CDF Detector Operations

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Co-Head CDF Detector Operations
DOE Tevatron Operations Review
March 27, 2007

CDF Detector Operations

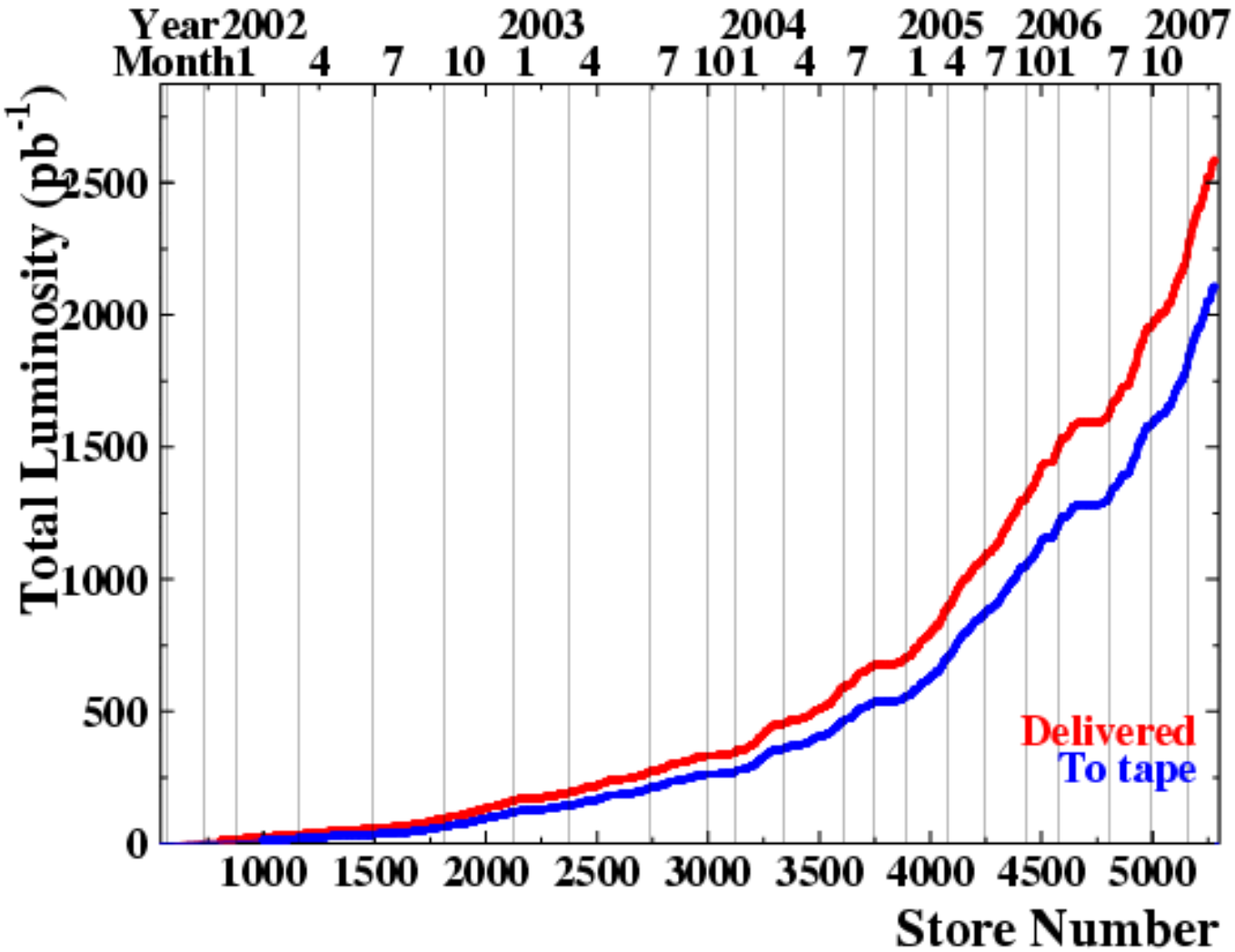
- Responsible for operating the CDF detector by directing Fermilab and collaboration-wide personnel to achieve the goal of efficient, safe, and reliable detector operation

- Our goal is to collect data with high efficiency, utilizing detectors that are stable, calibrated, aligned, and well understood

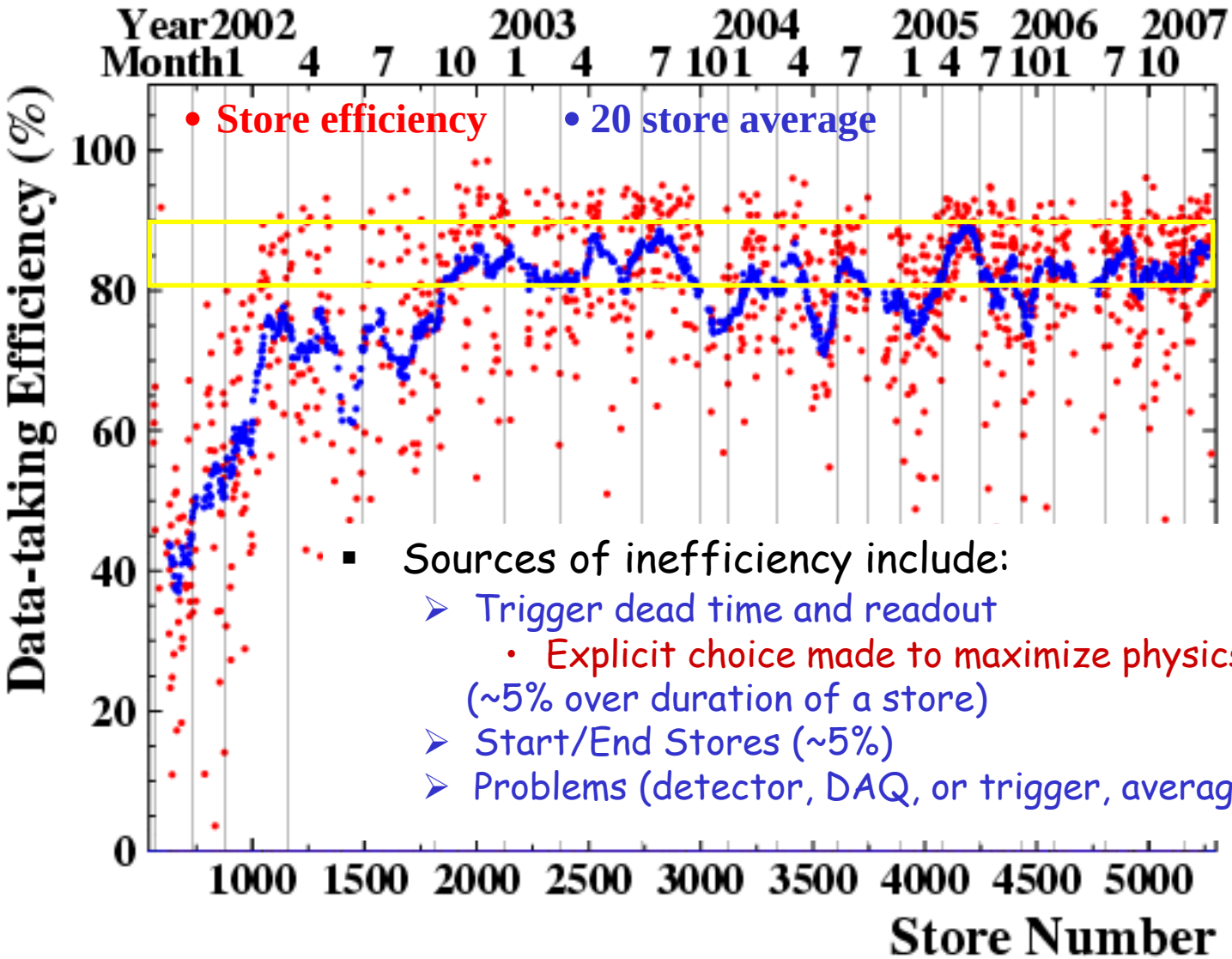
CDF Operational Safety

- CDF continues to be a very safe place to work
- CDF operations has not had an accident since Oct. 2003 (twisted ankle)
  - Goal is to complete Run II without another
- People are our first concern, but equipment safety is important also
  - ES&H safety specialist full-time in B0 building
- Continue to work hard at being procedure driven
  - Procedures and JHA's written by work performers
  - Used for emergency response and training also
- Regular walkthroughs of all areas to inspect for safety concerns is done by department management and Lab ES&H personnel
- Monthly safety meetings for Technical personnel
- Training ground for Experimental Physicists – integrating safety into young people's "culture" is a high priority for CDF

CDF Recorded Luminosity

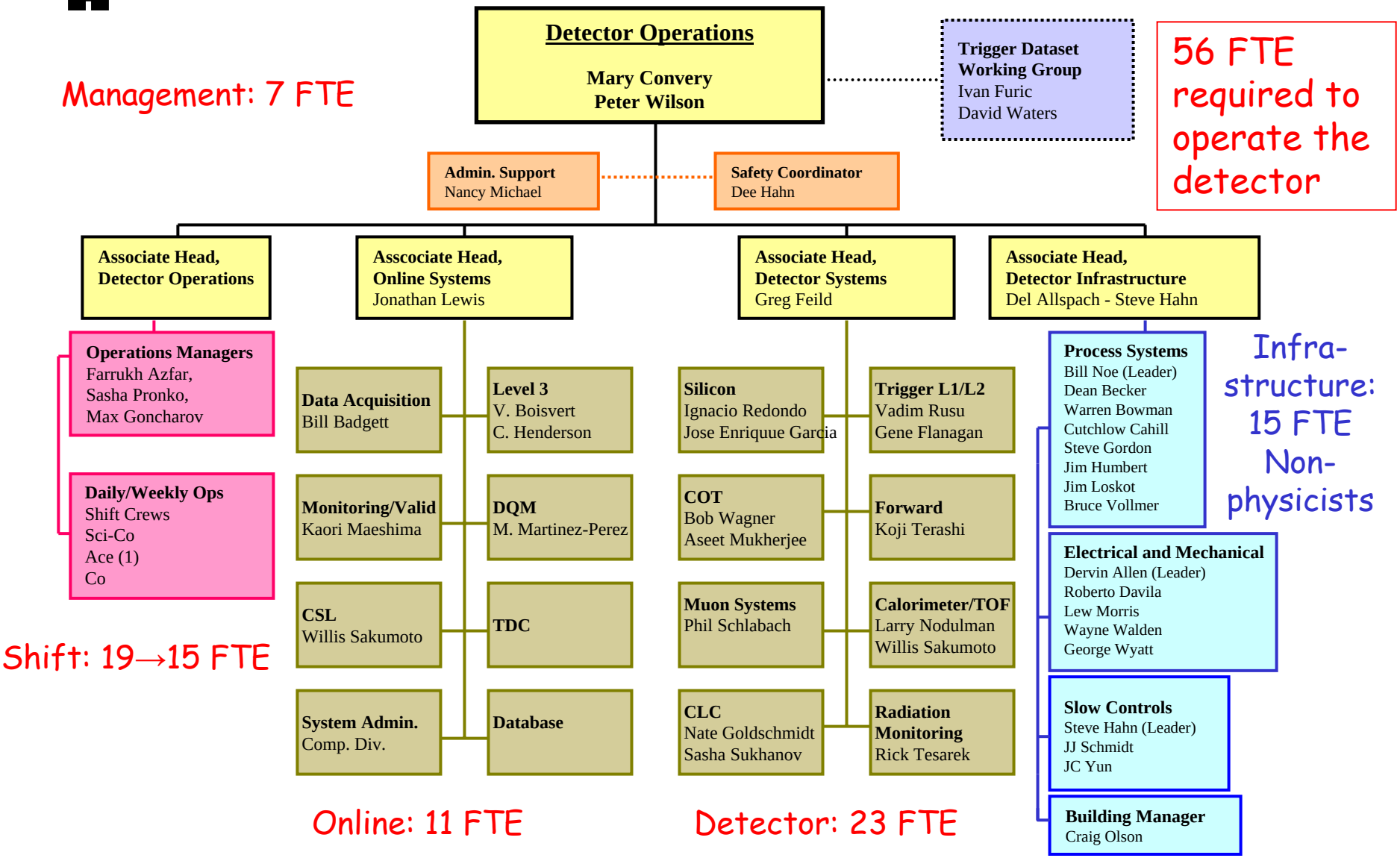


Data-Taking Efficiency



- Sources of inefficiency include:
  - Trigger dead time and readout
    - Explicit choice made to maximize physics to tape (~5% over duration of a store)
  - Start/End Stores (~5%)
  - Problems (detector, DAQ, or trigger, average ~5%)

CDF Detector Operations Organization

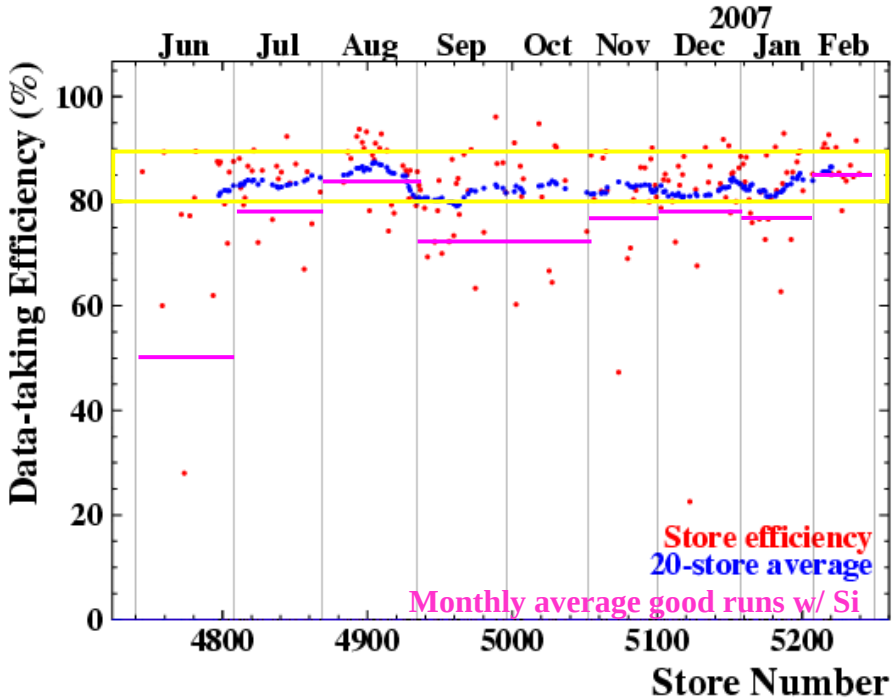


Example Operations Group Spreadsheet

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										

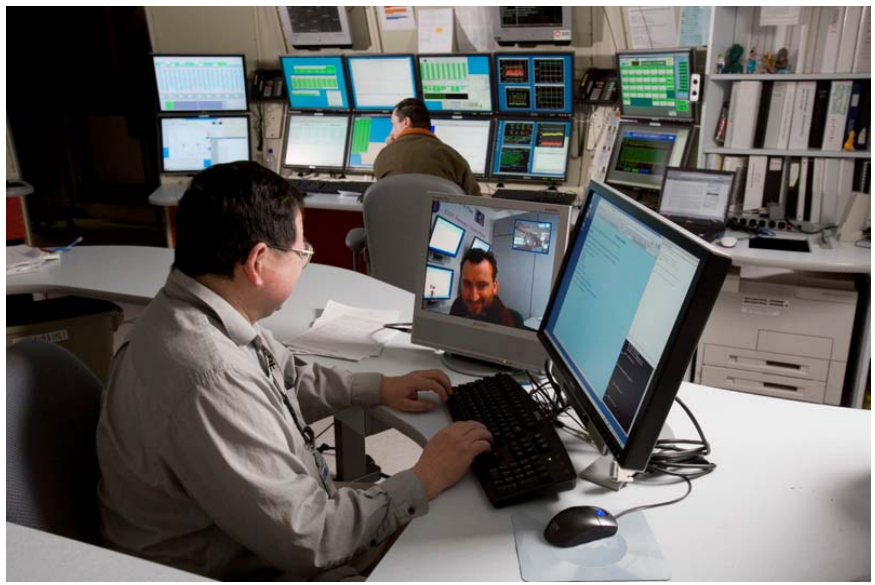
Streamlining Shift Operations – Reduced Crew

- Reduced shift crew by one member without sacrificing data-taking efficiency or safety of detector
  - Automated tasks to allow shift crew to focus on decision making
  - Redistributed tasks to other shift crew members
  - Students and postdocs freed from shift duties available elsewhere in detector operations, e.g. in the silicon group
  - Improving detector safety and data-taking efficiency
    - New tool for monitoring beam conditions automatically puts detector HV in a safe state if beam conditions are unsafe
    - Automatic recovery of silicon HV crate communication problems is faster and keeps shift crew in control room



Streamlining Shift Operations – Remote Monitoring

- Consumer Operator shifts for data quality monitoring for all detector subsystems done from remote site
  - All monitoring plots available via Web
- CO shift room in Pisa
  - Monitoring workstations and video conferencing to CDF control room
- Physicists in Pisa currently covering owl shift one week a month
  - Reduce need for travel for overseas members of CDF
  - Owl shift is 7:00-15:00 in Pisa, Italy or 15:00-23:00 in Tsukuba, Japan
  - Expect other European collaborators to take advantage of this
  - Extending to site in Japan



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
  - Delay in LHC turn-on and the success of the Tevatron has resulted in many more FTE's available for CDF
    - 30% increase over 2005 estimates
  - Students and post doc's decline at similar rate
  - Total head count remains steady at ~610 physicists

Collaboration Resources Needed

- Streamlining also being done to reduce people needed in offline operations and physics algorithms

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

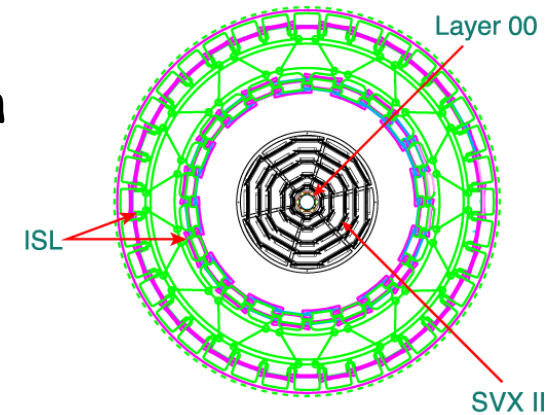
- We have sufficient resources to operate the experiment and perform the "core" physics analyses.
- These resources may not allow us to get all the physics we would like to out of the data

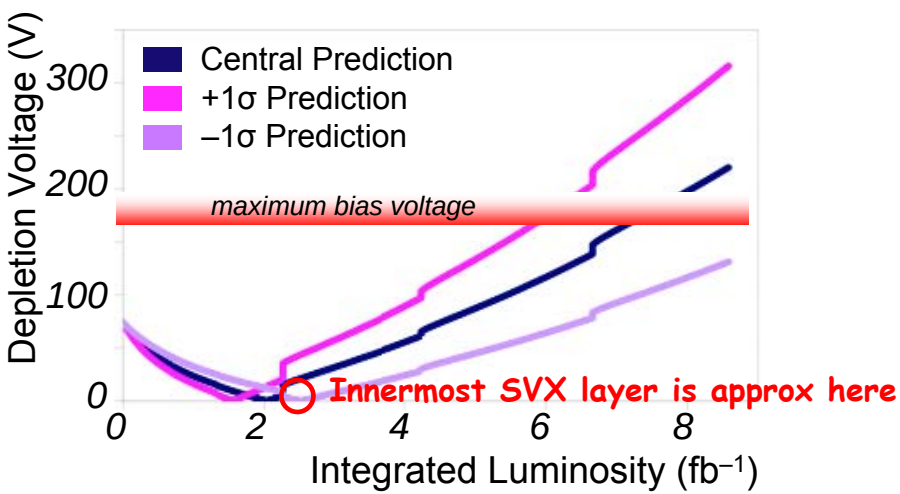
Detector Performance

- Silicon longevity
  - Expect silicon detector to last through 2009
- Monitoring of other detector concerns
  - Tracking chamber currently shows no signs of aging
  - Current issues
- Detector performance at high luminosity
  - Trigger and DAQ Upgrades

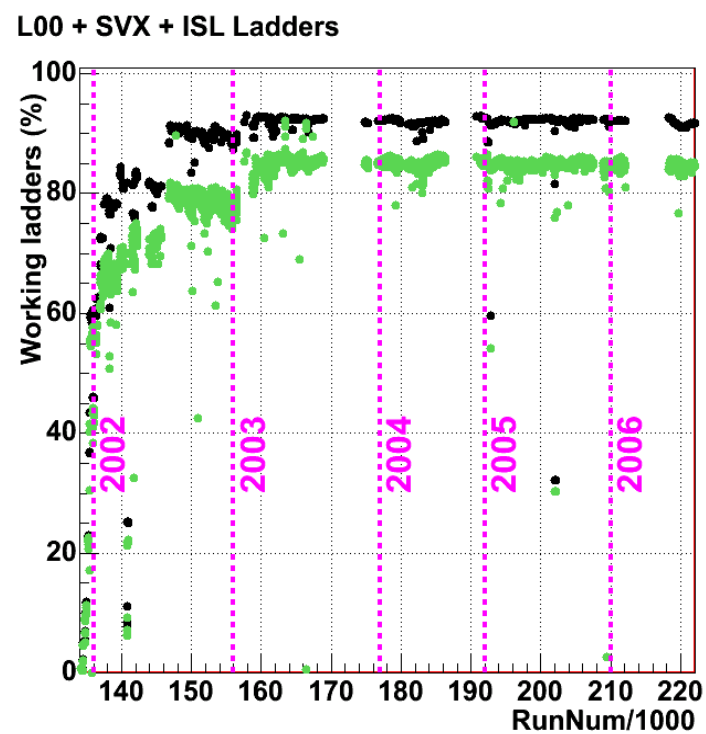
Silicon Longevity

- Bias voltage required to fully deplete Silicon sensors changes with irradiation
- Most of Layer 00 has already inverted
- Bias scans suggest innermost SVX layer is nearing inversion
- Results indicate that Silicon will outlast 8 fb^{-1}



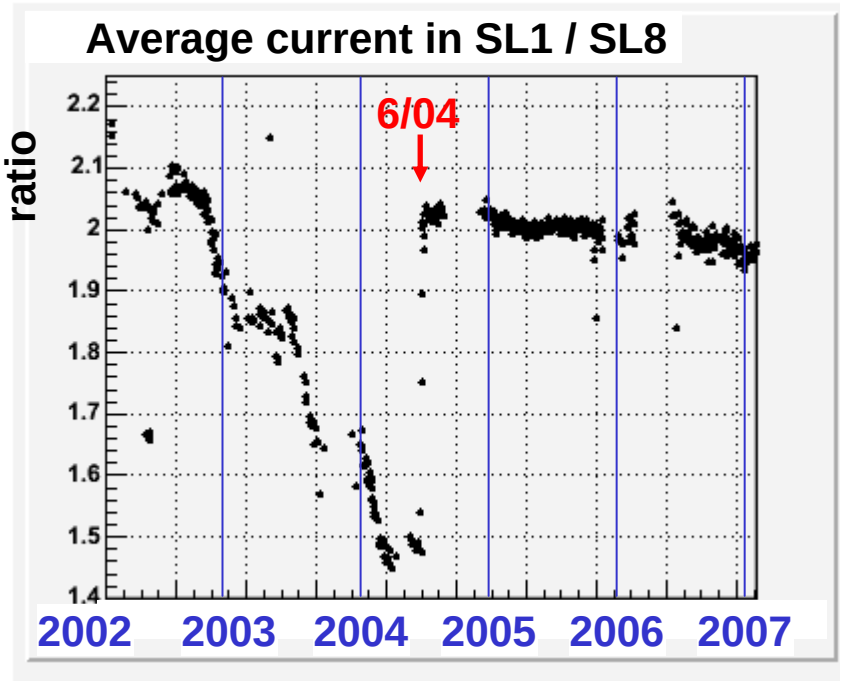


Model: S. Worm, *Lifetime of the CDF Run II Silicon,* VERTEX 2003



Tracking Chamber Performance

- CDF addressed a serious problem of aging 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
  - New gas purification system to clean re-circulated gas expected to be complete later this year
  - Can also increase amount of oxygen added



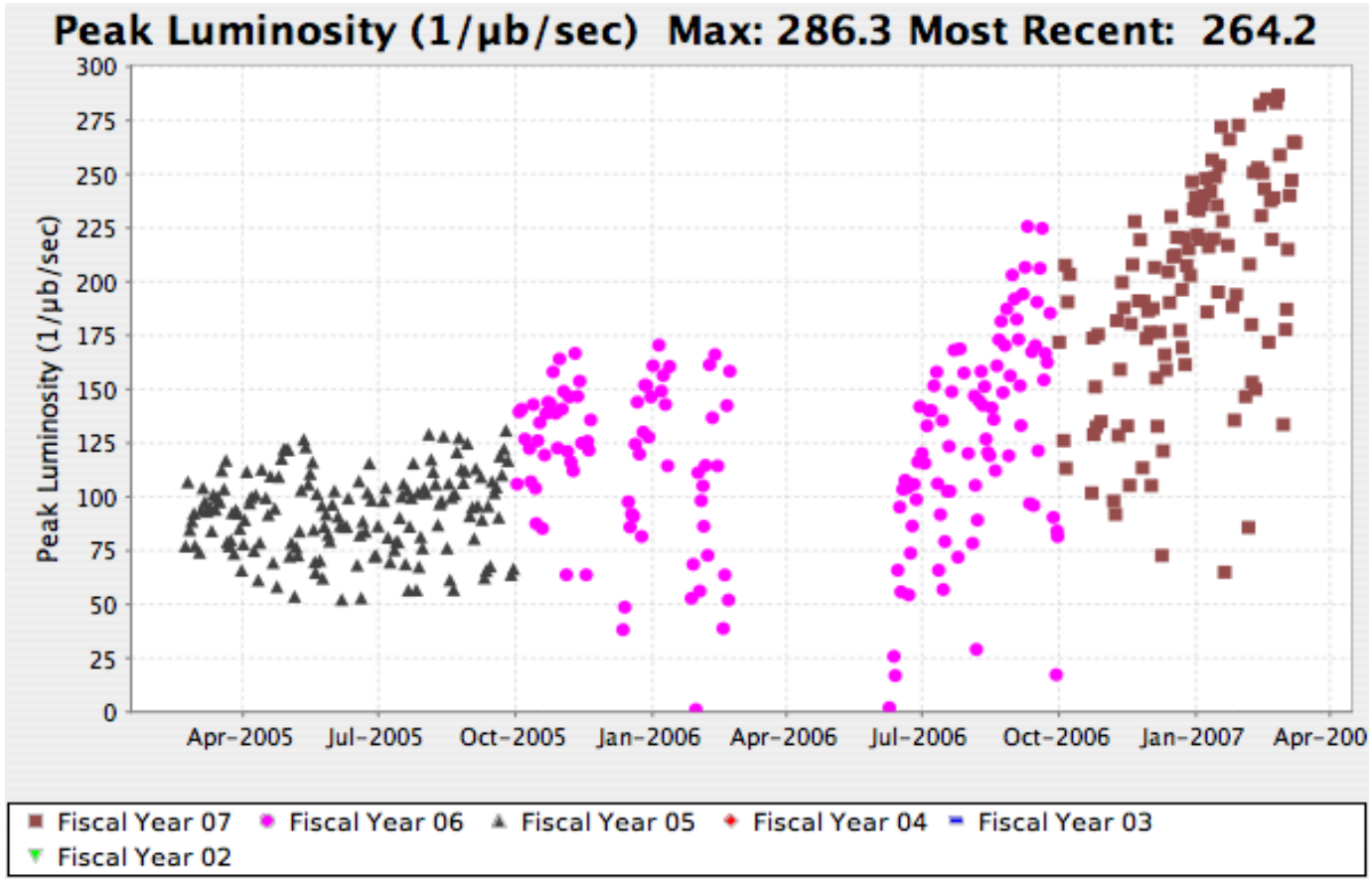
Current detector issues

- Current draw of COT HV supplies at high luminosities was approaching capacity of supplies for inner superlayers
  - Increased fuse size
  - Expect to be ok to luminosities beyond $400\times10^{30}cm^{-2}s^{-1}$
- Cooling for Intermediate Silicon Layer
  - Addressing a problem with high conductivity in the ISL cooling water and its associated effects (valves wearing out)
- Calorimeter readout LV power supplies
  - Investigation of failed power supply led to removal of another with flakey behavior
    - When same failure mode was seen, immediately removed two more "healthy" supplies for study
  - Renovate all supplies during summer shutdown
- Collision-related activation of electronics in forward areas
  - Will relocate to a more shielded location or add shielding

- Continuing to be vigilant …

Higher Instantaneous Luminosity

- Peak instantaneous luminosities have been climbing steadily
  - We must be prepared to take advantage of this
  - We should understand any impacts on physics analysis

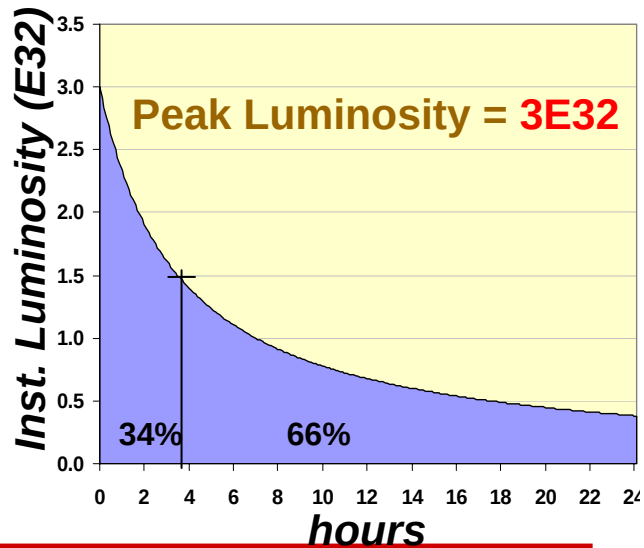


Trigger Rates at High Instantaneous Luminosity

- For a physics process, cross section σ is independent of instantaneous luminosity $\mathcal{L}$ (e.g. σ_{top}= 5pb)
- For trigger cross sections, we observe:

$$\sigma = A/\mathcal{L} + B + C\mathcal{L} + D\mathcal{L}^2$$

  - A, B, C, D are constants depending upon trigger
  - High purity triggers typically have $C \sim D \sim 0$
  - Two effects cause extra powers of $\mathcal{L}$:
    - Overlapping objects (e.g. Two track trigger with tracks from two different interactions)
    - Luminosity dependent fake rate
    - Fakes plus overlapping objects $\Rightarrow \mathcal{L}^2$
- Rate $R = \mathcal{L}\sigma$
- Note however, that even with peak luminosities of $300\times10^{30}cm^{-2}s^{-1}$, the majority of the store time is spent below $150\times10^{30}cm^{-2}s^{-1}$



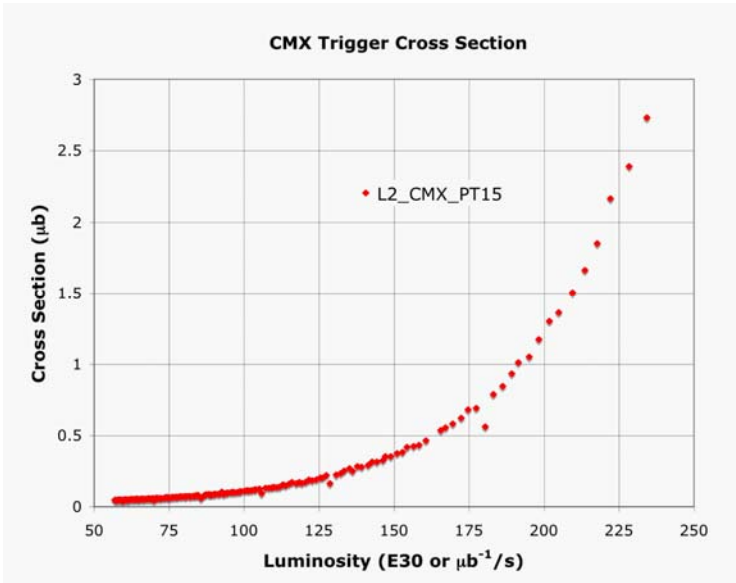
Upgrades for Higher Luminosity Running

- CDF II detector designed for $\mathcal{L}$ =200x10^{30} cm^{-2}s^{-1}
  - Run IIa: $\mathcal{L}$ < 100x10^{30}, bunch spacing of 396ns
  - Run IIb: $\mathcal{L}$ > 100x10^{30}, bunch spacing of 132ns
- Since bunch spacing will remain at 396ns, Run IIb Upgrades designed for $\mathcal{L}$ ~300x10^{30} with 396ns
  - Factor of 3 more interactions per crossing
  - Silicon, COT, Calorimeters, Muon chambers can handle occupancy. Exception:
    - Central PreRadiator (CPR): replaced chambers with scintillator
  - DAQ and Trigger Bandwidth
    - Handle higher rates at all stages
    - Address decreased purity from multiple interactions
    - Modernize systems (e.g. replace SGIs with Linux PCs)

Run IIb DAQ/Trigger Specification

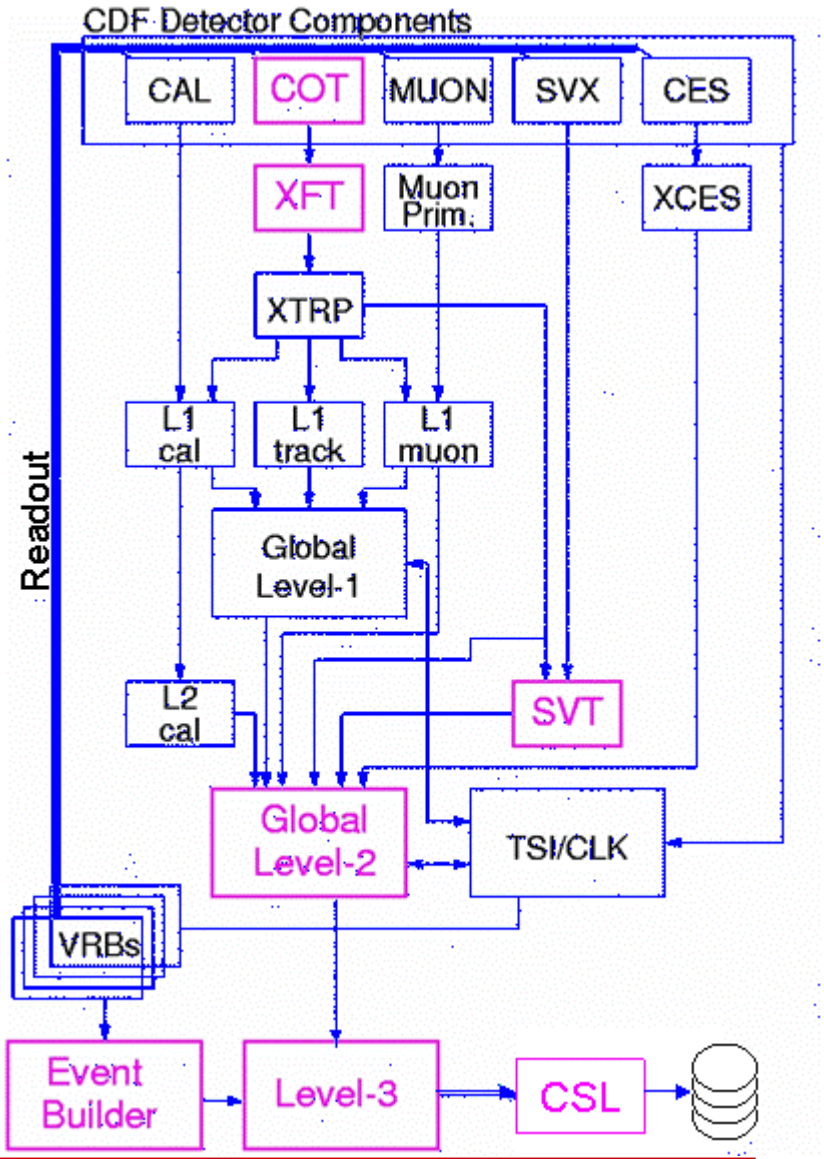
	Run IIa Specification	Run IIa Actual (2004)	Run IIb Specification
Luminosity	100×10^{30}	100×10^{30}	300×10^{30}
L1 Accept	45 kHz	25 kHz	30 kHz
L2 Accept	300 Hz	350 Hz	1000 Hz
Event Builder	75 MB/s	75 MB/s	500 MB/s
L3 Accept	75 Hz	80 Hz	>100 Hz
Rate to Storage	20 MB/s	20 MB/s	80 MB/s
Deadtime Trigger	5%	10%	10%

- Run IIa L1A limited by L2 trigger execution time
- Run IIa L2 High P_T CMX muon trigger alone has Rate>1kHz at 300×10^{30}
  - More L2 bandwidth
  - Improve L1 Purity



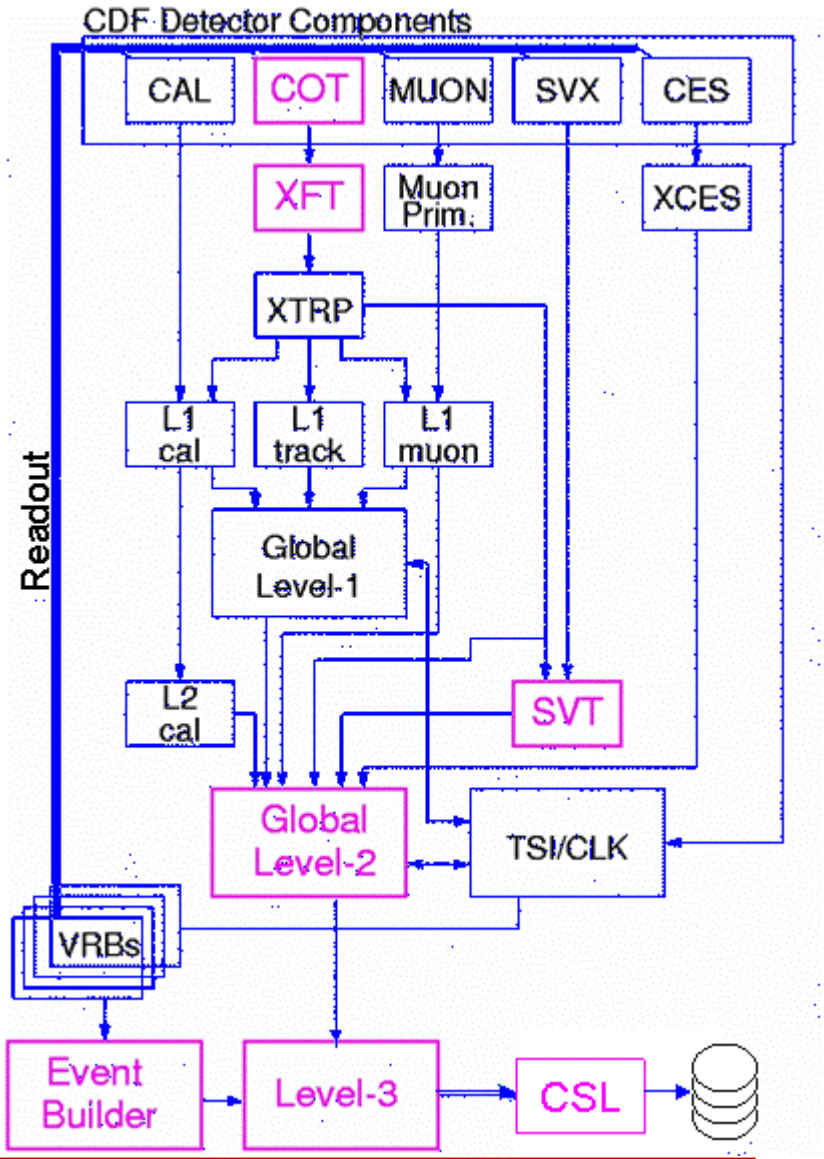
Trigger and DAQ Upgrades

- L1 Track trigger (XFT)
  - Add COT stereo layers to existing COT axial tracks
    - Completed Fall 2006
    - Used for high P_T muon triggers since October
  - Full stereo tracks at L2
    - Commissioning in progress
- Level 2 execution time
  - New L2 Decision system using "Pulsar" board and Linux PC
    - Completed March 2005
  - Upgrade Silicon Vertex Trigger using "Pulsar"
    - Completed February 2006
  - L2 execution time reduced by over 20μs to ~45μs at $\mathcal{L}$=100x10^{30}



Trigger and DAQ Upgrades

- Readout bandwidth
  - Modify COT TDCs - "Fast Clear" of out-of-time hits
    - Completed March 2006
  - New Event builder CPUs and network switch
    - Completed August 2005
  - Increased L2 output 350Hz to 950Hz at $\mathcal{L}$=200x10^{30}
- L3 Bandwidth
  - Increase L3 processing power from 1 to 2.6THz
    - Completed February 2006
- Bandwidth to tape
  - Consumer Server Logger: replace SGI with Linux, 20MB/s to 80MB/s
    - Completed November 2006

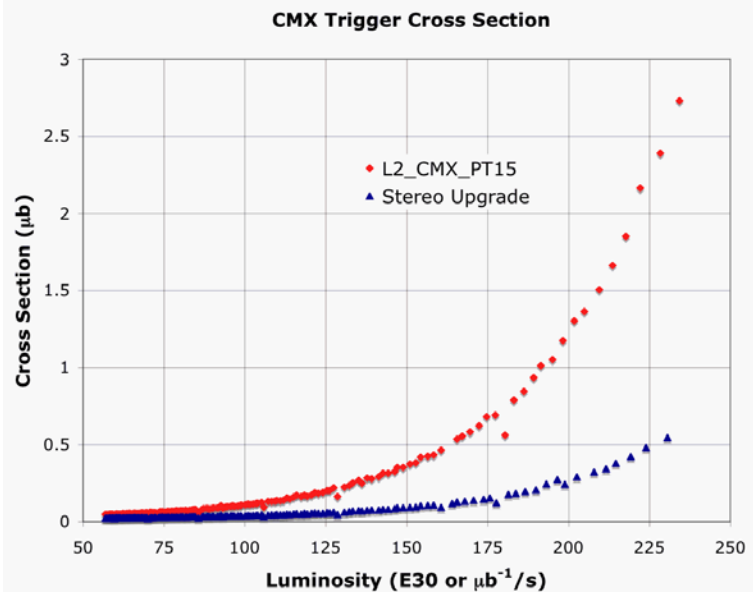


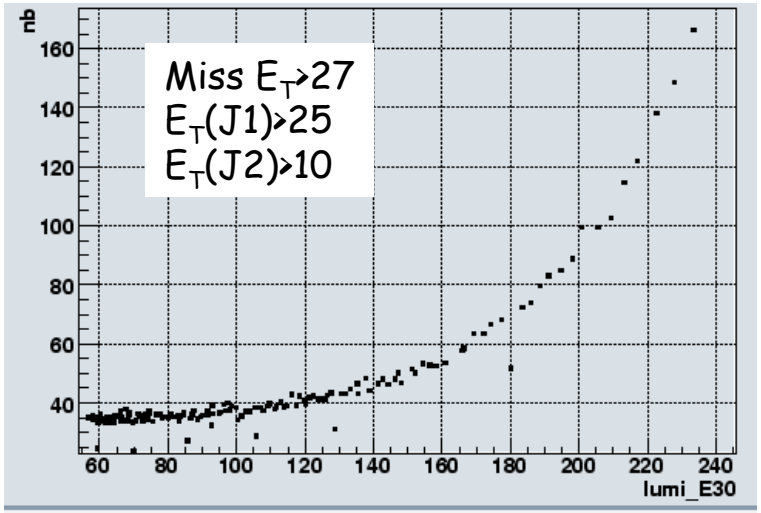
Run IIb Trigger Table

- Priorities set by Run IIb Working Group:
  - Higgs search, top physics, other searches
  - Others (e.g. B's) get available bandwidth at lower luminosity
- Implementation
  - Evolution of existing table taking advantage of upgrades
  - Core of program implemented in 2006
  - "Dynamic Prescales" optimize the use of bandwidth
    - High luminosity: high rate triggers have large prescales
    - Low luminosity: prescales automatically relaxed as bandwidth becomes available
- Bulk of triggers for Higgs are fully functional to at least 300×10^{30}
  - Address a few specific triggers of rate concern

Improving Trigger Table Performance

- High P_T muons - CMX
  - Track Trigger upgrade reduced rate factor of 4-5 with ~2% loss of efficiency
  - Spring 2007:
    - Matching in Z with full stereo tracks
    - Tighter r-ϕ match
    - Expect another factor of 2-3
- 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
  - Install and commission in Spring 2007



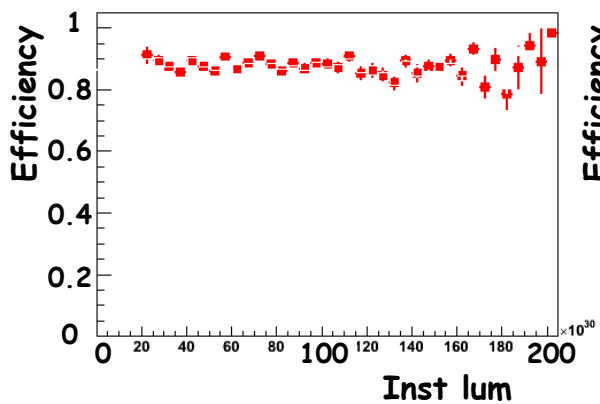


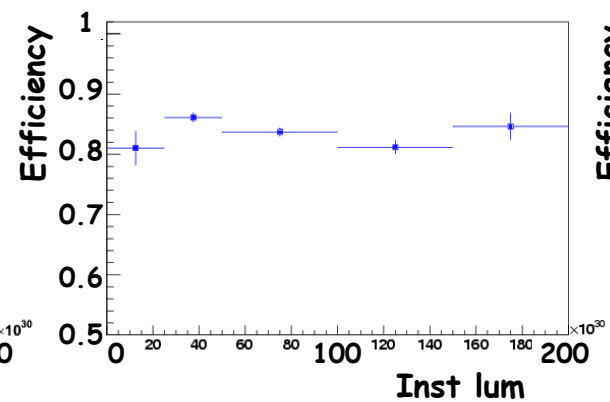
Physics at High Luminosity

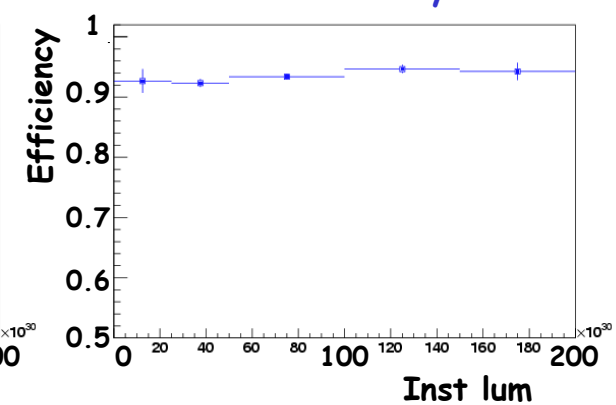
- Physics at high luminosity is under control

Plots made for data thru Dec 2006

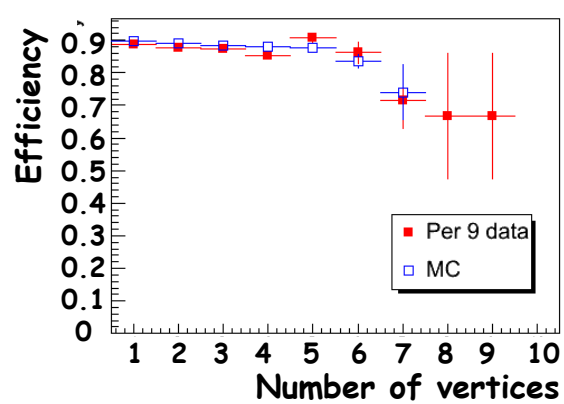
Muon L1 trigger efficiency



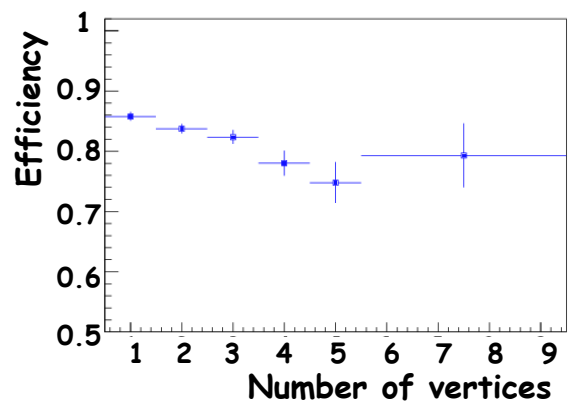




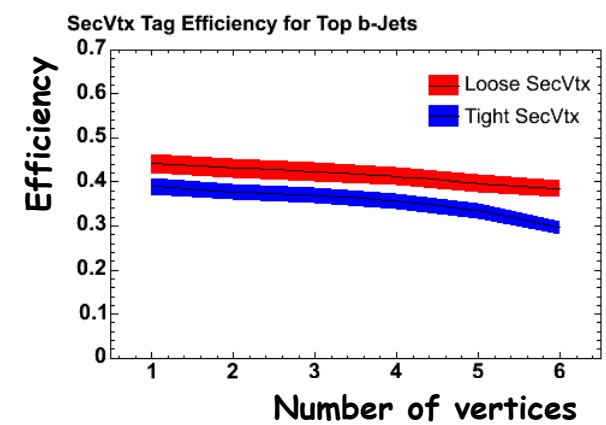
Electron ID efficiency



Muon ID efficiency



b-tagging



CDF Run II Journal Publications

Calendar Year	Publications
2003	4
2004	17
2005	44
2006	55
2007	7
Total to date	127*

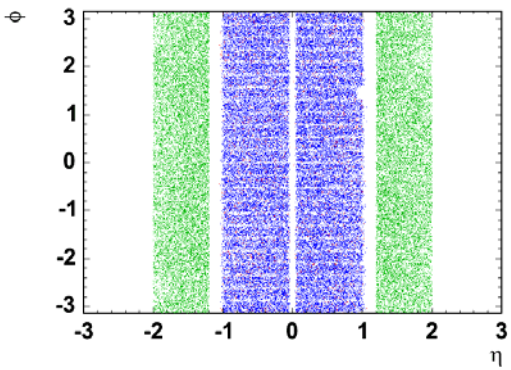
* Published + accepted + submitted

We have 50+ additional papers under internal review !

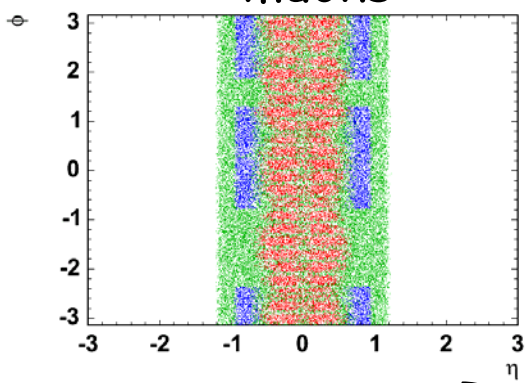
- Recent results highlighted in Wine and Cheese talks:
  - B_s Mixing Observation
  - Σ_b Observation
  - WZ Observation
  - B→hh Observation
  - All Hadronic Top Mass
  - Status of Single Top
  - Measurement of W Mass
  - Higgs → tau,tau
  - Small x and Diffractive Physics

Observation of WZ Production

electrons

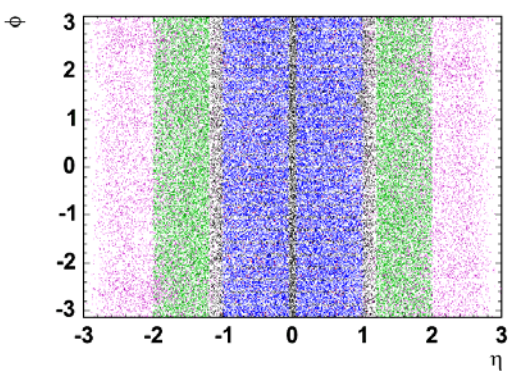


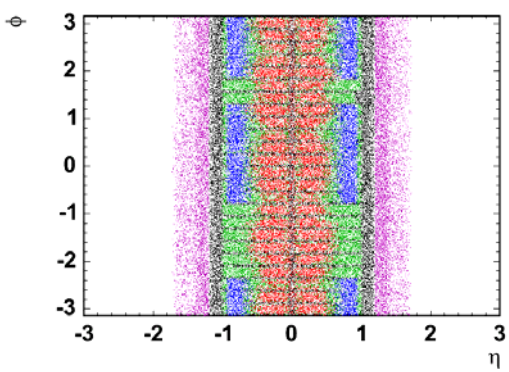
muons



+ more triggers
+ better selection
+ optimize cuts

Increased acceptance by adding plug calorimeter and tracks pointing to cracks





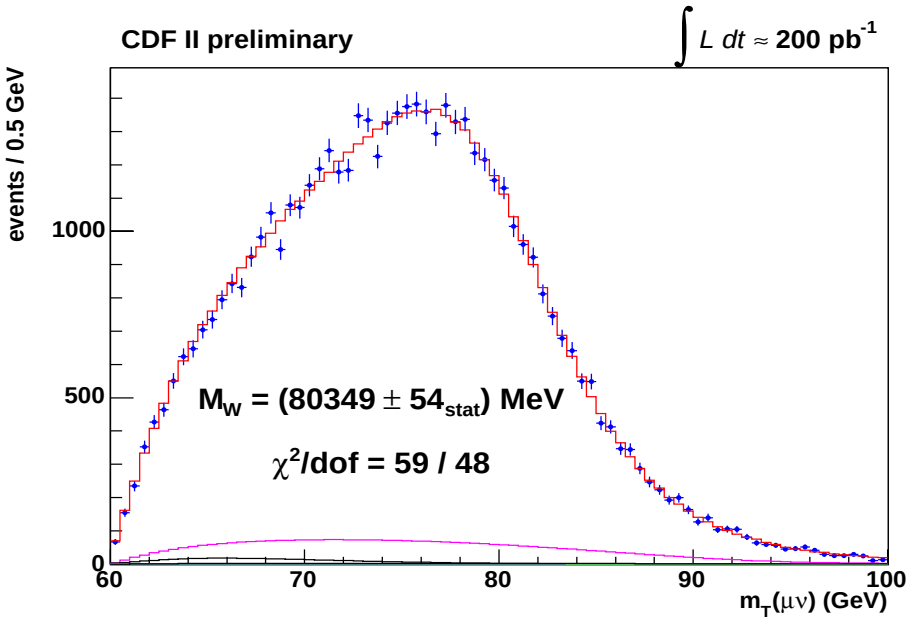
Source	Expectation ± Stat ± Syst ± Lumi
Z+jets	1.22 ± 0.27 ± 0.28 ± -
ZZ	0.89 ± 0.01 ± 0.09 ± 0.05
$Z\gamma$	0.48 ± 0.06 ± 0.15 ± 0.03
$t\bar{t}$	0.12 ± 0.01 ± 0.01 ± 0.01
WZ	9.79 ± 0.03 ± 0.31 ± 0.59
Total Background	2.70 ± 0.28 ± 0.33 ± 0.09
Total Expected	12.50 ± 0.28 ± 0.46 ± 0.68
Observed	**16**

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

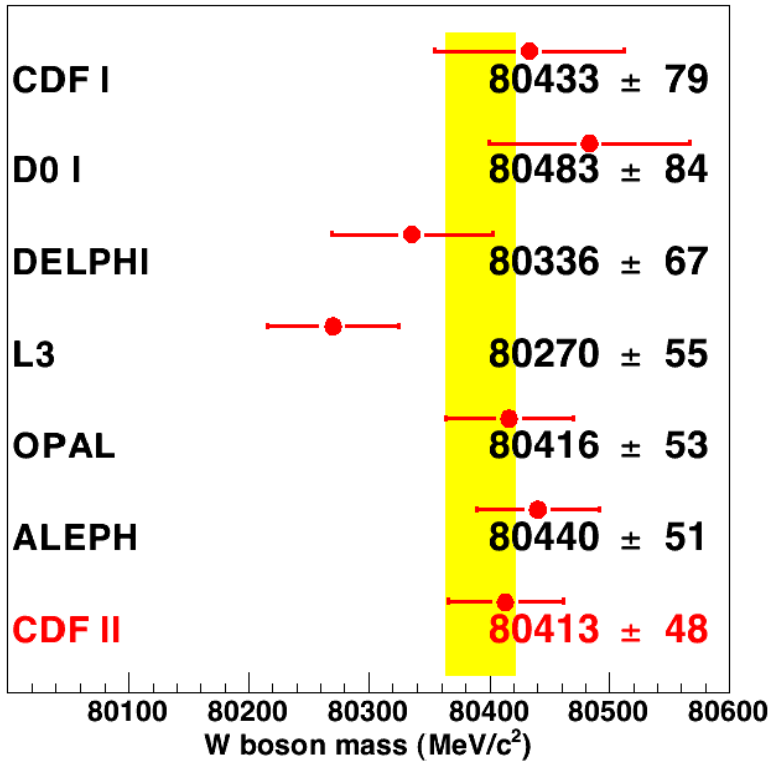
2 MET bins:
Prob(background only) < 2×10^{-9} (5.9σ)

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

W Boson Mass



Most Precise Single Experiment Measurement

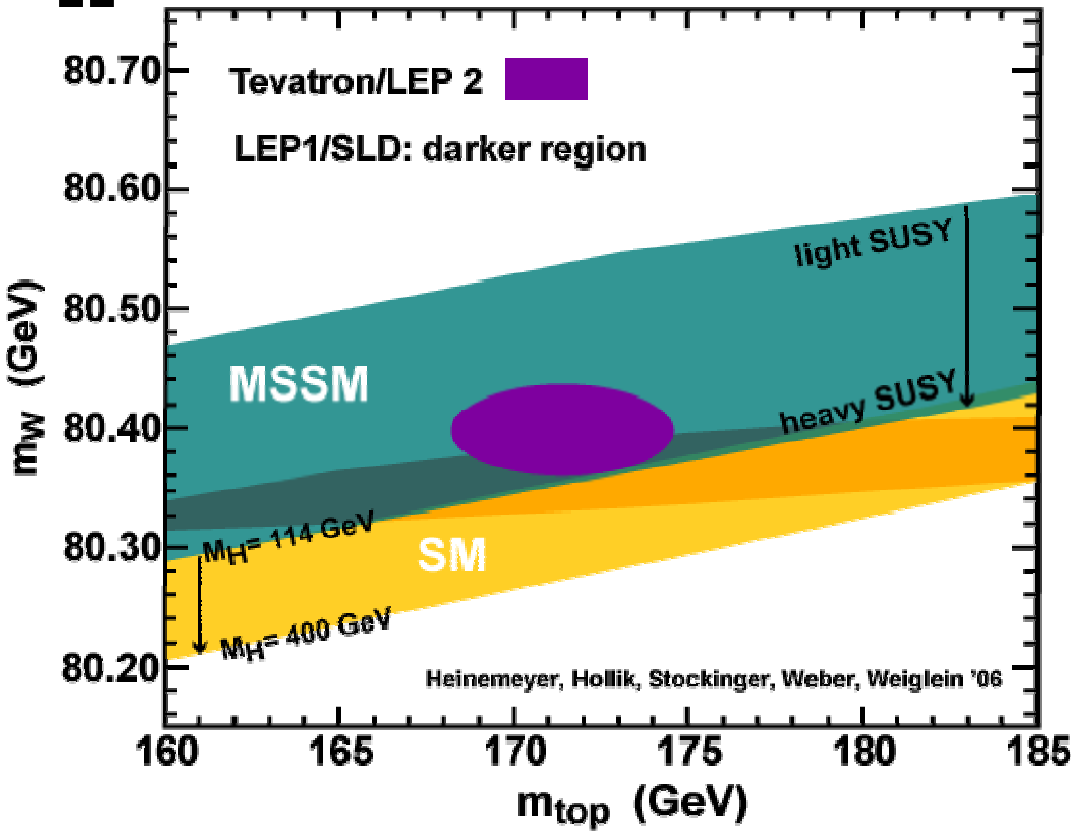


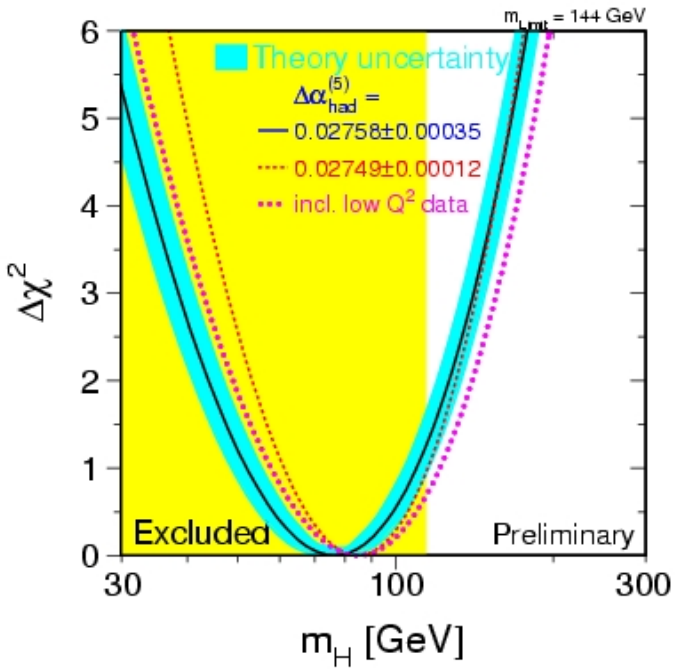
World Average W Mass:

$$M_W = 80.398 \pm 0.025\ GeV/c^2$$

A year ago 80.392 ± 0.029 GeV

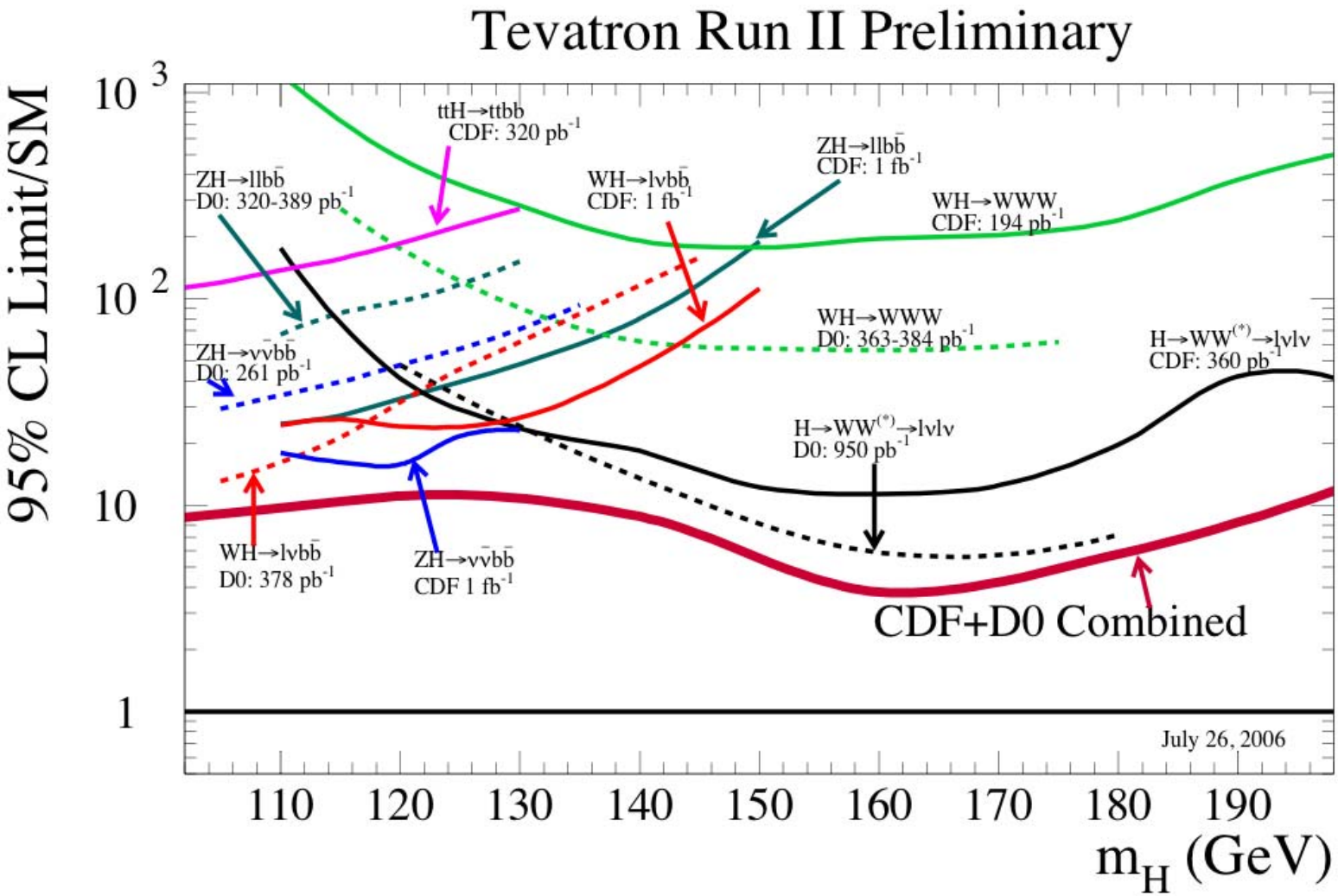
Higgs Mass Fit from W Mass and Top Mass





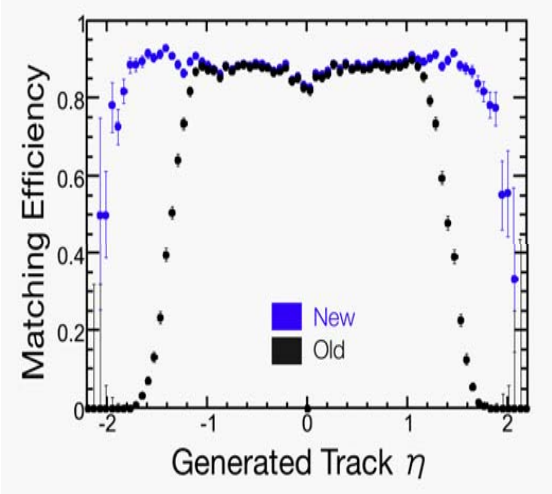
- CDF has the most precise top mass measurements in each of the 3 decay channels
- Standard Model Fit decreased 5 GeV based on updated W mass
- $M_H = 76^{+33}_{-24}$ GeV, $M_H < 144$ GeV @ 95 C.L.
- Good shot at finding the Higgs at the Tevatron!

Status of Higgs Search: 0.3-1.0 fb^{-1}

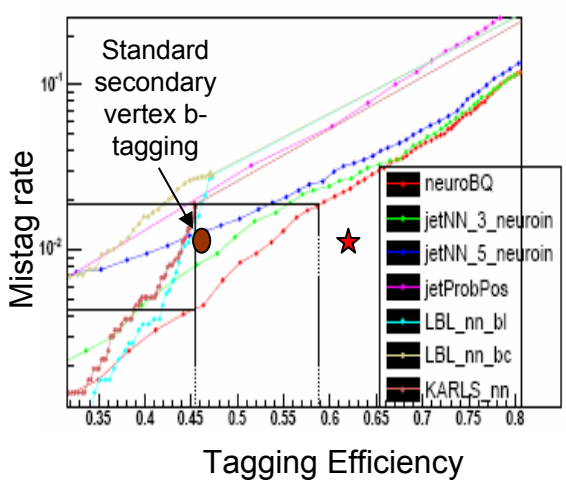


Getting closer to the Standard Model predictions…

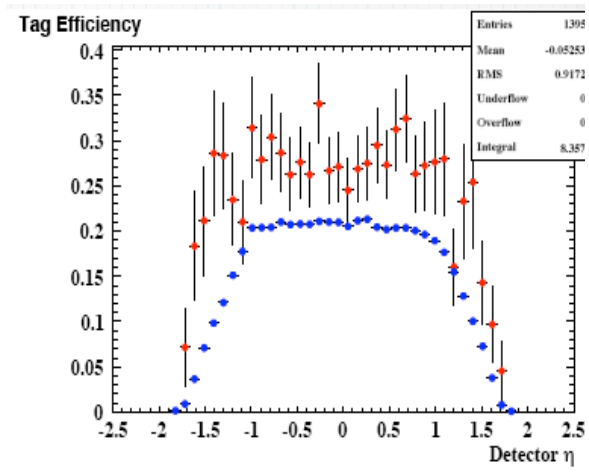
Example Improvements for Higgs Analyses



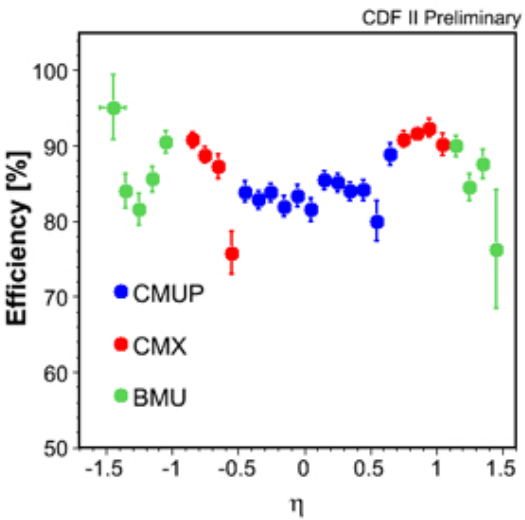
Forward tracking



Improved b-tagging

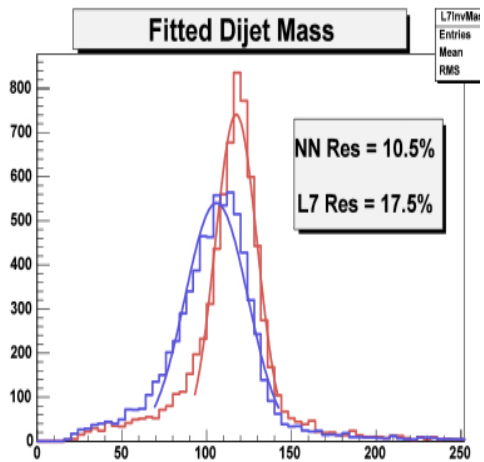


Forward b-tagging



Forward muons

Improved jet energy resolution



Conclusions

- CDF is running well
  - Operating efficiently and safely with reduced shift crew
- Safety is a priority, as evidenced by excellent record
- CDF is in good shape to run through 2009
  - Detector is still operating at performance levels specified in TDR
  - Detailed estimates of FTE available/needed indicate that we have sufficient resources to operate the experiment through 2009
- Preparing for luminosities beyond 300 E30
  - Run IIb upgrades complete and performing up to specifications
    - Stereo tracking at Level 2 and improved L2 calorimeter triggering expected to bring further gains at high luminosity and for Higgs
  - Able to do physics at high instantaneous luminosities
- We have a very exciting physics program
  - Observation of B_s mixing, Σ_b, $B \rightarrow hh$, WZ
  - Precision measurements of top mass, W mass
  - Getting ready to find the Higgs!

Backup

Core Physics Analysis

- Picked 10 physics analyses that are scientifically compelling measurements and demonstrate the potential of the collider program
  - a combination of precision measurements and searches/discovery potential
  - Searches
    - SM and MSSM Higgs, SUSY searches, Z', LED, $B_s \Rightarrow \mu\mu$
  - Precision
    - Top mass, Vtb, W mass, B_s mixing, B_s lifetime

Algorithm Development

ALGORITHMS	CDF FY07	CDF FY09	D0 FY07	D0 FY09
Muon Reconstruction	0.5	0.5	2.5	1.0
Tracking	5.1	3.4	2.9	1.9
Calorimetry	2.2	2.2	7.5	2.3
Taus	1.7	0.9	1.4	0.6
Jet Energy Scale	4.8	2.8	6.8	1.2
b-tagging	2.5	1.3	4.0	1.5
Trigger	7.8	4.1	17.4	4.0
Simulation	3.0	2.7	4.0	3.5
Luminosity	0.3	0.2	1.5	0.5
High Level Data Handling	7.5	7.5	6.5	4.5
Infrastructure	0.0	0.0	0.4	0.4
TOTAL ALGORITHMS	35.4	25.6	54.8	21.4

Core Physics Analysis

PHYSICS	CDF FY07	CDF FY09	D0 FY07	D0 FY09
Bs (Mixing, Rare Decay, Lifetime)	16.0	13.0	15.5	11.5
EW(W mass)	5.0	5.0	13.5	8.0
Higgs(SM and SUSY)	17.0	15.5	17.5	16.0
New Phenomena(Trilepton,Squarks & Gluinos, Stop&Sbottom, LED, Z')	11.5	7.0	9.0	6.0
Top (Mass and Single)	17.5	11.5	16.8	12.0
Core physics management	7.0	5.0	7.0	6.0
Tevatron Combination	3.0	3.0	3.0	3.0
Godparents/Ed.Boards	4.0	4.0	4.0	4.0
TOTAL PHYSICS	81.0	64.0	86.3	66.5