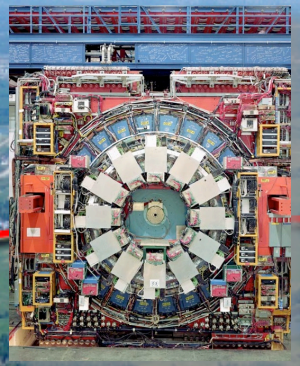
CDF IFC meeting

Fermilab, November 7th

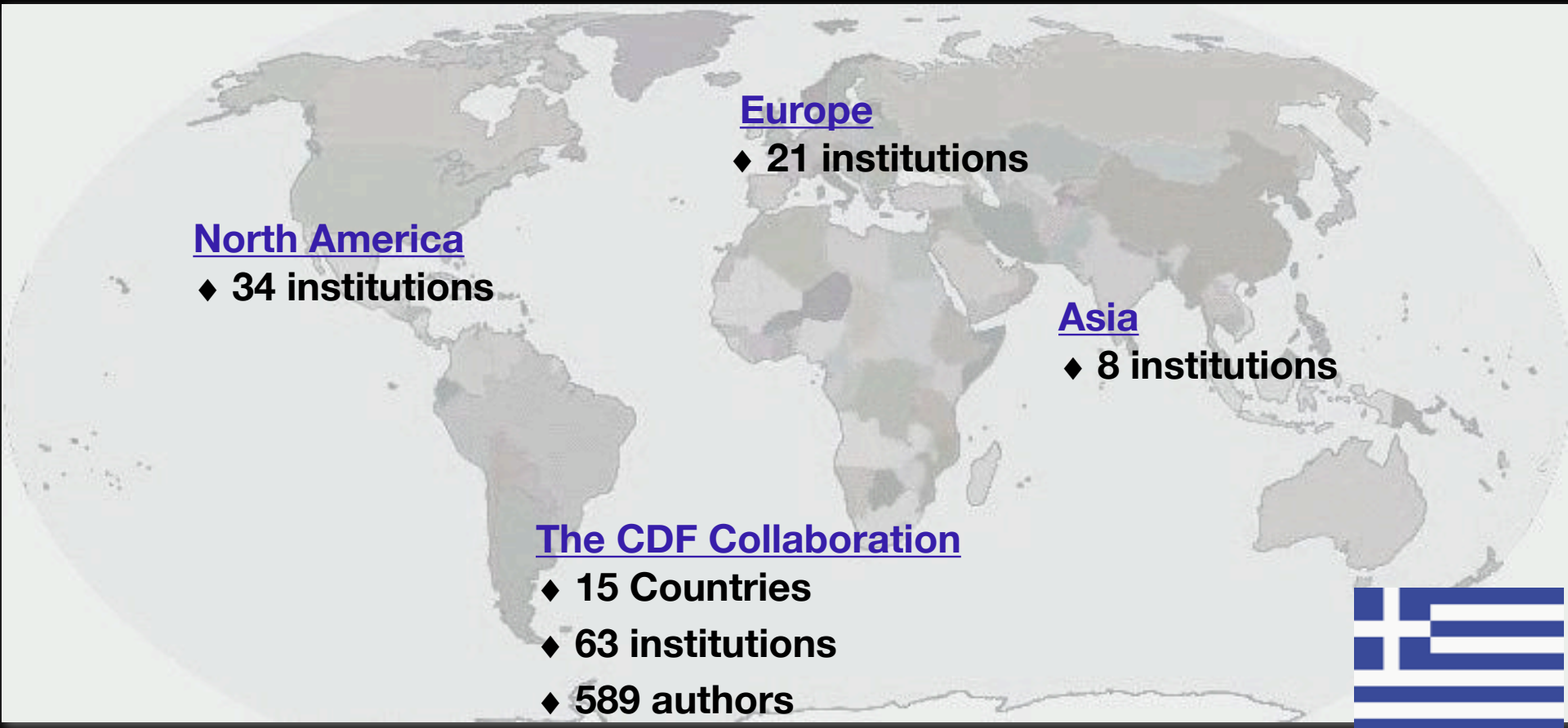


Jaco Konigsberg & Rob Roser

Outline

- Perspective
- Some highlights
- Outlook

The CDF Collaboration



Europe
- 21 institutions

North America
- 34 institutions

Asia
- 8 institutions

The CDF Collaboration
- 15 Countries
- 63 institutions
- 589 authors

Our Current Management Team

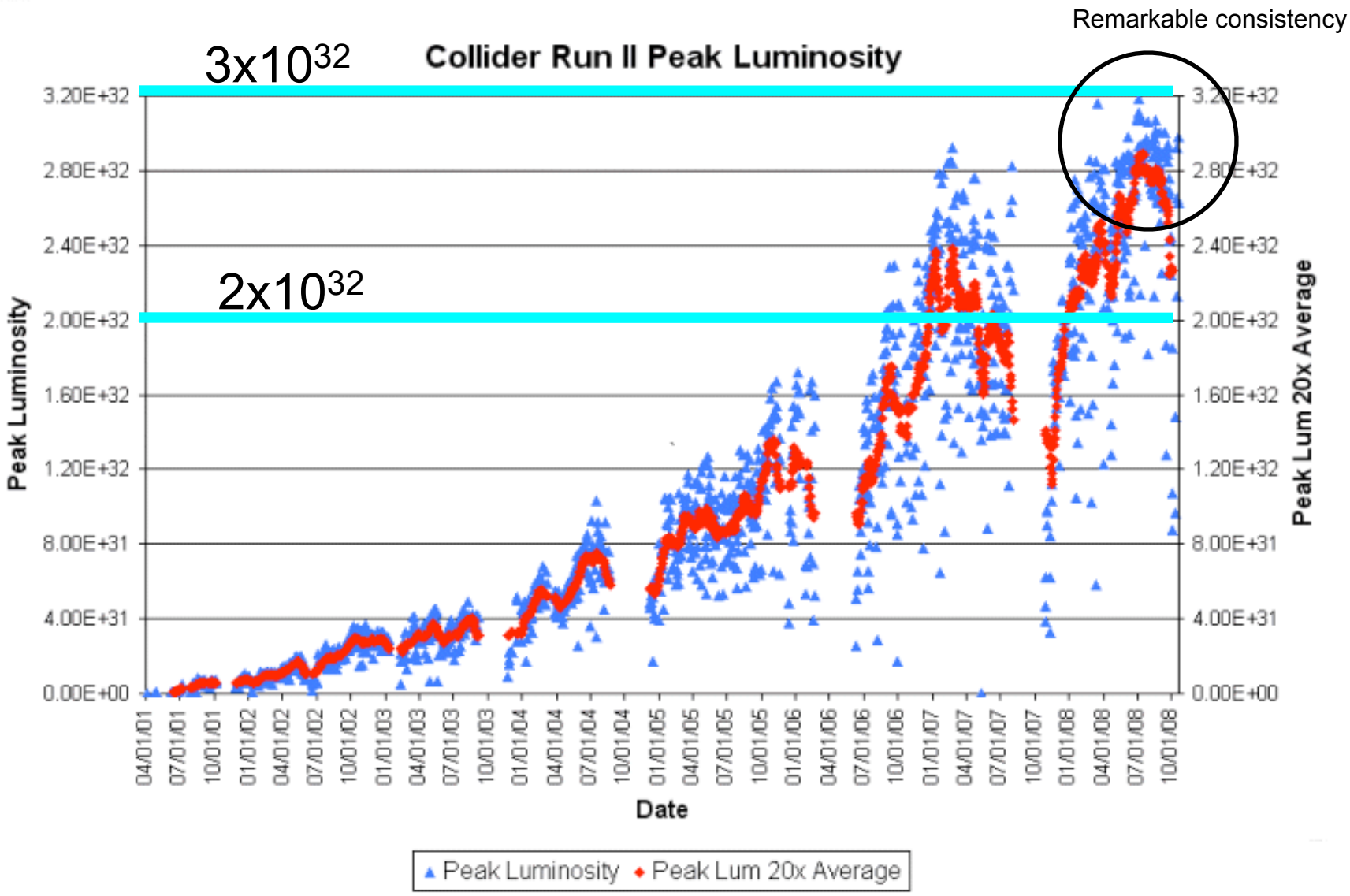
- Physics Coordinator
  - Kevin Pitts
- Detector Operations Heads
  - Massimo Casarsa
  - Phil Schlabach
- Offline Heads
  - Donatella Lucchesi
  - Rick Snider
- TDWG
  - Tom Wright & Laura Sartori
  - Emily Nurse
- Higgs
  - Mark Kruse
  - Matt Herndon
- Top
  - Florencia Canelli
  - Kirsten Tollefson
- Exotics
  - Ben Brau
  - Monica D'Onofrio
- EWK
  - Mark Lancaster
  - Larry Nodulman
- B
  - Giovanni Punzi
  - Manfred Paulini
- QCD
  - Sasha Pronko
  - Ken Hatakeyama

Strong participation and leadership from non-US institutions in management, in operations and in physics - THANK YOU

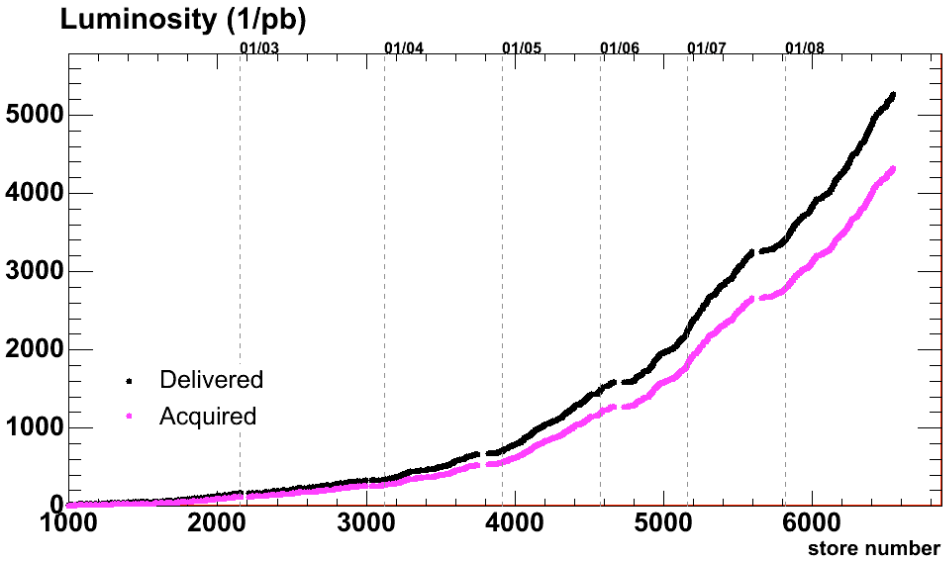
Accelerator Running Very Well

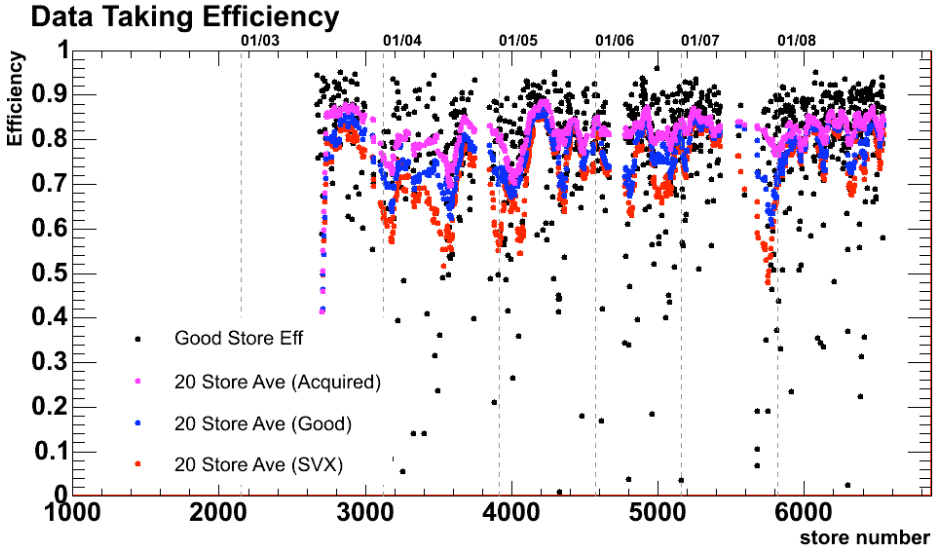
- **Setting lots of records!**
  - Highest instantaneous lum store: ~~3.18×10^{32}~~ ==> 3.32×10^{32}
  - Integrated lum over 1 week: 57.4 pb^{-1} [June 30-Jul 7]
  - Highest pbar stacking rate achieved: 27 mA/hr for one hour (regularly stacking at 24 mA/hr)
- **Integrating ~ 200 pb^{-1}/month**
- **Over 1.8 fb^{-1} delivered in FY08 !**
- **Good indication that we will make our goals for FY09 and FY10**

Instantaneous Luminosity



Operations and Performance





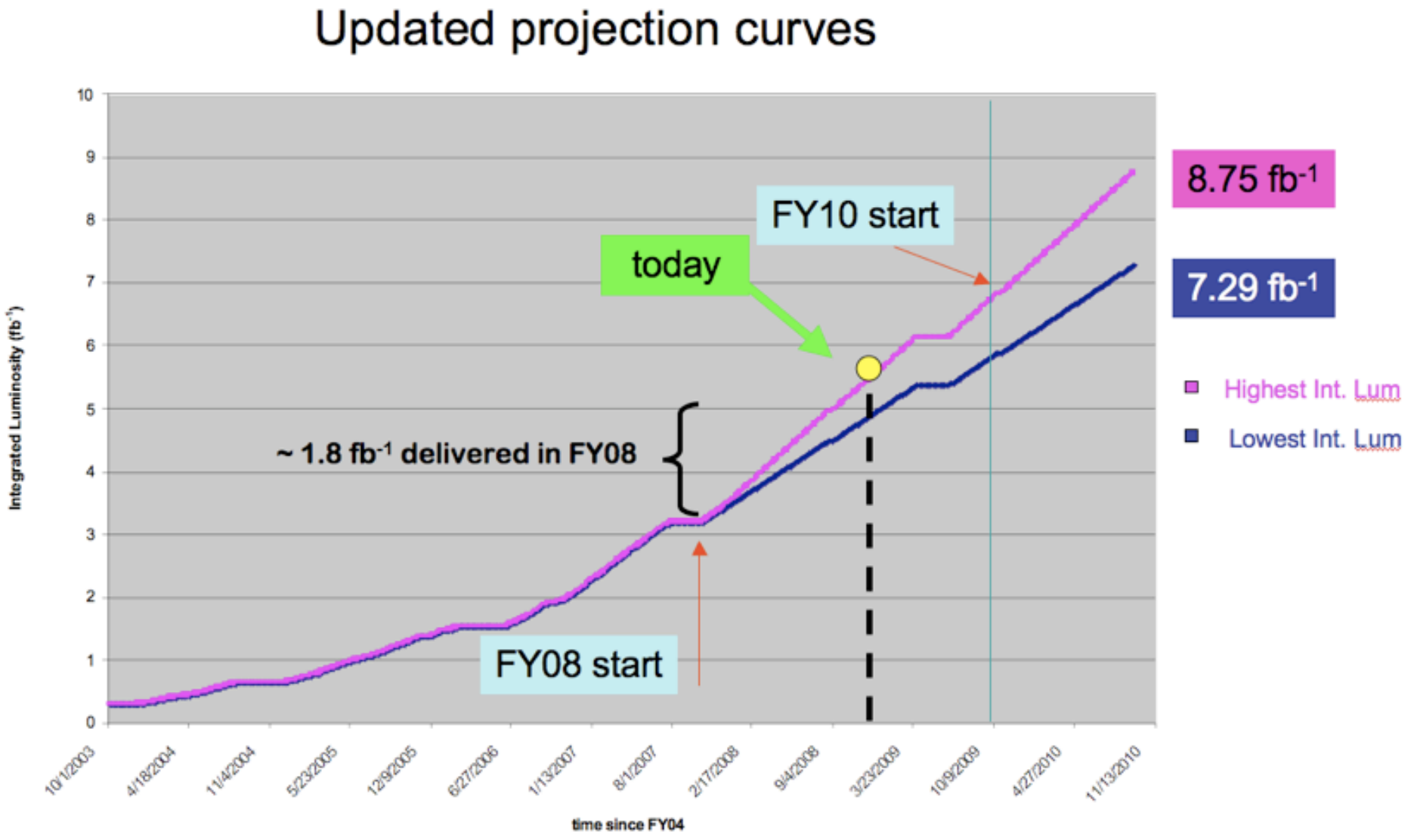
Total luminosity:

5.3 fb^{-1} delivered

4.4 fb^{-1} to tape

- **Stable collection of data: 85% efficiency (2003-present)**
- **No operational issues foreseen to reach 9 fb^{-1} or more by 2010**

Luminosity Perspective for Run II



Shutdown in 2009

- **Purpose:**
  - Overall maintenance of complex
  - Civil construction for Nova & Booster work
  - Reminder: the Summer'08 shutdown was postponed
    - great outcome in terms of additional integrated luminosity

- **Recently re-scheduled for June 15th to Aug 23rd**
  - ~10 weeks duration
  - Originally scheduled for April '09
  - CDF, Dzero and Numi/Minos preferred June

Detector

- Built to last !
- No foreseen issues to run it through 2010
- We've overcome significant challenges along the way
- ACEs, SPL's and Ops Managers are always needed

- Trigger keeps up with luminosity
  - Lots of handles to keep dead-time in check as the luminosity increases

- Experts in close orbit is key… we spend time on this

Computing

- Tremendous success in keeping up with the data
- Implementing a re-organization of our operations
  - Need to last well beyond end of data-taking
  - In close collaboration and coordination with FNAL's Computing Division
  - More matched to our current and expected resources
  - More efficient with better tracking of problems and operations
  - Continue to juggle the Grid landscape as it evolves
  - Started to look into data preservation and access
- We continually need people in computing operations
- See Rick and Donatella's talk for more details...

Physics

- Productivity is higher than ever
  - Rate of new results
  - # of conference submissions
  - # of publications
  - # of Godparent committees
- Stable tools and excellent understanding of detector/ data
- Having experts around is invaluable
- Offline team keeping up with data is also invaluable
- We now have fantastically large datasets
  - In some areas we are only scratching the surface
  - Still much potential for precision, reach and discovery
    - We need to keep exploiting the data from all angles

CDF Physics Program

We're addressing questions of fundamental importance:

- **Precision Tests**
  - B_s-Mixing, CKM Constraints, and CP-Violation
  - Heavy Flavor Spectroscopy and tests of Lattice Theory
  - Top-quark and W-boson Masses and EWK Symmetry Breaking
  - Di-Boson cross sections and SM Gauge Couplings

- **Unique window into the unknown**
  - Still at the Energy Frontier
  - Properties of Top-quark Production and Decay
  - Supersymmetry (gravity-, gauge-, anomaly-mediated, etc)
  - Extra Dimensions
  - Standard Model Higgs
  - Other Exotica

Physics Results - Summer'08

Bottom Physics

Analysis	Luminosity	More Information
Constraining CPV phase β_s using flavor tagged $B_s \rightarrow J/Psi\phi$	3 fb^{-1}	WebPage
A Precision Determination of the mass of X(3872) using $J/\Psi\,\pi\,\pi$ Decays	2.4 fb^{-1}	WebPage
Search for the Lepton Flavor Violating Decays $B_{s(d)} \rightarrow e\mu$	2 fb^{-1}	Webpage
Measurement of Λ_b Lifetime using $\Lambda_b \rightarrow \Lambda_c\pi$ Decays	1 fb^{-1}	Webpage
Measurement of the B^+ Lifetime using a MC-Free Analysis Method	1 fb^{-1}	WebPage
Measurement of the B_c Lifetime using Semi-leptonic Decays	1 fb^{-1}	WebPage
Search for Narrow Resonances below the Y	0.6 fb^{-1}	Webpage

Electroweak Physics

Analysis	Luminosity	More Information
Towards an Improved W-mass Determination using 2.3 fb^{-1} of Data	2.3 fb^{-1}	WebPage
Limits on Anomalous Triple Gauge Couplings using ZZ events	2 fb^{-1}	WebPage

Exotic Physics

Analysis	Luminosity	More Information
Search for STop Pair Production Mimicking Top Pair Events	2.7 fb^{-1}	WebPage
Search for High Mass Resonance Decaying to $\mu^+\mu^-$	2.3 fb^{-1}	WebPage
Search for New Physics using γ + lepton + b-jet + Missing Energy Signature	2 fb^{-1}	WebPage
Search for New Physics using γ + b-jet + Missing Energy Signature	2 fb^{-1}	WebPage
Search for Anomalous Production of γ + Jet + Missing Energy	2 fb^{-1}	WebPage
Search for Gluino Mediated SBottom Production	2 fb^{-1}	WebPage
Search for Like Sign Top Pair Events arising from MaxFV Models	2 fb^{-1}	WebPage
Search for New Physics using DiJet + Missing Energy Final States	2 fb^{-1}	WebPage
Search for Technicolor Particle $\varrho_T \rightarrow \pi_T W$	2 fb^{-1}	WebPage
Search for High Mass Resonances Decaying to Leptons of Different Flavor	1 fb^{-1}	WebPage

http://www-cdf.fnal.gov/physics/S08CDFResults.html

Physics Results - Summer'08

Higgs Physics

Analysis	Luminosity	More Information
Search for H → WW Events	3 fb^{-1}	WebPage
Search for WH→ lν bb Events	2.7 fb^{-1}	WebPage
Search for ZH→ lepton + lepton + bb Events	2.4 fb^{-1}	WebPage
Search for ZH→ lepton + lepton + bb Events ME technique	2.0 fb^{-1}	WebPage
Search for VH→ MET+ bb Events	2 fb^{-1}	WebPage
Search for WH→ WWW* Events	2 fb^{-1}	WebPage
Updated CDF SM Higgs Combination	1-3 fb^{-1}	WebPage
Updated CDF+D0 SM Higgs Combination	3 fb^{-1}	WebPage

QCD Results

Analysis	Luminosity	More Information
Measurements of the Underlying Event using DY Processes	2.7 fb^{-1}	WebPage
Measurement of the Inclusive Z+Jets Cross Section	2.5 fb^{-1}	WebPage
Diffractive W and Z Production	0.6 fb^{-1}	WebPage
Measurement of the Inclusive Photon Production Cross Section	0.5 fb^{-1}	WebPage
Measurement of the MinBias Cross Section	0.5 fb^{-1}	WebPage

http://www-cdf.fnal.gov/physics/S08CDFResults.html

Physics Results - Summer'08

Top Physics

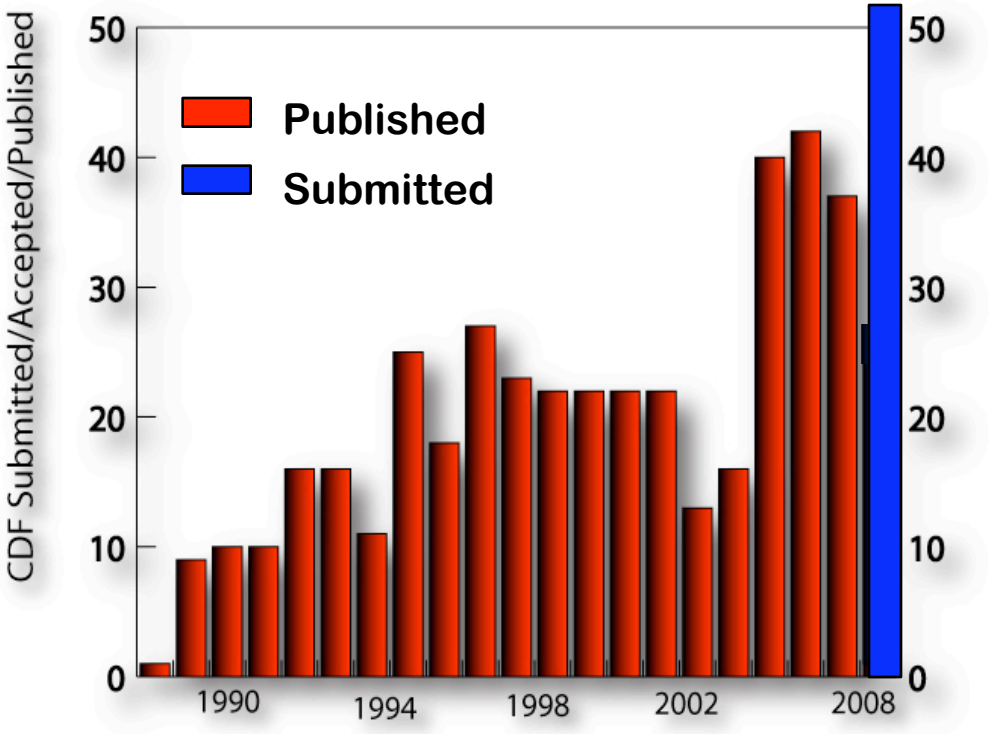
Analysis	Luminosity	More Information
Search for Single-Top Production using a Matrix Element Method	2.7 fb^{-1}	WebPage
Search for Single-Top Production using a Neural Network Discriminant	2.7 fb^{-1}	WebPage
Search for Single-Top Production using a Likelihood Function Discriminant	2.7 fb^{-1}	WebPage
Search for Single-Top Production using a Boosted Decision Tree Discriminant	2.7 fb^{-1}	WebPage
Search for s-Channel Single-Top Production using a Neural Network Discriminant	2.7 fb^{-1}	WebPage
Combination of CDF Single-Top Results	2.7 fb^{-1}	WebPage
Search for Anomalous Single-Top Production	2.2 fb^{-1}	WebPage
ttbar Cross Section using ee, μμ, eμ Dilepton Events	2.7 fb^{-1}	WebPage
ttbar Cross Section using Dilepton + BTagged Events	2.7 fb^{-1}	WebPage
ttbar Cross Section using Lepton+Jet Events with a Secondary Vertex Tag	2.7 fb^{-1}	WebPage
ttbar Cross Section using Lepton+Jet Events using a NN Discriminant	2.7 fb^{-1}	WebPage
ttbar Cross Section using Lepton+Jet Events with a Soft Muon Tag	2 fb^{-1}	WebPage
ttbar Cross Section using Lepton+Jet Events with a Soft Electron Tag	1.7 fb^{-1}	WebPage
Combination of CDF ttbar Cross Section Results	2.7 fb^{-1}	WebPage
Measurement of M_t using Matrix Element Method in Lepton+Jet Events	2.7 fb^{-1}	WebPage
Measurement of M_t using ν Weighting Method in Lepton+Track Events	2.7 fb^{-1}	WebPage
Measurement of M_t in All Hadronic Events	2.1 fb^{-1}	WebPage
Measurement of M_t using Variables Independent of Jet Energy	2 fb^{-1}	WebPage
Most Recent Tevatron Combination of Top Mass Results	3 fb^{-1}	WebPage
Search for Massive T' Decaying to Wq in Lepton+Jet Events	2.7 fb^{-1}	WebPage
Search for Charged Higgs in Top Pair Events	2.2 fb^{-1}	WebPage
Search for Invisible Top Decays	2 fb^{-1}	WebPage
Measurement of the $gg \rightarrow tt$ Fraction using DiLepton Events	2 fb^{-1}	WebPage
Combination of CDF W-Helicity Results	2 fb^{-1}	WebPage

snapshot of http://www-cdf.fnal.gov/physics/W08CDFResults.html

FNAL Wine and Cheese Seminars -since a year ago

- Sept 28: MSSM higgs searches
- Dec 11: Study of CP violation in Bs to J/psi phi
- Jan 11: Do-Do-bar mixing
- Feb 1: ZZ observation
- Feb 8: SUSY with trileptons
- Mar 28th: Single-top production
- Apr 4: FCNC in Top
- Apr 25: SM Higgs => tau, tau
- May 30: Global Serch for New Physics
- Jun 20: Results on Rare HF Physics
- Jul 25: Results for ICHEP08
- Aug 15: Recent CDF results
- Oct 10: Top Cross Sections
- Nov 12: Multi-muons
- Dec 5: TBD
- Dec 19: TBD

Publications



- CDF: ~435 publications total
  ~185 in Run 2
- 51 submitted so far in 2008
  32 of them published
- 60+ in internal review
- 142 students currently at CDF

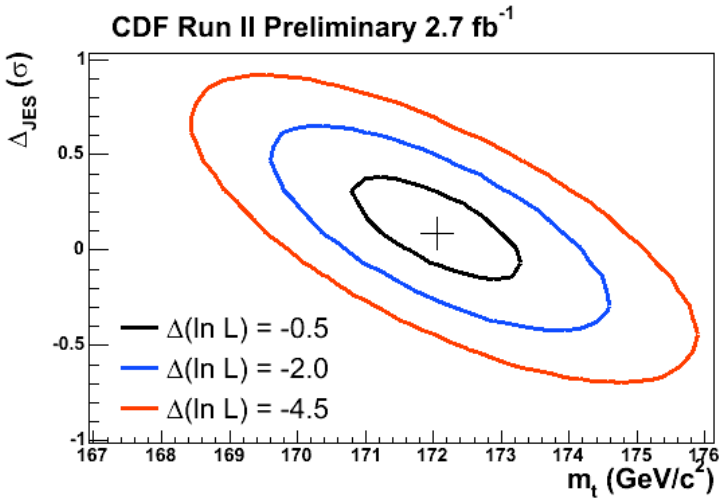
Some Physics Highlights

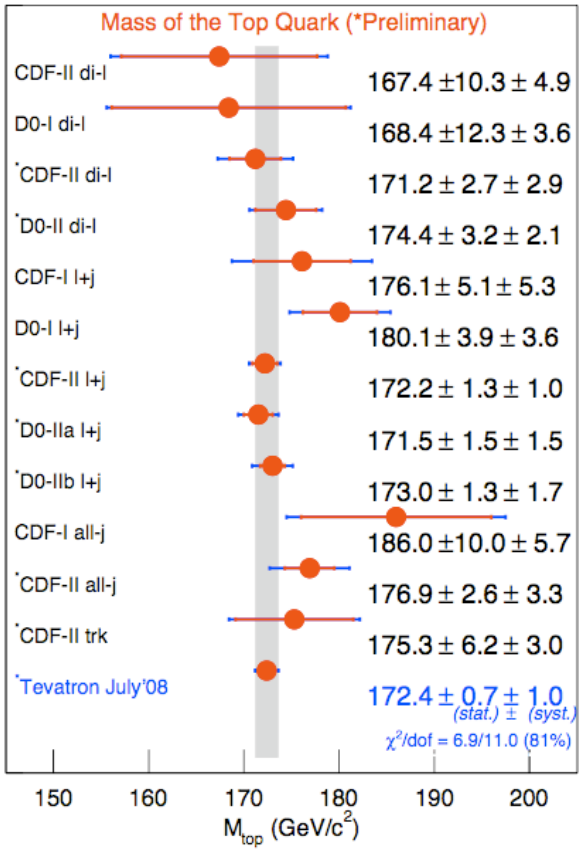
- ✓ Observation of Bs-mixing
  - Δm_s = 17.77 +- 0.10 (stat) +- 0.07(sys)
- ✓ Observation of new baryon states
  - Σ_b and Ξ_b
- ✓ WZ discovery (6-sigma)
  - Measured cross section 5.0 (1.7) pb
- ✓ ZZ observation
  - 4.4-sigma
- ✓ Single top evidence (5-sigma sens./2.2 fb^{-1})
  - cross section = 2.2 (0.7) pb
  - $|V_{tb}|$= 0.88 ± 0.14 (exp.) ± 0.07 (th.)
- ✓ Observation of new charmless B==>hh states
- ✓ Observation of exclusive/diffractive production
  - Di-jets, W/Z, charmonium, etc
- ✓ Observation of D^o-D^obar mixing
- ✓ Measurement of Sin(2β_s)
- ✓ …

Most are world's best results

- ✓ Precision W mass measurement
  - Mw_cdf = 80.413 GeV (48 MeV)
- ✓ Precision Top mass measurement
  - Mtop_cdf = 172.2 (1.6) GeV
- ✓ W-width measurement
  - 2.032 (.071) GeV
- ✓ Extended exclusions on BSM
- ✓ Continued improvement with Higgs
  - Exclusion of 170 GeV Higgs

Precision - Mtop





CDF: m_t = 172.2 ± 1.0 ± 1.3 GeV

- **A legacy measurement**
  - Very sophisticated

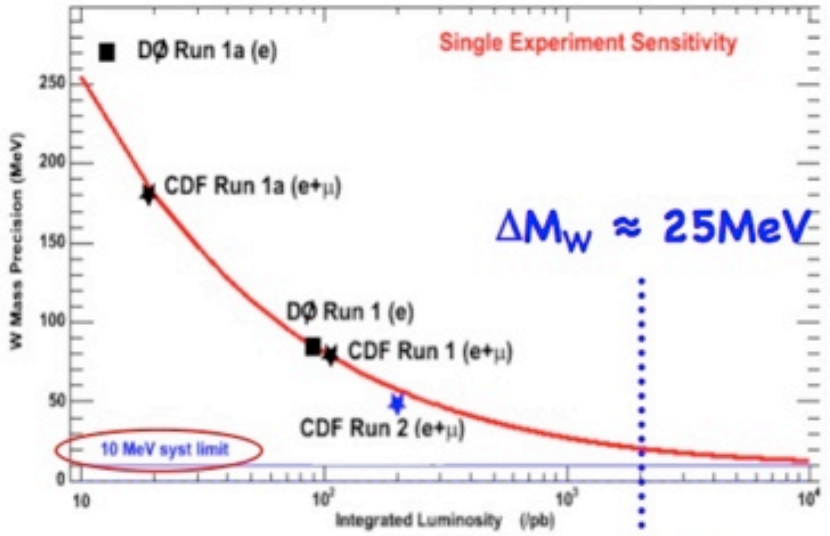
World average top quark mass (ICHEP 08)

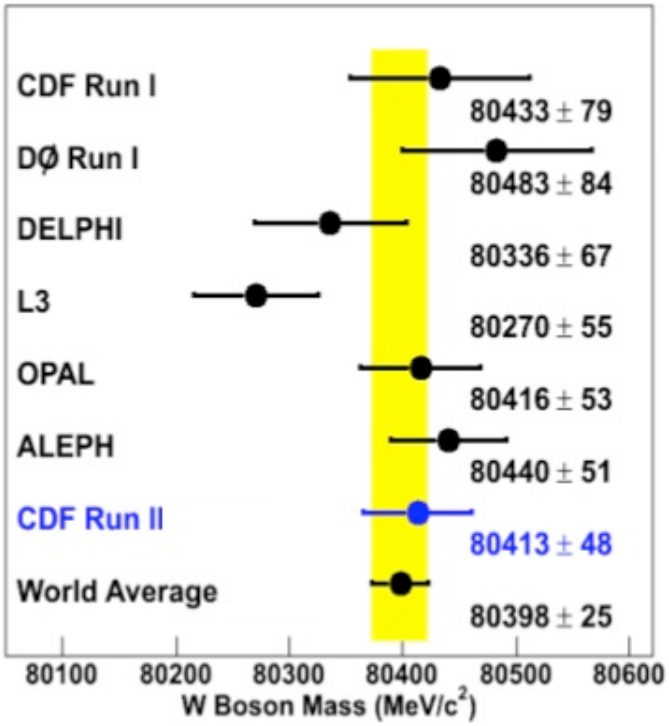
m_t = 172.4 ± 0.7 ± 1.0 GeV

0.7 % precision

Mw - precision

What can we do with > 2fb^{-1} ?





momentum and energy scales

recoil

backgrounds

theoretical uncertainties

CDF II preliminary — L = 200 pb^{-1}

m_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	9	9	9
Recoil Resolution	7	7	7
$u_\parallel$ Efficiency	3	1	0
Lepton Removal	8	5	5
Backgrounds	8	9	0
$p_T(W)$	3	3	3
PDF	11	11	11
QED	11	12	11
Total Systematic	39	27	26
Statistical	48	54	0
Total	62	60	26

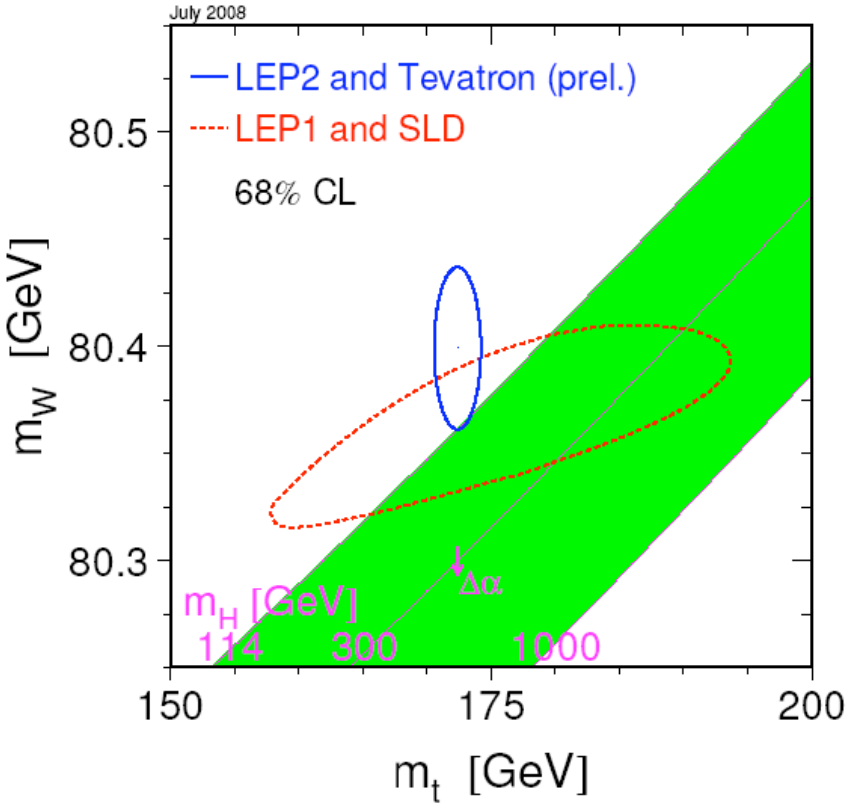
Mw - passion

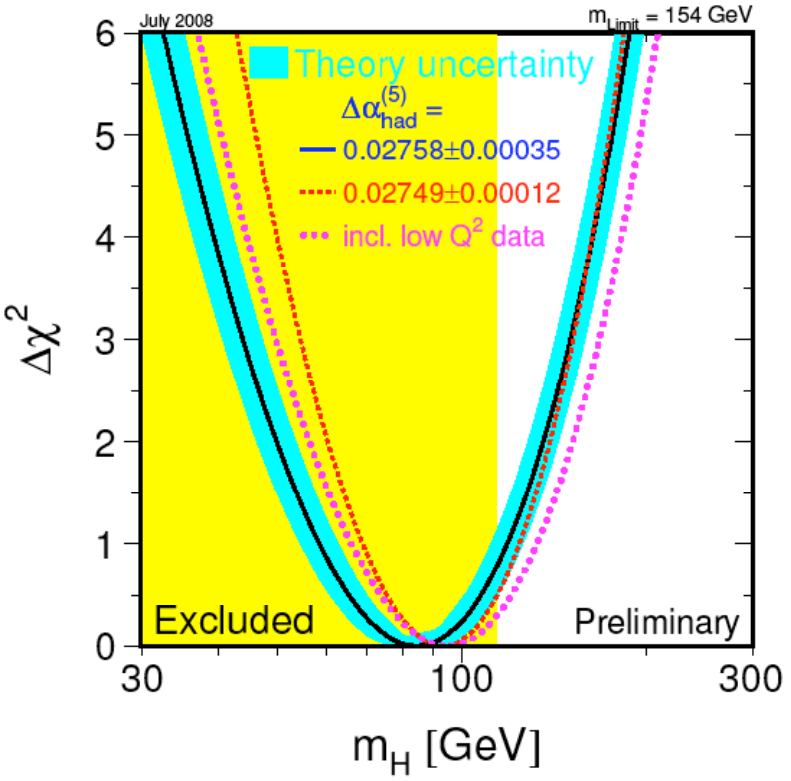
Workshops

≈18 hours of W mass / day …

discussions with action items resolved overnight

Constraining M_H



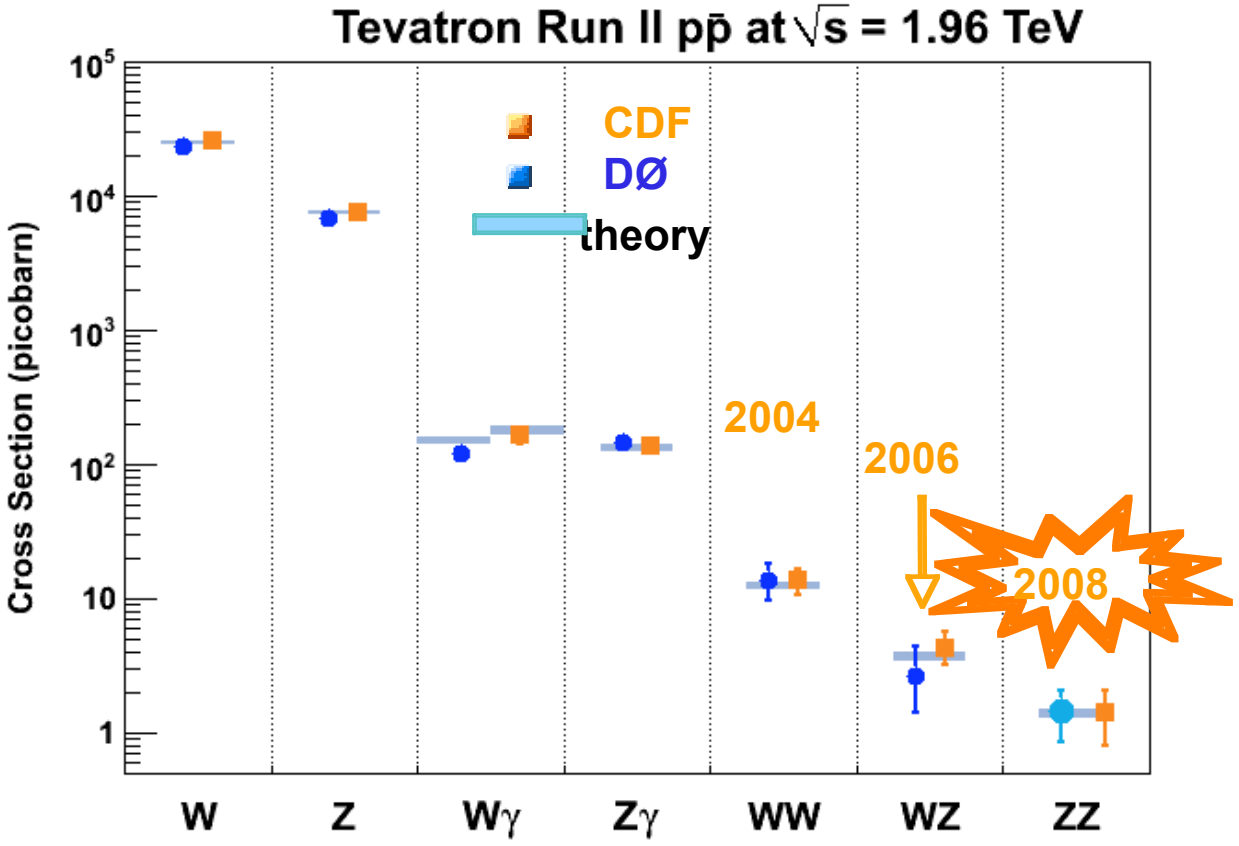


- **SM Higgs is light…**

$m_H = 84^{+34}_{-26}$ GeV

$m_H < 154$ GeV @ 95% CL

Di-bosons progression

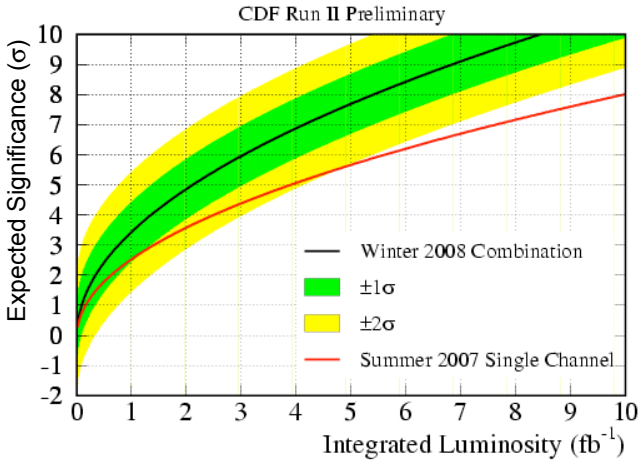


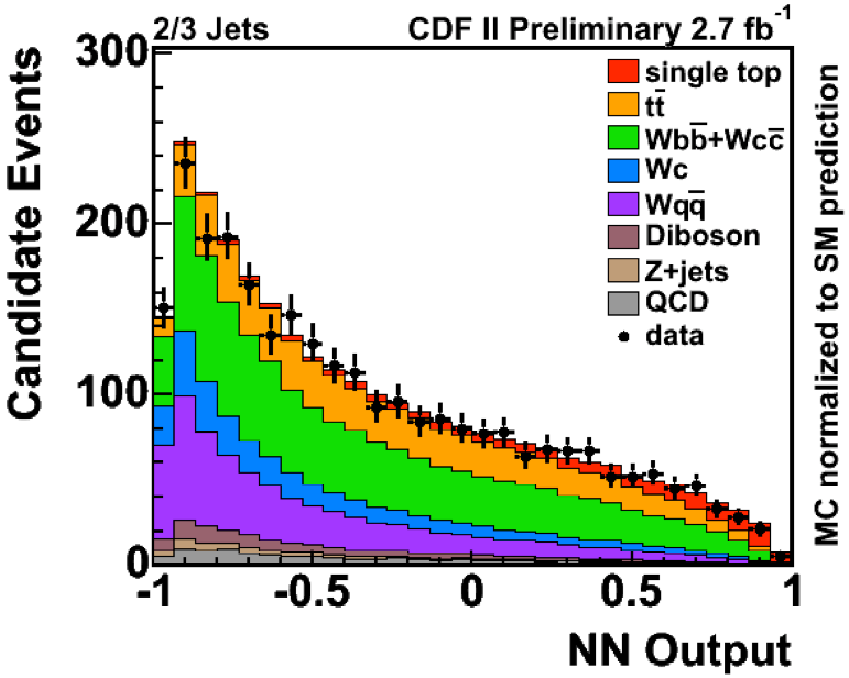
Both CDF and DØ combine ZZ→llνν and ZZ→llll channels to obtain 4.4σ and 5.7σ significance respectively

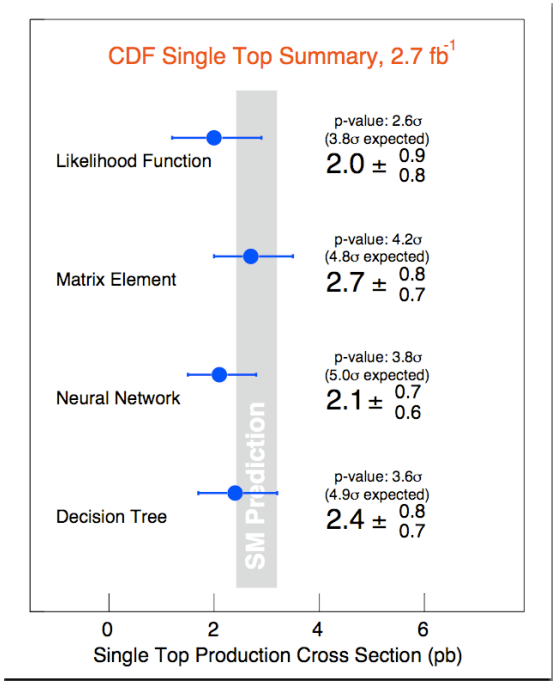
Cross sections measured in agreement with SM prediction of 1.4 pb

Single Top progression

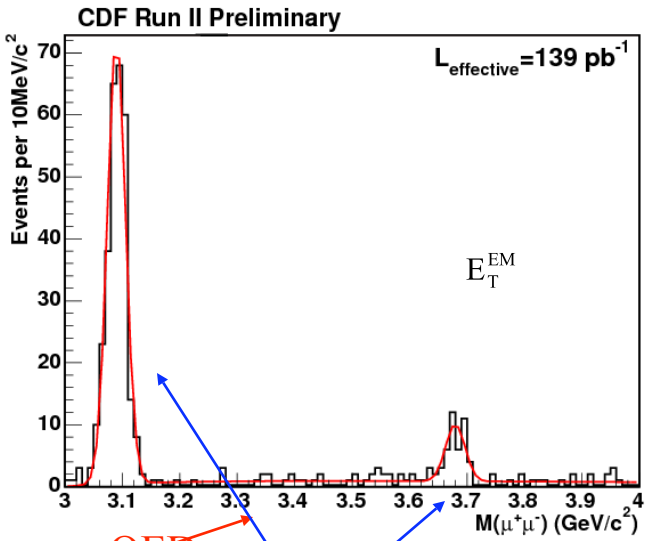
- We have now 5-sigma sensitivity !
- Multivariate analyses to dig out a very small signal from large backgrounds

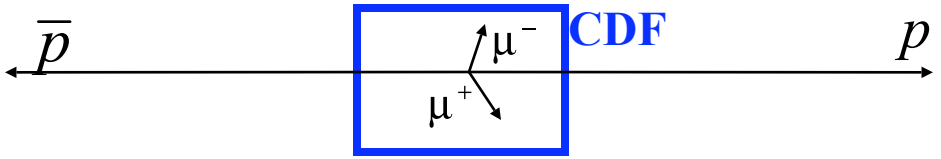






Observation of Exclusive Charmonium Production and $\gamma\gamma \to \mu^+\mu^-$ in $p\bar{p}$ Collisions at $\sqrt{s}$=1.96 TeV.

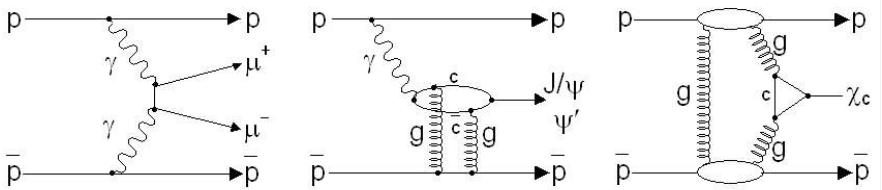




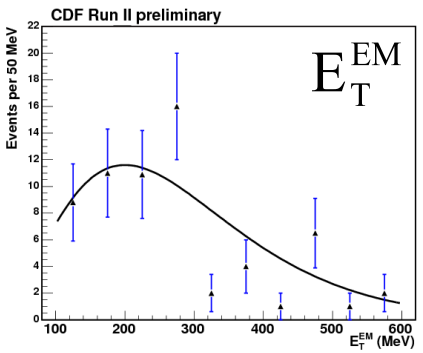
No other particles produced: detectors to $|\eta| = 7.4$

Quantity	This analysis	Theory
$\frac{d\sigma}{dy}(y=0) J/\psi$ (nb)	3.96±0.64	$2.7^{+0.6}_{-0.2}$
$\frac{d\sigma}{dy}(y=0) \psi(2S)$ (nb)	0.53±0.15	$0.46^{+0.11}_{-0.04}$
$\frac{d\sigma}{dy}(y=0) \chi_c^\circ$ (nb)	66±13	130± ≈50
$\sigma(box, QED, pb)$	2.6±0.5	2.18 ± 0.02
$\frac{O}{\gamma}$	< 0.38(95% c.l.)	0.3 - 0.6
$\frac{OP \to J/\psi}{PP \to \chi_c}$	<0.06 (95% c.l.)	No Prediction

Continuum = QED

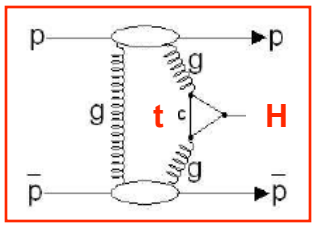


® $J/\psi + \gamma$



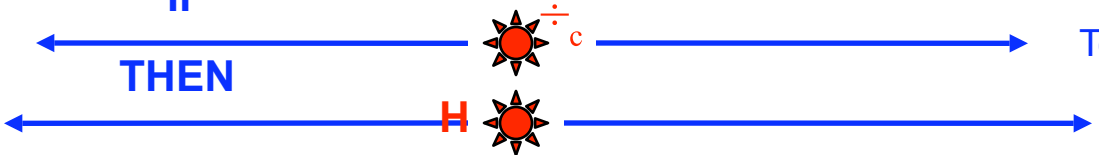
Vector mesons = photoproduction

Scalar meson = gg (double pomeron)



IF

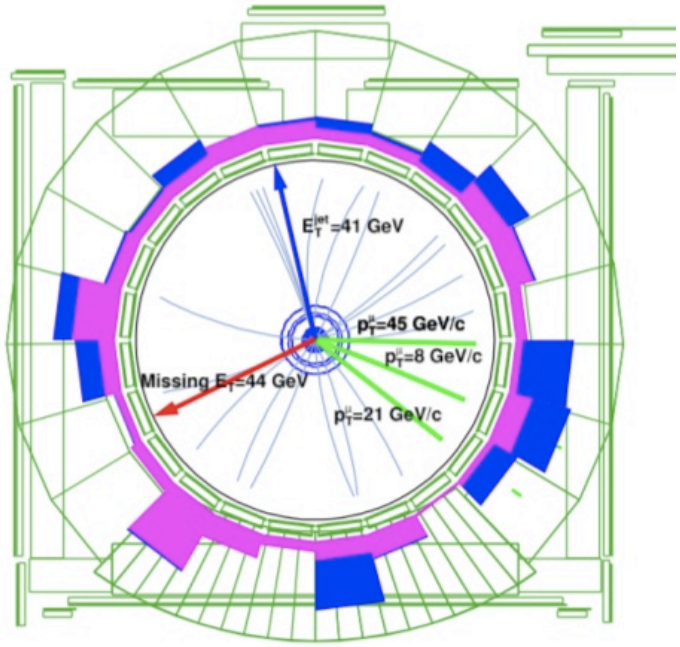
THEN

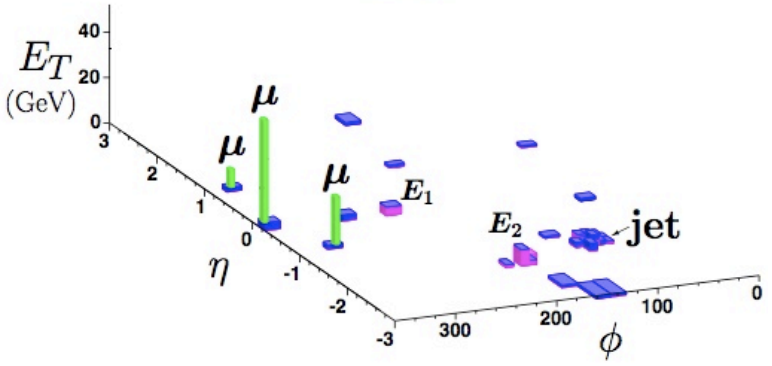


New physics watch

- Several analysis with deviations:
  - Sin(2 βs)
  - t-prime
  - Like-sign dileptons
  - Delayed photons
  - Photon+met
  - Structure in J/Psi Phi mass spectrum
  - Multi-muons
  - Etc.

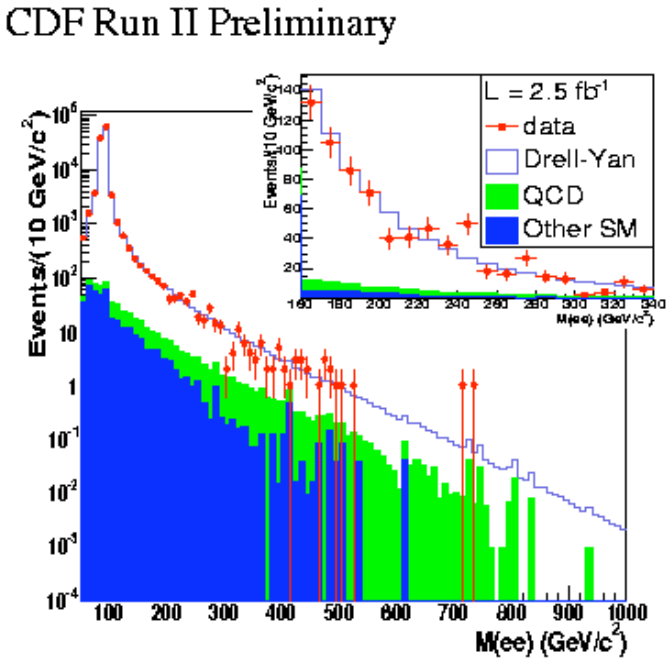
- We need to try to NOT miss anything…

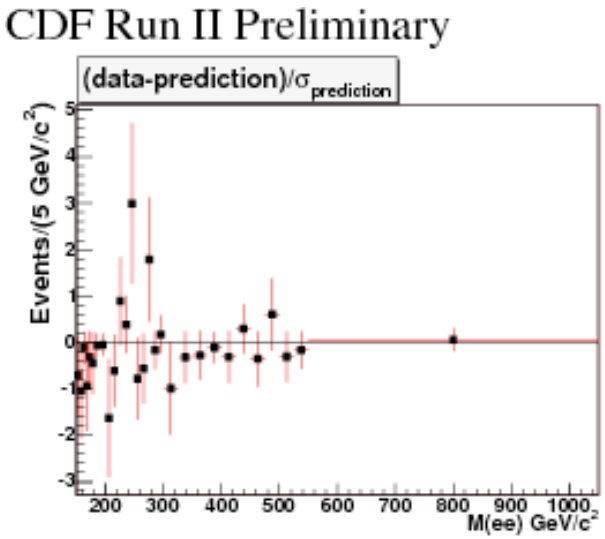




Nice tri-muon + Met + jet event

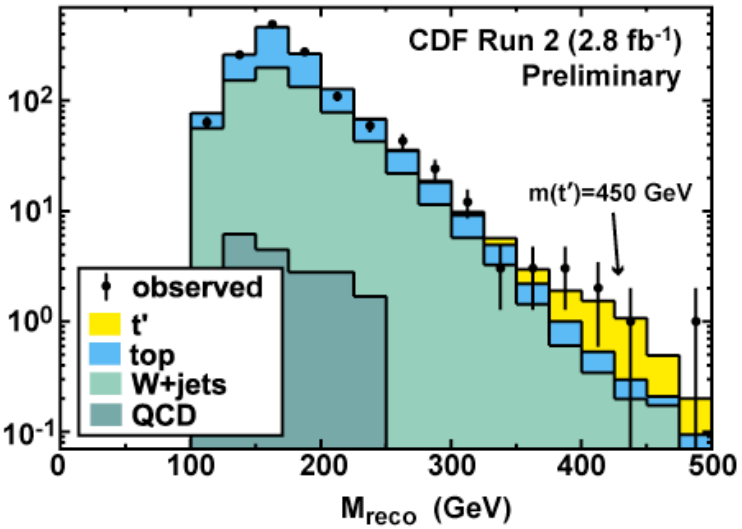
Ex: New Physics watch





di-electrons

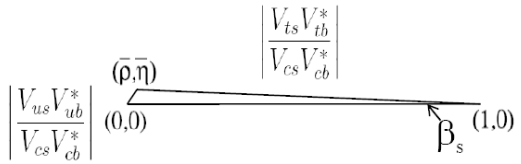
2.5 sigma



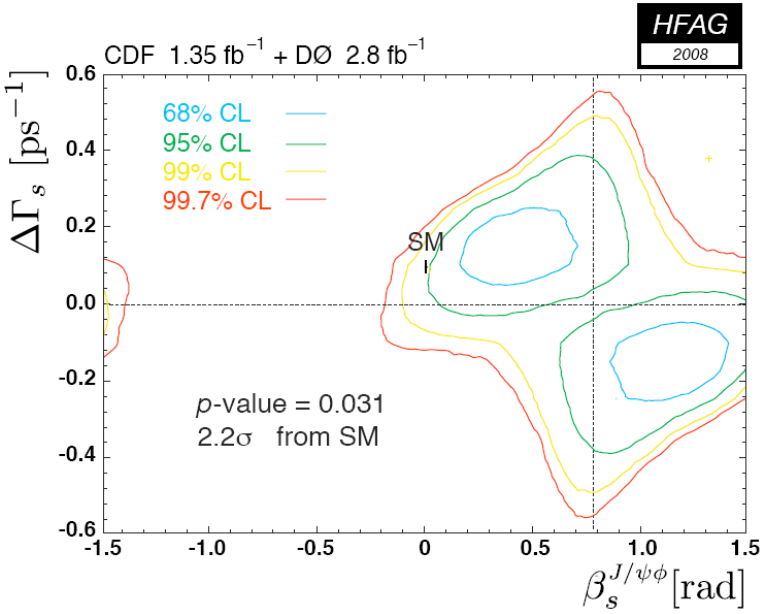
t' search

~ 2.5 sigma

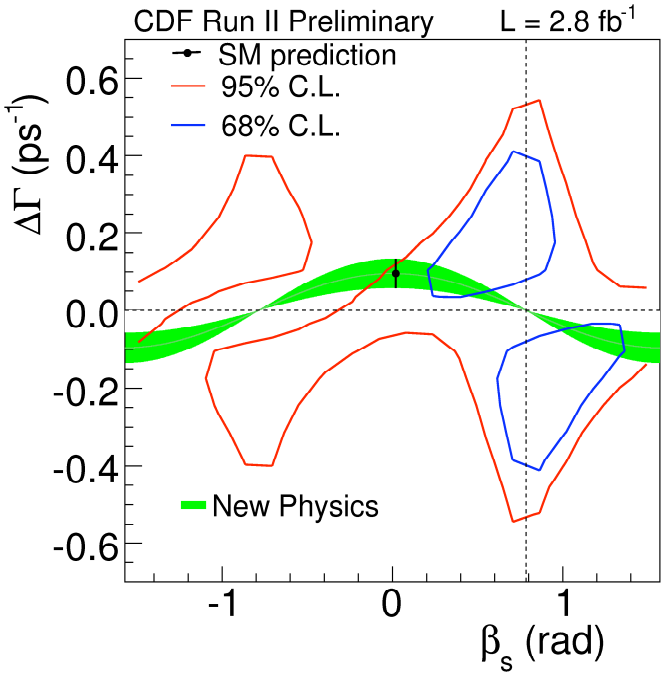
CPV phase Sin $(2\beta_s)$



$$B_s \to J/\psi\,\varphi$$



First combination of CDF and DØ results without assumptions on strong phases: compatible at 2.2 standard deviations level with SM (p-value 0.031)

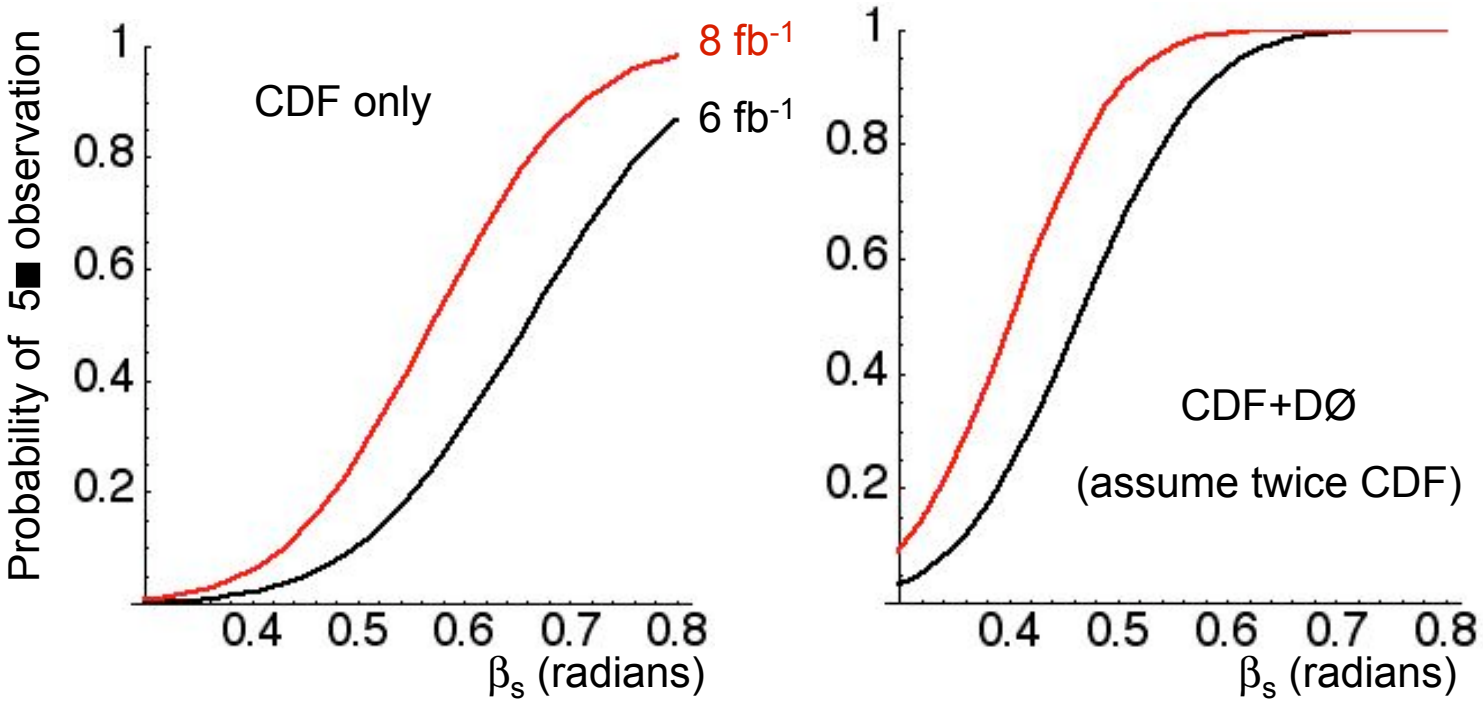


CDF: updated result with 2.8 fb^{-1}
Inconsistency with SM increased (p-value from 0.15 to 0.08, corresponding to 1.8 standard deviations)

More data to come, look also in other channels (asymmetry in semileptonic decays)

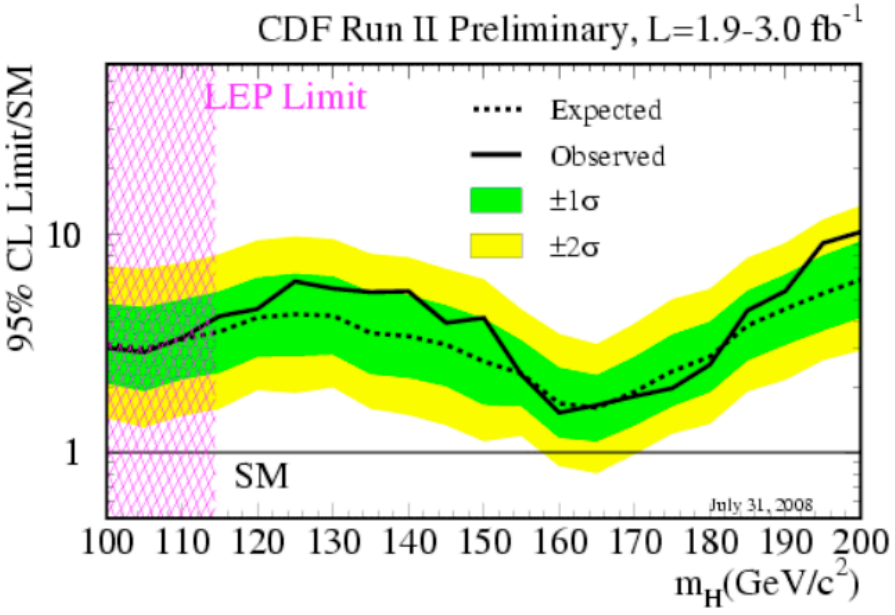
Possibilities

- **Could have a 5-sigma effect on CP-violation**

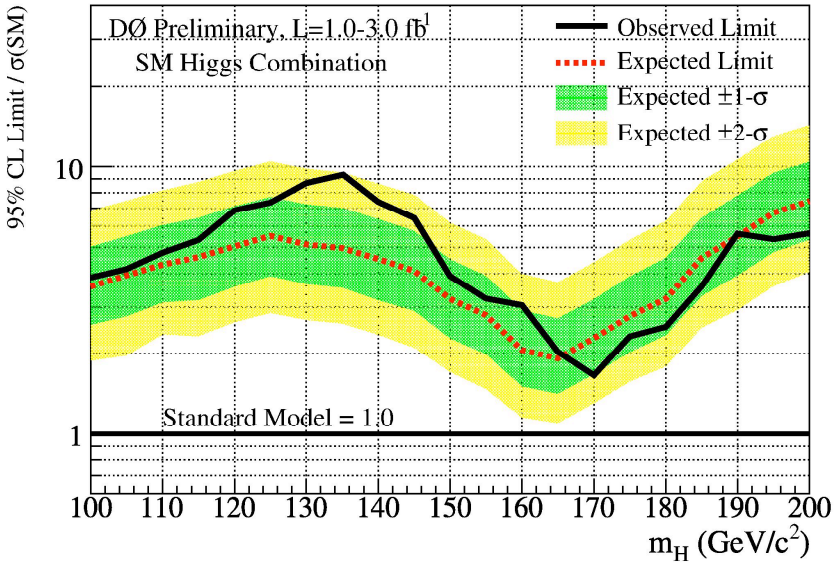


Quick Higgs Update

- For ICHEP08
- Updated all of our channels with many improvements (Lum: 1.9-3.0 fb-1)



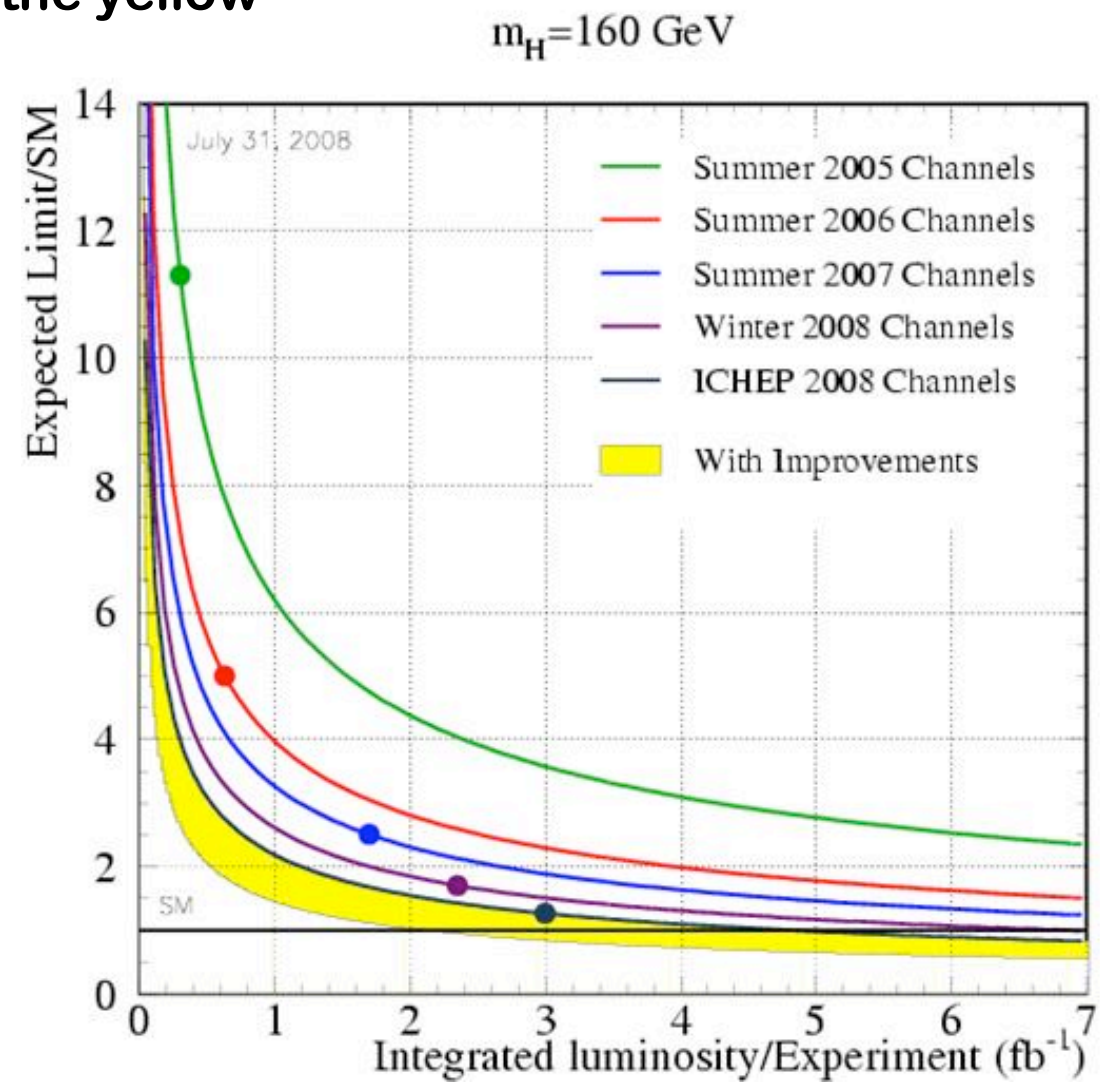
CDF



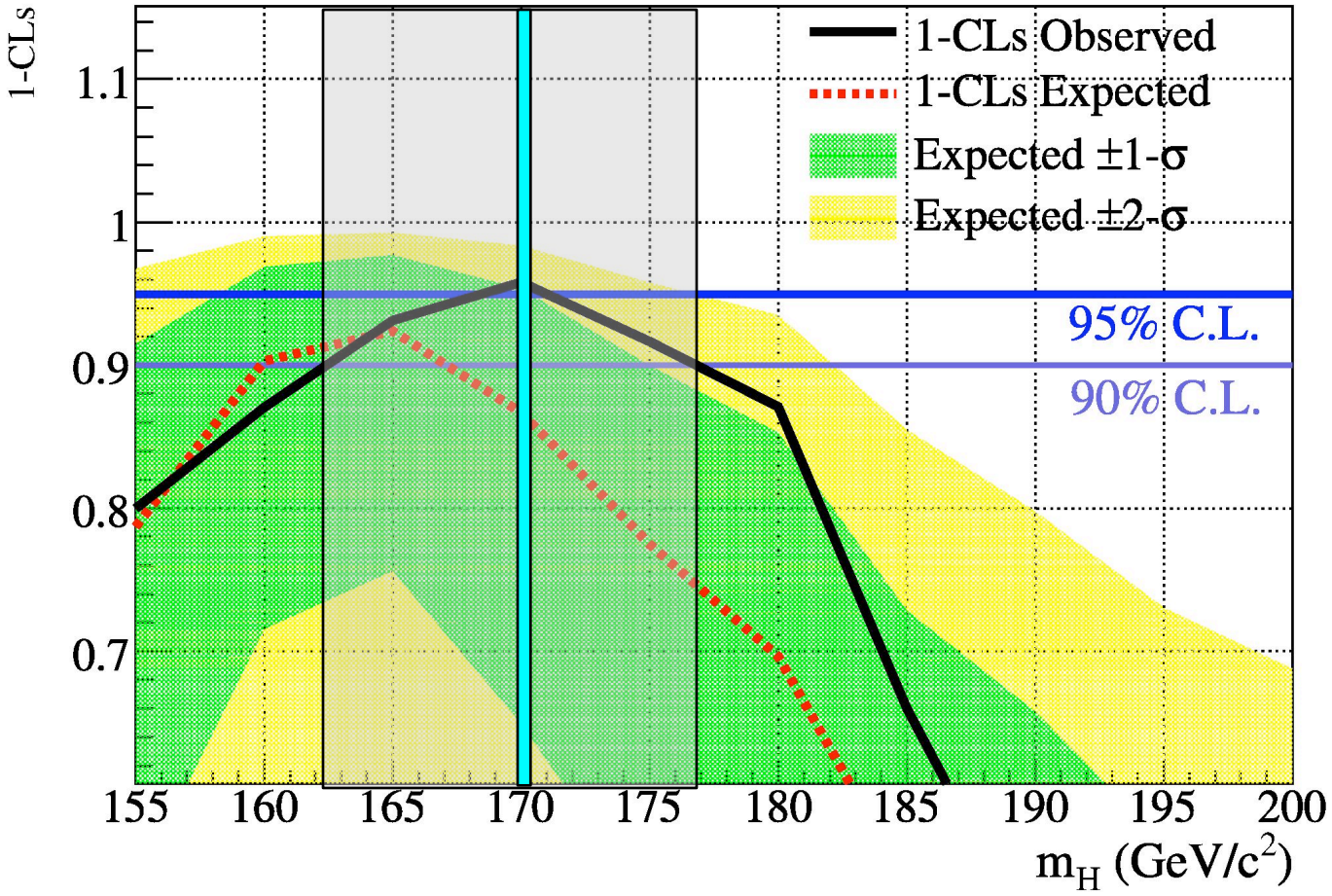
D0

Higgs reach status

- Continued and fast-paced progress !
- Diving into the yellow

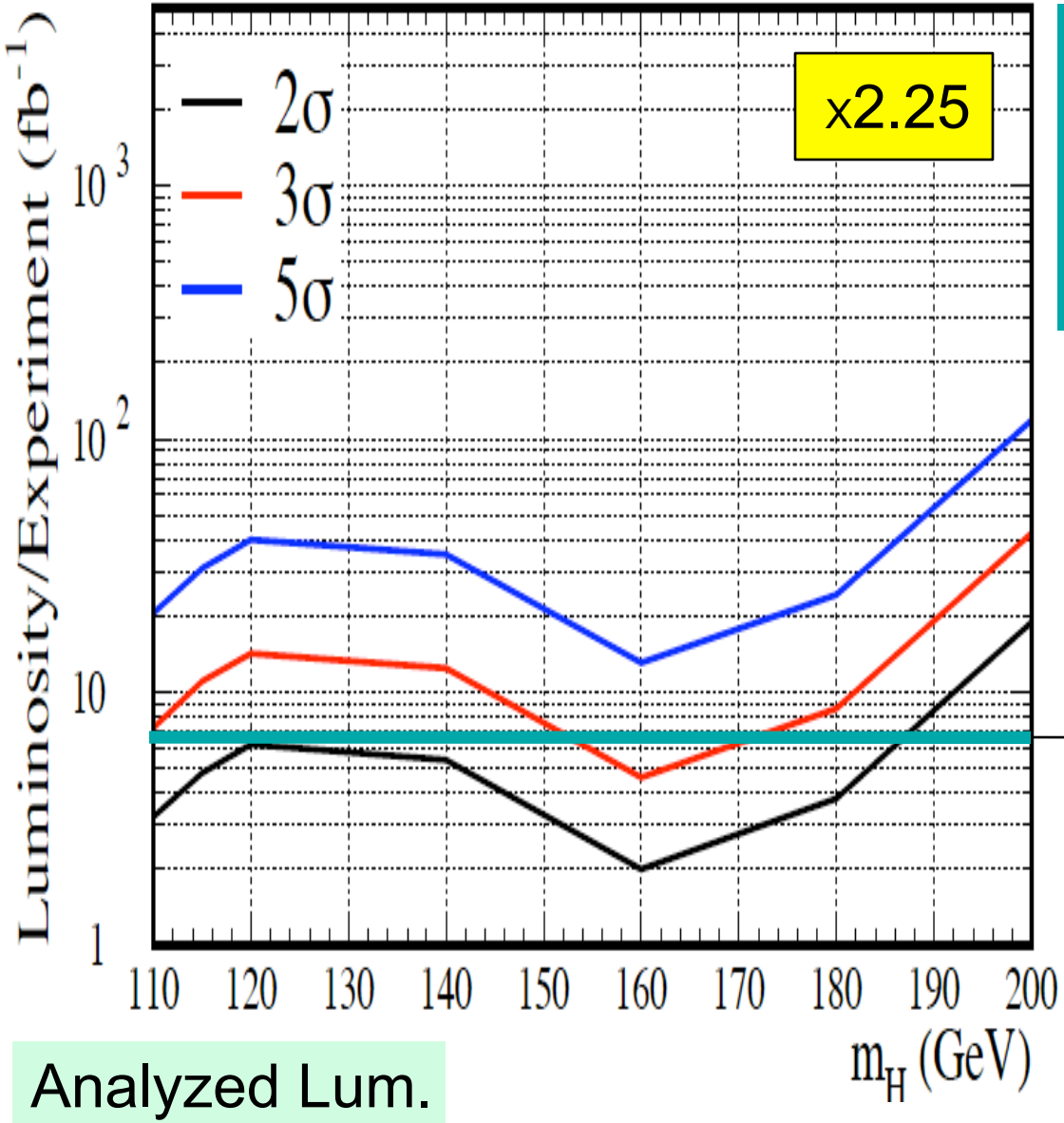


First Higgs Exclusion @ Tevatron !



- One mass, 170 GeV, excluded @ 95% CL
- A 15 GeV window [162:177] excluded @ 90% CL

Higgs reach - achievable -



With 7 fb^{-1}

- exclude all masses !!! [except real mass]
- 3-sigma sensitivity 150:170 LHC's sweet spot

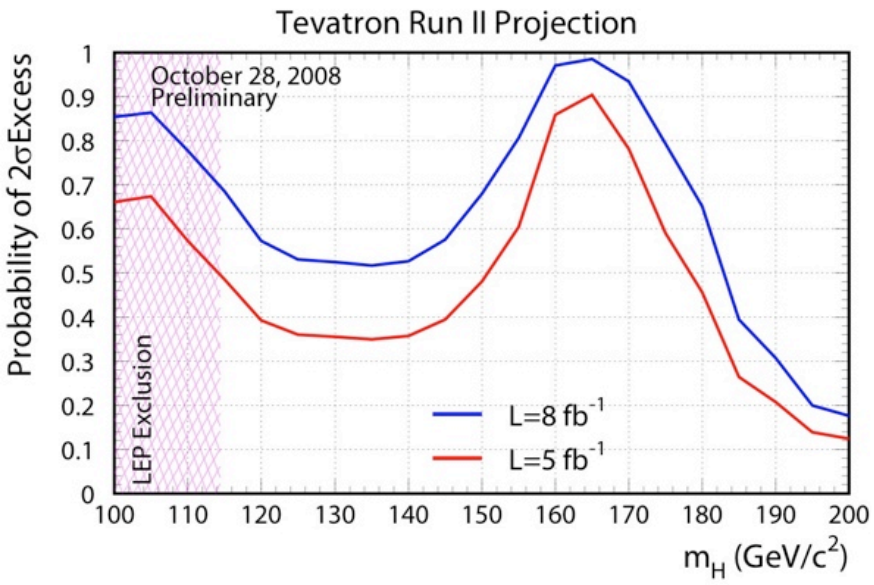
7.0

This is very compelling

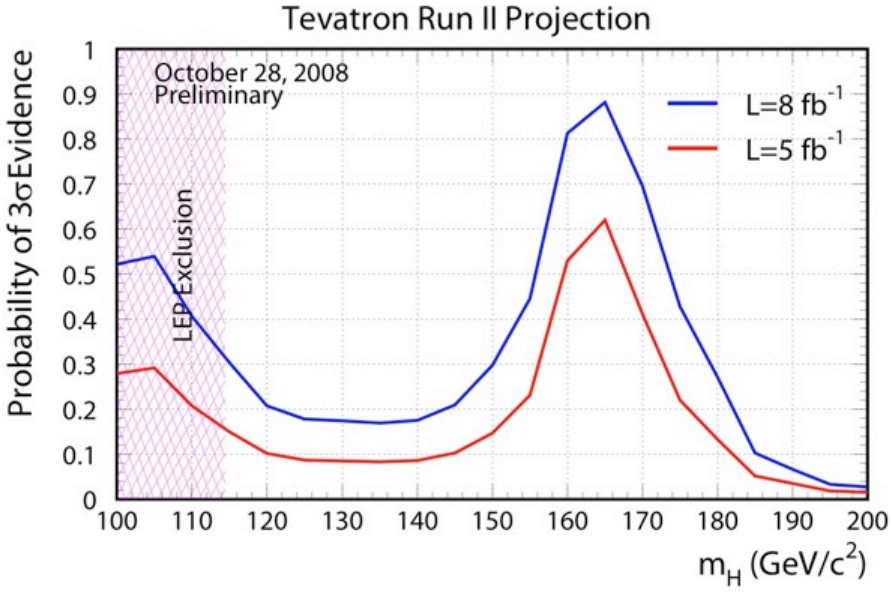
Analyzed Lum.

In terms of probability

- **Significant increase in 2-3 sigma sensitivity with more and more luminosity**



2-sigma



3-sigma

Physics Challenges

- **Operational goals**
  - Publish the 3 fb^{-1} analyses - ongoing !
  - Towards 4 fb^{-1} for upcoming Winter conferences
  - Analyze ~5 fb^{-1} for Summer'09 !
    - This will be a major milestone

- **Program goals**
  - Extract as much juice from the data as possible
    - Precision, new measurements, new processes, New Physics
  - Each Physics Group revisiting their program
    - What should go on with increasing lum
    - What should wrap up
    - Easy access to tools
  - Higgs reach as benchmark

- **Need to make sure teams are in place for key analyses**

Running in 2010

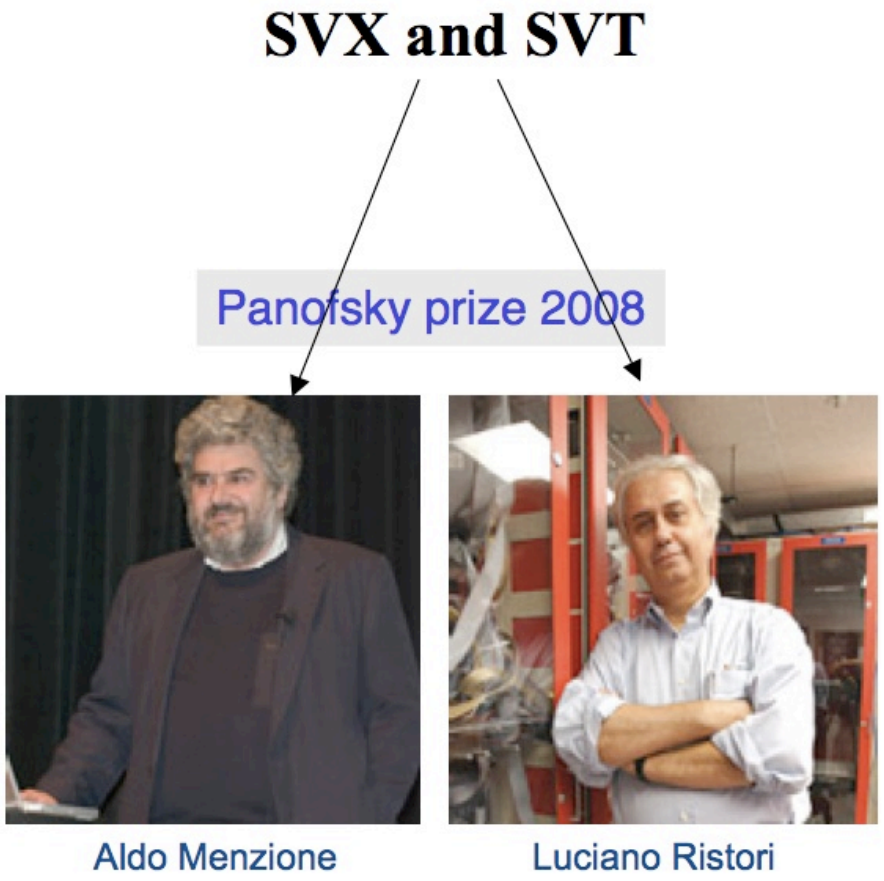
- We put together a very good case at the end and it had a lot of traction with the Lab, with the DOE and with the HEP community
- The lab is planning to run in 2010 if the budget allows
- We are proceeding, in everything we do, as if we are running in 2010

2009 Panofsky Prize

- *"For their leading role in the establishment and use of precision silicon tracking detectors at hadron colliders, enabling broad advances in knowledge of the top quark, b-hadrons, and charm-hadrons."*

- **This was of course a true international collaborative effort**

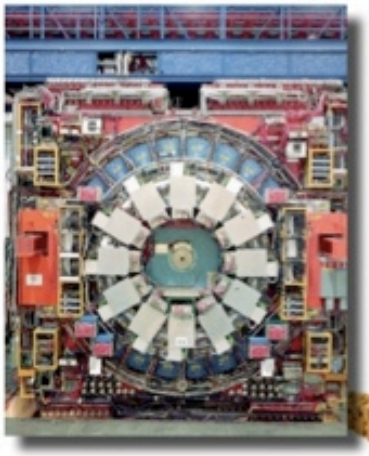
- **A great honor for CDF**



Summary

- CDF and the Tevatron are running very well
- We should be able to go into 2010 smoothly
- Need to make sure [key] people remain engaged

- The physics program is rich and compelling
- Need to finish flagship/legacy analyses
- Need to reach full sensitivity for Higgs search
- Combining a slew of results with D-zero
- Need to follow every hint of new physics



Meanwhile…

Thanks for your continued commitment and support of CDF

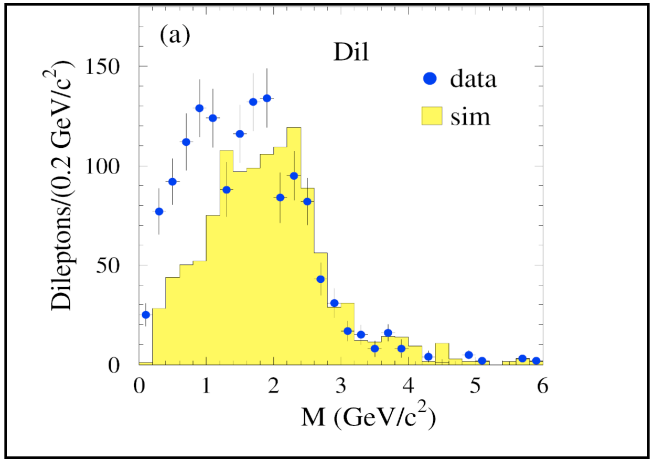
Multimuon Analyses

Motivated by three long-standing discrepancies dating back to Tevatron Run I:

1. $\sigma(pp \rightarrow bbX)$ larger than expected from NLO QCD
2. Time-integrated mixing measured at Tevatron larger than LEP average

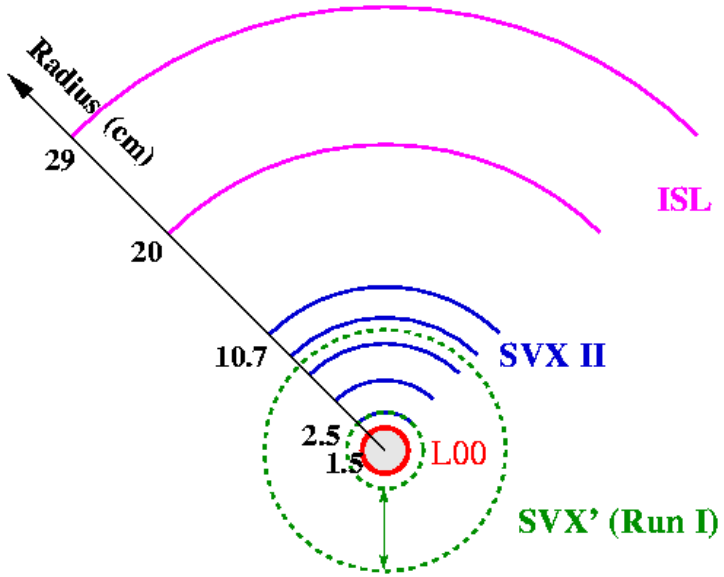
$$\bar{\chi} = \frac{\Gamma\left(B^0 \rightarrow \bar{B}^0 \rightarrow l^+ X\right)}{\Gamma\left(B \rightarrow l^{\pm} X\right)} = \frac{\text{"same sign"}}{\text{"total"}}, \quad B^0 = B_d^0 \text{ or } B_s^0$$

3. Low mass dilepton spectrum inconsistent with expectations from heavy flavor.

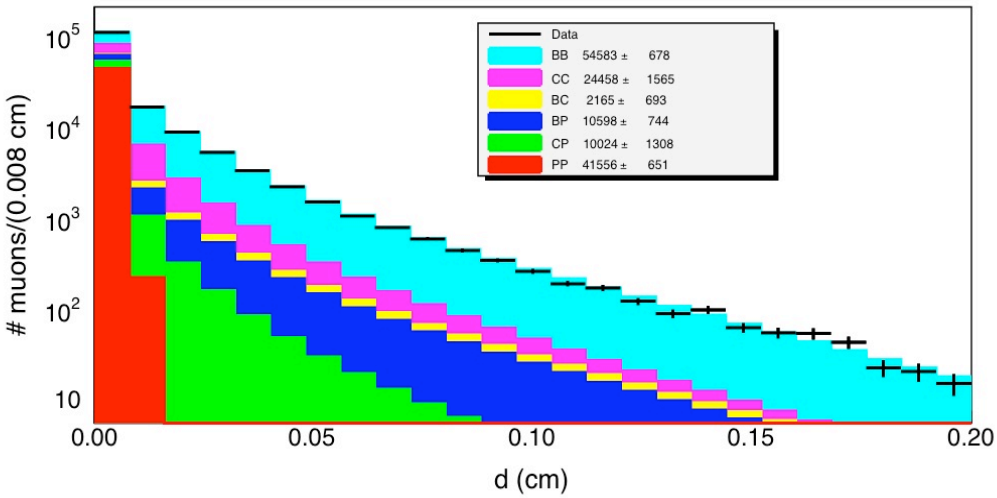


First, re-measure $\sigma(pp \to b\bar{b}X)$

- PRD 77, 072004 (2008)
- Strategy
  - Select dimuon events enriched in $b \to \mu$, $\bar{b} \to \mu$
  - Require our highest tracking precision to separate out prompt and charm backgrounds.
  - Fit muon impact parameters to separate contributions
- Sample
  - Well modeled by simulation
  - High purity: ~40% $b\bar{b}$
- Result
  - Measurement accuracy 9%
  - Good agreement with theory
  - Sample composition understood

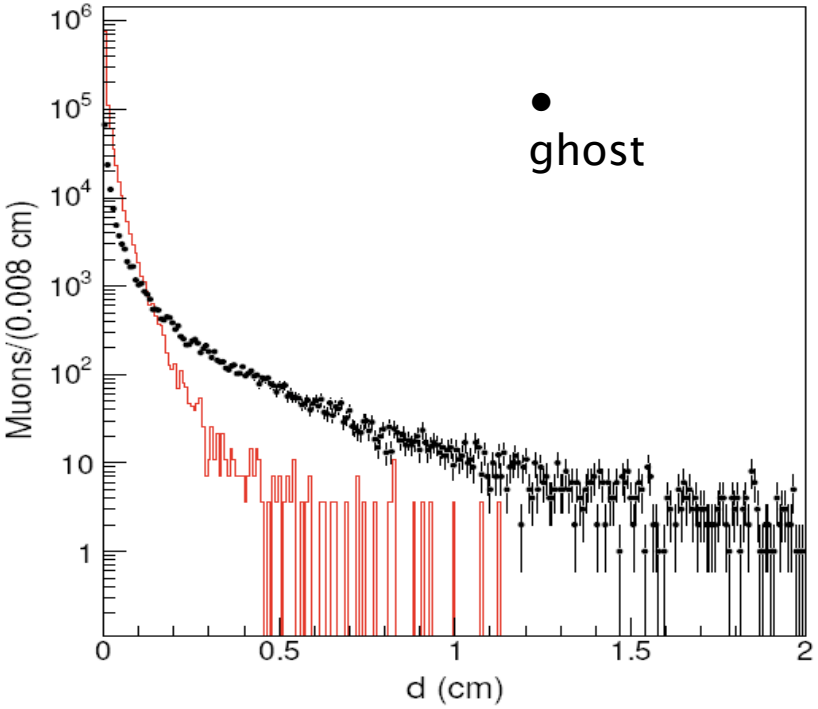


Require muons have hits on innermost silicon layers (R=1.5cm)



Next, investigate sample further

- Tight silicon cuts [inner layer hits] on muons reject more events than expected
  - extra events referred to as “ghosts”
  - ghosts have large impact parameter tails
  - origin outside the beampipe
- QCD sources (including heavy flavor) of dimuons have d_0<0.5cm



Ghost characteristics & sources

- The rate of muons in the ghost sample is four times higher than the expectation (~10% in ghosts) - persists with tighter muon selection
- Extra muons also have long impact parameter tails
- Factor of two more tracks than expected near muons
- Correlations between properties of cones around each primary muon

Several known sources have been evaluated:

- Hadrons faking muons
- decay-in-flight of $K^{\pm}$, $\pi^{\pm}$, K_S, Λ, etc.
- Interactions in detector material
- Heavy Flavor

- At this point, these sources do not seem to explain the entire sample.
  - We are in a region of parameter space that is very challenging and largely unexplored
  -

CDF's statement on analysis

- We state we do not fully understand the source
- We have not ruled out that what we see comes from instrumental effects or not-understood background
- We are not making a new physics claim
- Regardless of the source these events have not been quantified before and offer a plausible explanation for the discrepancies listed above
- We reached a plateau in our understanding and decided to publish a responsible paper that presents just that. Still:
  - The analysis is technically complex and in a region of detector phase-space that we had not tackled before
  - Not everyone followed the discussions
  - The paper is not conclusive
- Due to these last three points, about 1/3 of the collaboration opted not to be listed as authors