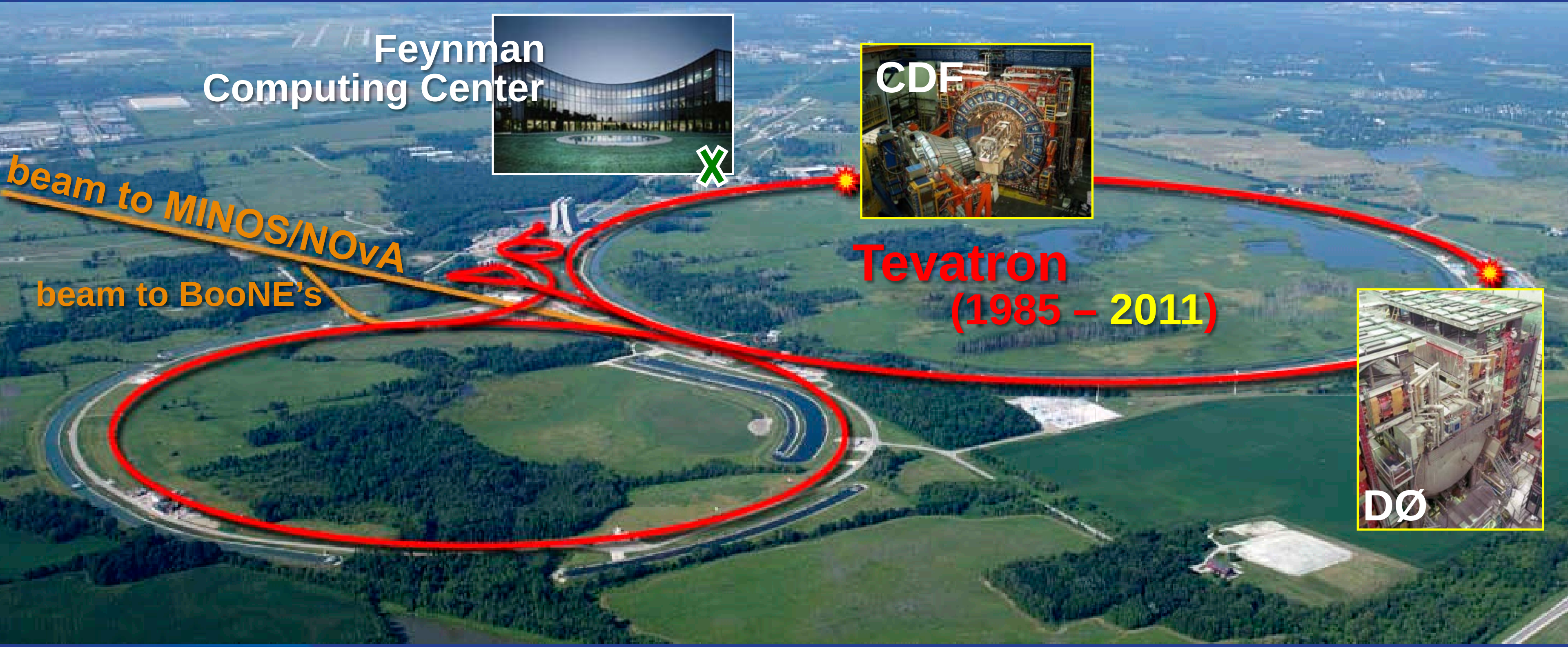
Tevatron Collider Program



Young-Kee Kim
Fermilab and Univ. of Chicago

HEPAP Meeting, October 22-23, 2009

U.S. DEPARTMENT OF ENERGY

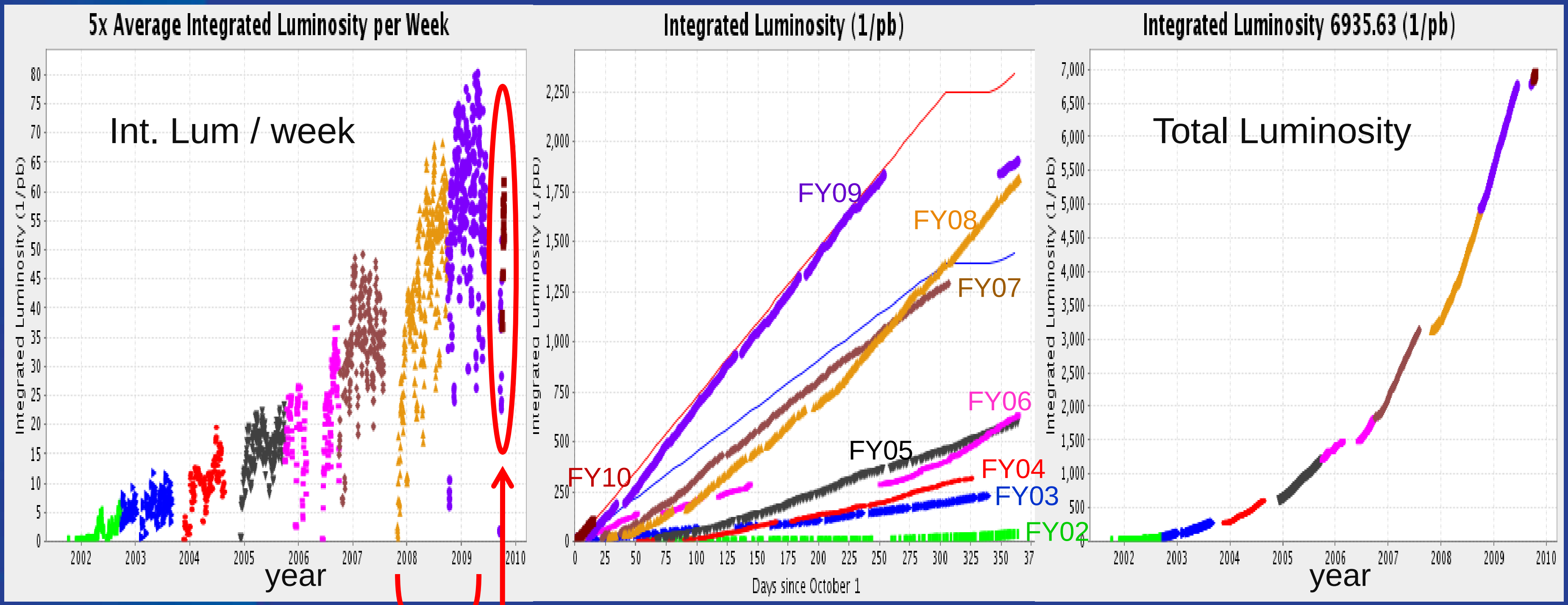
Fermilab

Outline: Tevatron Collider Program

- Accelerators
  - Performance so far and Prospects
- Detectors and Computing
  - Performance so far and Prospects
- Collaborations
  - Current Status and Prospects
- Physics
  - Highlights and Prospects
- Conclusion

Accelerators

Tevatron Performance: Run II from 2002 to 2009



Ran ~20 months without a long shutdown

Coming back very fast after a long shutdown

Initial instantaneous lum ~ 3 x 10^{32} $cm^{-2}s^{-1}$

History of Accelerator Performance

anti proton usage

Fiscal Year	nb^{-1}/ mA
Run I	2.9
2002	2.3
2003	6.4
2004	12.0
2005	12.8
2006	12.9
2007	14.6
2008	15.2
2009	16.9

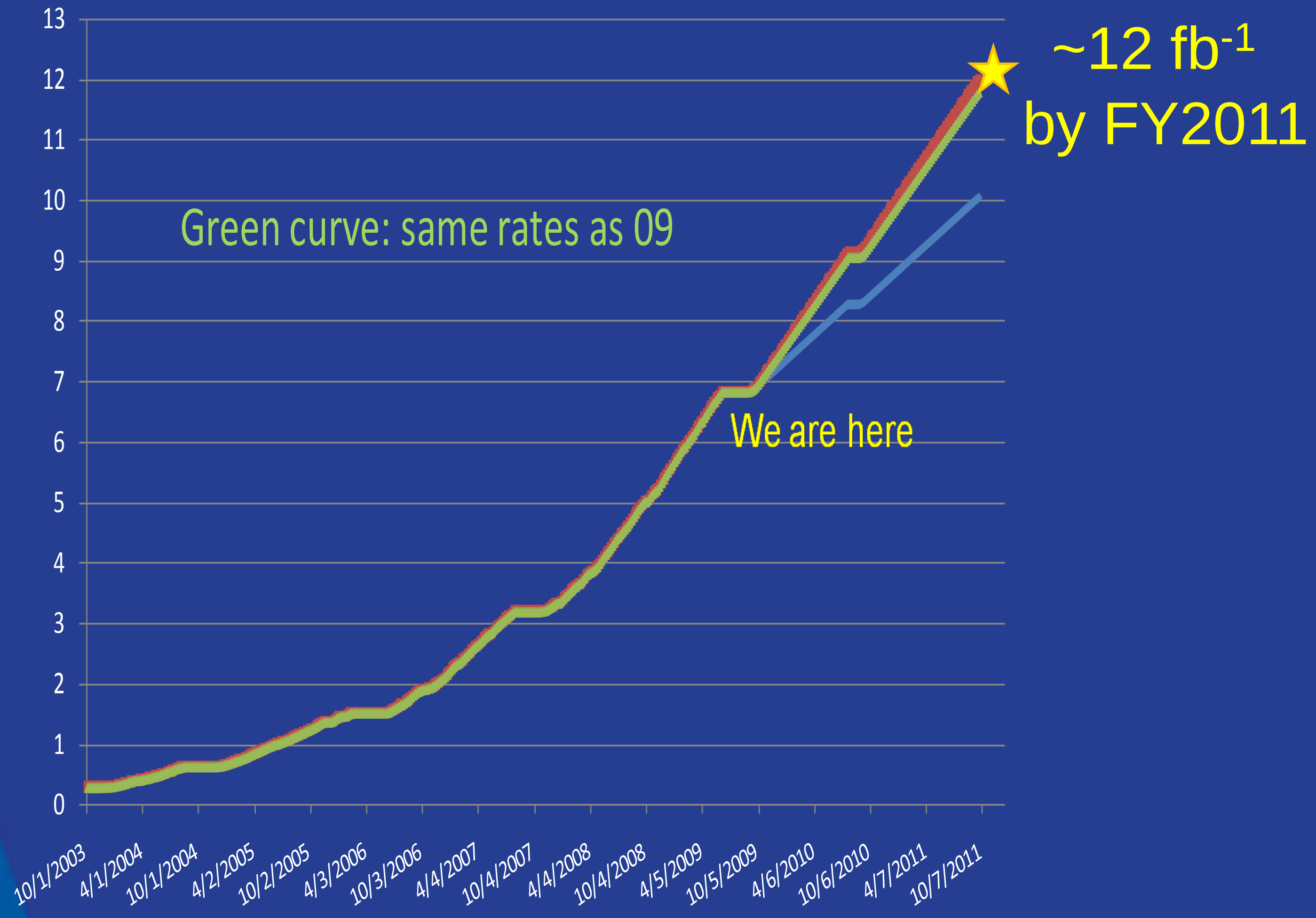
store termination

Fiscal Year	%Planned Termination
2003	30%
2004	66%
2005	69%
2006	63%
2007	80%
2008	84%
2009	88%

Accelerator Strategy to complete Tevatron

- Maximize the delivered luminosity
  - Continue to make small improvements with short payback times
  - Optimize running conditions to take advantage of improvements
  - Strive to increase overall machine reliability
  - No long-term shutdown

Total Integrated Luminosity: Projections

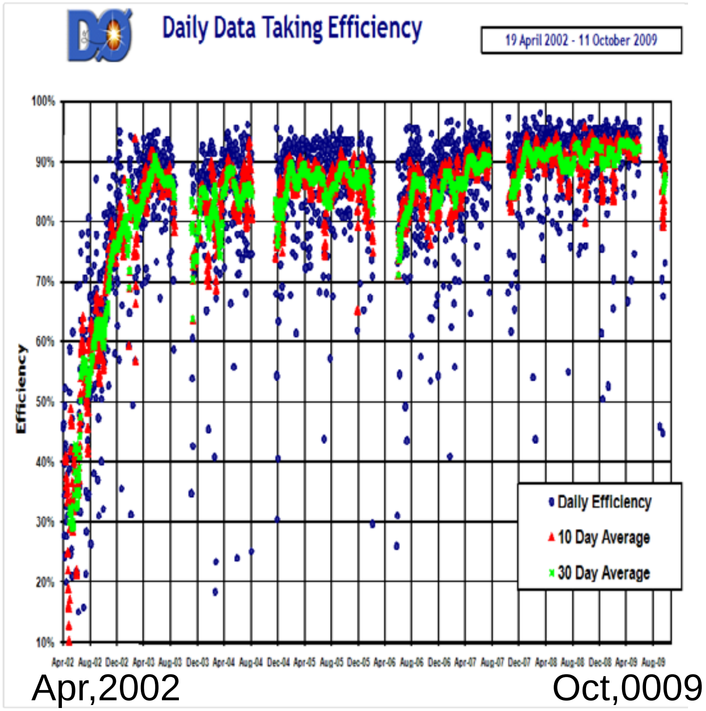


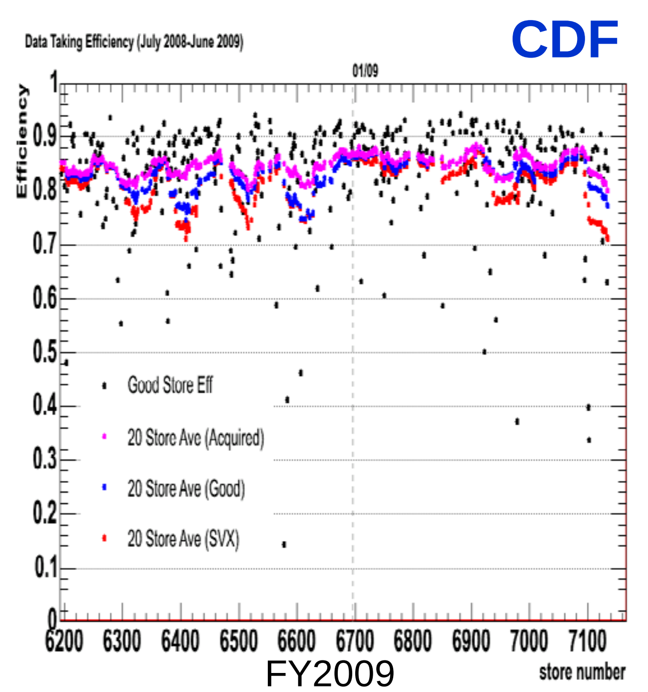
Detectors

Computing

Detectors operating well

data taking efficiency

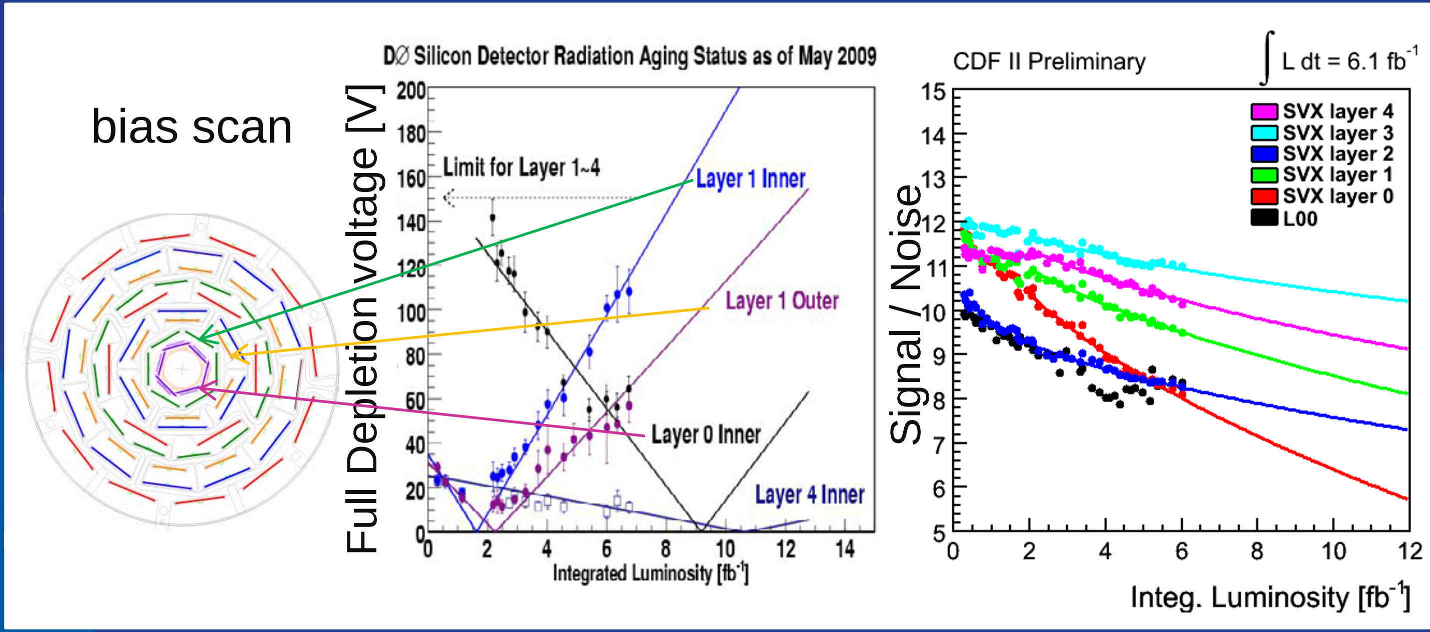




- Operations Improvements
  - streamlined operations; automate many operational and monitoring tasks

Detector Longevity: Silicon Detectors

- No effects on physics program expected
  - DØ :Some layer 1 sensors reach bias voltage limit before 12 fb^{-1}, but covered by layer 0 + outer layers
  - CDF: bulk of ladders fully depleted through 12 fb^{-1}. Signal/noise projections – no tracking deg. expected



Computing after Tevatron turn-off

- Fully support analysis computing capability for ~5 years including
  - Data re-processing and Monte Carlo production capability: in addition, opportunistic use of other Grid resources at Fermilab and worldwide

- Computing Division / CDF / DØ continue to work with the community on efforts towards long term preservation of both data and analysis capabilities

Collaborations

CDF
15 Countries
62 Institutions
602 Members

DØ
18 Countries
90 Institutions
507 Members

Effort required to run the experiments

- This is the effort required to do everything except the physics analysis itself

Physicist FTEs	Ops	Algorithm	Comp	Manage-ment	Support Total
DØ 2008 Actual	55	26	16	10	107
DØ 2011 Estimate	50	20	15	10	100
CDF 2009 Actual	45	20	20	10	95

- 30% less than a few years ago due to efforts on streamlined operations
  - Agreed with prediction ~3 years ago

Available Physicists: Total and Physics

- Based on direct feedback from institutions

	CDF 2009	CDF 2010	CDF 2011	CDF 2012	DØ 2008	DØ 2011
Total FTE	292	249	191	141	307	170
U.S.	46%	48%	50%	52%	51%	50%
Postdocs	71	65	47	29	65	24
Students	100	77	51	33	124	53
Univ. Faculty Lab. scientists	121	107	93	79	117	93
Run Expt.	95	90	75	15	107	100
Physics	197	159	117	125	200	70

- Enough to run the experiment and produce key physics results

Additional Statistics about Collaborations

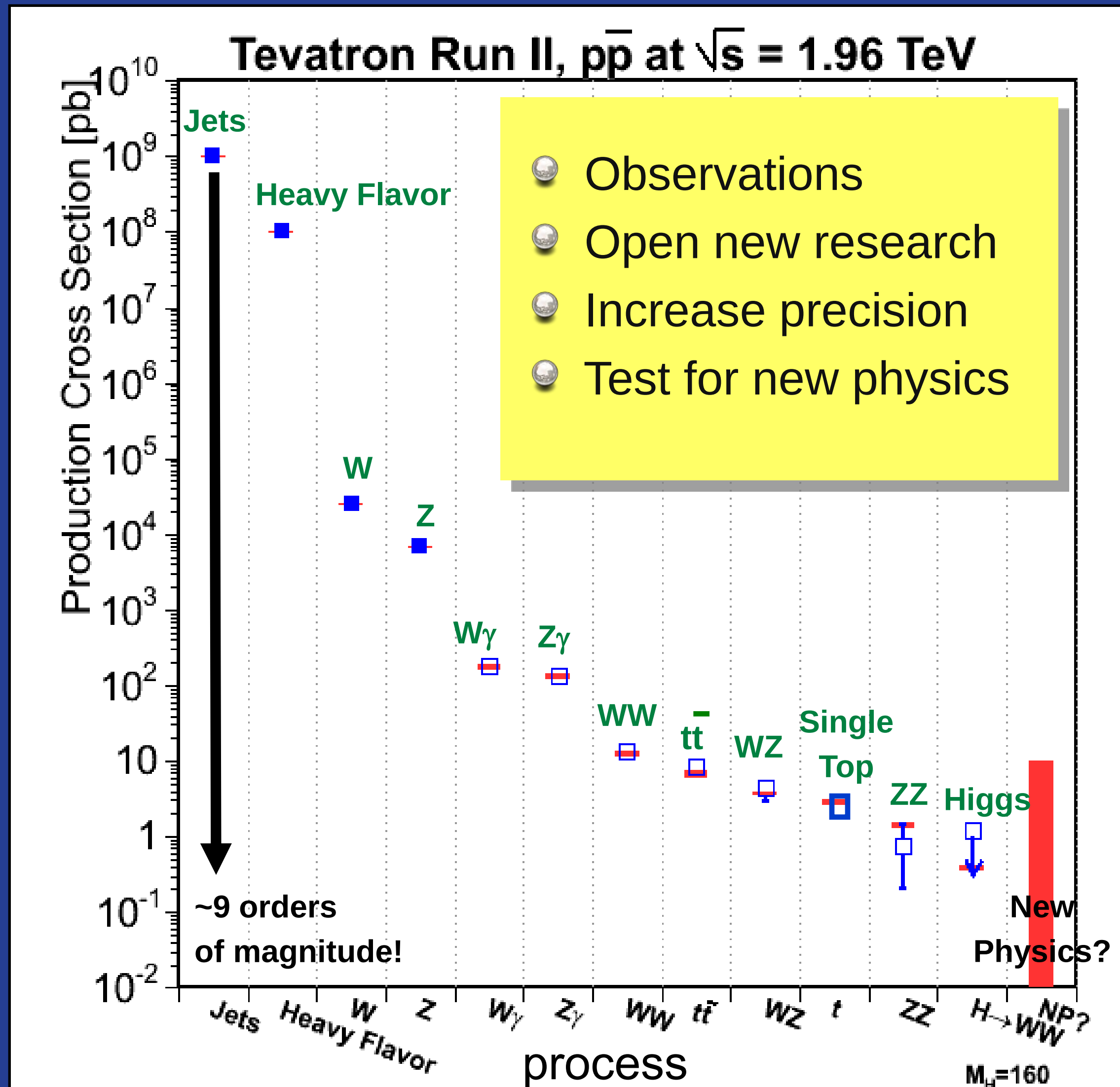
- In the last few years, collab. decreases <10% per year. Much smaller than expected (~30%)
  - PI's moved their center of mass to LHC slower
  - Many postdocs who thought they would work 1-2 yrs at Tevatron and then do LHC did not moved
  - Assistant professors stayed longer
  - New graduate students join
    - e.g. DØ: ~35 joined over last year (~50% from US); Ph.D. students, diploma, and masters students; ~12 have worked on LHC expt.s before joining DØ
  - We attribute this to the success of Tevatron program, the impact young people can make at the Tevatron, the leadership they can take on, LHC delay etc.

The Tevatron Physics Program

- Precision, new observations, new physics searches
  - Mixing, CKM Constraints, and CP-Violation
  - Heavy Flavor Spectroscopy
  - New Heavy Baryon states
  - Tests of QCD and Heavy Flavor production
  - Top-quark and W-boson masses
  - Top quark properties
  - Di-boson production and SM gauge coupling
  - The standard model Higgs is now within reach !
  - New exclusive/diffractive processes
  - Searches for supersymmetry, extra dimensions, other exotica: still at the energy frontier
  - Probing the Terascale as luminosity increases

Addressing questions of fundamental importance

The Tevatron: A Luminosity Story



- Observations
- Open new research
- Increase precision
- Test for new physics

Physics Production

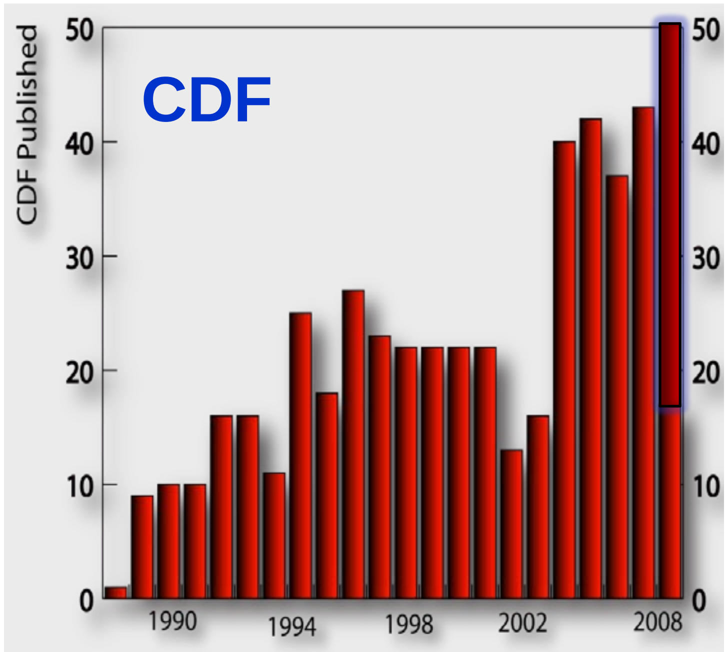
- Stable tools and an excellent understanding of the detectors and the data

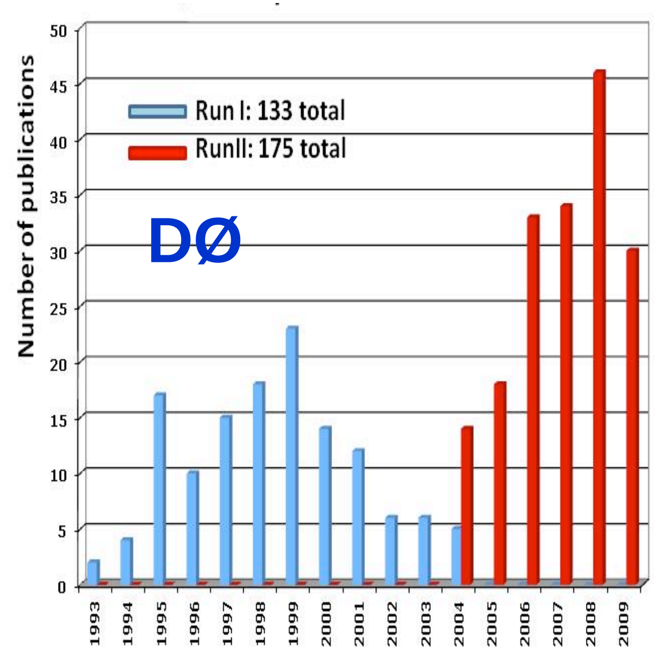
- Productivity is higher than ever
  - Nearly 200 new results between Summer 2008 and Summer 2009
  - Tevatron results are dominant in HEP conferences

- Still in some areas only scratching the surface
  - Much potential for further precision, reach, and observation
  - We keep exploiting the data from all angles

Tevatron Physics Impact

of publications / year vs. CY year





CY 2009: additional ~20 papers / experiment

About 100 journal publications this year alone (~2 per week)

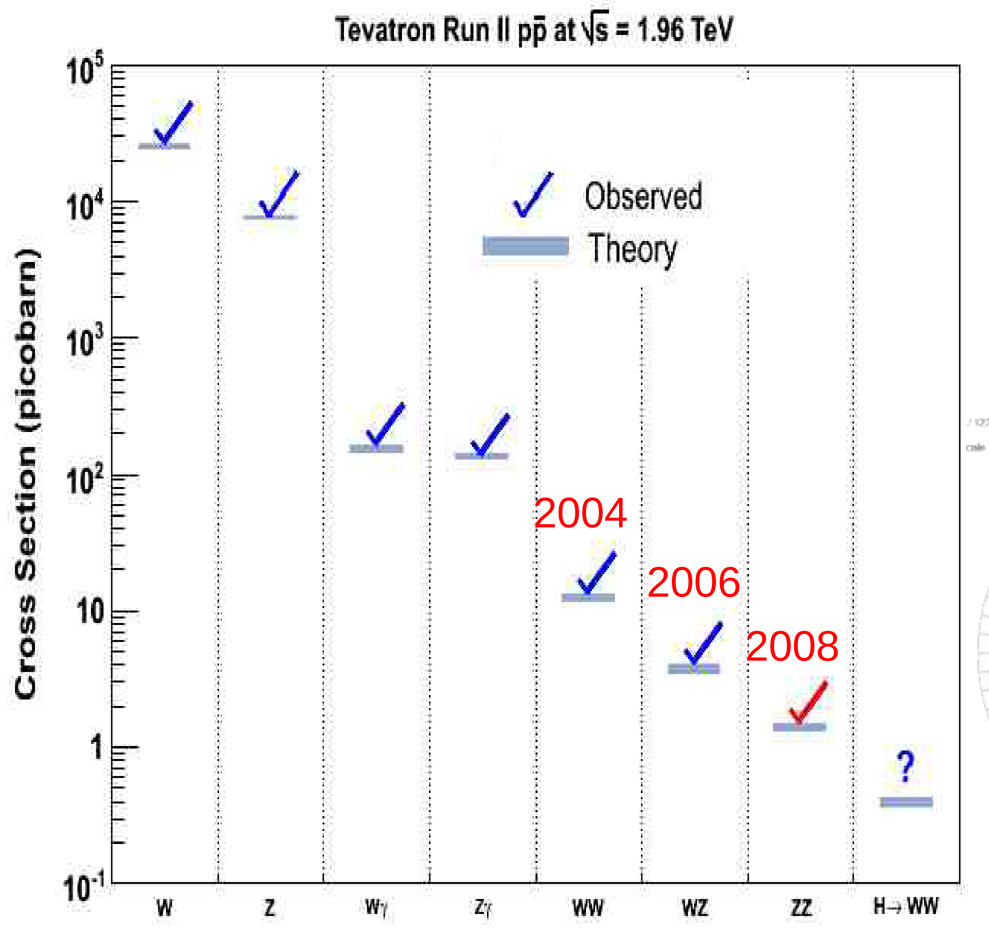
~60 Ph.D.s / year over the last few years

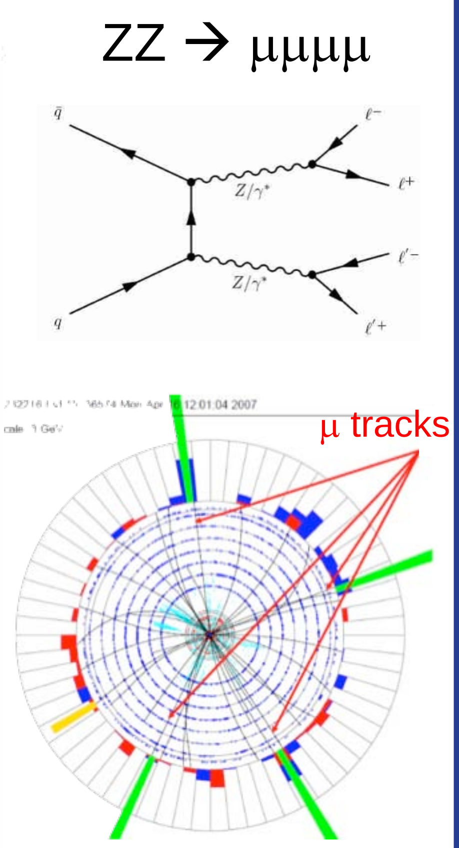
~350 conference presentations / year

~3,500 physicists have participated in CDF and DØ experiments

Physics Highlights

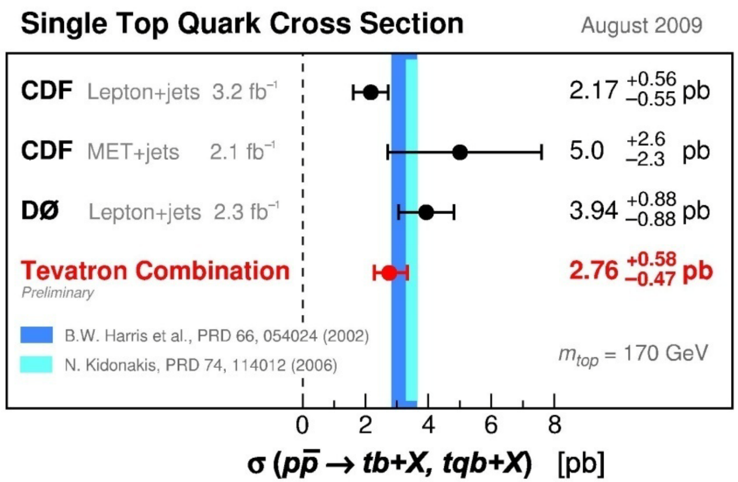
Observations: rare SM processes

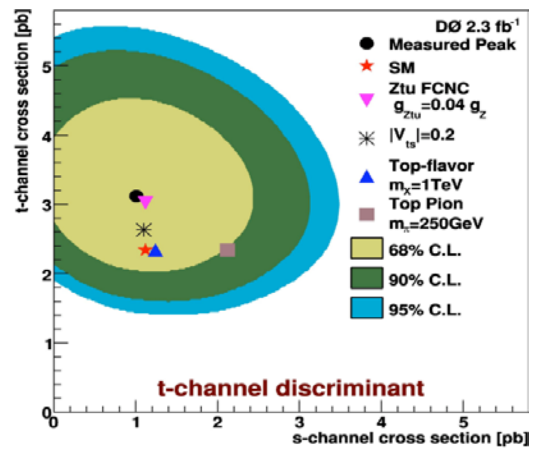


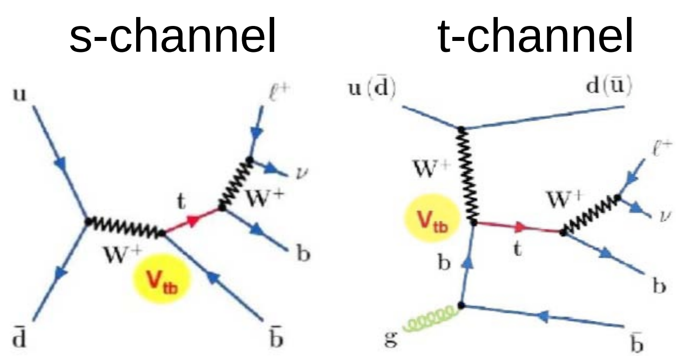


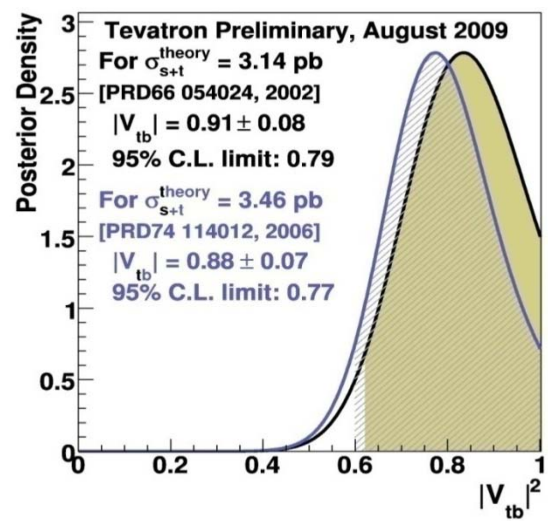
Diboson production: more luminosity allows access to smaller cross sections

Observation in 2009: Single Top





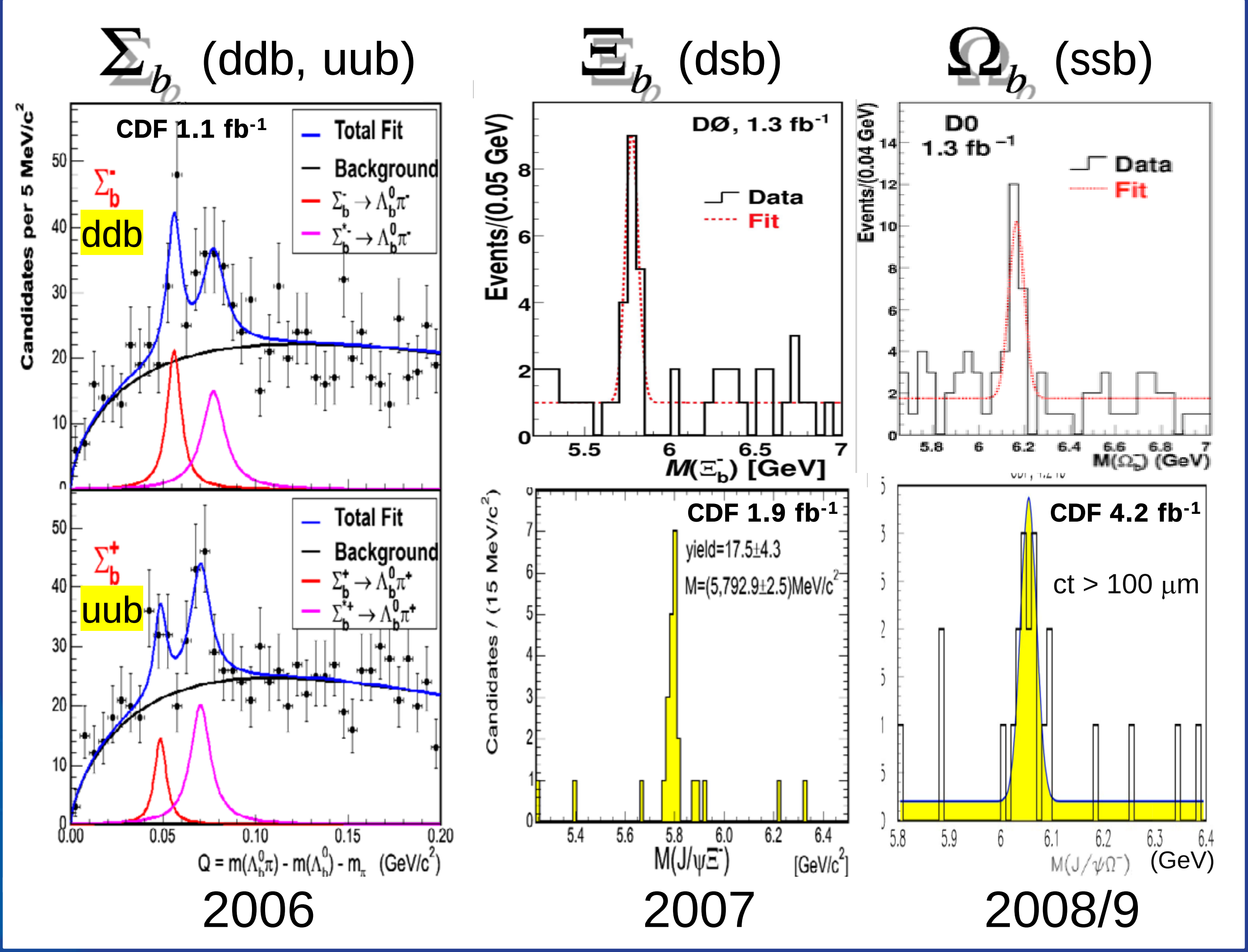




Test s- vs t-channel (new physics)

V_{tb} (precision)

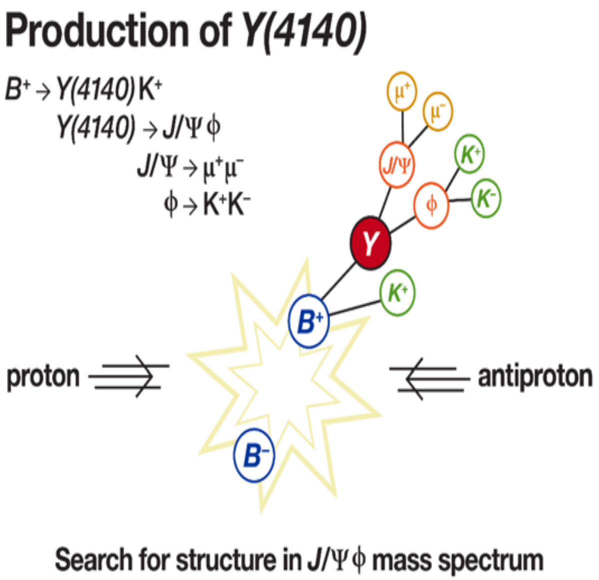
Observation of New Heavy Baryons

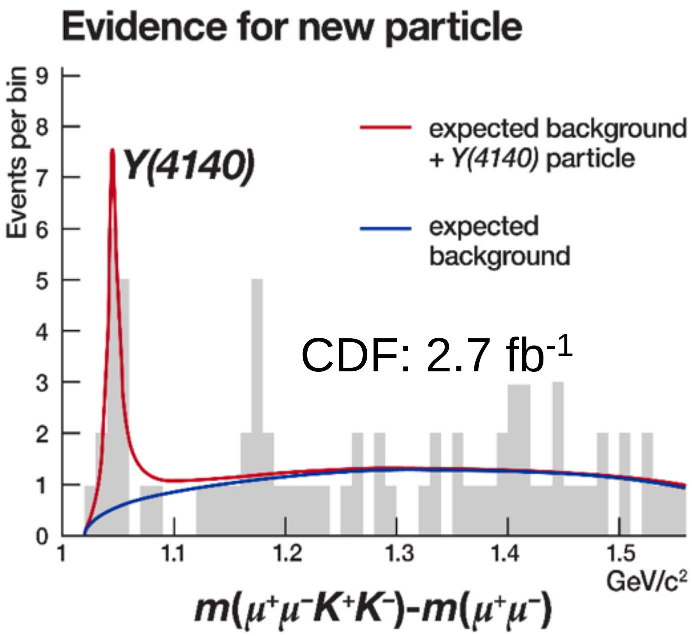


Fermilab

With more data: emergence of a new particle

unknown composition



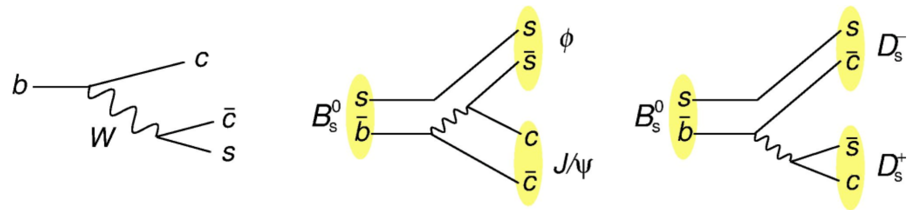


2009

These new particles yield a few events/fb^{-1}

→ new areas of research @ 10fb^{-1}

Precision: CPV phase in B_s system

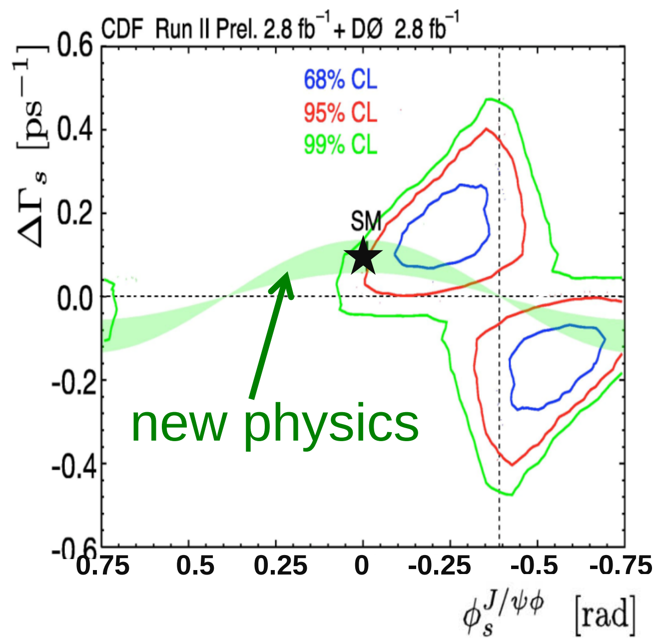


(SUSY, ED…)

$$i\frac{d}{dt}\begin{pmatrix}B_s^0\\ \bar{B}_s^0\end{pmatrix} = \begin{pmatrix} M - \frac{i\Gamma}{2} & M_{12} - \frac{i\Gamma_{12}}{2} \\ M_{12}^* - \frac{i\Gamma_{12}^*}{2} & M - \frac{i\Gamma}{2}\end{pmatrix}\begin{pmatrix}B_s^0\\ \bar{B}_s^0\end{pmatrix}$$

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H \sim 2|\Gamma_{12}|\cos\phi_s$$

$$\phi_s^{SM} = \arg[-M_{12}/\Gamma_{12}] \rightarrow \underset{\sim 0.004}{\phi_s^{SM}} + \phi_s^{NP}$$



p-value(SM)=3.4%   More data to come

Look also in other channels (asym in semileptonic decays)

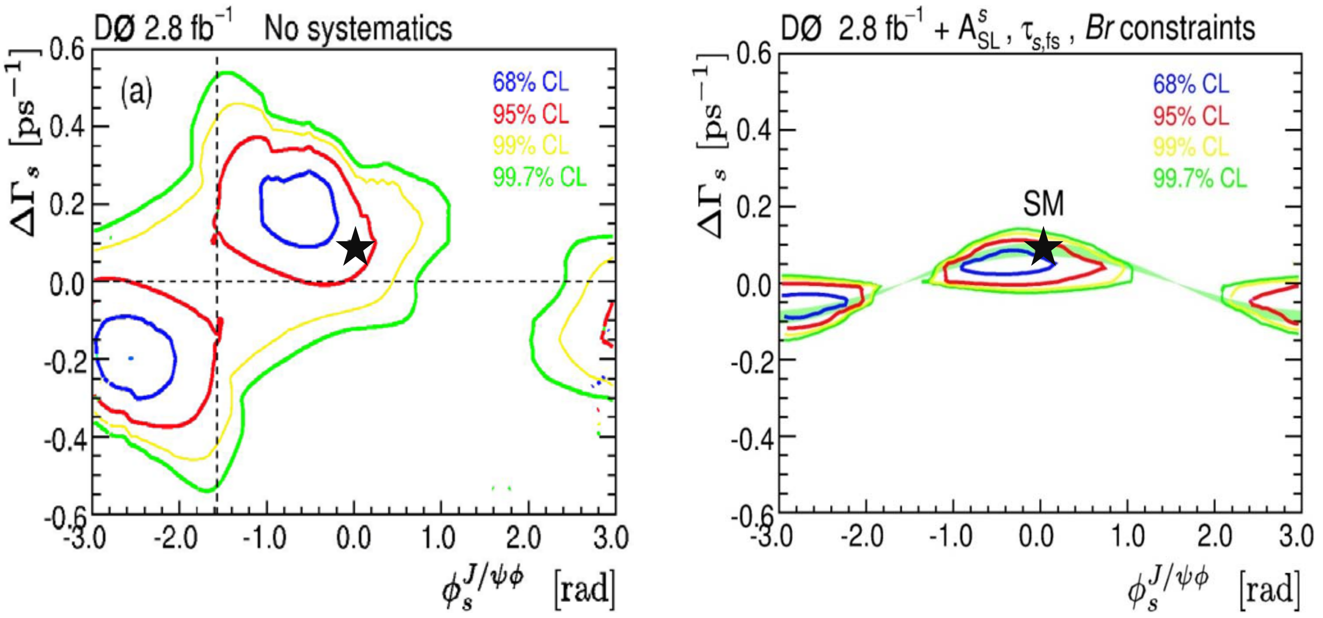
Precision: CPV phase in B_s system

Adding constraints from other recent measurements

CP Violating Asymmetry in semi-leptonic B_s decays

Flavor-specific B_s lifetime

$Br[B_s \rightarrow D^+_s(*)\ D^-_s(*)]$



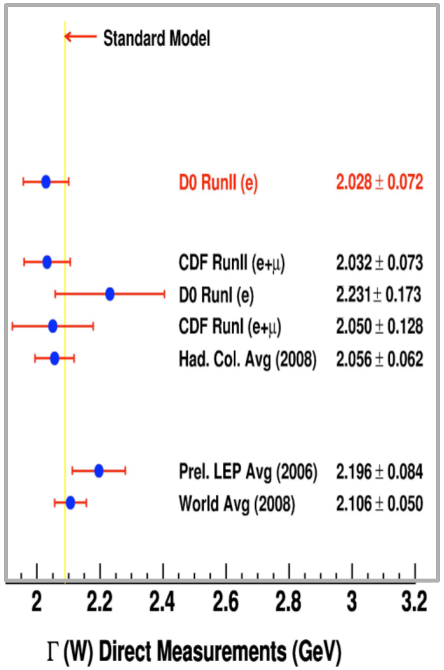
DØ: p-value(SM)=10% statistics limited

Precision: Electroweak Measurements

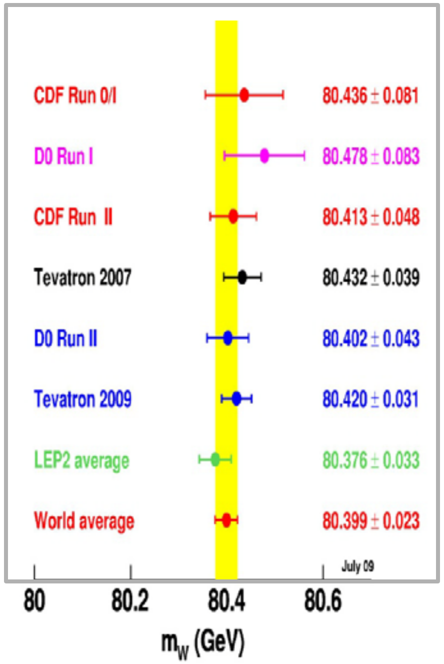
Most precise measurements

Legacy measurements: it will take a long time to get better

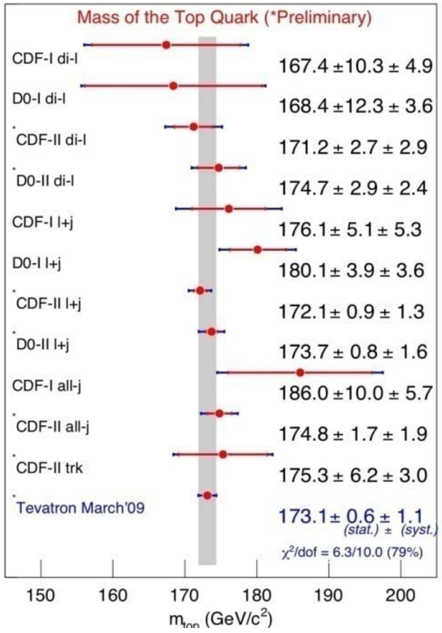
W width



W mass

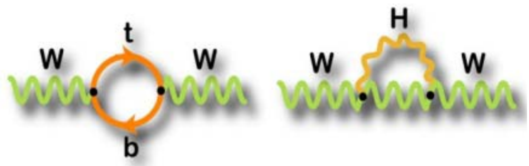


Top mass

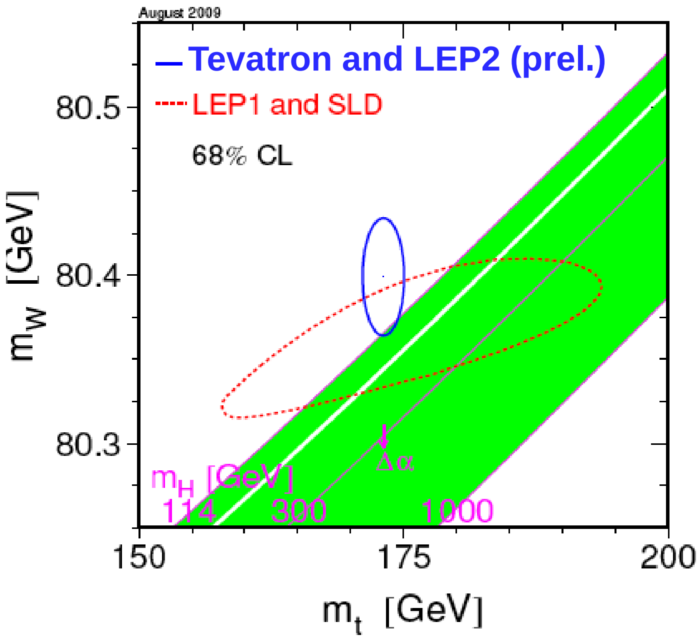


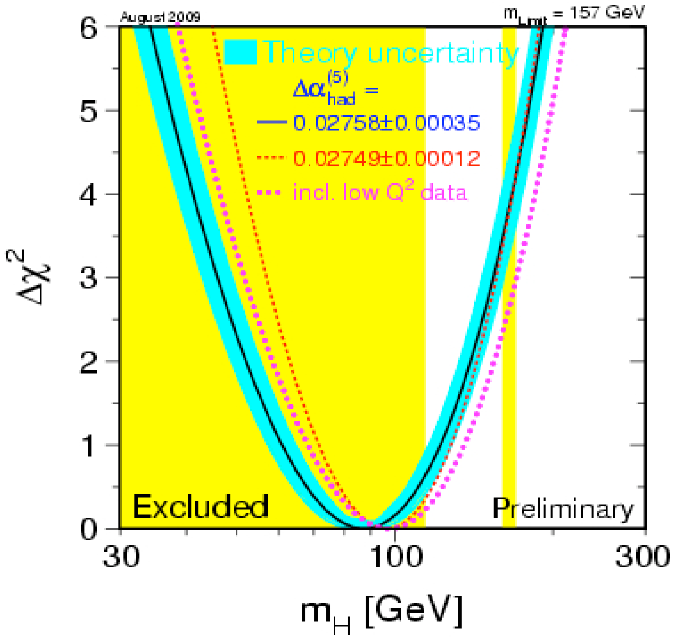
Tevatron:	3%	0.04%	0.7%

Precision → Higgs constraints



$m_H = 87^{+35}_{-26}$ GeV





Now $m_H < 157$ GeV @95%CL

($m_H < 186$ GeV when LEP limit inclued)

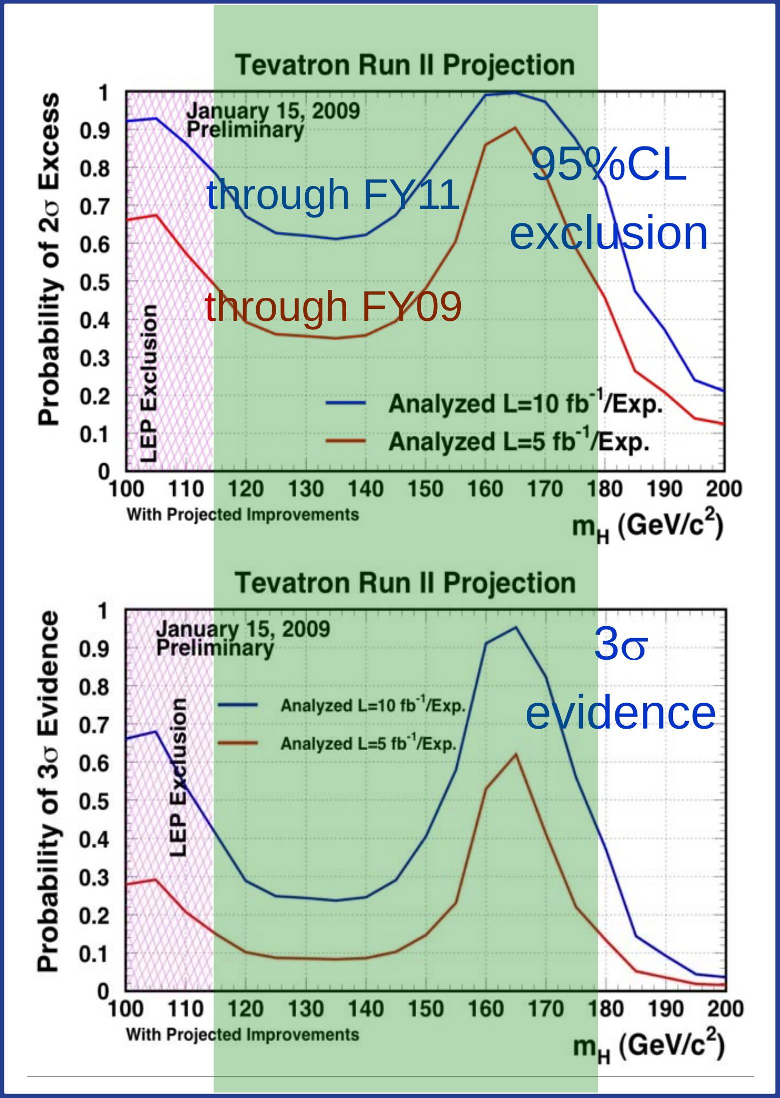
with 10 fb^{-1} $m_H < 117$ GeV @95%CL (δm_W=15MeV, δm_t=1GeV)

The Higgs Search

- The SM Higgs (if it exists) is being produced NOW at the Tevatron! We have enough energy
  - Just not that often & it's buried in "backgrounds"
  - It's a story of luminosity, passion, persistence and luck
  - We know how to look for it and we are in fact closing in!
- Over the last years, there's been a dramatic infusion of people, effort and ideas, aimed at finding the Higgs

and some luck

Favored mass region

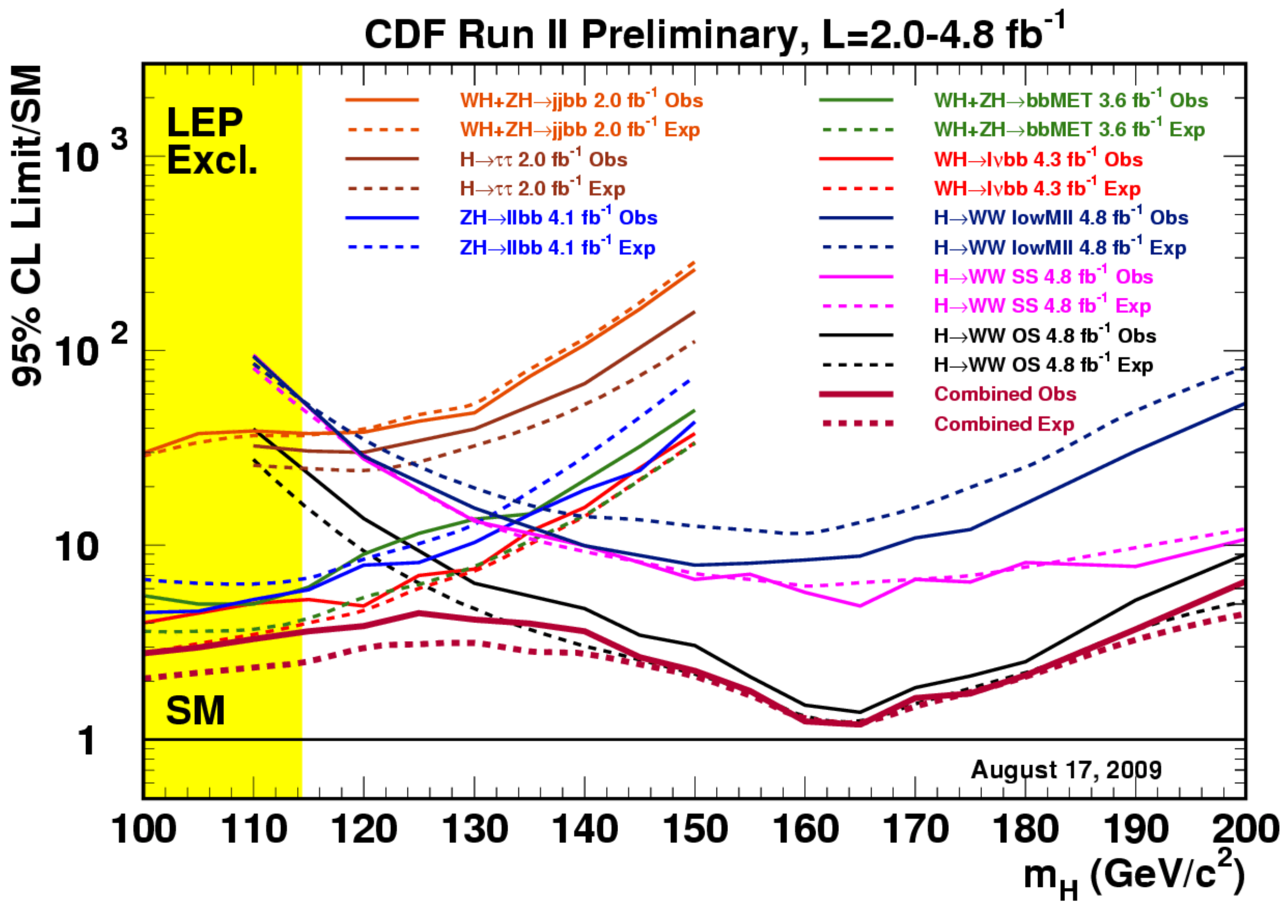


Higgs reach with continued analysis improvement

running through FY09 (red) FY11(blue)

Fermilab

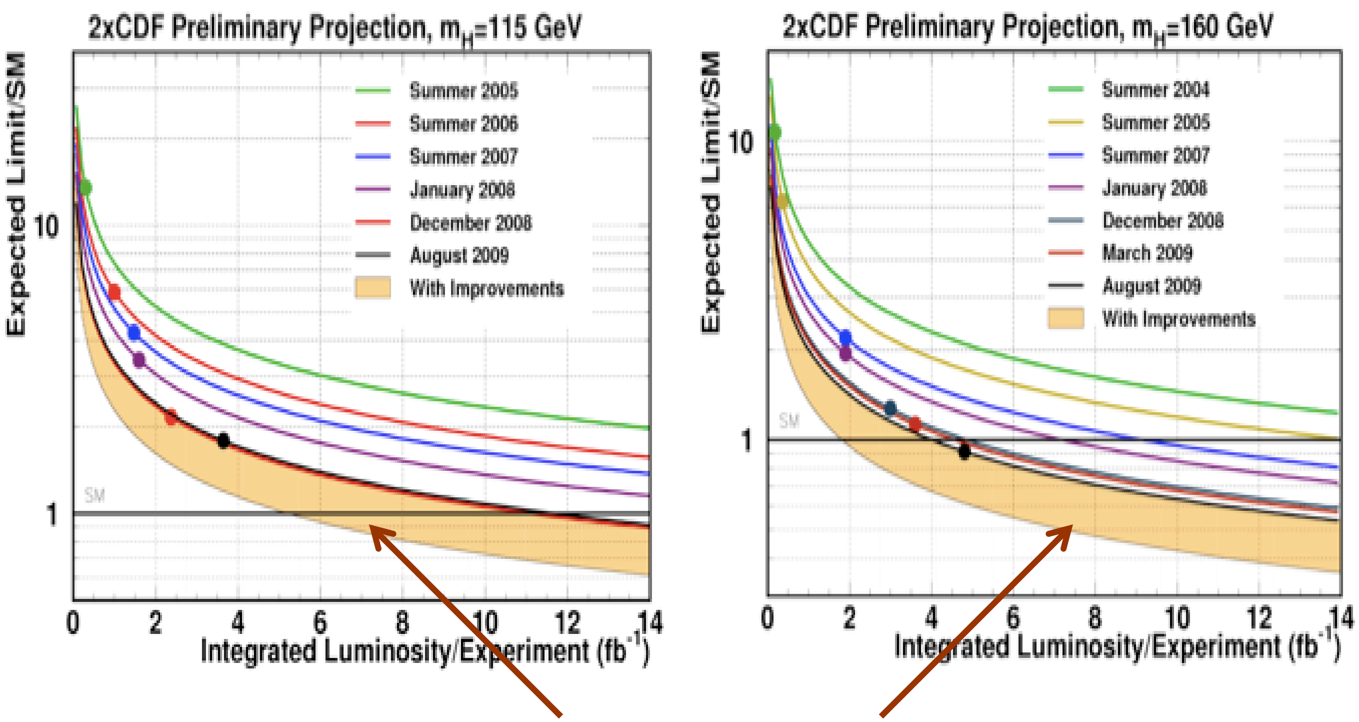
Many channels / experiment



CDF + DØ : up to 70 analyses

Higgs Search Progress

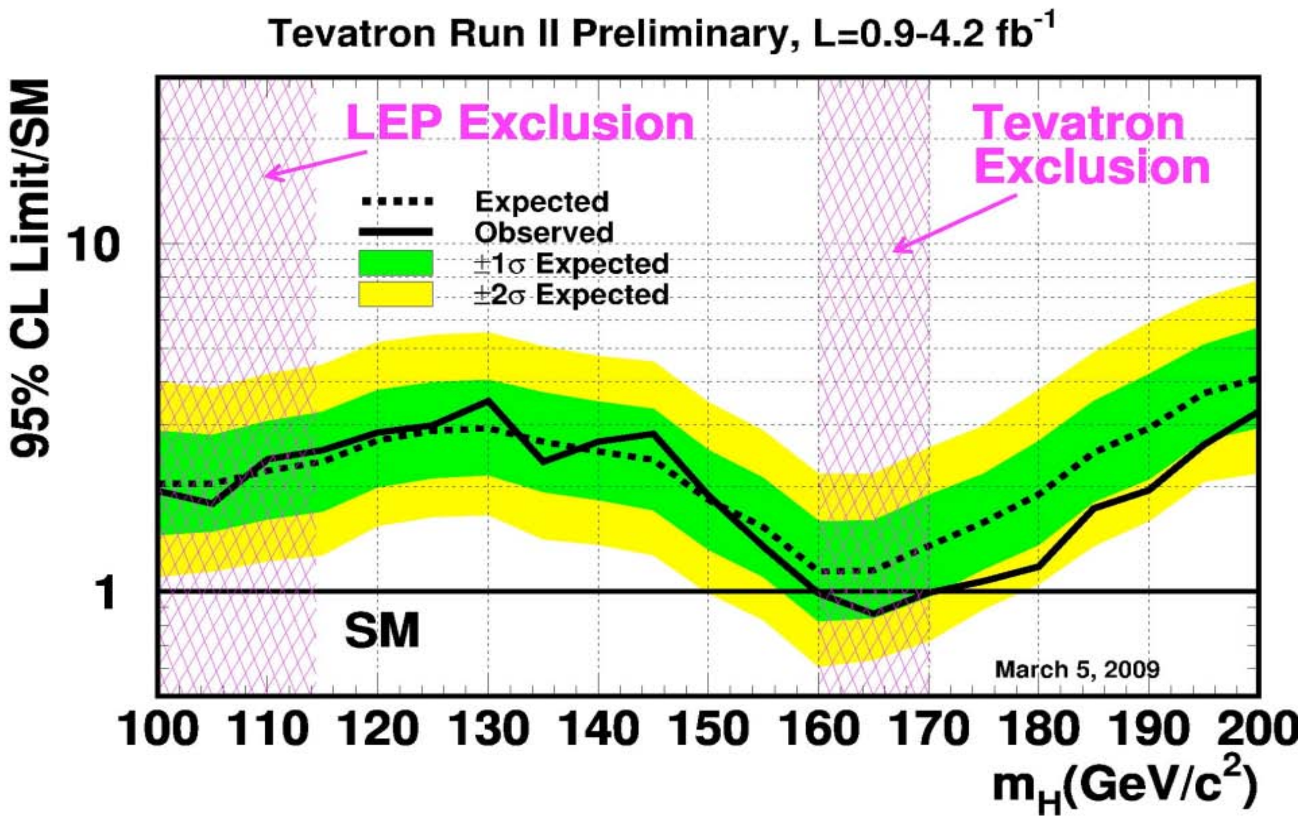
Progress through analysis improvements and luminosity



Expected improvement factors for future analysis

SM Higgs Search Result: March 2009

Tevatron combination: March 2009

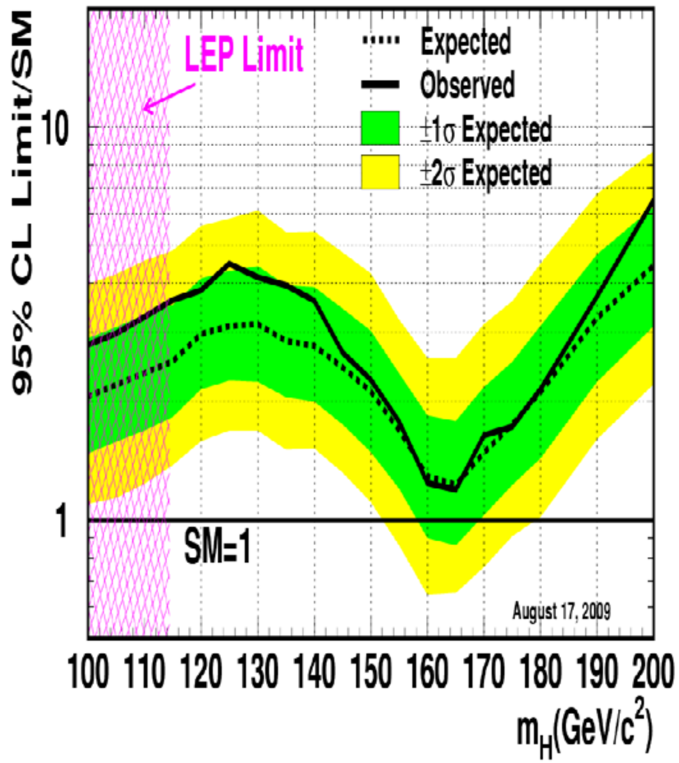


160 < Higgs Mass < 170 GeV is excluded at 95% CL

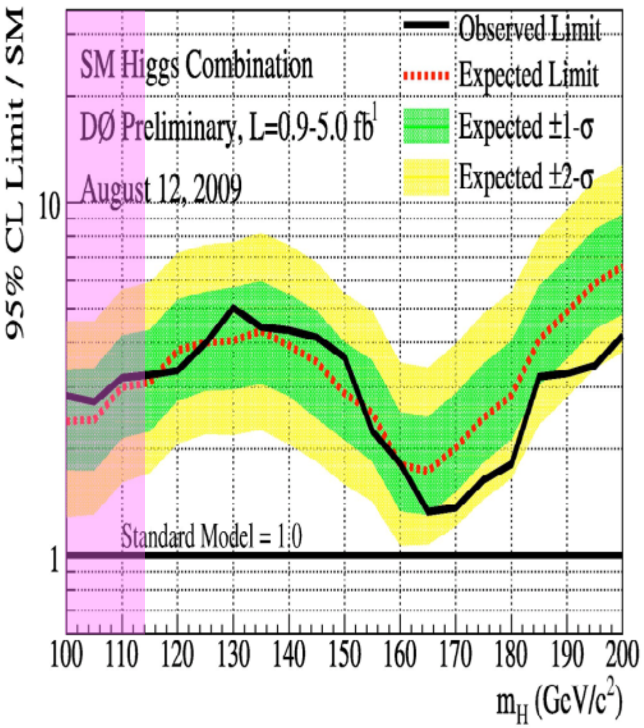
SM Higgs Search Result: November

Update and new Tevatron combination expected for HCP conference in November

CDF Prelim. 2.0-4.8 fb^{-1}



DØ Prelim. 0.9-5.0 fb^{-1}



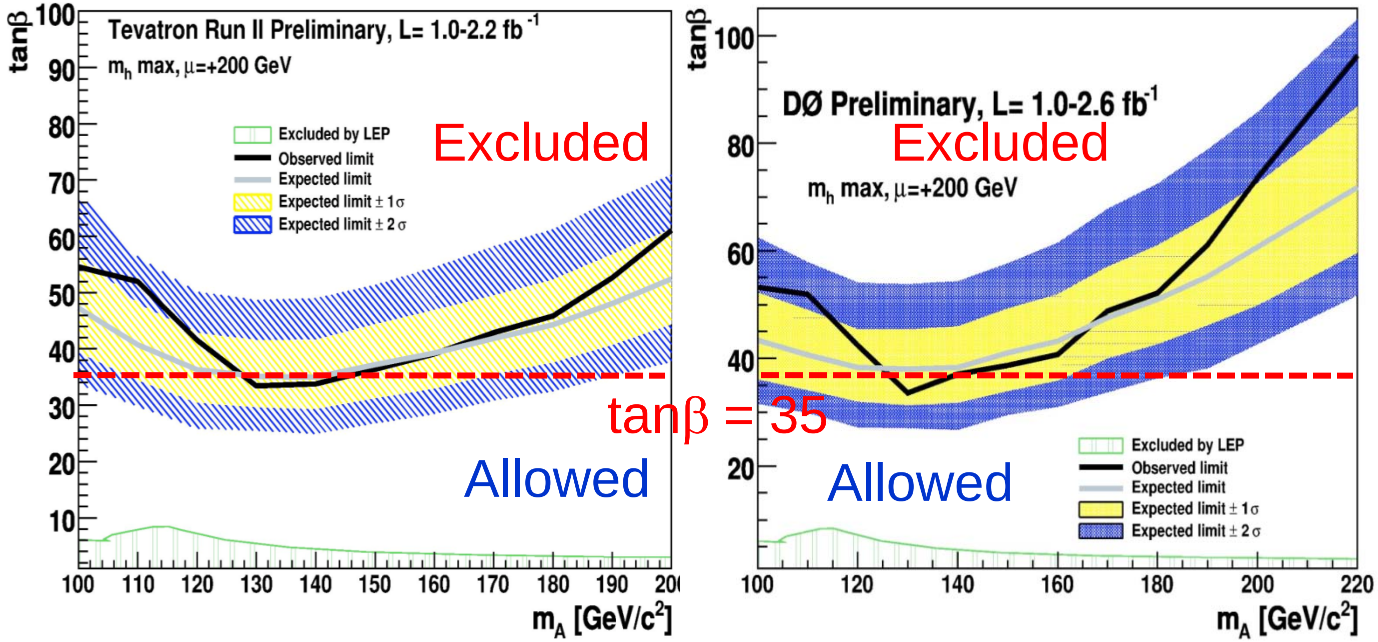
Supersymmetry Higgs (MSSM)

Tevatron Combination

h → ττ

DØ Combination

h → ττ, bh →bττ, bbb

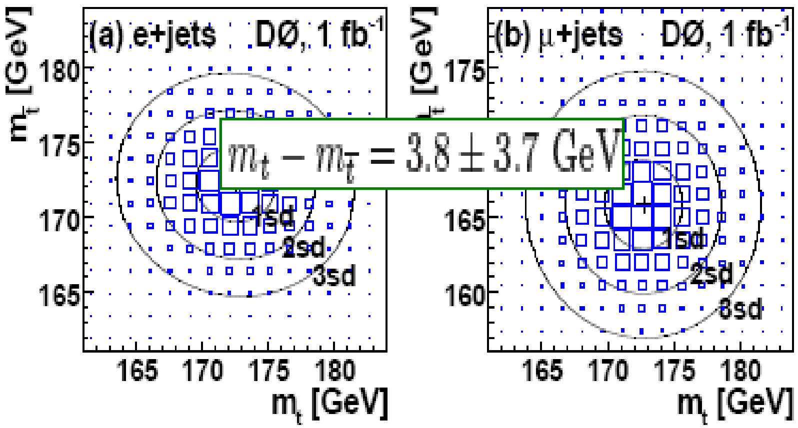


Reach sensitivity in interesting region where tanβ = 35
with 10 fb^{-1} over a wide Higgs mass range

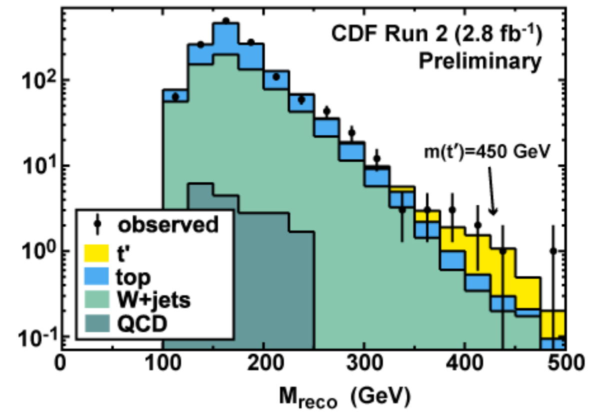
Complementary to $B_s \rightarrow \mu\mu$ (Tevatron:4×10^{-8}@95%CL,SM:$3\text{-}4\times10^{-9}$)

The first, the new, to be watched…

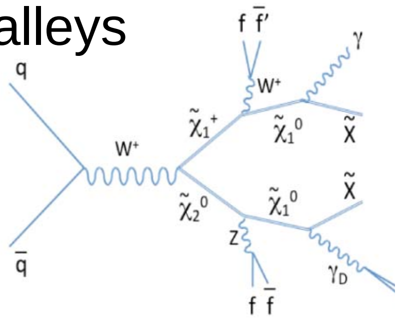
CPT test via a ‘free’ quark
and anti-quark mass diff.

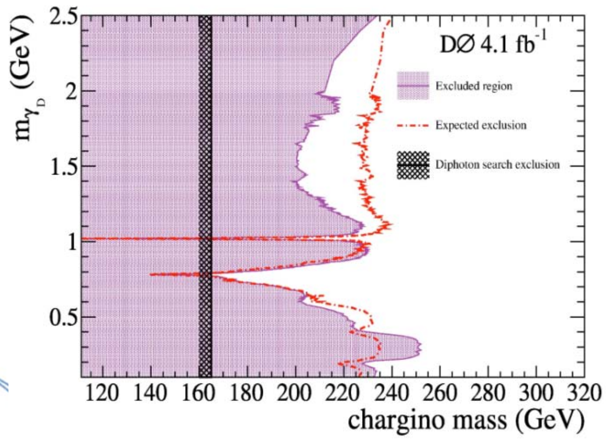


2.5σ effects



Dark photons
from Hidden Valleys





Conclusion

- Tevatron program continues to be remarkably successful
- Accelerators, detectors, triggers and computing are expected to operate well through 2011
- Accelerators
  - Nearly double the integrated luminosity
- Computing
  - Provide full support for analysis computing capability
- Collaborations: physicists
  - estimates 170-190 FTEs available / experiment in 2011
  - estimates ~100 (or less) FTEs to run each experiment
  - enough physicists to do wide spectrum of analyses
  - young scientists stay, new students join

Conclusion

- Program goals
  - Extract as much juice from the data as possible
    - Precision, new processes / measurements, new physics, Higgs, …
  - Revisit program, prioritize analysis
    - What should go on with increasing luminosity
    - What should wrap up
    - Easy access to tools

- Physics with FY2011 run
  - Doubling the dataset
  - Uniqueness of some physics at the Tevatron
  - Legacy measurements
  - Discovery potential
  - Higgs possibilities

Draft 2010-13 Accelerator Experiments' Run Plan

Draft 2010-13 Fermilab Accelerator Experiments' Run Schedule

Typically Revised Annually - This Version from October, 2009

Calendar Year		2010	2011	2012	2013
Tevatron Collider		CDF & DZero	CDF & DZero OPEN		OPEN
Neutrino Program	B	MiniBooNE	MiniBooNE		OPEN
	B	OPEN	OPEN		MicroBooNE
	MI	MINOS	MINOS		OPEN
	MI	MINERvA	MINERvA		MINERvA
	MI	ArgoNeuT			
	MI			NOvA	NOvA
SY 120	MT	Test Beam	Test Beam		Test Beam
	MC	OPEN	OPEN		OPEN
	NM4	E-906/Drell-Yan	E-906/Drell-Yan		E-906/Drell-Yan

This draft schedule is meant to show the general outline of the Fermilab accelerator experiments schedule, including unscheduled periods.

Major components of the schedule include shutdowns:
- In Calendar 2010, a 4-6 week shutdown for maintenance is shown.
- In Calendar 2011, no shutdown for maintenance is shown.
- A 2012-3 11-month shutdown is shown to upgrade the proton source and change the NuMI beam to the Medium Energy (ME) config.

- RUN/DATA
- STARTUP/COMMISSIONING
- INSTALLATION
- M&D (SHUTDOWN)

19-Oct-09

- 4th workshop on physics with a high intensity proton source
  - Nov. 9-10 (Mon-Tue), 2009
  - http://www.fnal.gov/directorate/Longrange/Steering_Public/workshop-physics-4th.html

- Muon collider physics (detector, machine-detector interface) workshop
  - Nov. 10-12 (Tue-Thu), 2009
  - http://www.fnal.gov/directorate/Longrange/Steering_Public/workshop-muoncollider.html
  - Synergy: ILC-CLIC-Muon Collider