30: Small x and Diffractive Physics
  - April 20: reserved for W-width
  - June 8th: reserved
  - June 22nd: reserved
- PLUS a lot of press…

A few highlights

Observation of WZ Production

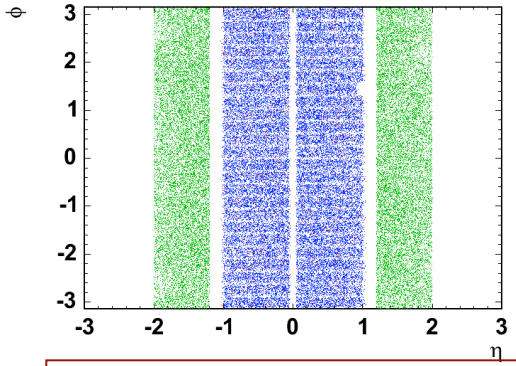


NLO cross section: 3.7 ± 0.1 pb

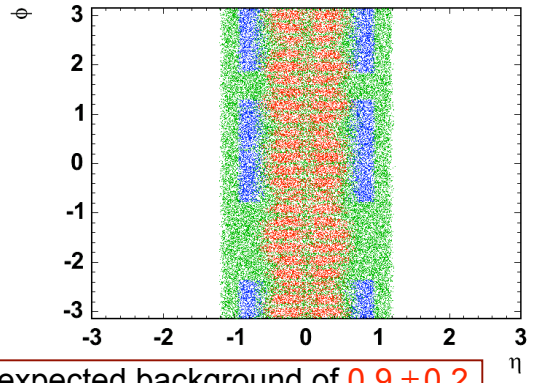


3 leptons + MET
1.1 fb-1

electrons

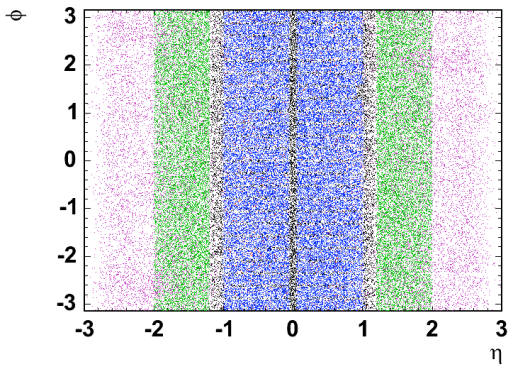


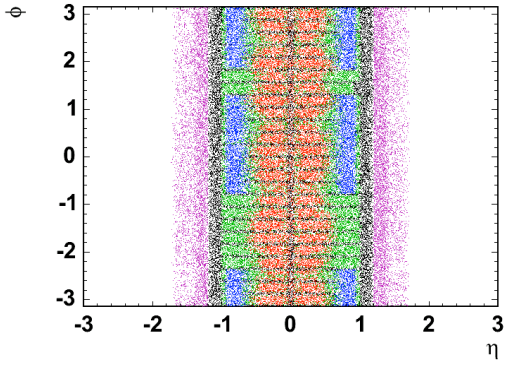
muons



1st pass: observed 2 events with expected background of 0.9 ±0.2 and expected signal of 3.7 ±0.3

Increased acceptance by adding plug calorimeter and tracks pointing to cracks: 16 obs vs 3 bcknd





+ more triggers
+ better selection
+ optimize cuts

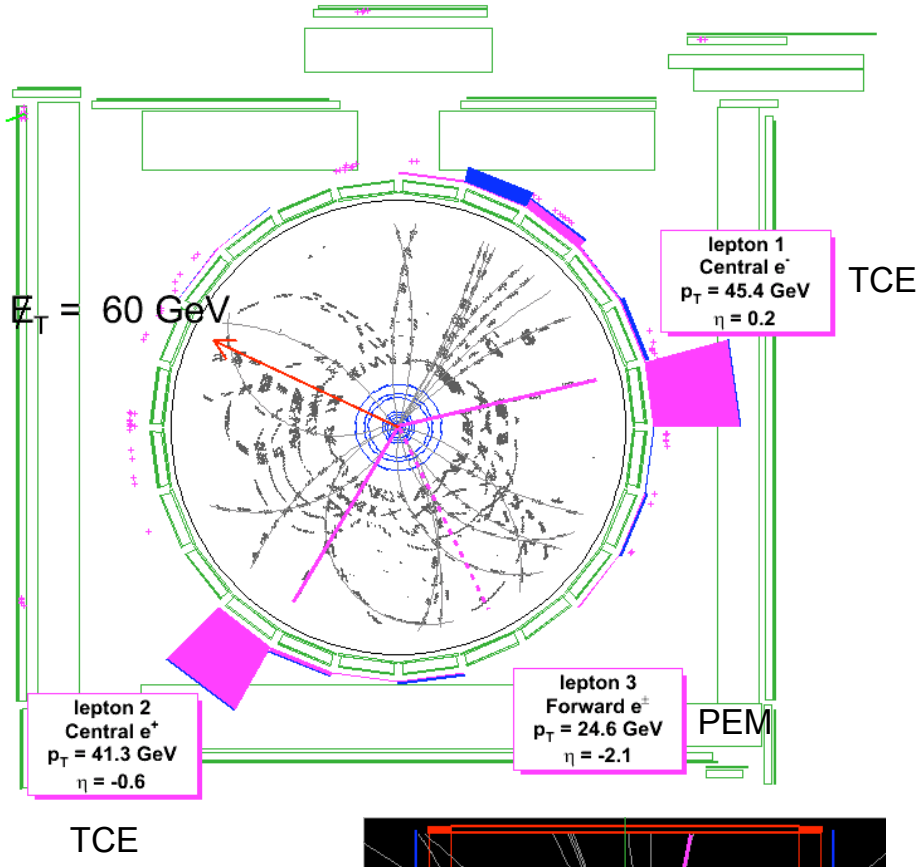
Source	Expectation ± Stat ± Syst ± Lumi
Z+jets	$1.22 \pm 0.27 \pm 0.28 \pm$ -
ZZ	$0.89 \pm 0.01 \pm 0.09 \pm 0.05$
$Z\gamma$	$0.48 \pm 0.06 \pm 0.15 \pm 0.03$
$t\bar{t}$	$0.12 \pm 0.01 \pm 0.01 \pm 0.01$
WZ	$9.79 \pm 0.03 \pm 0.31 \pm 0.59$
Total Background	$2.70 \pm 0.28 \pm 0.33 \pm 0.09$
Total Expected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

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

2 MET bins:
Prob(background only) < 2×10^{-9} (5.9σ)

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

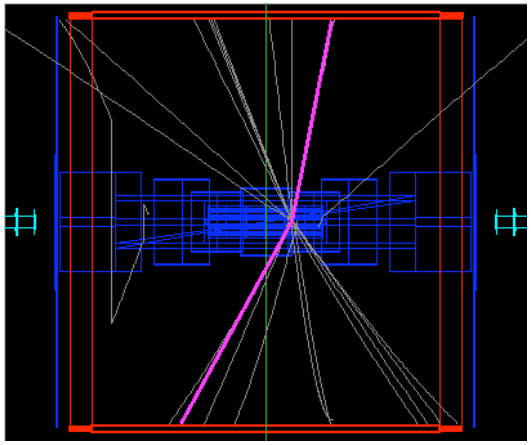
WZ Candidate: e e e

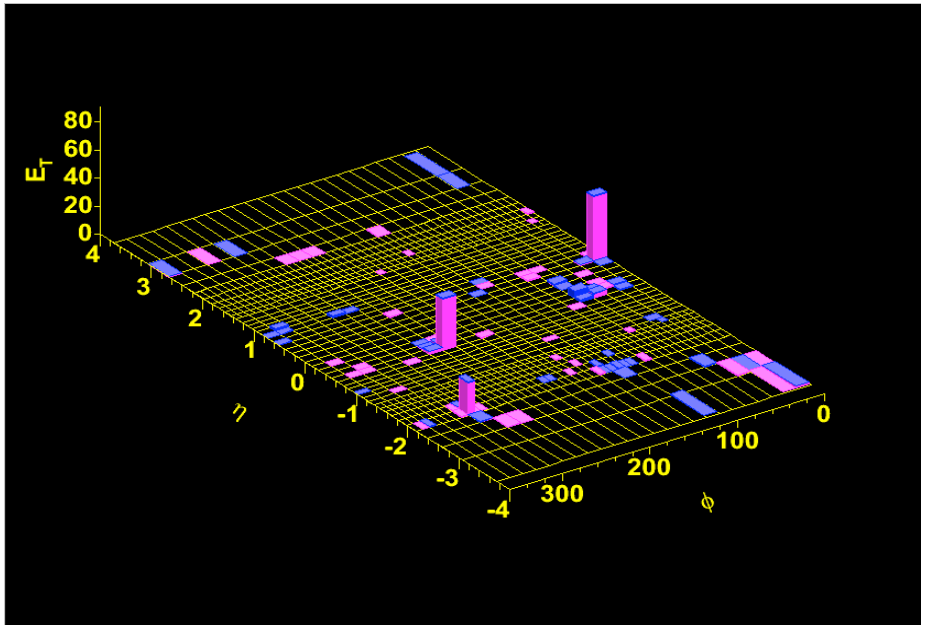


Run=154799 Event=1795709

m_{12}=87.91 GeV $\quad |\not\!\!E_T|$=60.5 GeV
m_{13}=104.37 GeV $\quad \Delta\phi(\not\!\!E_T, \text{lepton, jet})$=1.5
m_{23}=59.62 GeV

Type	p_t	η	ϕ	
Central e	45.4	0.2	0.2	TCE
Central e	41.3	-0.6	-2.1	TCE
Forward e	24.6	-2.1	-1.1	PEM

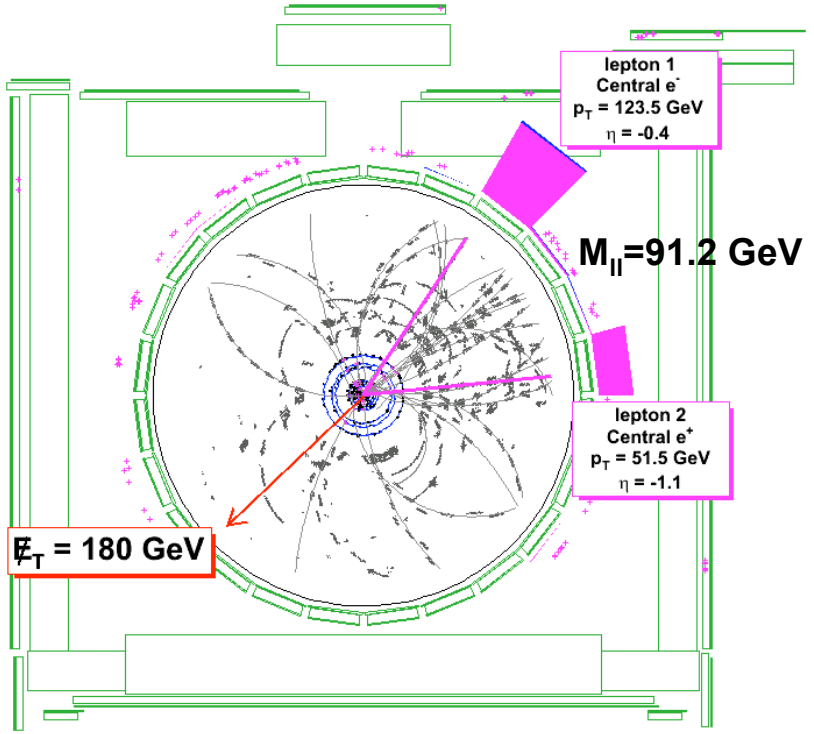




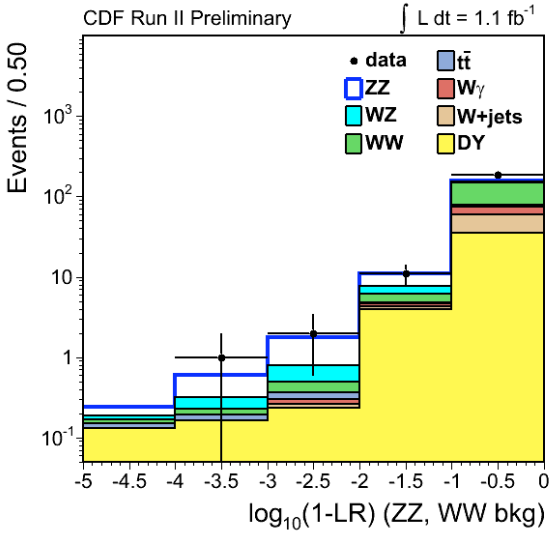
Evidence for ZZ production (1.4 fb^{-1})

Two Modes are better than one:

- **Added data to old 1.1 fb^{-1} 4-lepton**
- **Added new channel + technique:**
  - **llνν w/ Matrix Element based discriminant to separate** *WW and ZZ*



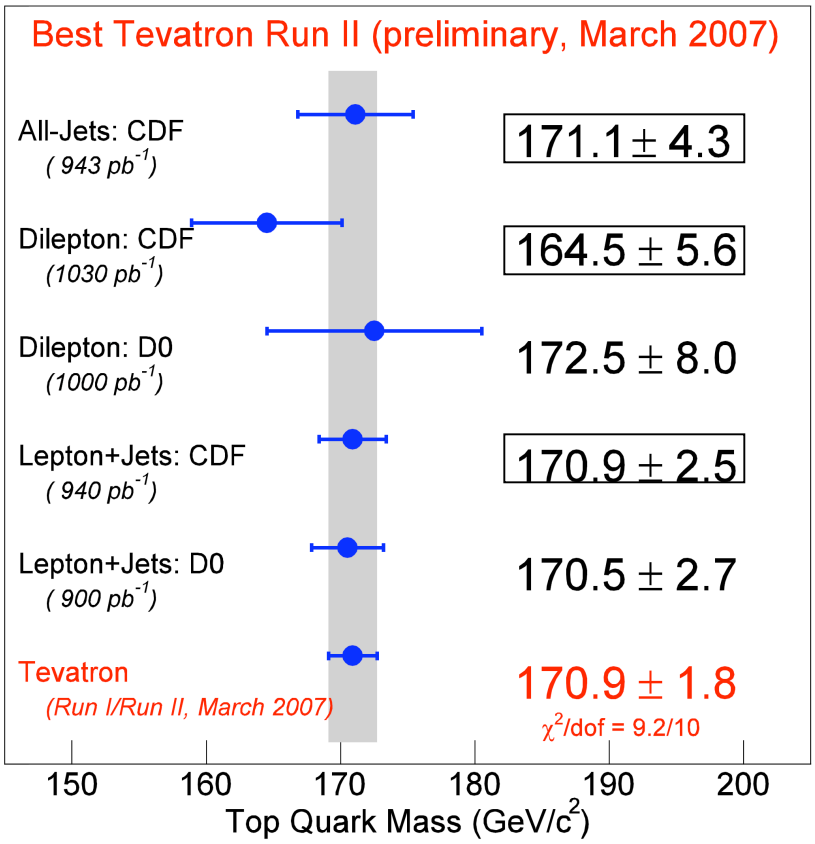
llνν results:

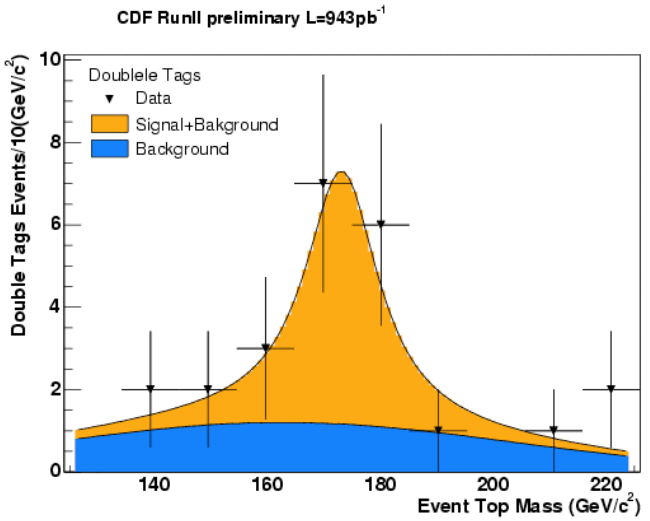


3σ effect
for the combined channels

$$\sigma_{obs} = 1.14^{+1.1}_{-0.8}\ pb \quad (\sigma_{NLO} = 2.1\ pb)$$

Top Quark Mass





New CDF all-jets double-tagged

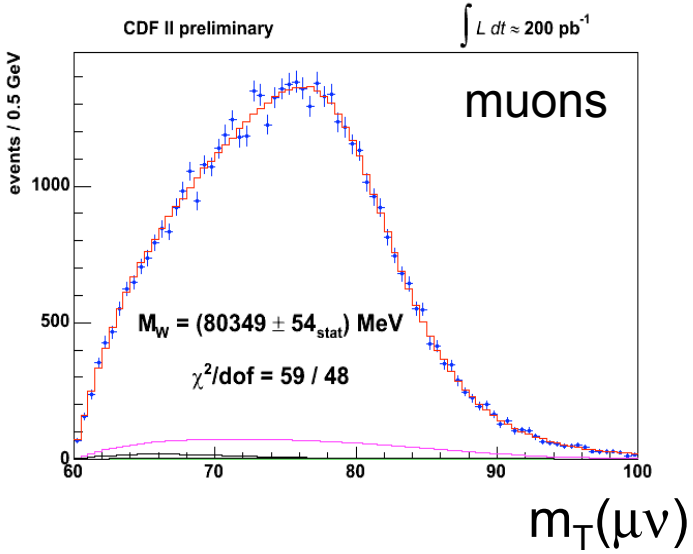
Tevatron combined:

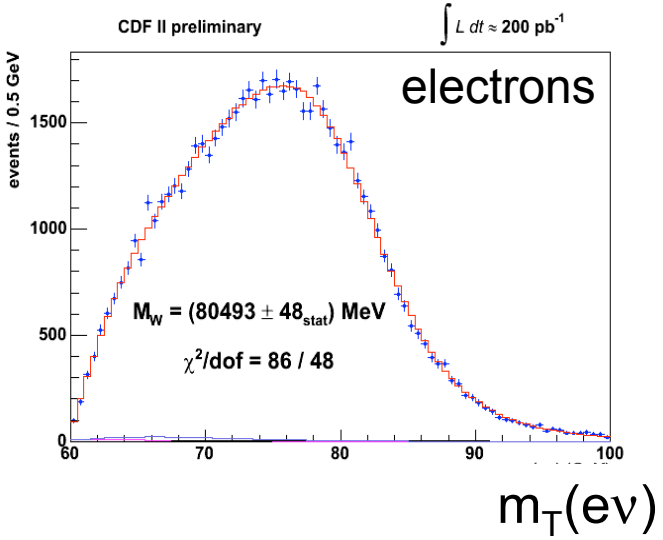
$$M_{top} = 170.9 \pm 1.8\ GeV\ (\sim 1\%)$$

A year ago 172.7 ± 2.9 GeV/c^2 (1.7%)

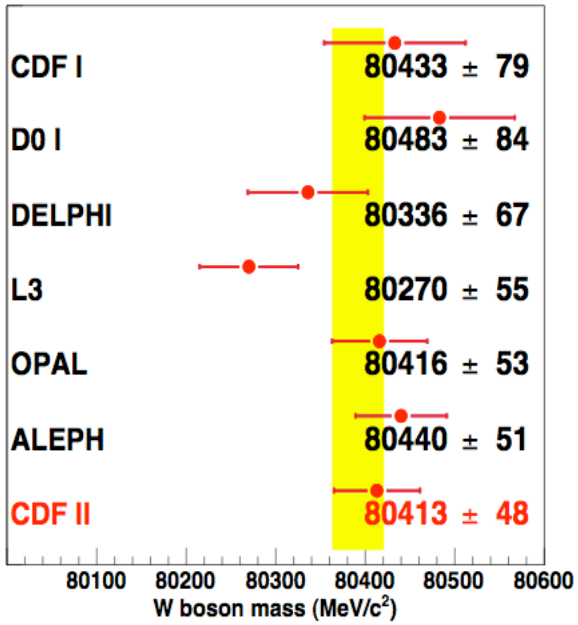
Best results in each final state

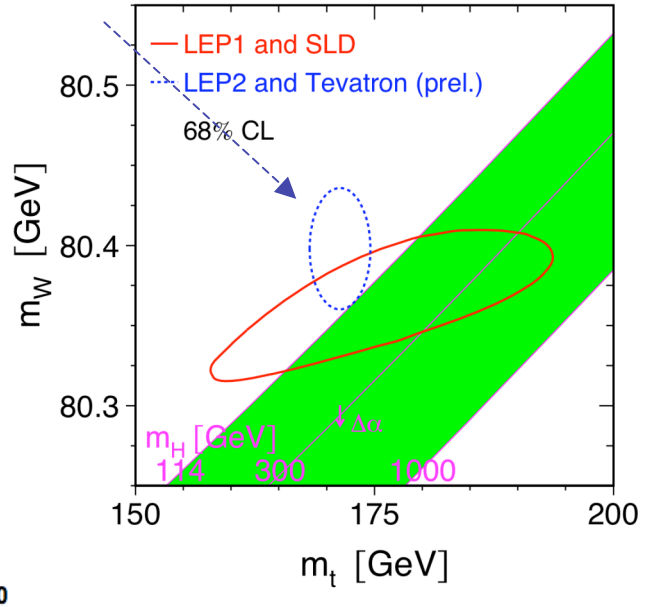
W mass measurement





- Mass extracted from fits to the m_T, p_T and MET distribution from $W\to e\nu$ and $W\to\mu\nu$ decays
- Important components:
  - precise detector calibration (few 1/10000 in p_T and E_T)
  - fast simulation describing relevant details of hadronic W production, decay and interaction with the detector
- Measure: $M_W = 80413 \pm 48$ MeV/c^2 (the world's most precise single measurement)
- New world average: 80398 ± 25 MeV/c^2 (previous average: 80392 ± 29 MeV/c2)

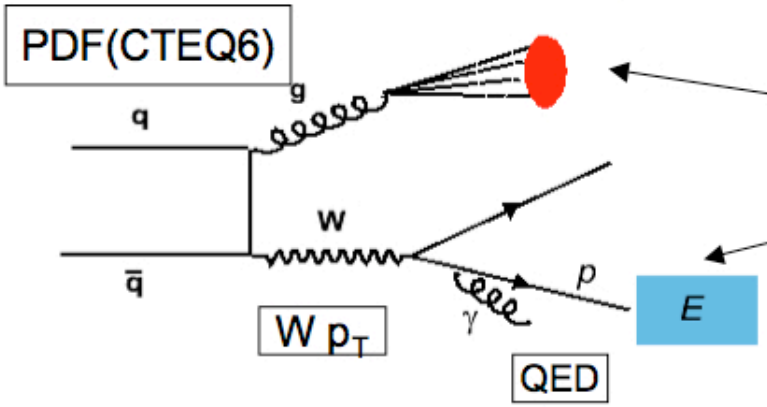




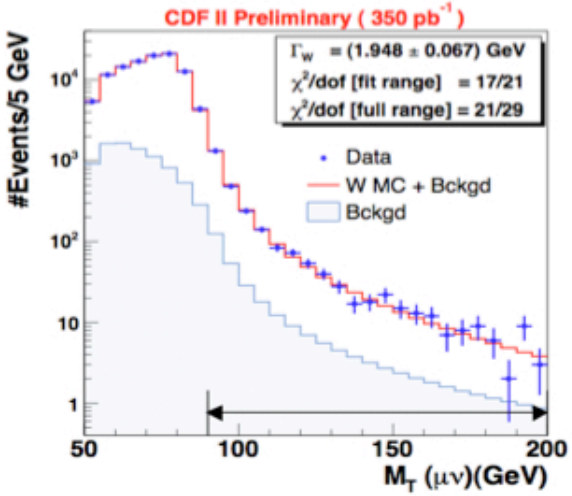
W-width measurement

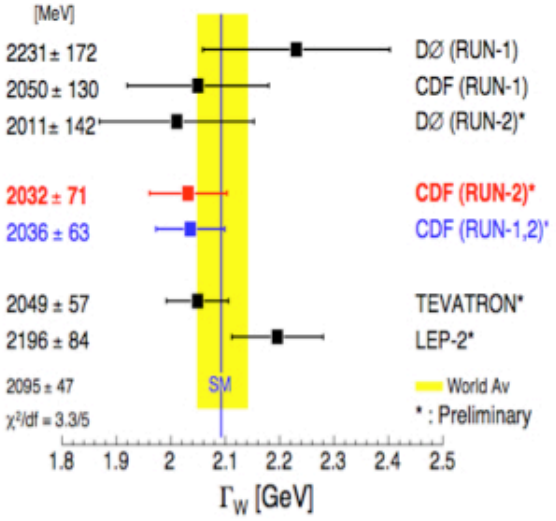
Γ_W is obtained by fitting to the tail of the M_T distribution in W→eν and W→μν events

$$M_T = \sqrt{2p_T^{\ell} p_T^{\nu}(1 - \cos(\Delta\Phi^{\ell\nu}))}$$

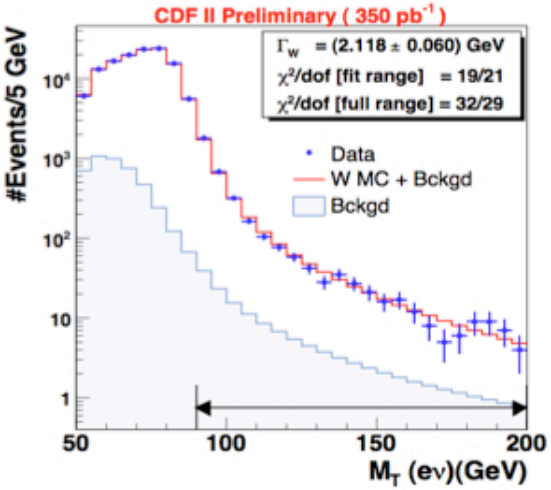


- Calorimeter response to recoil
- lepton energy scale and resolution
- lepton momentum scale and resolution
- Backgrounds added to MC





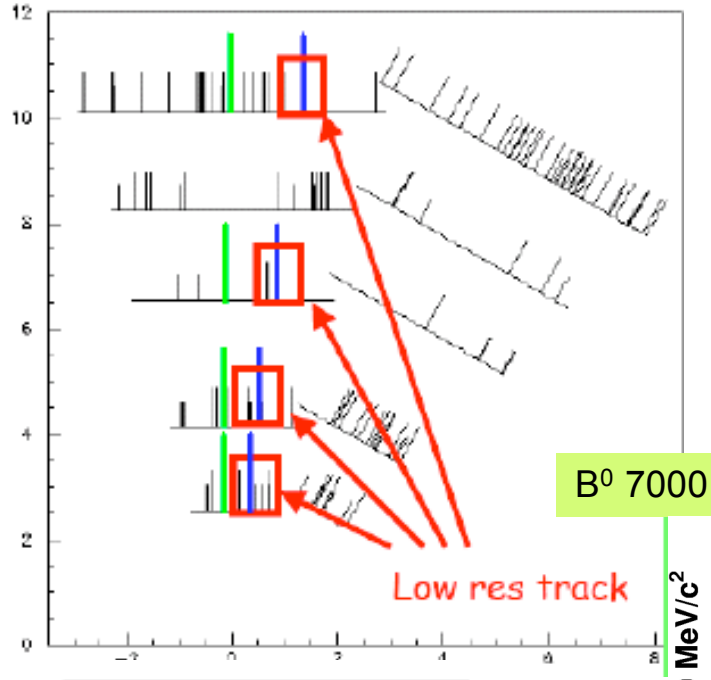
Γ_W = 2032 ± 71 MeV/c²
(the world's most precise single direct measurement)

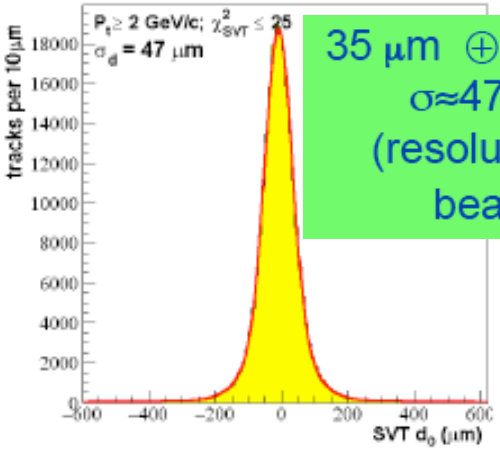


CDF SVT Trigger

First slide of Gigi Rolandi's Moriond QCD summary talk

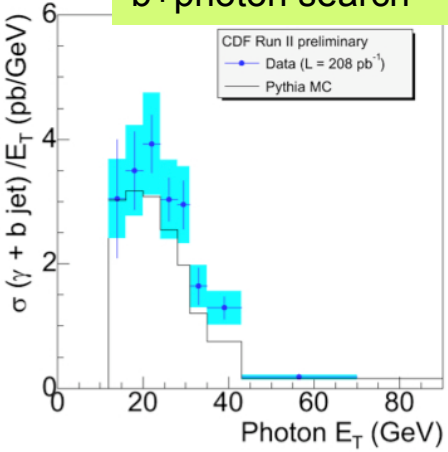
Finding tracks in the silicon

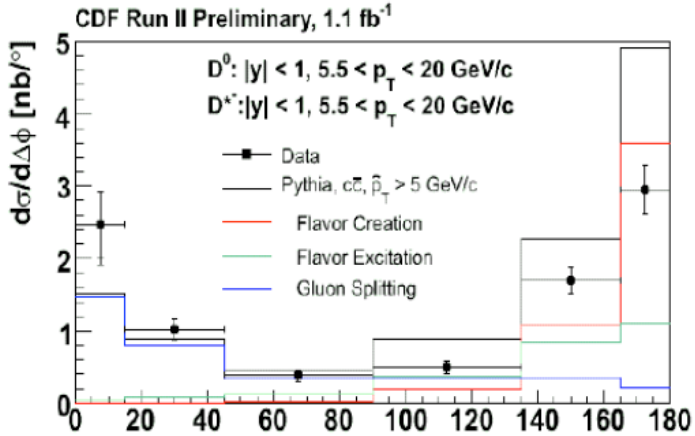




35 μm ⊕ 33 μm = σ≈47 μm (resolution ⊕ beam)

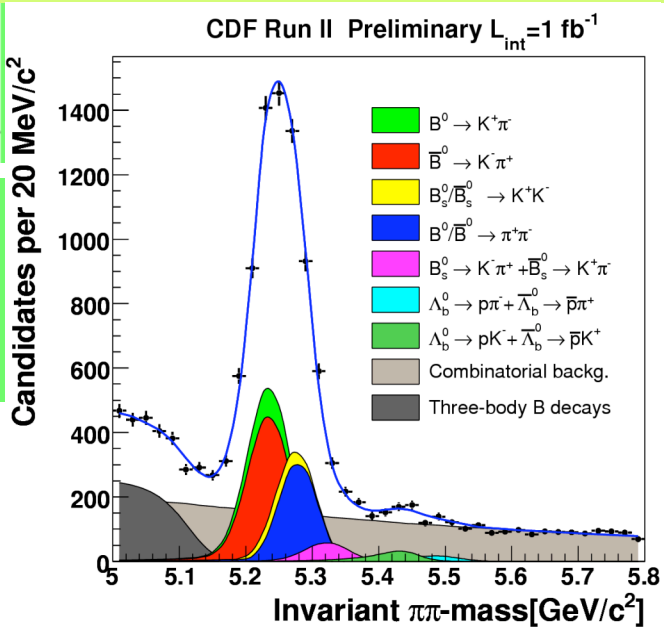
b+photon search



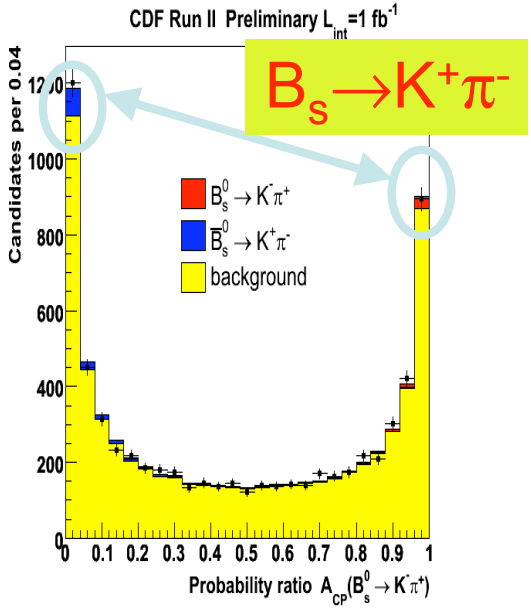


Angular Correlation of charm pairs

B^0 7000 Signal events S/B ≅ 8.3 at the peak



B_s Direct CP Asymmetry



A look ahead: Summer 2007

Summer'07 expected results

Push the physics program to ~ $2fb^{-1}$

- **Top Physics Goals**
  - Top mass in all channels (~1% CDF alone)
  - Improved single-top analyses (close to 5-sigma…)
  - Precision ttbar cross-section (near 10% Run 2 goal)
  - Update other top properties

- **B-Physics Goals**
  - Improve NP constraints in Bs system: DGs, fs, Am
  - More B==>hh
  - D-mixing results (3-sigma sensitivity)
  - Improved sensitivity to discover more b-baryons and measure their properties

More for Summer'07

- **QCD and Electroweak Physics Goals**
  - Update inclusive di-jet mass spectrum
  - Update inclusive photon cross-sections
  - Produce W/Z + jet and W/Z+h.f. cross-sections
  - Update di-boson cross-sections
- **Higgs and New Phenomena Search Goals**
  - Improved sensitivity to Z' in ee and mm channels
  - Improved sensitivity to Extra-Dimensions (gg, ee, met+jet)
  - Improved sensitivity to SuSy
  - Long-lived decays, CHAMPs, multi-leptons, Bs==>m+m-
  - Significantly improved sensitivity for SM Higgs 110 < mh < 190 GeV/c2
  - Improved sensitivity to h==>tau,tau

Something to look forward to

People

streamlining + automating + recruiting

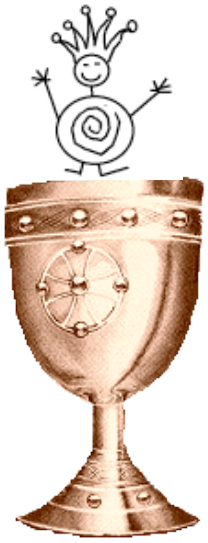
Recent collaboration survey

	CY 2007	2008	2009
US FTE	222	162	127
Non US FTE	170	135	109
Total US + Non US	392	297	236
Post Doc's	101	73	53
Students	147	102	77

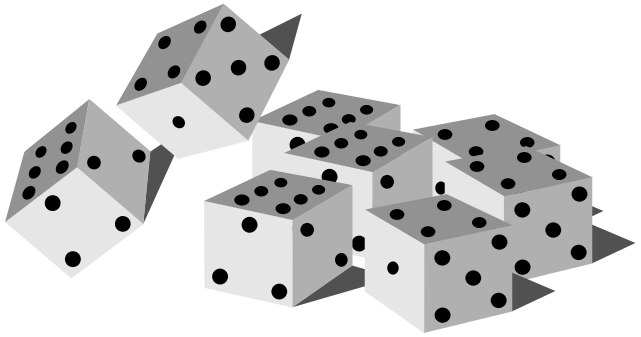
Collaboration members available in units of FTE

- ~30% more FTE in CY07 than estimated in CY05 !
  - Delay in LHC turn-on
  - Tevatron and CDF experiment running very well
  - Physics and leadership opportunities at CDF
- It takes ~100 FTE to Run CDF

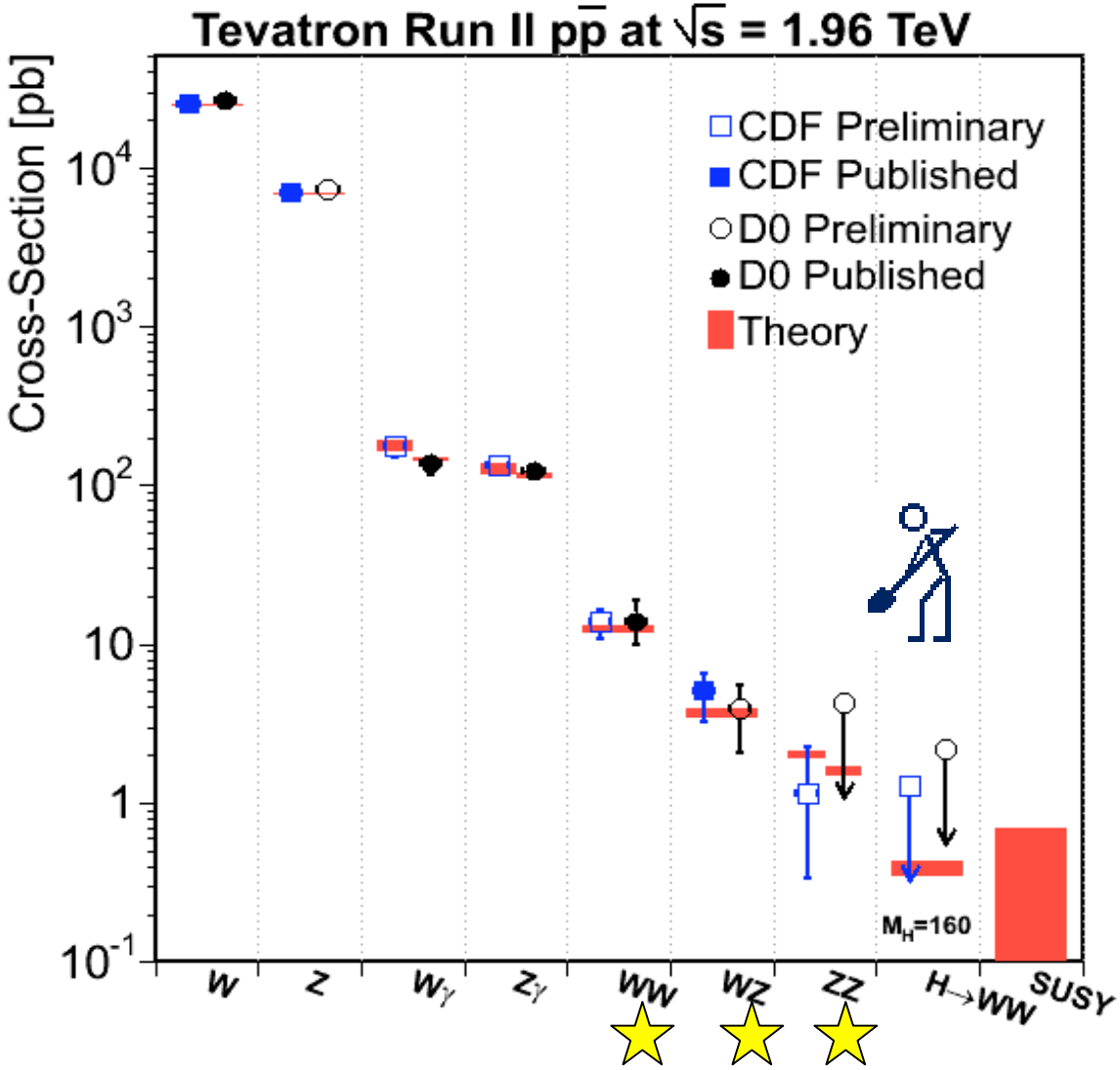
Enough people to run the experiment and accomplish the physics



The road to the Higgs



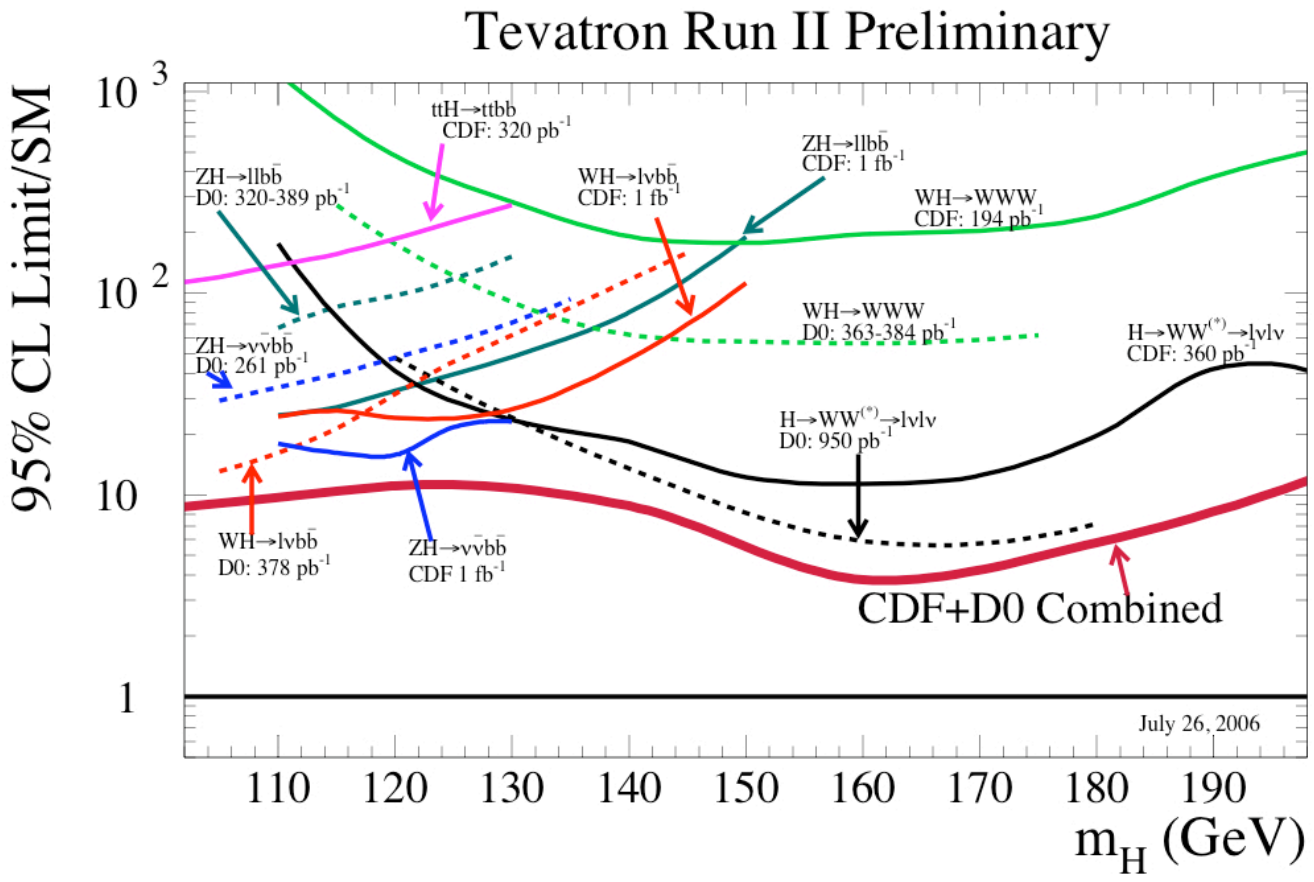
Marching along… digging deeper

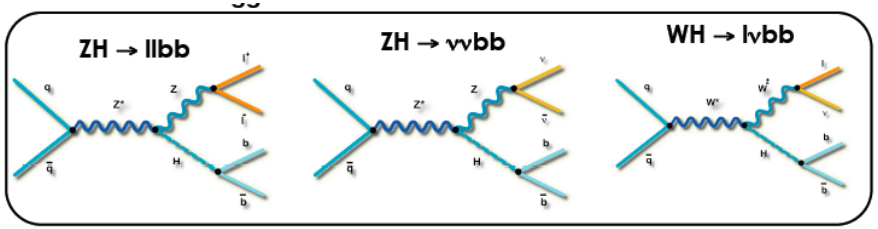


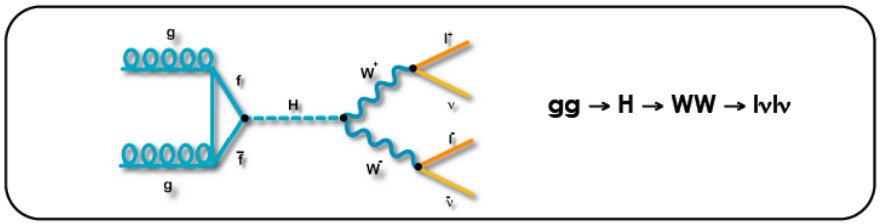
Given enough time [data] we can get there

Status circa Summer'06

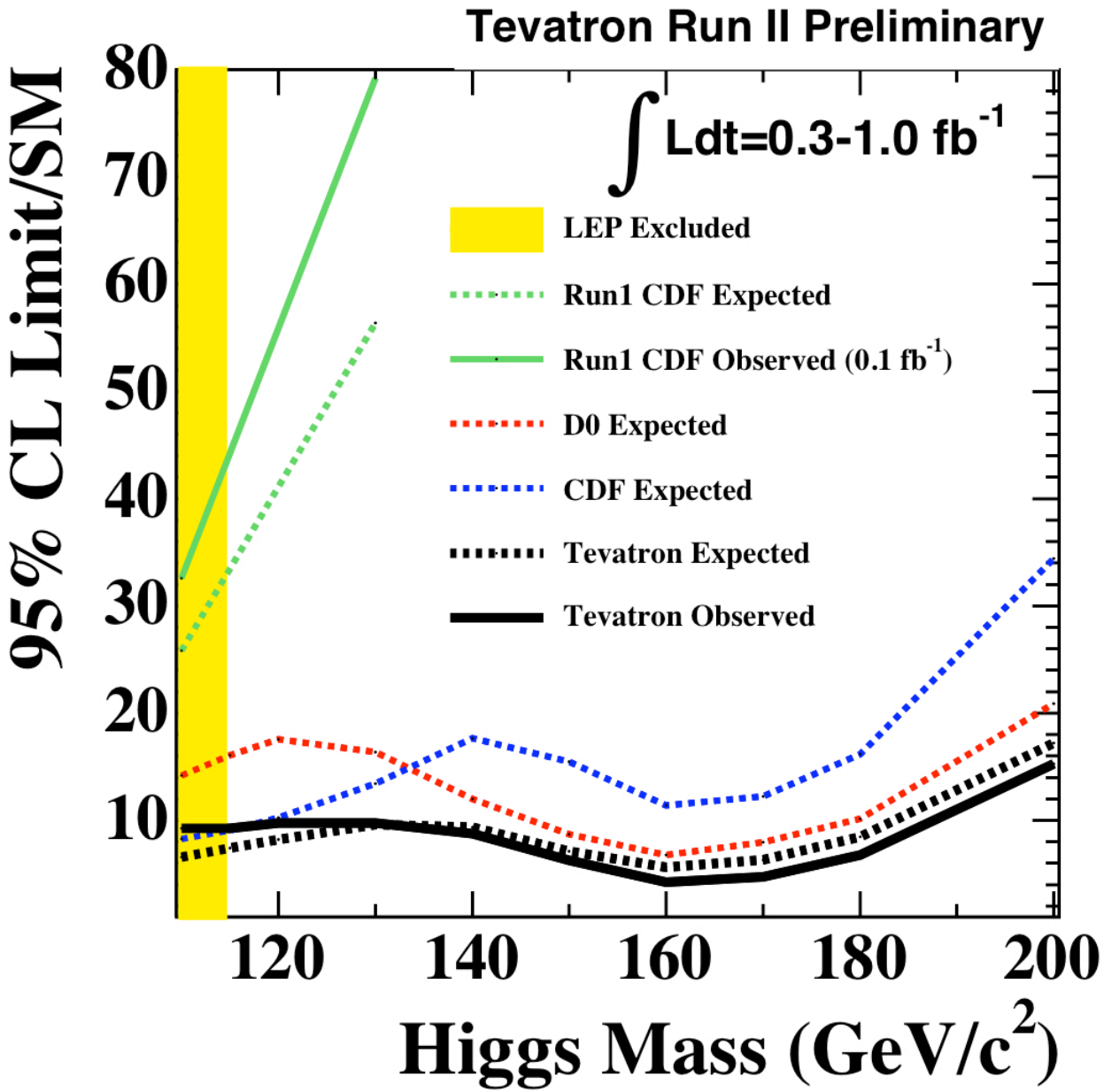
Lum {0.3,1.0 fb^{-1}}





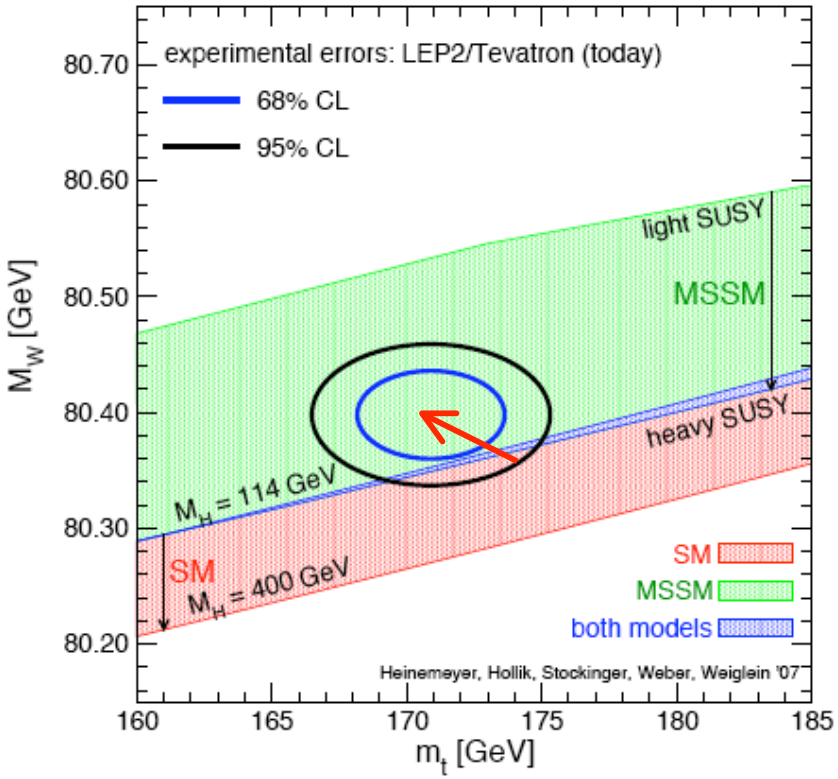


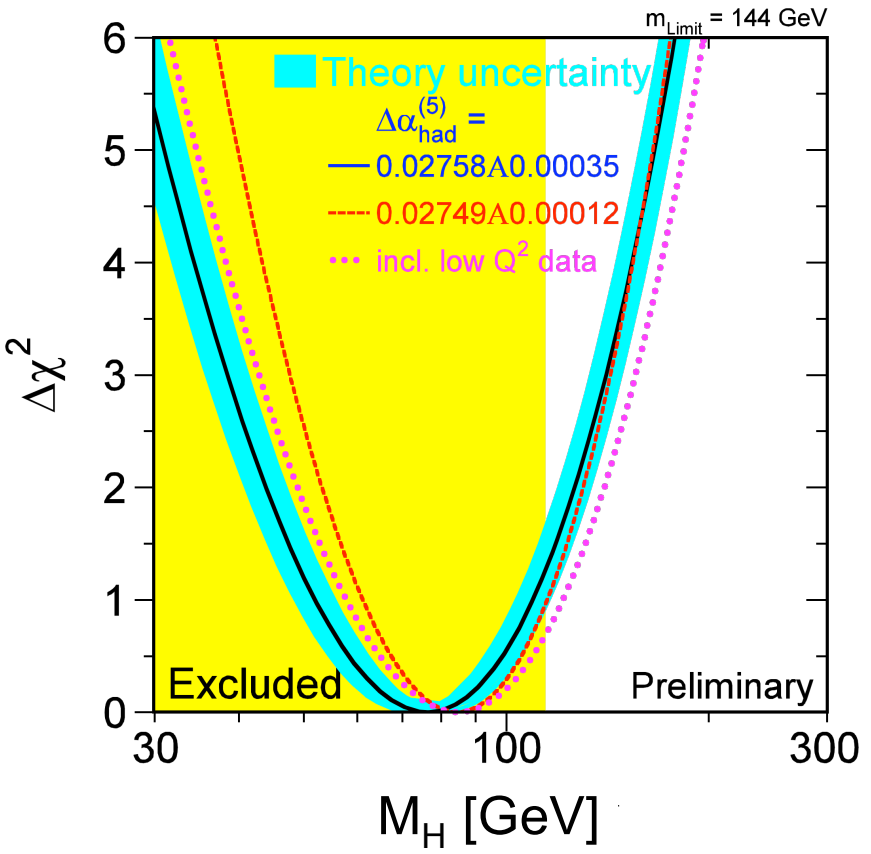
In perspective with Run 1



Where can it be ?

NEW! **March 2007, LEP EW WG**





Preferred value: m_H = 76 GeV at minimum

Upper limit: m_H < 144 GeV @ 95% C.L.

Our M_{top} and M_W results are having an interesting effect

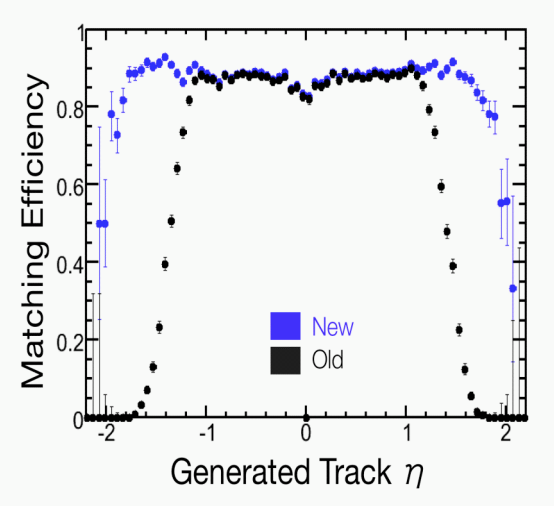
More sensitivity for Higgs

- **NEED TO EXPLOIT EVERY BIT OF SENSITIVITY that we can find:**
  - **5 x 10% losses ==> our dataset is reduced by x 2 !**

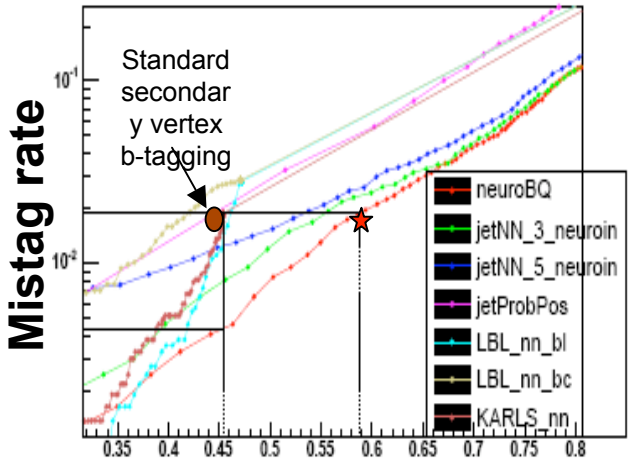
We need to go after as many 5-10% effects as possible

- **And we are doing just that:**
  - Better b-tagging overall
  - Forward tracking and forward b-tagging
  - Include all lepton types with maximal efficiency
  - Improve Jet E resolution, B-jet E resolution
  - Better use of existing triggers
  - Trigger upgrades
  - Open trigger to include maximum searchable phase space
  - Improve analysis techniques

Ex: Improvements on their way to Higgs analyses

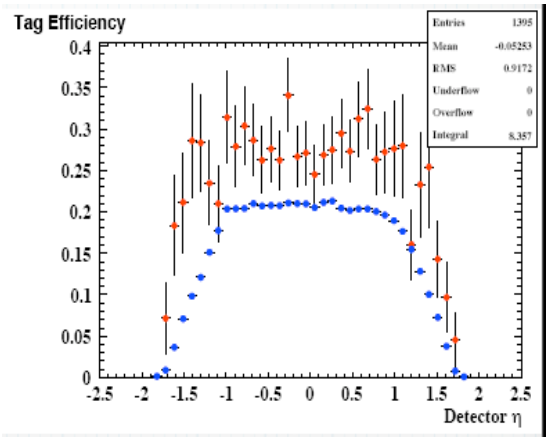


Forward tracking

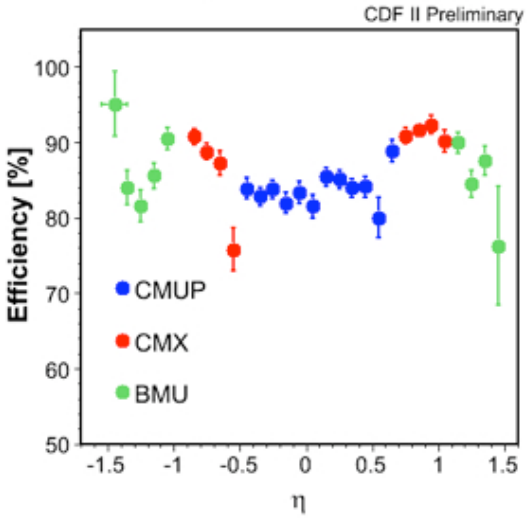


Tagging Efficiency

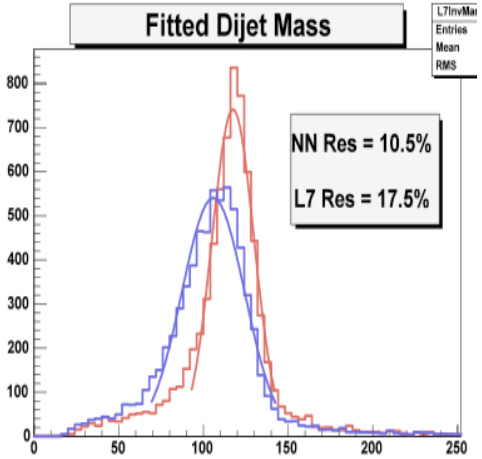
Improved b-tagging



Forward b-tagging



BMU muons

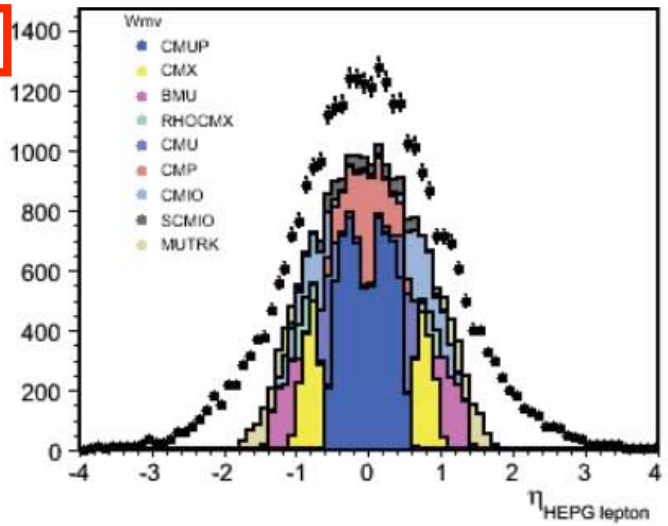


Improved Jet E res

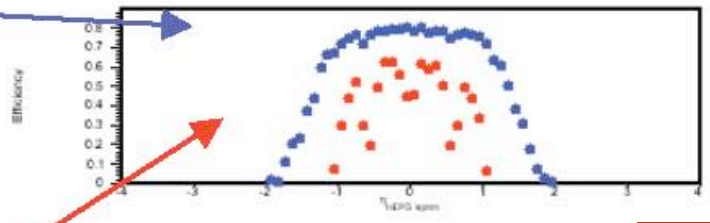
Higgs Trigger Task Force

- **Charge: make sure we are squeezing every last bit of acceptance out of our trigger**
  - Improve trigger algorithms to reflect what we've learned with 1fb^{-1} analyses
  - Take advantage of trigger upgrades (XFT, SVT, L2 Cal, EVB)
- **Example: improving acceptance for WH→μνbb**
  - Existing analysis using central muons has a 31% acceptance.
  - New triggers and algorithms could potentially double our acceptance.

Gain 0.311078 -> 0.631478
CMUP 22.09 +/- 0.23
CMX 9.02 +/- 0.16
BMU 5.92 +/- 0.13
RHOCMX 1.59 +/- 0.07
CMU 4.58 +/- 0.12
CMP 6.44 +/- 0.14
CMIO 7.32 +/- 0.15
SCMIO 2.08 +/- 0.08
MUTRK 4.12 +/- 0.11



"improved" eff ~63%



"default" eff (CMUP, CMX only) ~31%

Techniques:

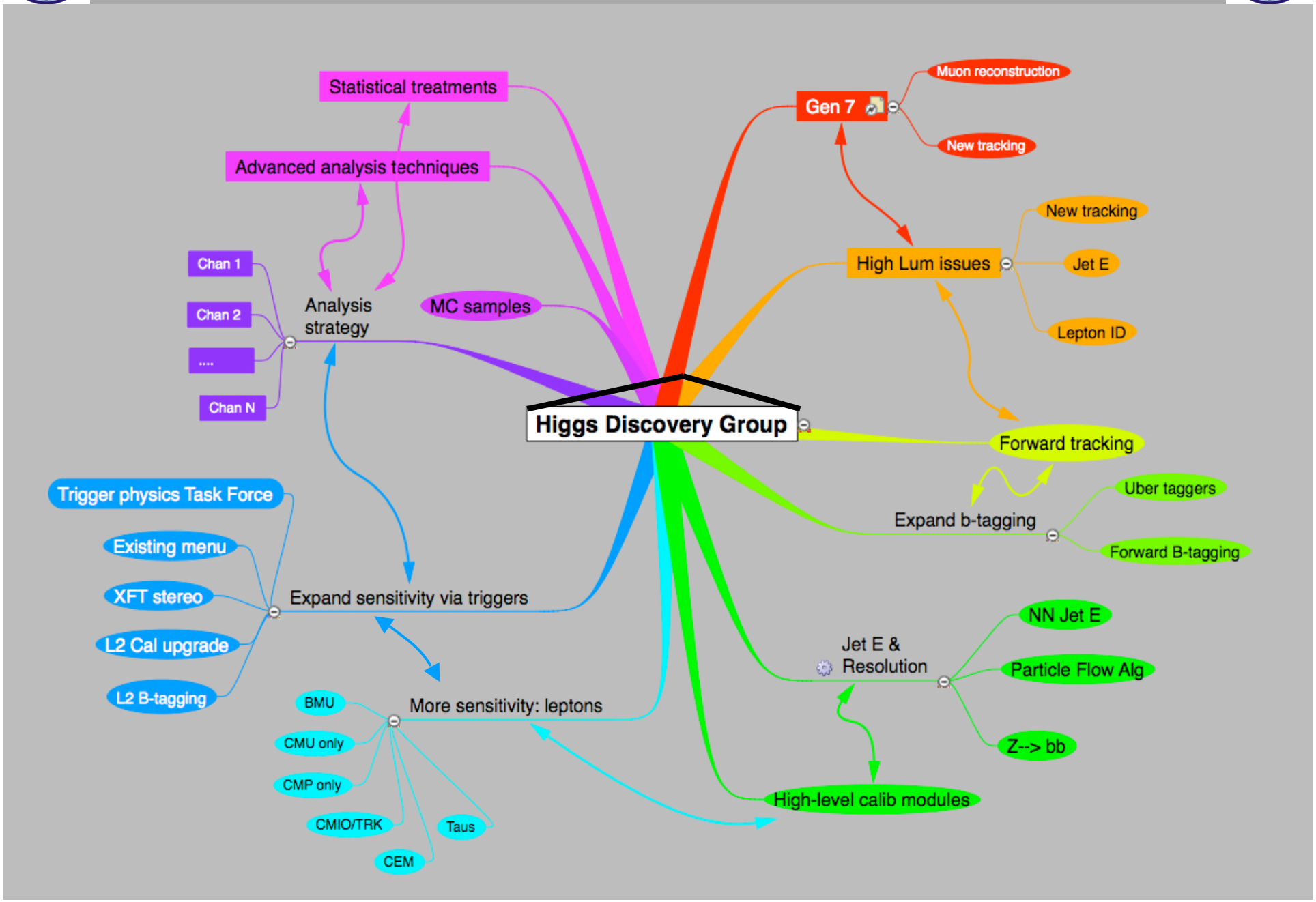
- Reduce rates by tightening muon matching cuts
- Trigger on "gap" muons (CMU only, CMP only)
- Get stubless and forward muons from 2-jet + MET trigger.

~35 people contributing !

New Higgs Discovery Group

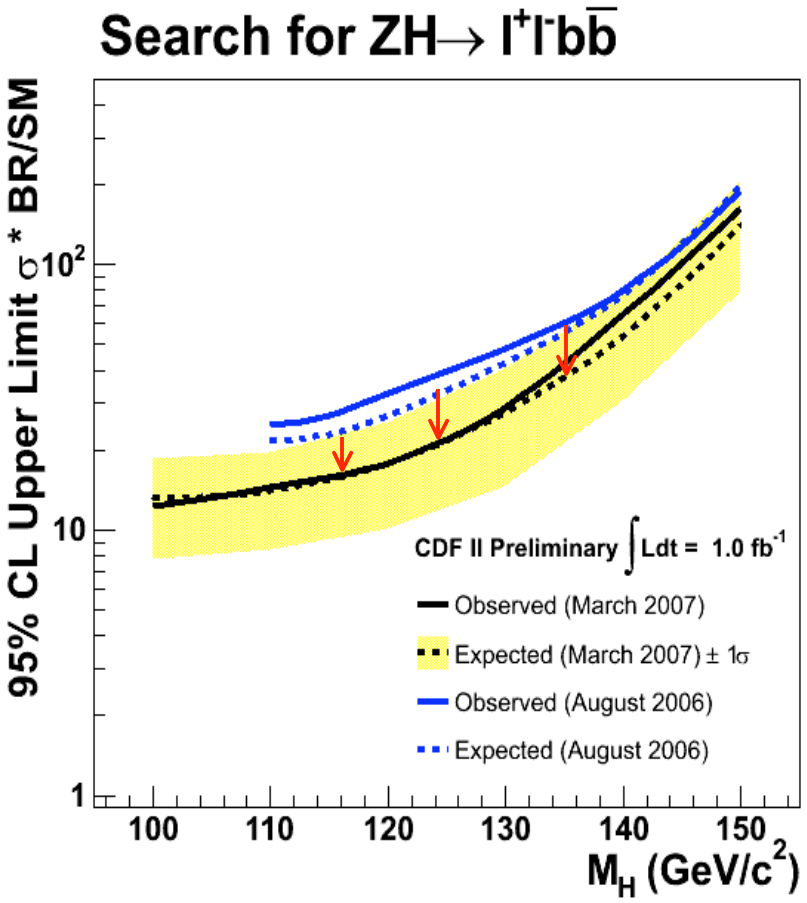
- Elevated the status of the subgroup to “Physics Group”
- Link intimately all the tools to the group’s work and focus
- Many institutions are adding new people to work on such a broad Higgs effort
- Many young and talented people expressed interest in staying at CDF to do exactly this
- Such a mission will help pull CDF together in the years ahead
  - both in spirit and operationally
- It has energized the collaboration!
- Maybe our smart and hard work and Nature’s kindness will allow us to discover the elusive Higgs !

The Road to the Higgs



Example: New $ZH \Rightarrow l^+l^-bb$

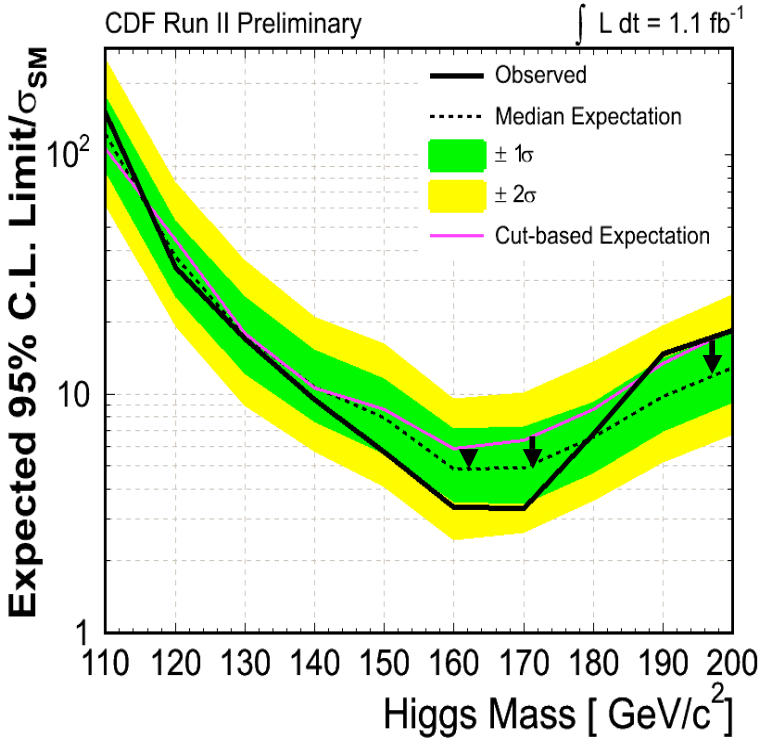
- **Recent improvements**
  - Improved di-jet resolution
    - 16% to 10%
    - Using a MET correction
  - Improved NN inputs
    - More angular info
  - Split 1 and 2 tag events
    - Better use of bcknd info
- **Still more room:**
  - More triggers
  - More lepton categories
    - i.e. taus (~50%)
  - Better tagging
  - Matrix Element
  - ?



Same luminosity, better sensitivity

Example: H==>WW @ 1.1 fb-1

- New, increased sensitivity
  - Matrix elements in likelihood ratio discriminants
    - vs mass
  - Added lepton categories a'la WZ discovery
  - ~50% more effective lum at 160 GeV
- Still more room
  - taus
  - NN + ME
  - ?



Same luminosity, better sensitivity

More than just 1/sqrt(Lum)

- **Tools examples** (experience, a person, a mission)
  - B-tagging
  - Forward tracking
  - Jet E resolution
  - More lepton times
  - Trigger maximization

- **Analysis examples** (better techniques, more channels, time)
  - Top mass
  - W mass
  - Bs-mixing
  - WZ discovery
  - ZZ evidence
  - Newest Higgs searches

We will never mature !

Summary

- The Tevatron is performing great
- CDF is in good shape across the board
- Will continue our streamlining and staffing efforts

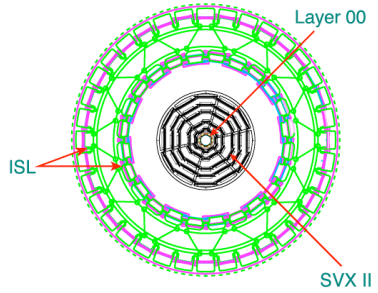
- Our physics program is rich and ground-breaking
- We are publishing our results
- We are constantly improving our techniques and reach
- Will continue on this path as we near the Higgs Horizon…

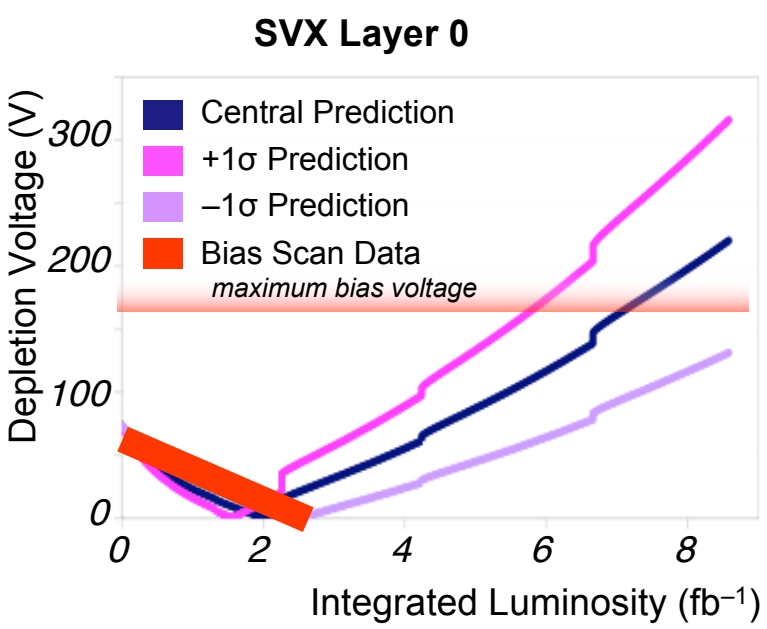
At CDF it is harvest time and we are on a mission !

BACKUP

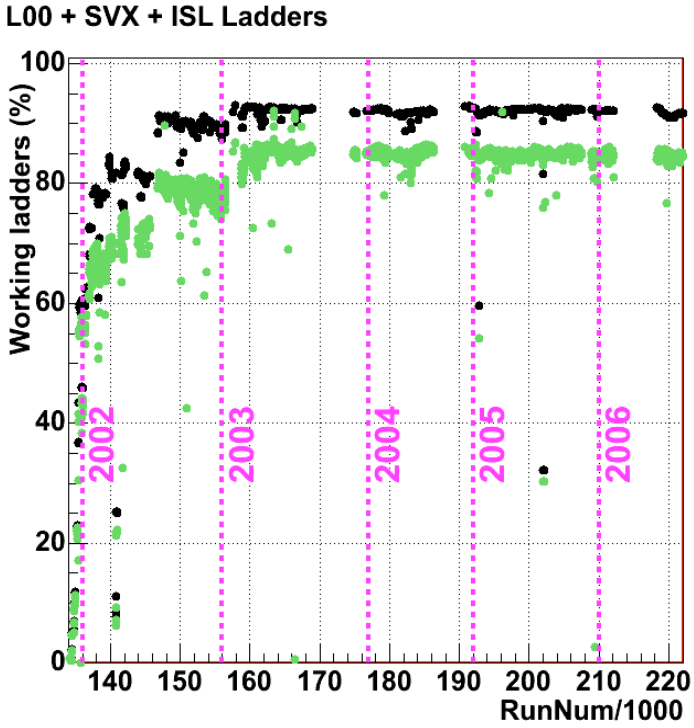
Silicon Longevity - details

- Bias voltage required to fully deplete Silicon sensors changes with irradiation: decrease – type inversion – increase
- If depletion voltage larger than maximum safe bias voltage:
  - cannot fully deplete sensors → efficiency loss
- Bias scans show innermost SVX layer (most vulnerable) is nearing inversion
  - Closer to -1-sigma prediction





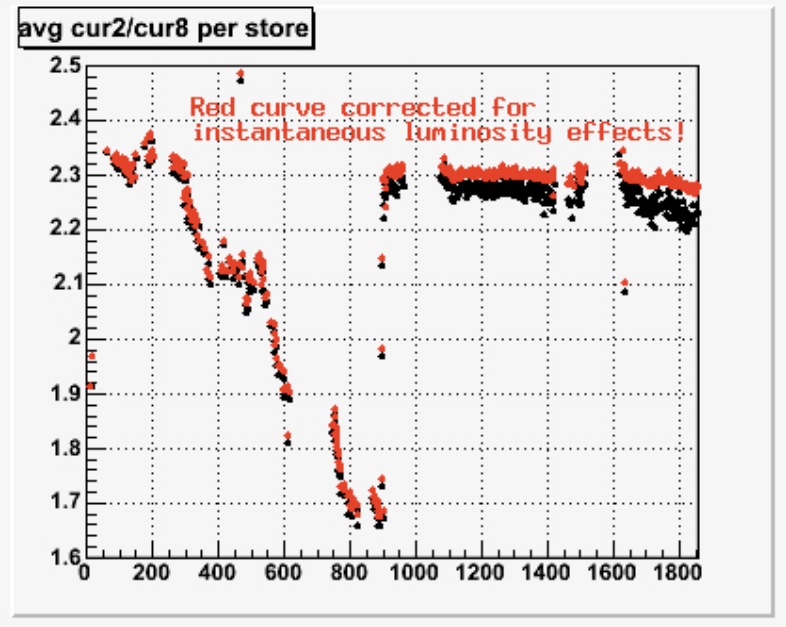
Model: S. Worm, *Lifetime of the CDF Run II Silicon,* VERTEX 2003



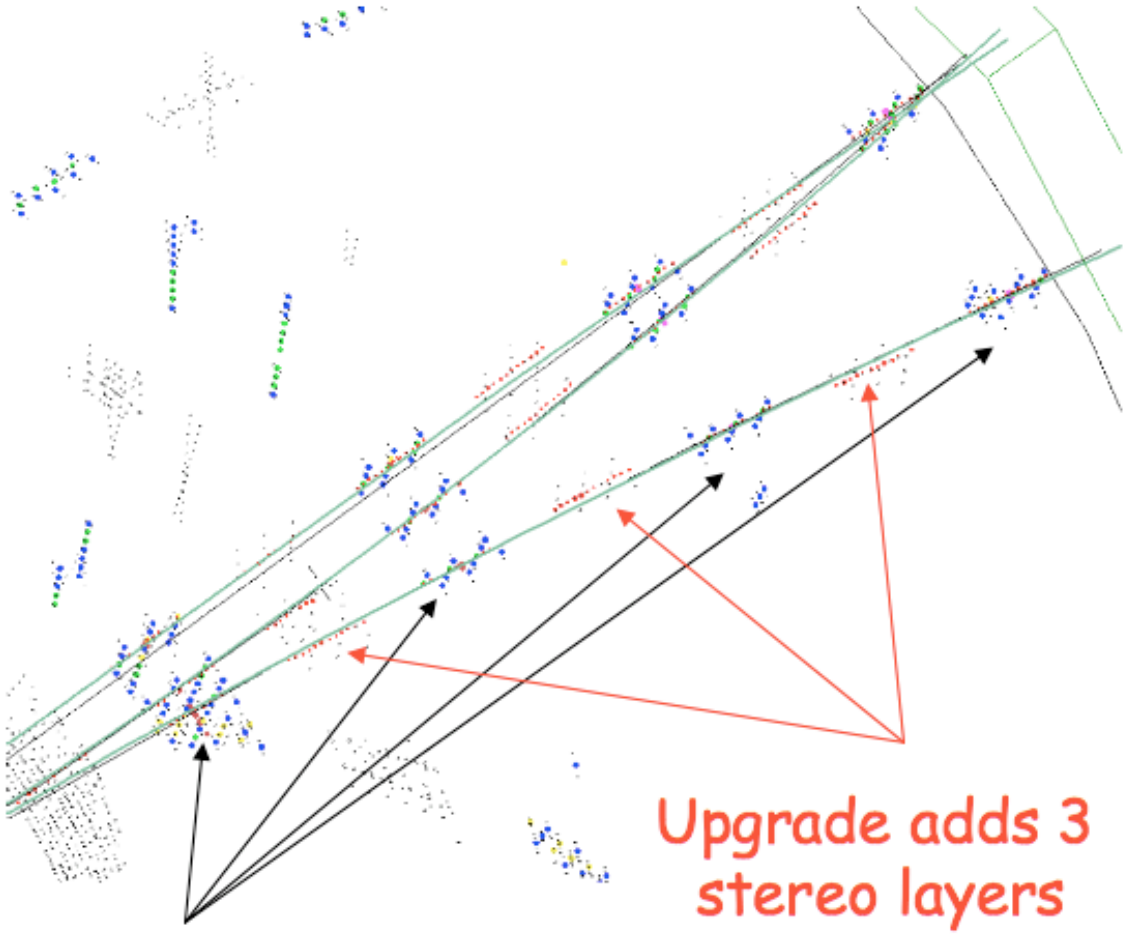
Silicon stable and expected to outlast 8 fb⁻¹

Tracking Chamber - details

- **We addressed an aging problem of the Central Outer Tracker drift chamber in 2004**
  - Aging was found to be due to hydrocarbon growth on wires
  - Addition of O_2 to gas in June 2004 restored gain to original 2002 levels
  - Possible new evidence of aging at the highest luminosities
    - Minimal, if at all
    - New gas purification system to clean re-circulated gas expected to be complete later this year
    - Can also increase amount of oxygen added



XFT Upgrade



- XFT originally only utilized axial layers
- Upgrade adds 3 stereo layers to 4 layer axial XFT system
  - better fake rejection
  - better resolution

Recent survey of collaboration resources

	CY 2007	2008	2009
US FTE	222	162	127
Non US FTE	170	135	109
Total US + Non US	392	297	236
Post Doc's	101	73	53
Students	147	102	77

- Collaboration members available in units of FTE
- ~30% more FTE in CY07 than estimated in CY05 !
  - Delay in LHC turn-on
  - Tevatron and CDF experiment running very well
  - Physics and leadership opportunities at CDF
- It takes ~100 FTE to Run CDF

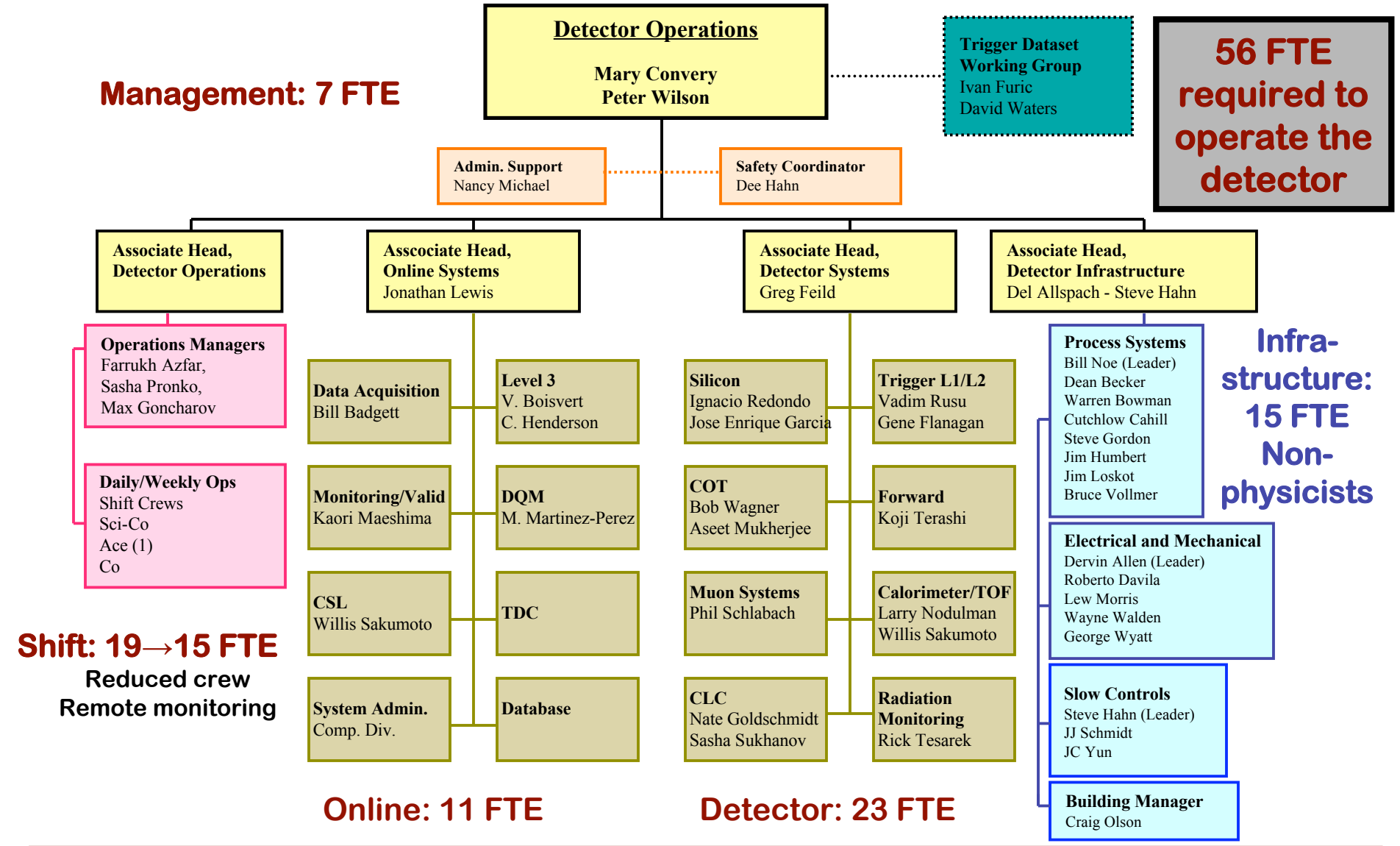
Enough to run the experiment and accomplish the physics

Collaboration Resources Needed

	CY 07	CY 09
Detector Ops	56	51
Offline	26	20
Algorithms	32	21
Management	10	10
Total for Ops	124	102
Resources Available	392	236
FTE for Physics	392 – 124 = 268	134

Enough to run the experiment and accomplish the physics

CDF Detector Operations Organization



streamlining + automating :: ease of operation + less personnel

New: "gap analysis" spreadsheets

PROJECT	FTE %	Q1 06	Q2 06	Q3 06	Q4 06	Q1 07	Q2 07	Q3 07	Q4 07	Q1 08
Trigger										
SPL	20	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	…	…	…
SPL	20	Greg Field	Greg Field	Greg Field	Greg Field	Greg Field	Gene Flanagan	Gene Flanagan	Gene Flanagan	Gene Flanagan
L1 Calorimeter (Dirac, CS, PreFRED)										
Primary Expert	25	Carla Pilcher	Carla Pilcher	Carla Pilcher	Carla Pilcher	Carla Pilcher	Carla Pilcher	Carla Pilcher	Carla Pilcher	Carla Pilcher
Backup Expert	5	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	Vadim Rusu	Chicago
Backup Expert	5	Peter Wilson	Peter Wilson	Peter Wilson	Peter Wilson	Peter Wilson	Peter Wilson	Peter Wilson	Peter Wilson	Peter Wilson
Muon Trigger										
Primary Expert	10	Eric James	Eric James	Eric James	Eric James	Eric James	Eric James	Eric James	Eric James	Eric James
Backup Expert	5	UM GS	UM GS	UM GS	UM GS	UM GS	UM GS	UM GS	UM GS	UM GS
XTRP and L1 Two Track Trigger										
Pager	10	Chris Marino	Chris Marino	Chris Marino	Chris Marino	Chris Marino	Chris Marino	Chris Marino	Chris Marino	UofI
Expert (Map Code)	5	Kevin Pitts	Kevin Pitts	Kevin Pitts	Kevin Pitts	Kevin Pitts	Kevin Pitts	Kevin Pitts	Kevin Pitts	Kevin Pitts
L1 Decision and TSI										

For all systems: find holes early, streamline further and recruit