CERN Theory Institute
“From the LHC to Future Colliders”, Feb 9-27, 2009

Recent Results and Prospects from the Tevatron

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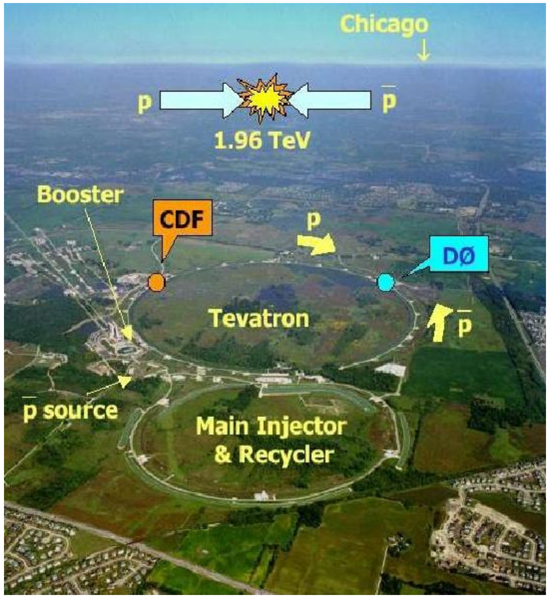
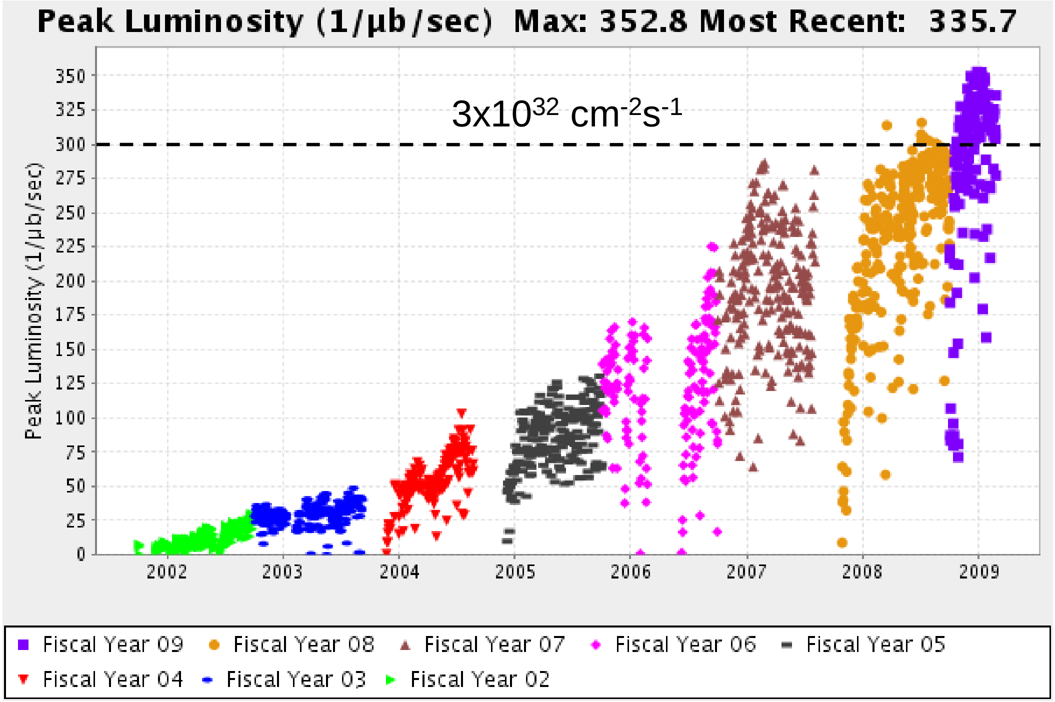
For the CDF and DØ Collaborations

Tevatron Accelerator

	1992-1996	2001-2006	2006-?
	Run I	Run IIa	**Run IIb**
Bunches in Turn	6 × 6	36 × 36	**36 × 36**
√s (TeV)	1.8	1.96	**1.96**
Typical L ($cm^{-2}s^{-1}$)	1.6×10^{30}	1×10^{32}	**2.8×10^{32}**
∫ Ldt (pb^{-1}/week)	3	15-20	**50-60**
Bunch crossing (ns)	3500	396	**396**
Interactions/crossing	2.5	2.5	**7.0**





Current status:

- Typical instantaneous luminosity: $>3.0 \times 10^{32}$ $cm^{-2}s^{-1}$
  Record inst. lum.: 3.6×10^{32} $cm^{-2}s^{-1}$
- Integrated lum./week: ~60-70 pb^{-1}
  ➔ equiv. Run I dataset in 2 weeks

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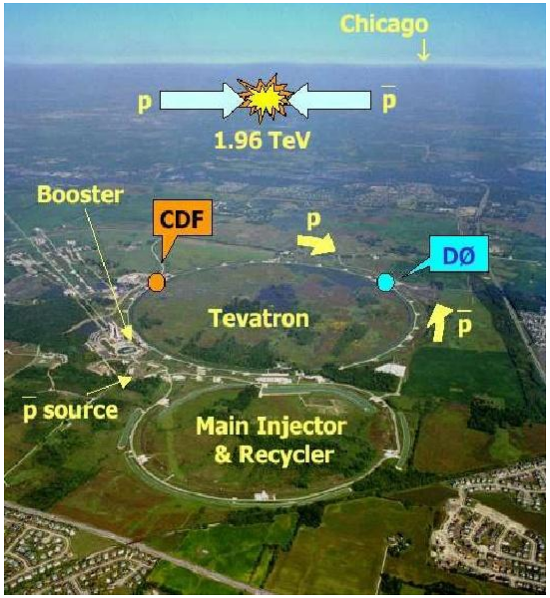

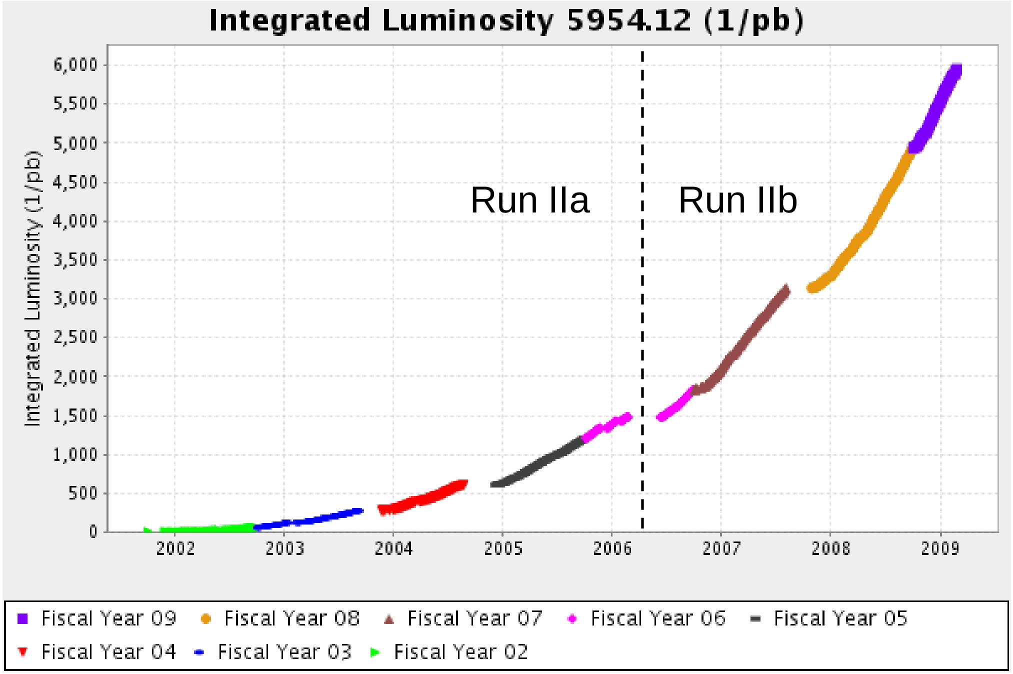

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- Delivered ~6 fb^{-1}

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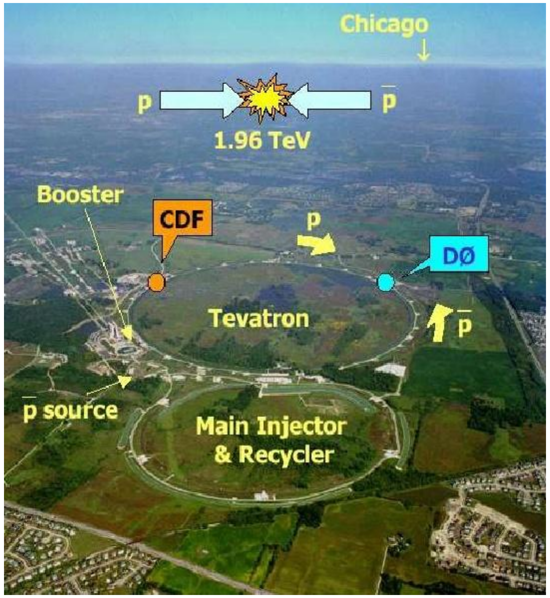

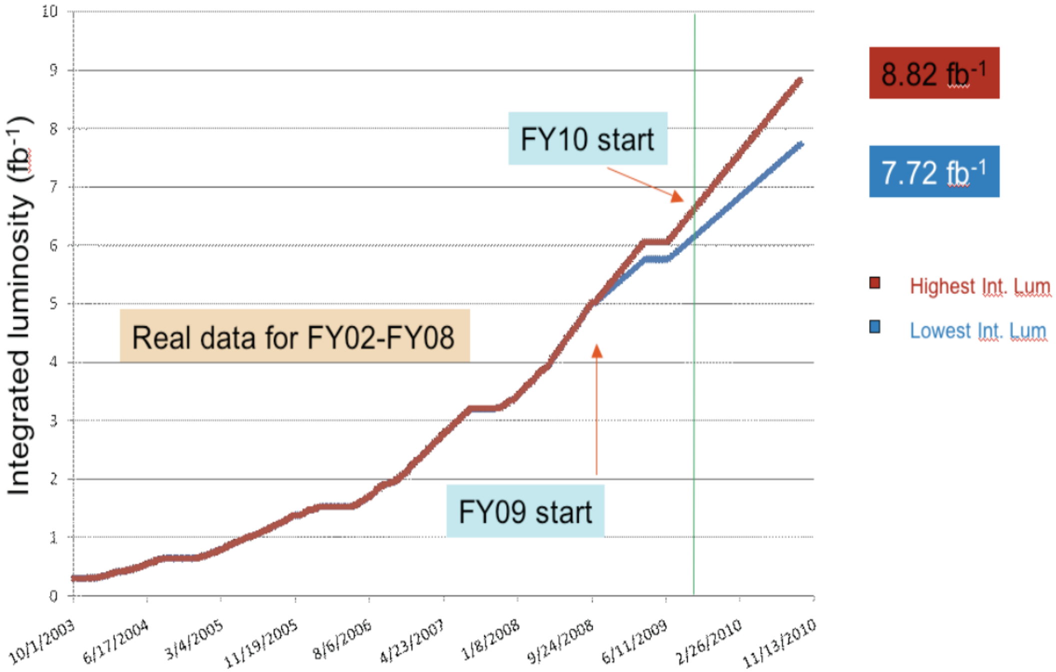

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- Shutdown: Jun 15 - Aug 23, 2009
- Planning to run in 2010.
- Project ~7.7-8.8 fb^{-1} by end of FY10…

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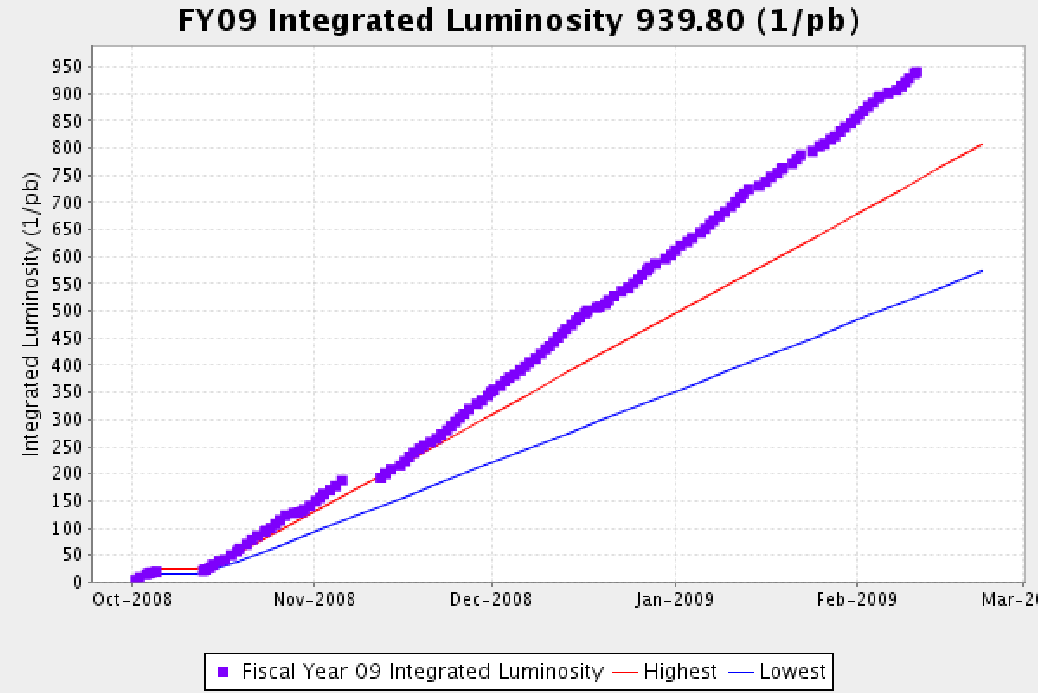

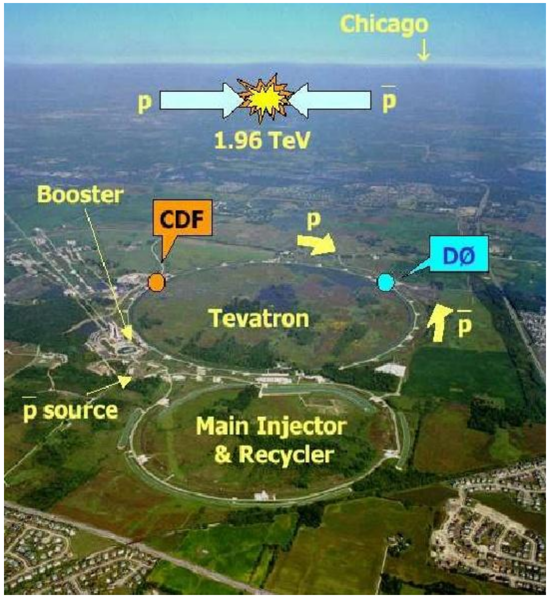

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  …but in end of FY08 and beginning of FY09 better slope than “Highest Lum” projection!

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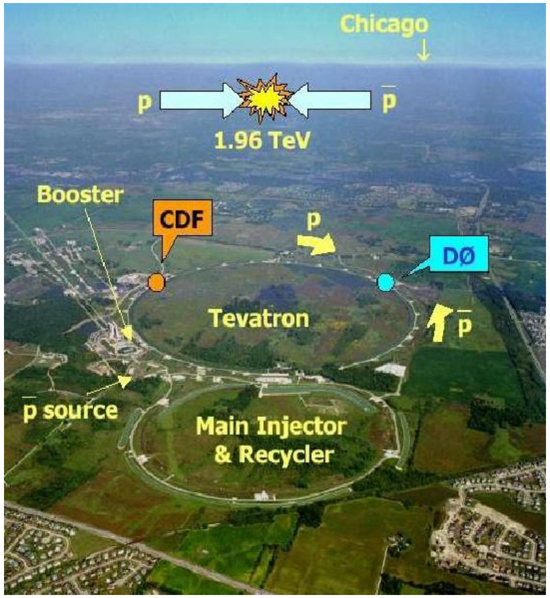
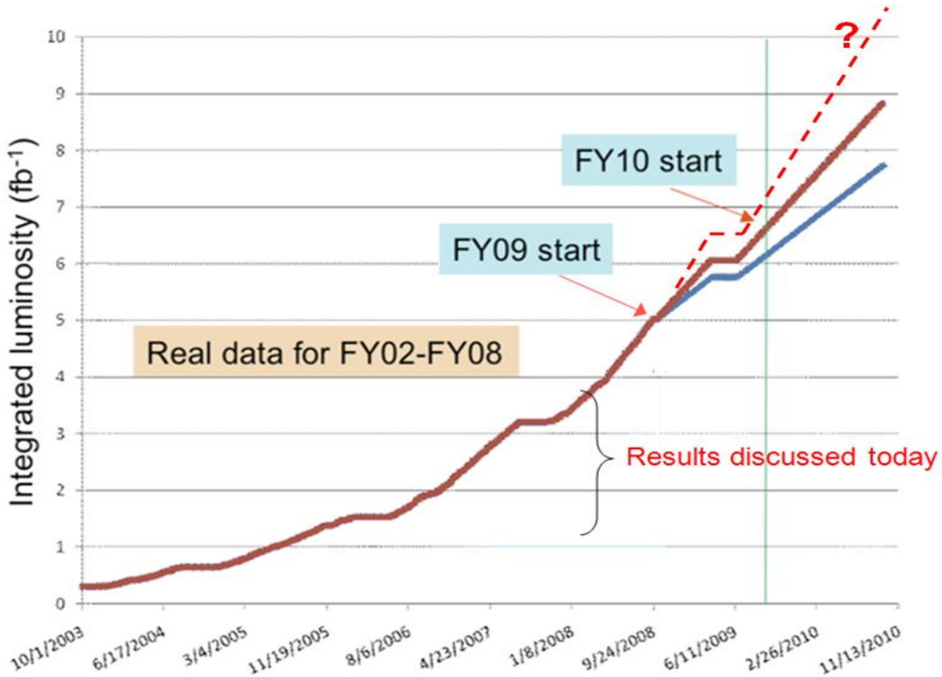
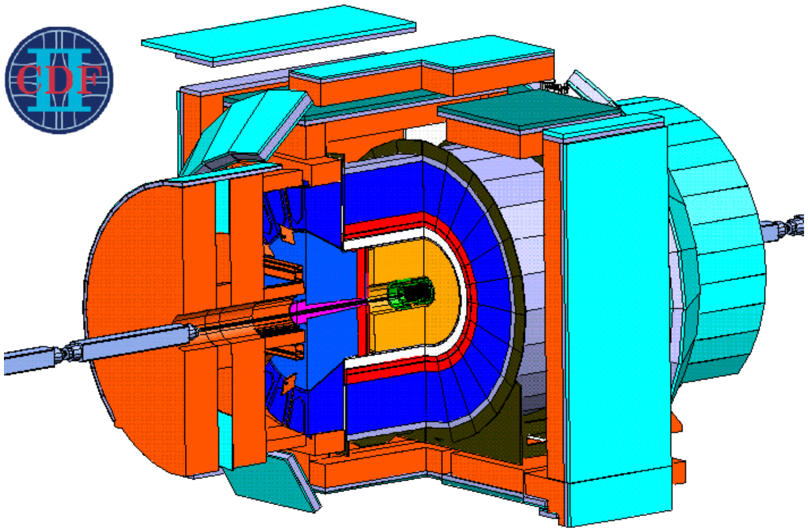




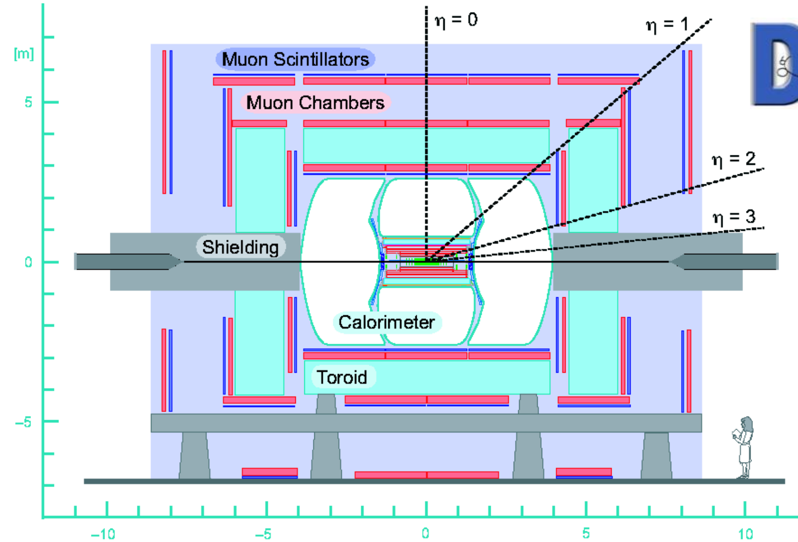
Plans:

- Shutdown: Jun 15 - Aug 23, 2009
- Planning to run in 2010.
- Recently started discussions on 2011 running.
- My personal expectation:
  - By LP2009: ~7.0 fb^{-1} deliv.
    ➔ results with ≥5 fb^{-1}
  - By end of FY10: ~10 fb^{-1} deliv.
  - By end of FY11: ~13 fb^{-1} deliv.
    ➔ results with ~10 fb^{-1}

CDF and DØ Detectors



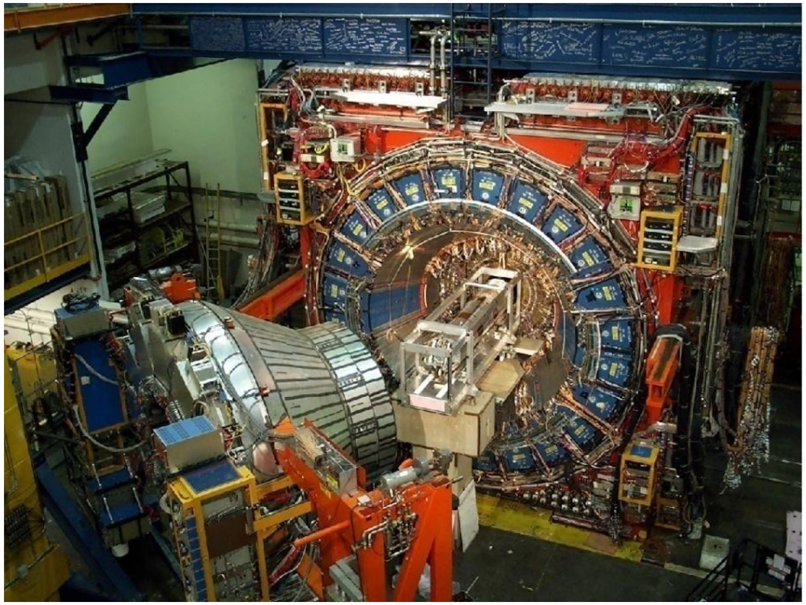
63 institutions (15 countries)
589 physicists

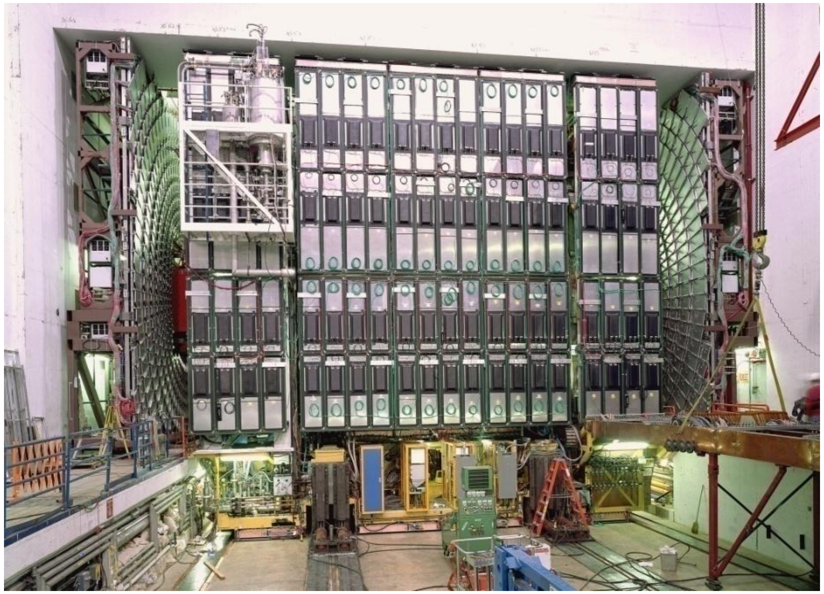


90 institutions (18 countries)
554 physicists

- Multipurpose detectors:
  - Central tracking system embedded in a solenoidal magnetic field:
    - Silicon vertex detector
    - Tracking chamber(CDF)/fiber tracker(DØ)
  - Preshowers
  - Electromagnetic and hadronic calorimeters
  - Muon system

CDF and DØ Detectors





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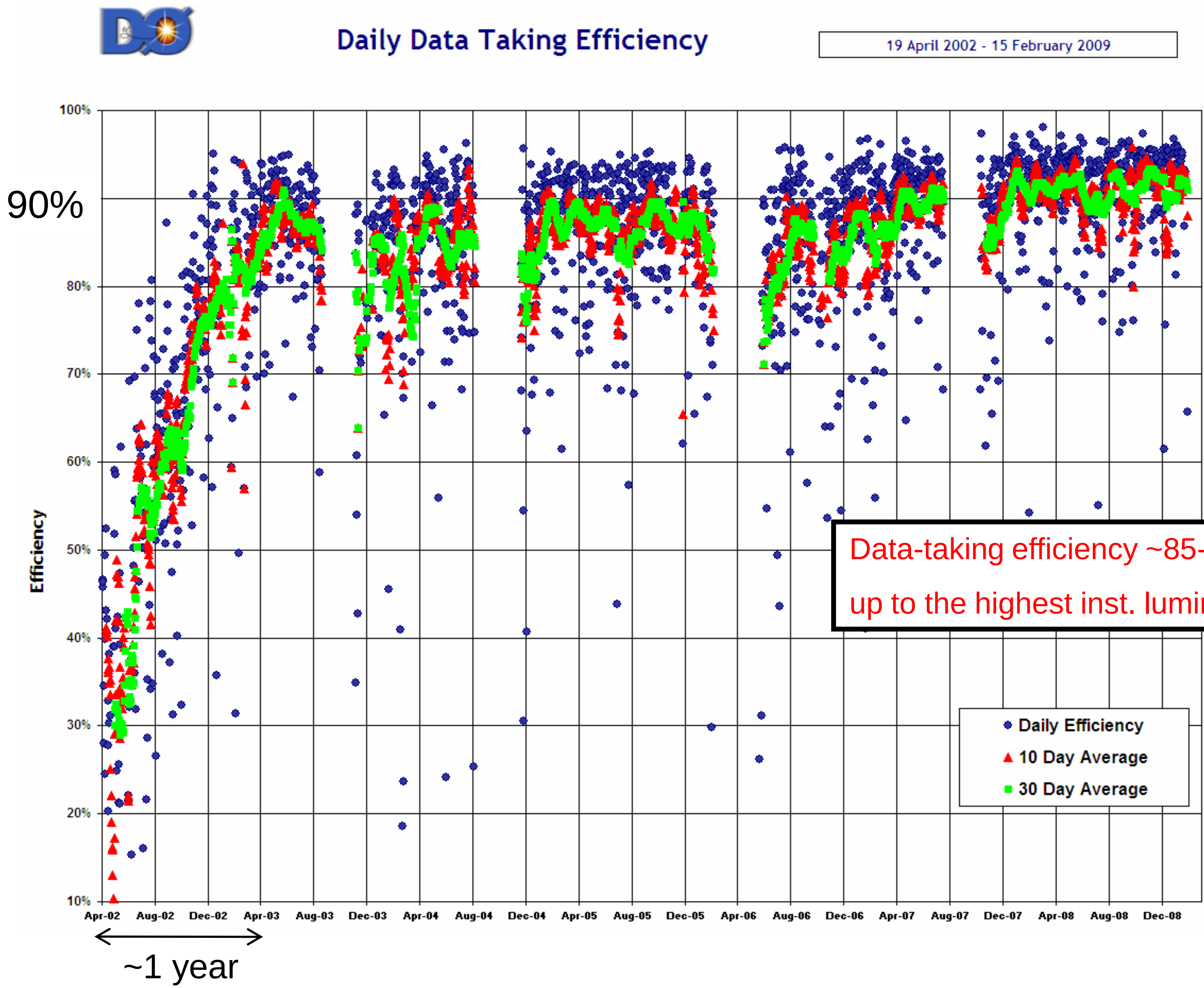
Executive summary:

- All detector subsystems expected to survive till the end of the run.
- No further upgrades, stable triggers.

CDF and DØ Detectors

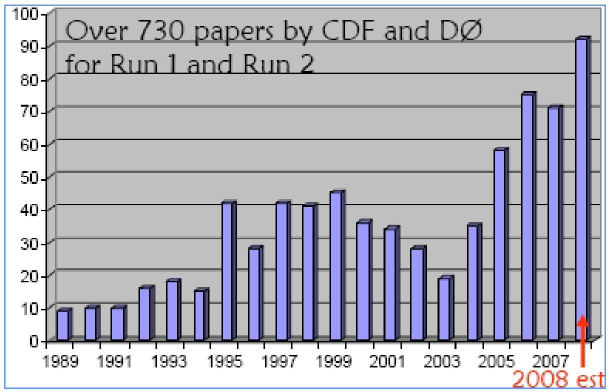


Data-taking efficiency ~85-90%

up to the highest inst. luminosities

Physics Program at the Tevatron

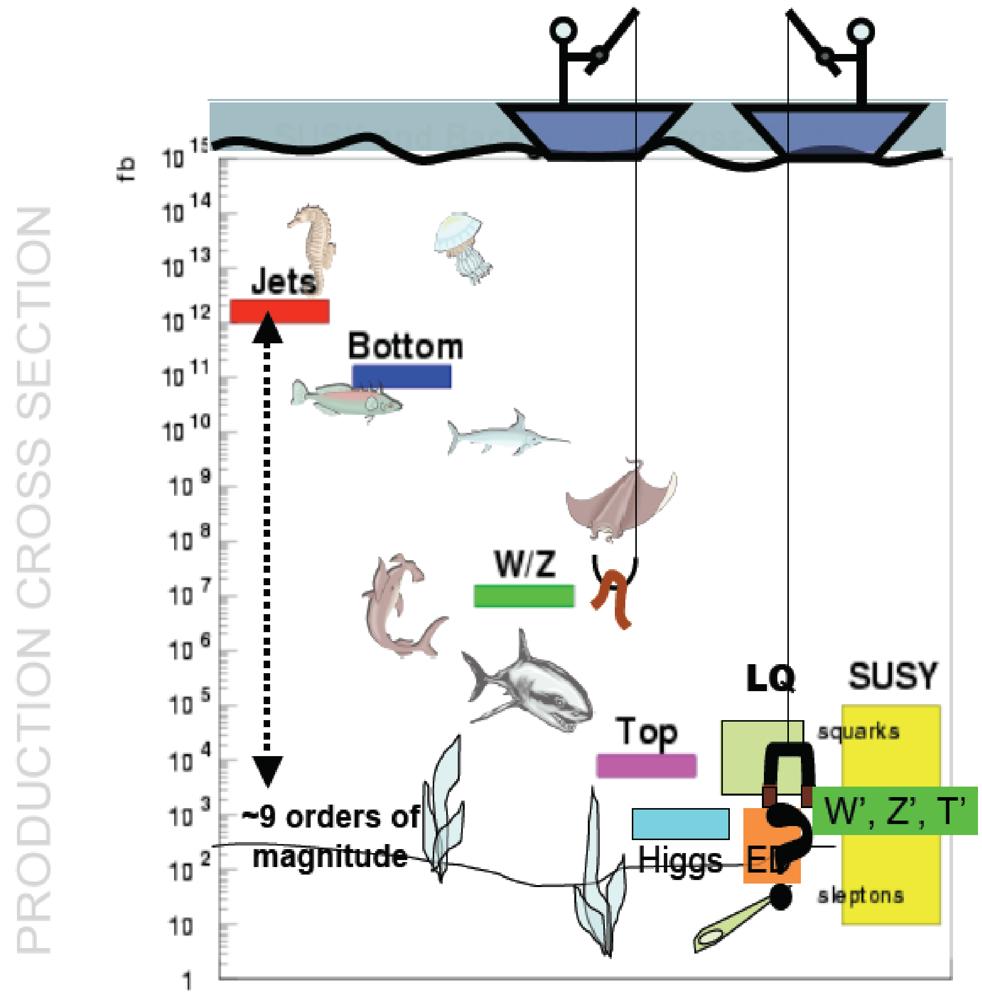
- Broad and deep program being fully exploited.



- Recorded luminosity to date: ~5.3 fb^{-1}

- Physics analyses to date typically use ~1-3 fb^{-1}, so final results with the full dataset will have ~2.5-10 times more statistics.

- This talk will only cover a subset of recent results spanning the whole physics program.

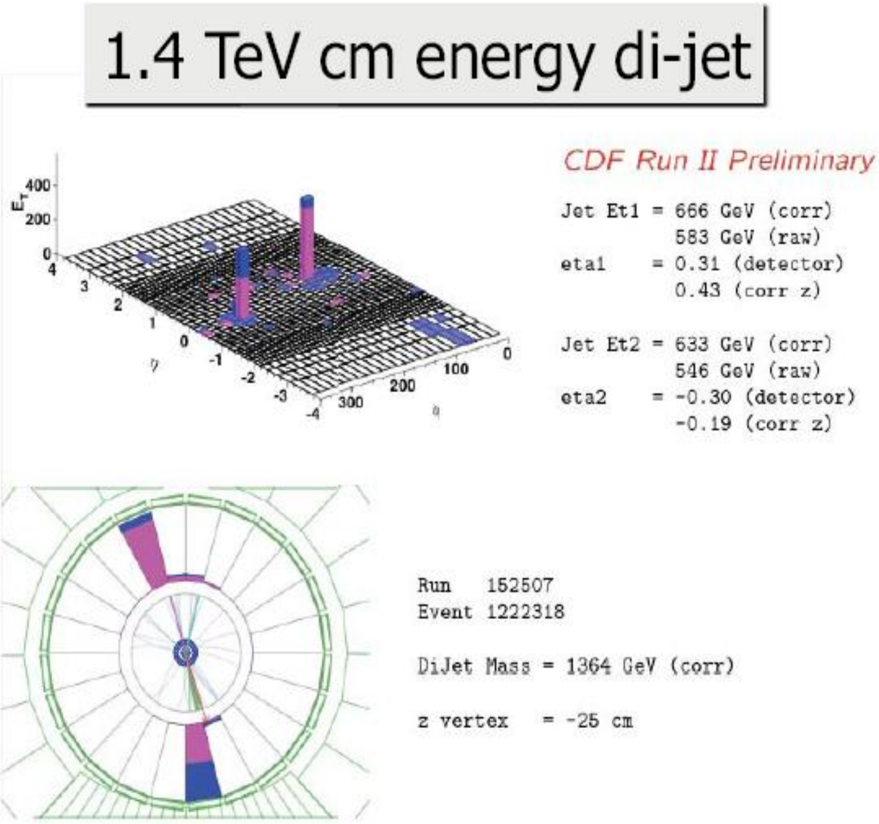


QCD Program

- Physics at a hadron collider (Tevatron, LHC) requires precise understanding of QCD:
  - Hard interactions of 2 partons, PDFs
  - Multi-parton interactions (underlying event)
  - Soft/hard initial/final state radiation
  - Hadronization/fragmentation

Full program of measurements:

- Jet production
  - Inclusive jet p_T, dijet mass, dijet angular distributions,…
  - Vector boson + jets
- Photon production
  - Diphoton
  - Photon + X
- Heavy-flavor production
  - Inclusive
  - Associated with vector bosons
- Underlying event, jet fragmentation
- Diffractive program

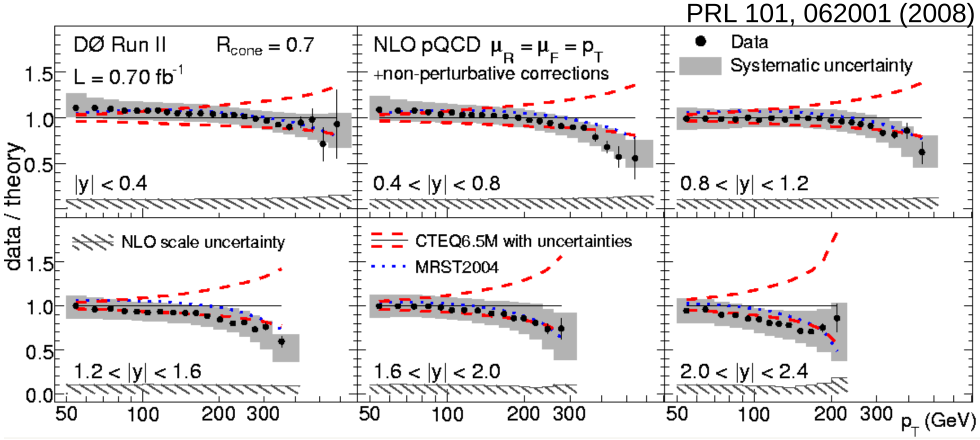


Jet Production

Inclusive jet cross section

- Stringent probe of pQCD over 8 orders of magnitude!
- Forward jets: sensitive probe of gluon PDF at high x.
- Central jets at high p_T: sensitive probe of New Physics.
- After years of work, achieved jet energy calibration ~1-2%.

PRL 101, 062001 (2008)



Significant constraints to the gluon PDF.

Extremely useful input for the LHC.

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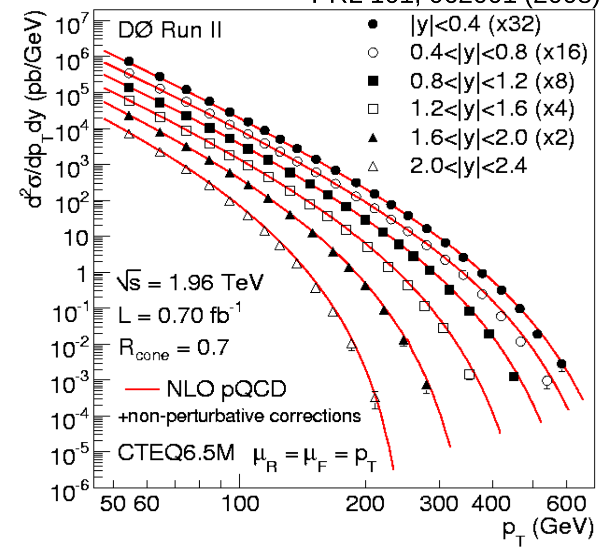
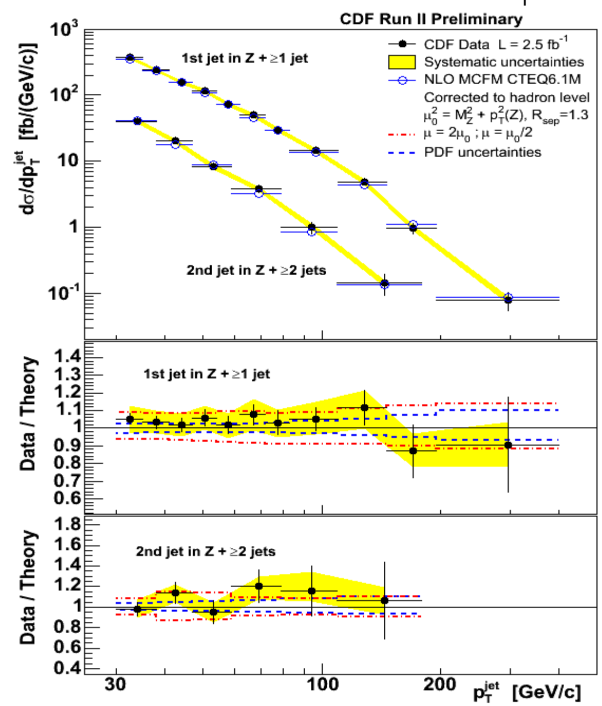


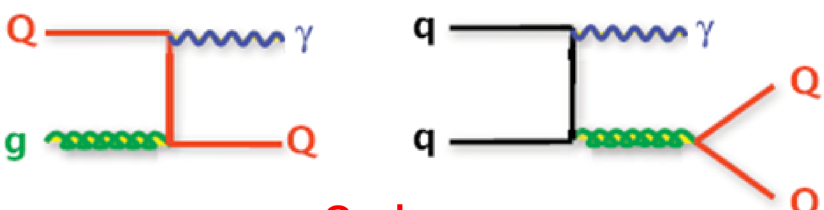
W/Z+jets total/differential cross sections

- Test of pQCD predictions at high momentum transfers.
- Main backgrounds to top, Higgs, New Phenomena searches ⇒ critical to validate theoretical calculations and Monte Carlo event generators.



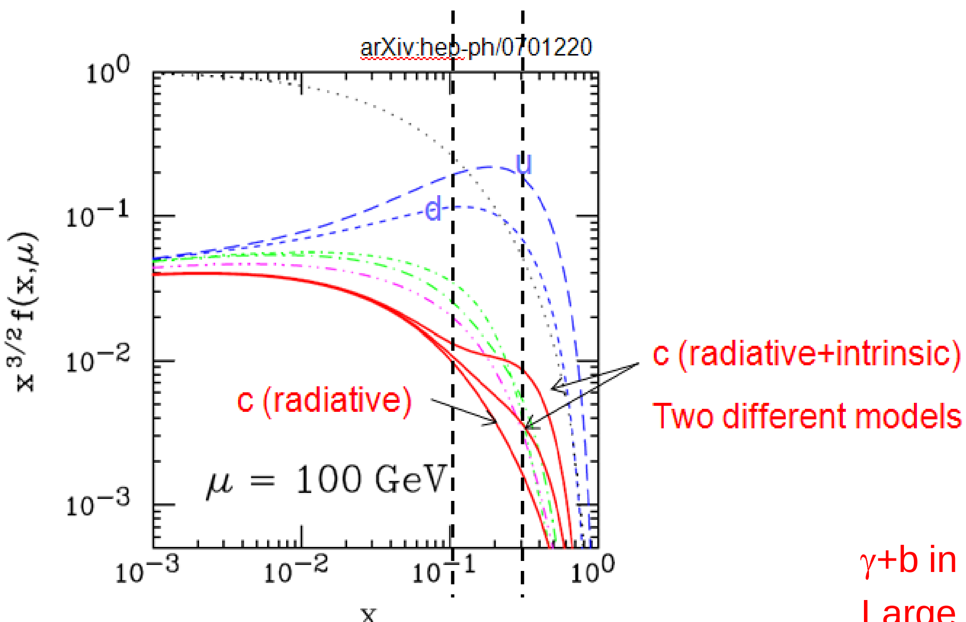
Vector Boson + Heavy Flavor Jets

- Sensitive to production mechanism and the heavy quark content of the proton. Also probes fragmentation into heavy quarks.

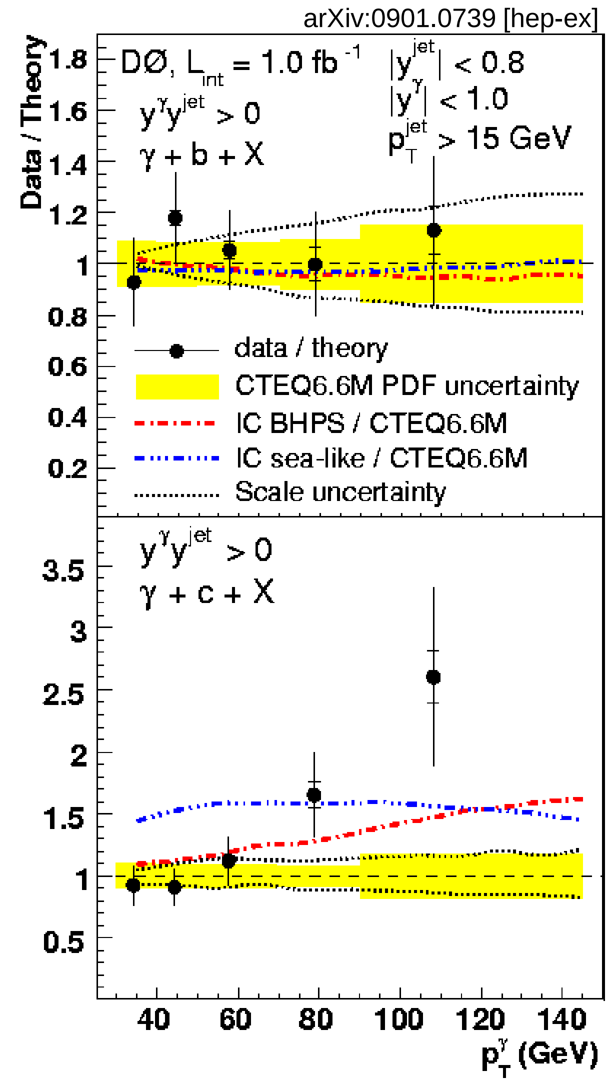


Q = b,c

- Is there an “intrinsic charm” (non-perturbative) component of the proton?



Region probed: $0.1<x<0.3$, $0.9\times10^3<Q^2<2\times10^4$ GeV^2



γ+b in agreement with NLO QCD

Large discrepancy for γ+c at high p_T^{γ}

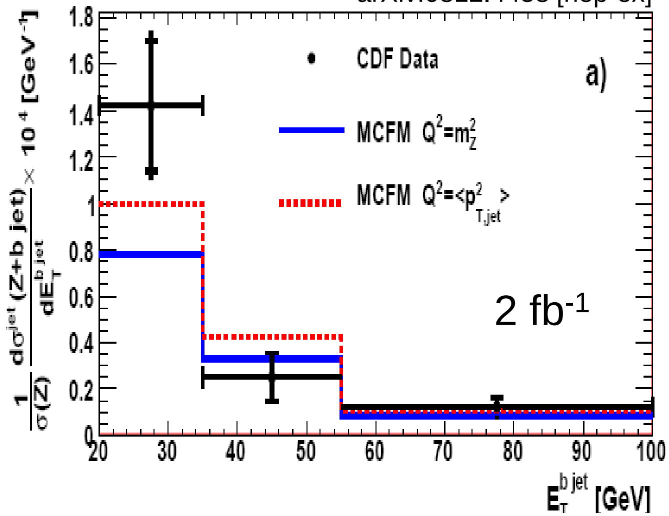
Non-intrinsic charm? Gluon splitting?

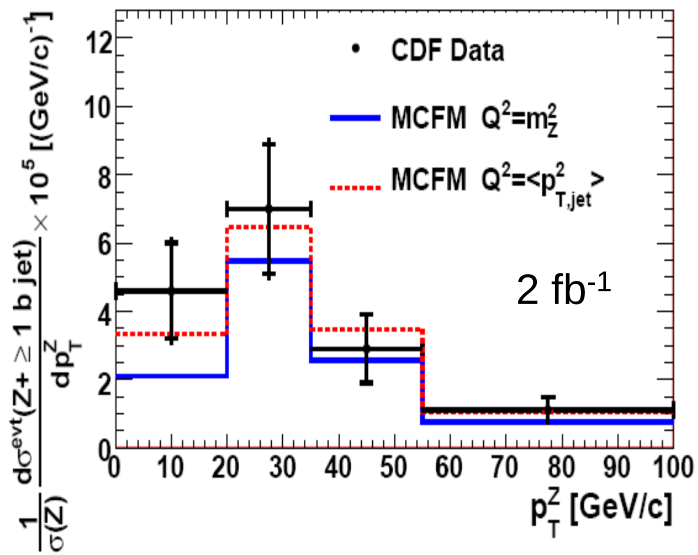
Vector Boson + Heavy Flavor Jets

- Sensitive to production mechanism and the heavy quark content of the proton. Also probes fragmentation into heavy quarks.

- Z+b jets constitute main background for Higgs or sbottom searches.
- First differential distributions (normalized to $\sigma(Z)$).
  - Partial-NLO MCFM prediction shows sizeable scale dependence.
  - Data seems to prefer lower scales.

arXiv:0812.4458 [hep-ex]





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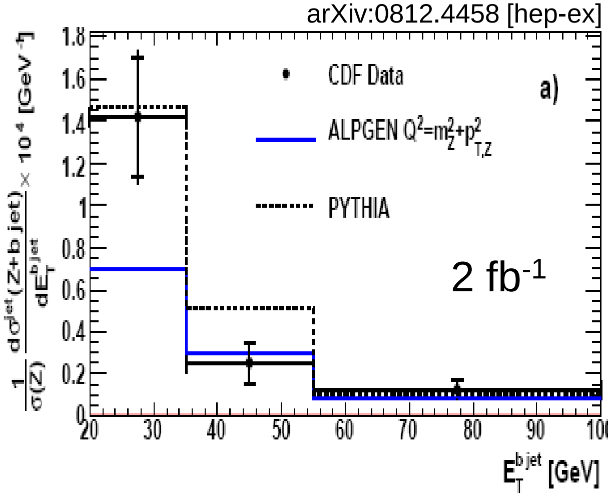


Higher luminosity measurements will allow more stringent tests of theoretical predictions

Heavy Flavor Program

- Large production cross section (~0.1 mb).
- Many b,c species are produced at the Tevatron:

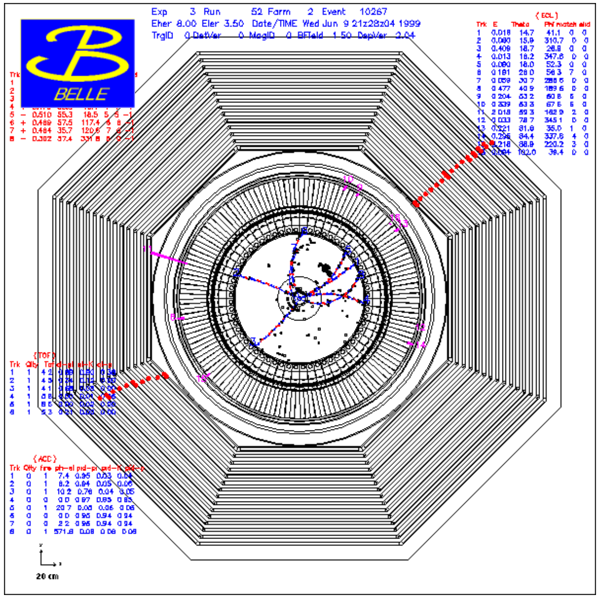
$$\bar{B}^0 = |b\,\bar{d}\rangle,\ B^- = |b\,\bar{u}\rangle \quad \Lambda_b^0 = |b\,d\,u\rangle,\ \Sigma_b^- = |b\,d\,d\rangle$$
$$\bar{B}_S^0 = |b\,\bar{s}\rangle,\ B_c^- = |b\,\bar{c}\rangle \quad \Xi_b^- = |b\,d\,s\rangle \quad \cdots$$

many of which are inaccessible at the B factories.

- Low p_T lepton (CDF+DØ) and displaced track (CDF) triggers allow for rich samples of semileptonic and hadronic decay modes.

- Hadron collider environment challenging but sufficient statistics and detector capabilities allow for an extremely rich program:
  - Precise cross section, mass & lifetime measurements
  - Exclusive decays, branching fractions & rare decays
  - Mixing and CP violation
  - Spectroscopy & decay properties
  - Discovery of new states

"Typical" event display at the B-factories:



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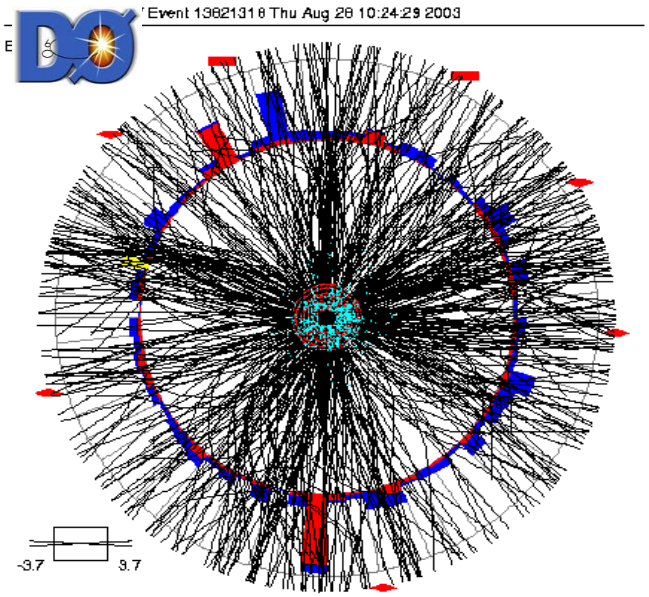
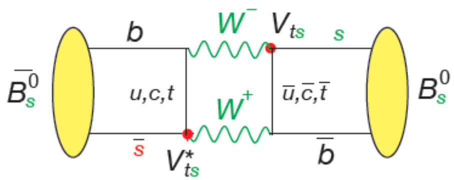


CP Violation in B_s Decays

$B_s^0 - \bar{B}_s^0$ mixing



Weak eigenstates:

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

Mass eigenstates:

$$|B_s^H\rangle = p|B_s^0\rangle + q|\bar{B}_s^0\rangle \quad |B_s^L\rangle = p|B_s^0\rangle - q|\bar{B}_s^0\rangle$$

B_s meson allows to probe the entire matrix:

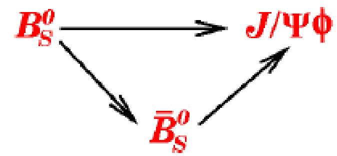
$\Delta m_s = M_H - M_L \sim 2|M_{12}|$ Sensitive to New Physics

$\Delta\Gamma_s^{CP} = \Gamma_{even} - \Gamma_{odd} \sim 2|\Gamma_{12}|$ Not sensitive to New Physics

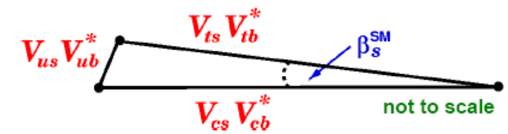
$\Delta\Gamma_s = \Gamma_L - \Gamma_H \sim 2|\Gamma_{12}|\cos\phi_s$ VERY sensitive to New Physics

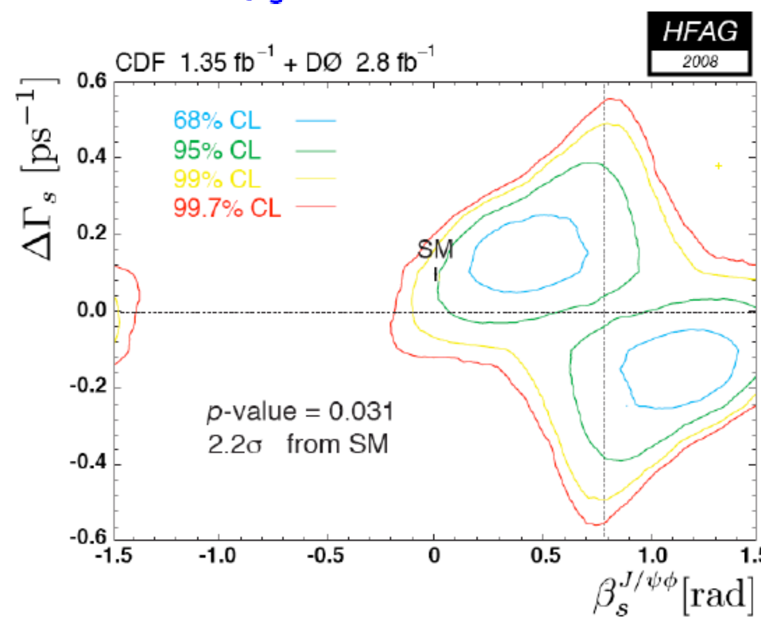
$$\phi_s^{SM} = \arg[-M_{12}/\Gamma_{12}] \rightarrow \underbrace{\phi_s^{SM}}_{\sim 0.004} + \phi_s^{NP}$$

Time-dependent angular analysis in flavor-tagged $B_s \rightarrow J/\psi\phi$ decays:



=> sin $2\beta_s^{SM}$

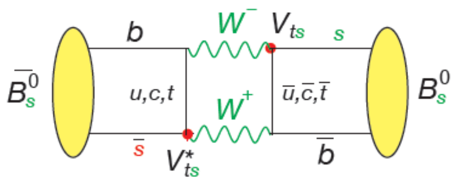




Combination of CDF and DØ measurements w/o assumptions on strong phases yields 2.2σ deviation from the SM (p-value=3.1%).

CP Violation in B_s Decays

$B_s^0 - \bar{B}_s^0$ mixing



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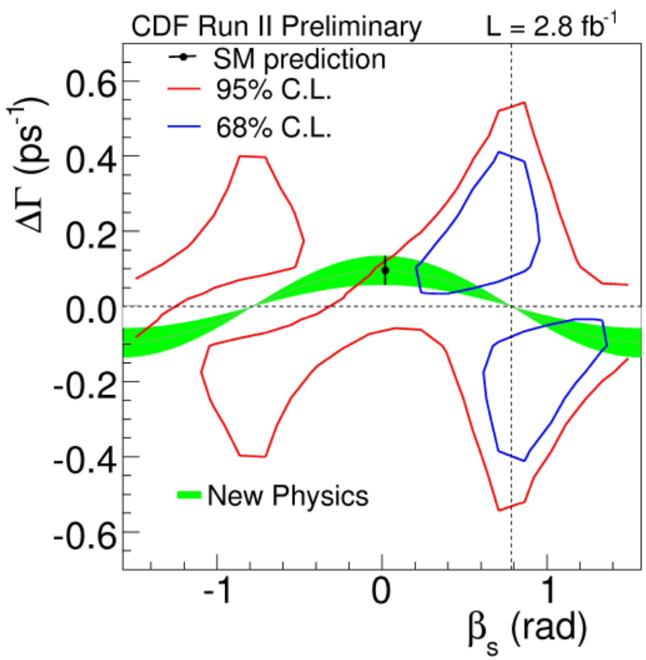
$$\phi_s^{SM} = \arg[-M_{12}/\Gamma_{12}] \rightarrow \underbrace{\phi_s^{SM}}_{\sim 0.004} + \phi_s^{NP}$$

Updated CDF result with 2.8 fb^{-1}: consistency with the SM further decreased (p-value= 0.15 → 0.08).



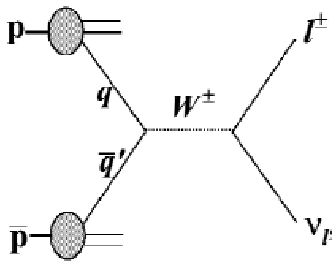
Very exciting prospects in the near future:

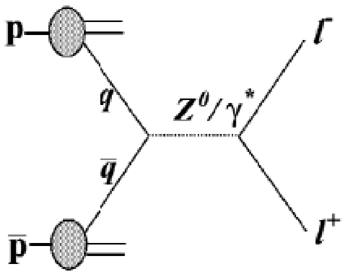
- Updates with 4-5 fb^{-1} by Winter'09 Confs.
- Additional measurements (charge asymmetries) underway.

Electroweak Program

- Single $W(\to l\nu)/Z(\to l^+l^-)$ production occurs at high rate: O(100k-10k)/week!!
- Provide "standard candles": lepton ID/trigger efficiencies vs. time, integrated luminosity verification, electron energy scale, etc.
- Inclusive production cross section in good agreement with theoretical prediction.

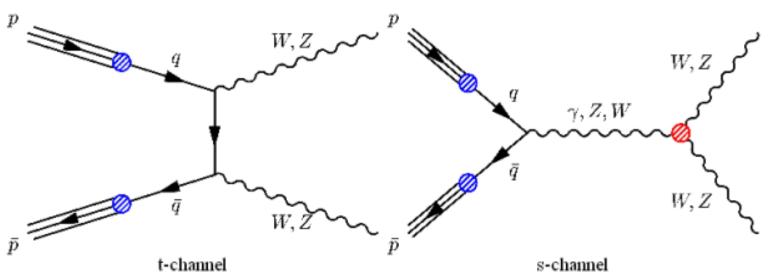
  ➔ could be used to overcome ~6% luminosity uncertainty in many measurements.





Extensive and very competitive program:

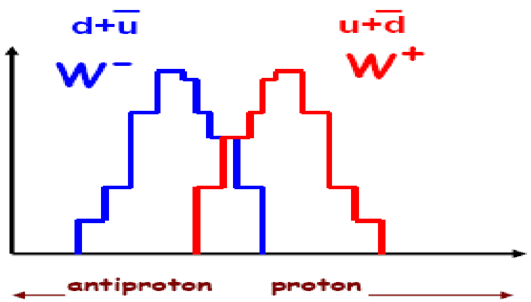
- W/Z production cross sections and differential distributions
- Precision measurements: M_W, Γ_W, $\sin^2\theta_w$,…
- Diboson physics



W/Z Asymmetries

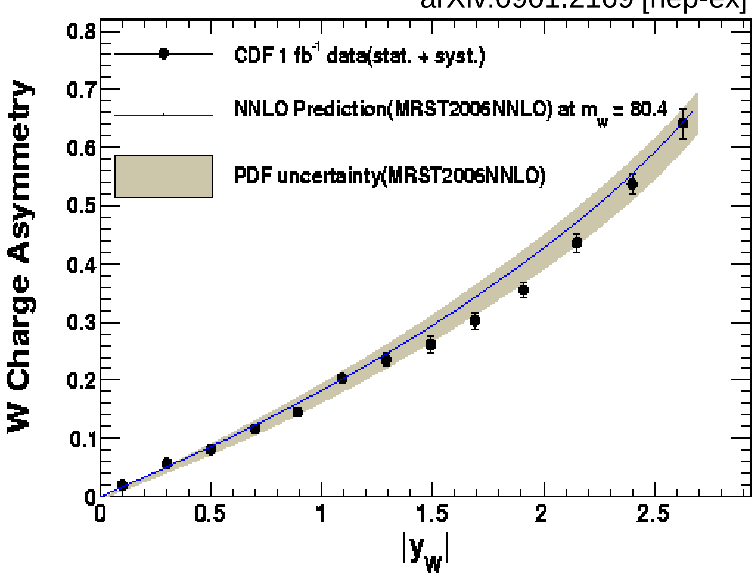
- Differential distributions provide important information on production mechanism.

W charge asymmetry



$$A(y) = \frac{d\sigma(W^+)/dy - d\sigma(W^-)/dy}{d\sigma(W^+)/dy + d\sigma(W^-)/dy}$$

arXiv:0901.2169 [hep-ex]



Significant constraints on PDFs!

Forward-backward asymmetry in $Z/\gamma^* \to e^+e^-$

- Measurement of A_{FB} as a function of M_{ee}.
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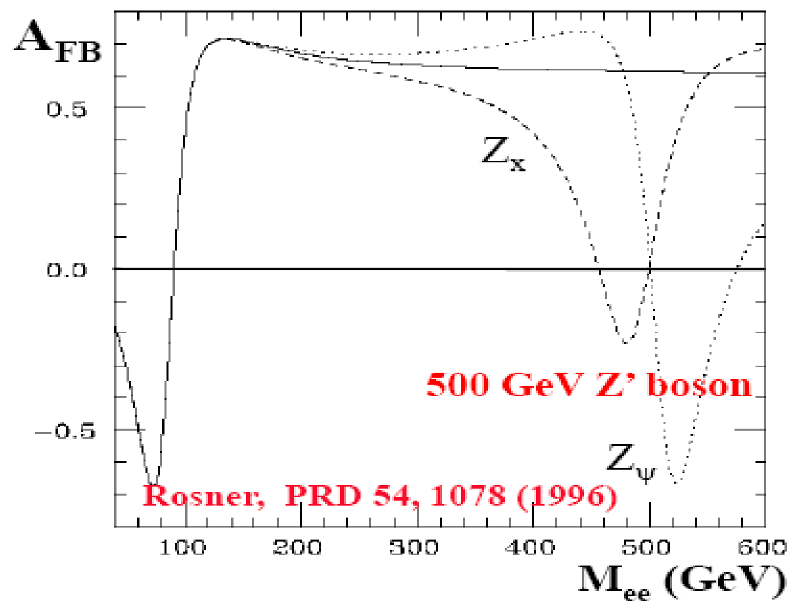

W/Z Asymmetries

- Differential distributions provide important information on production mechanism.

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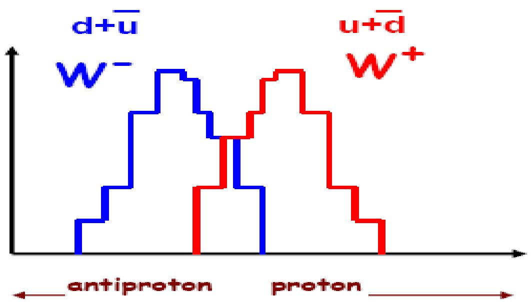

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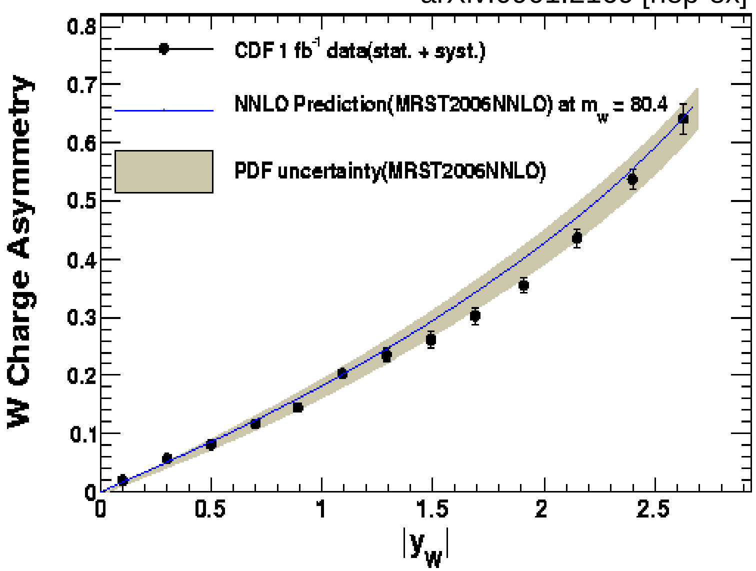

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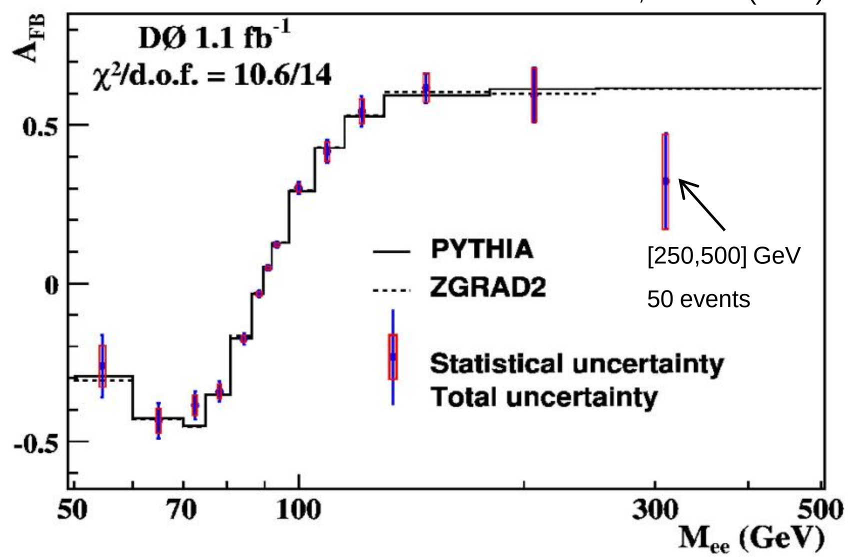
PRL 101, 191801 (2008)



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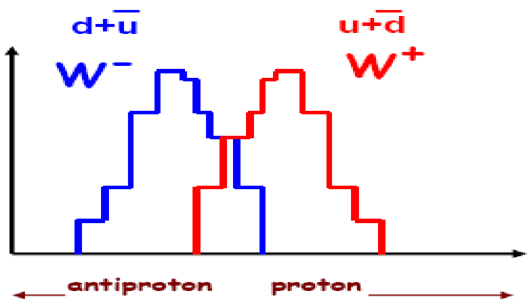

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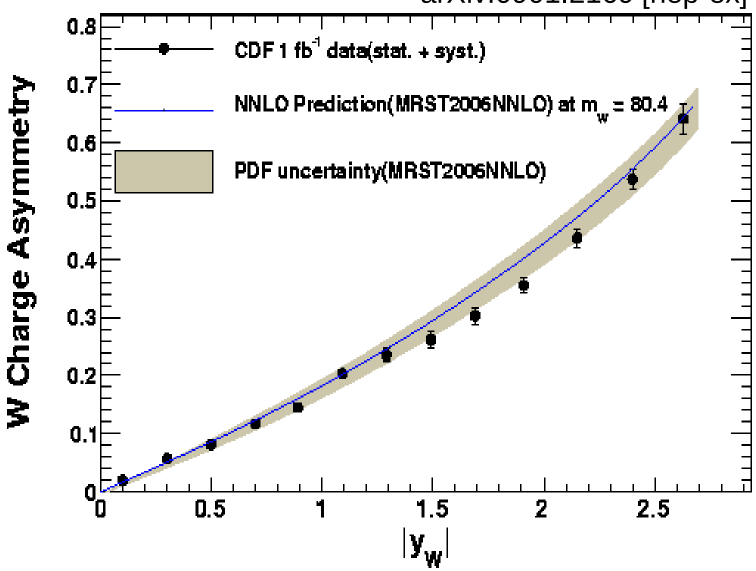

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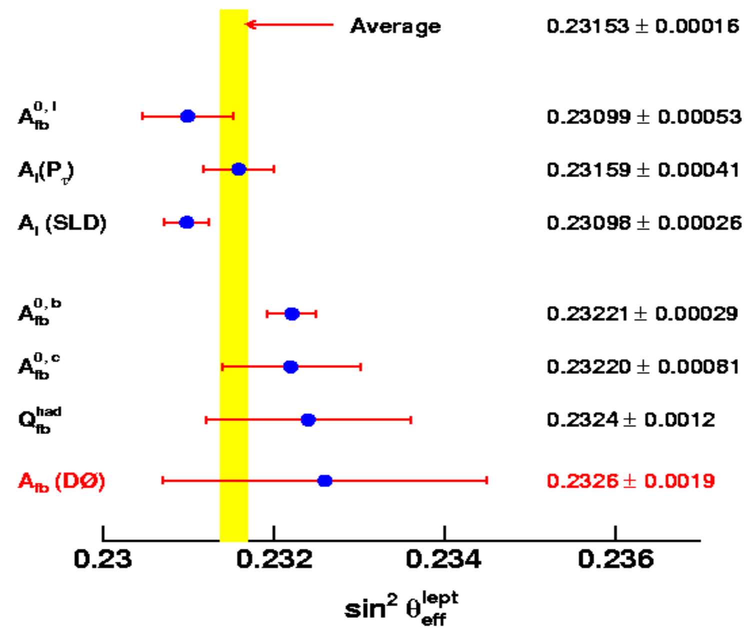
DØ (1.1 fb⁻¹)



Competitive measurement with full dataset and CDF+DØ.

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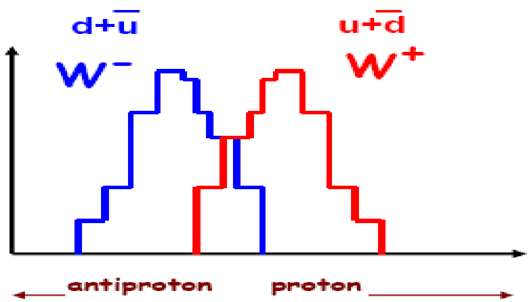

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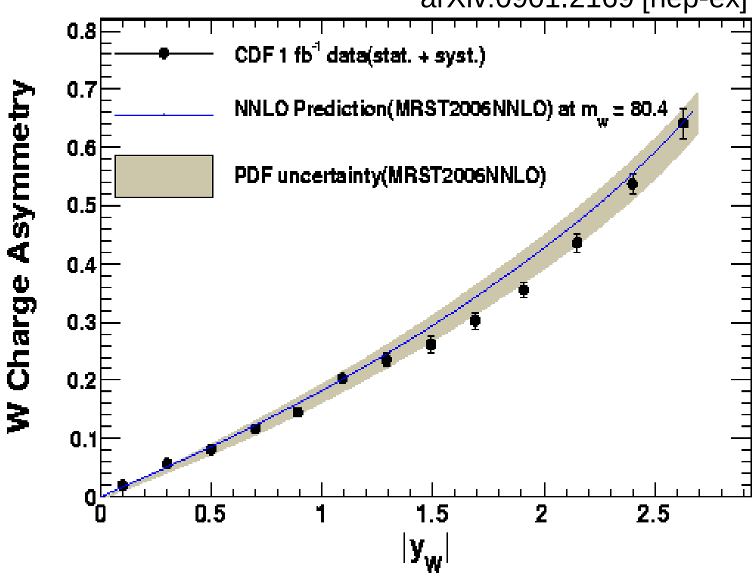

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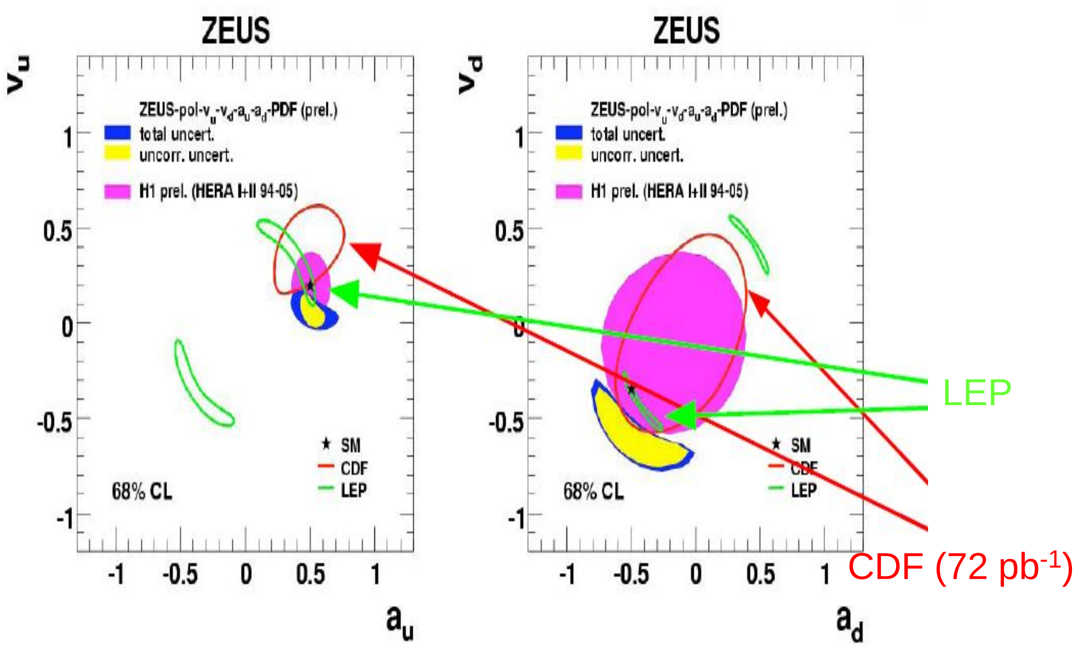


Uncertainties will shrink by ~x10!

W Boson Mass

- Constraint on SM Higgs mass is now dominated by the W mass uncertainty:

  Δm_t = 1.2 GeV ➔ ΔM_H = +9/-8 GeV

  ΔM_W = 25 MeV ➔ ΔM_H = +17/-13 GeV

- Measured from template fits to W transverse mass, lepton p_T and MET distributions.

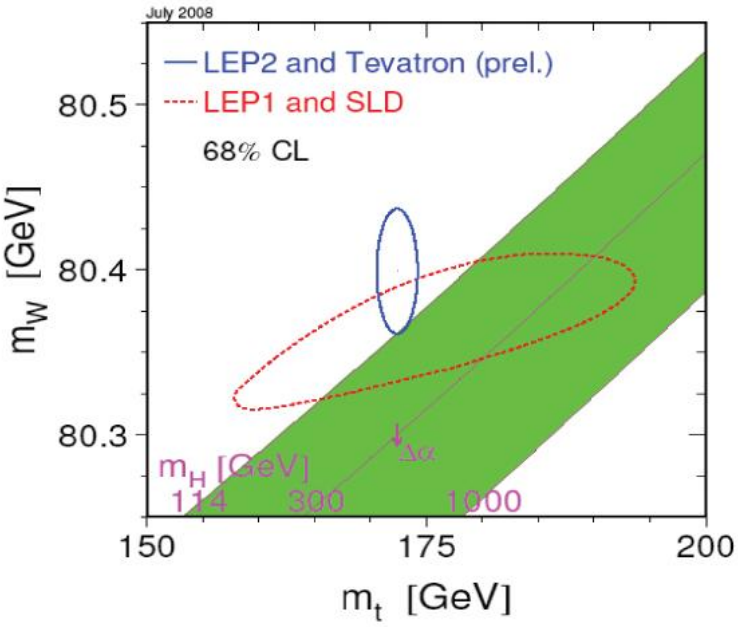
- Exquisite understanding of the detector response, noise and pileup required:

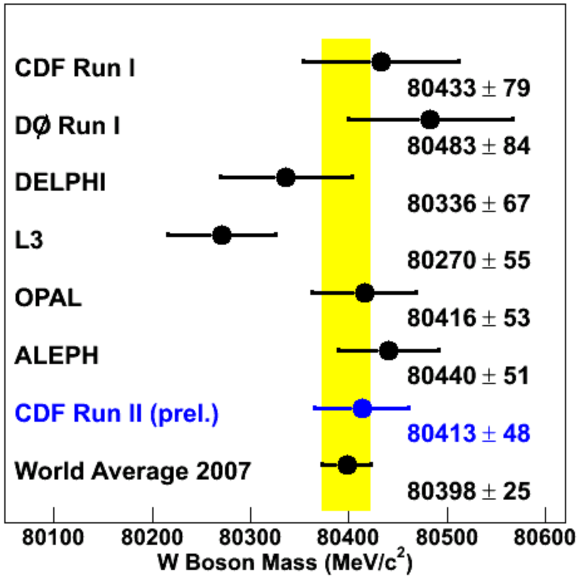
  ~ few MeV for quantities ~40 GeV!

- Uncertainty currently dominated by statistics of Z sample used for calibration.

  Theoretical uncertainties ~10-15 MeV.

- New results expected soon!
  - CDF working on 2.4 fb^{-1} measurement
  - DØ working on 1 fb^{-1} measurement





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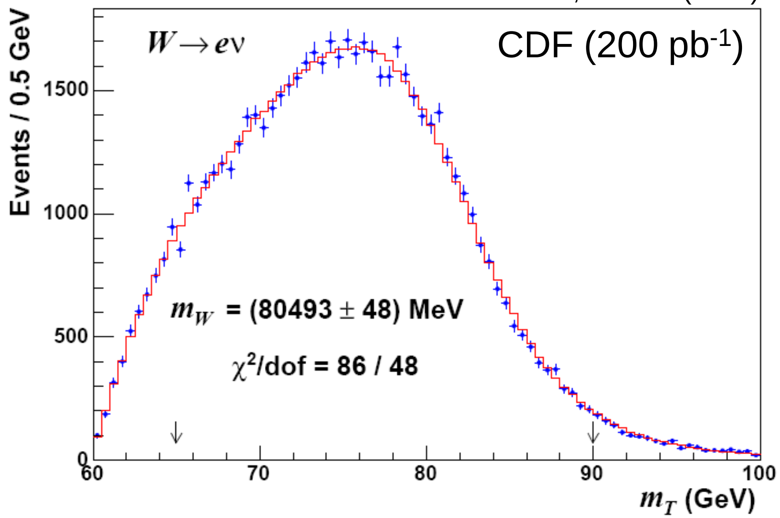
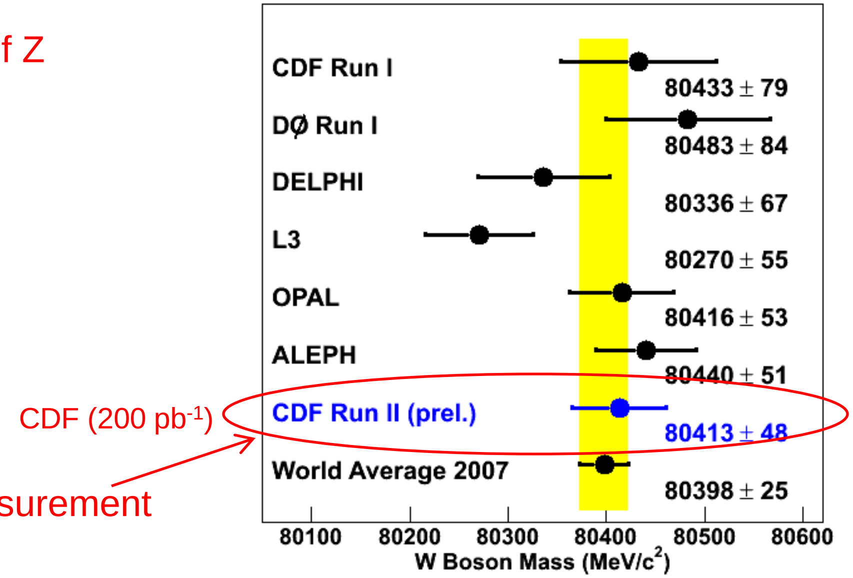
PRL 99, 151801 (2007)





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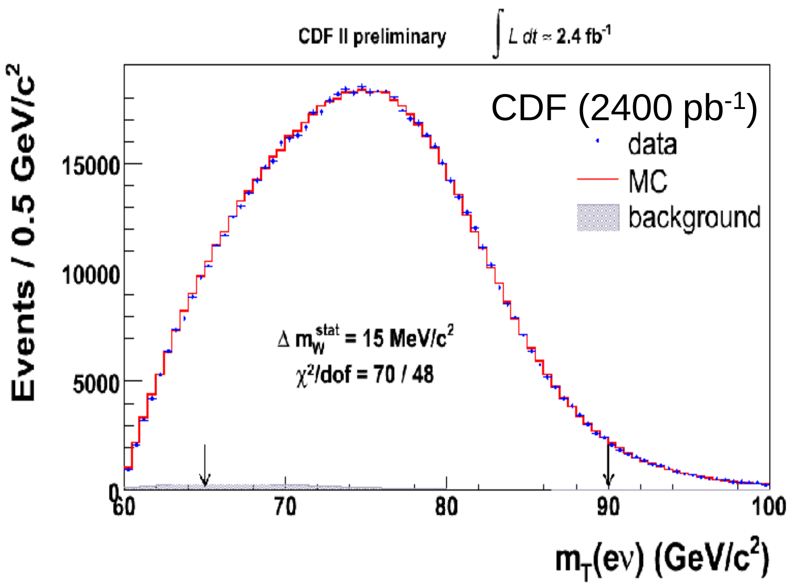
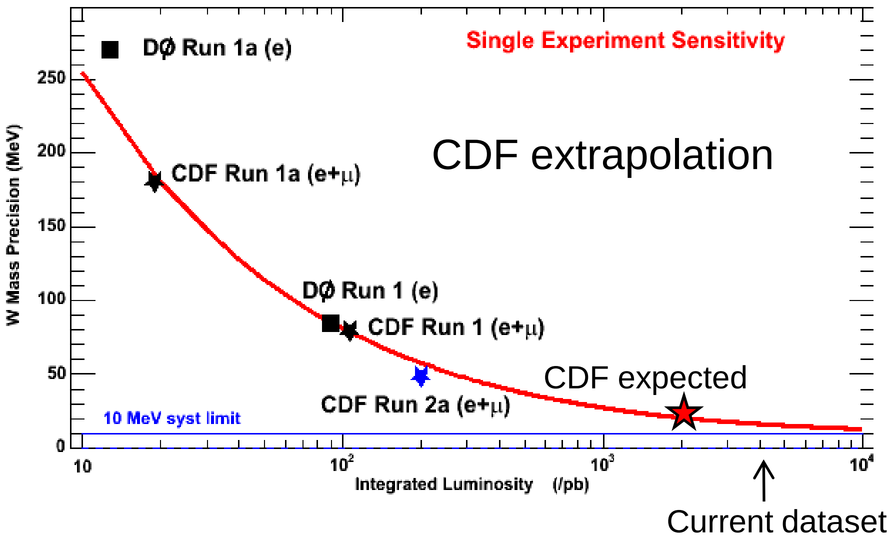
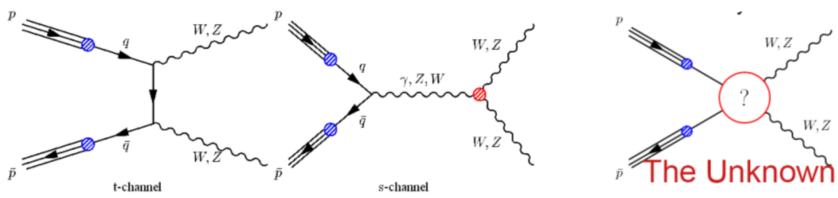
With full data sample expect CDF+DØ combined uncertainty of ~15-20 MeV.





Diboson Production

- Probe of non-abelian structure of SM and sensitive to New Physics.



- Background to many direct searches (e.g. Higgs, SUSY) for New Physics. Reality check for NP searches.

- Recent observation of ZZ production in ll$\nu\nu$ and 4l channels by DØ (5.7σ). Evidence at CDF (4.4σ). Measured cross section in agreement with SM (1.4 pb).

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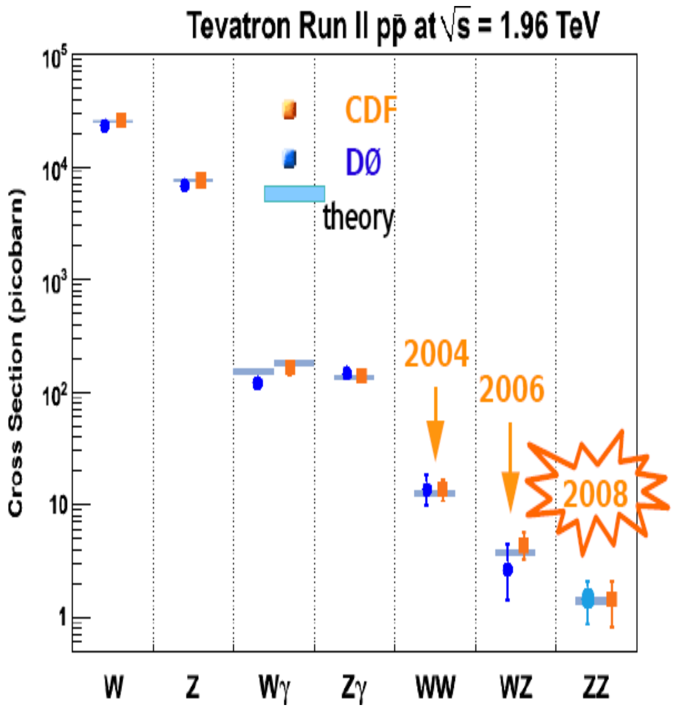

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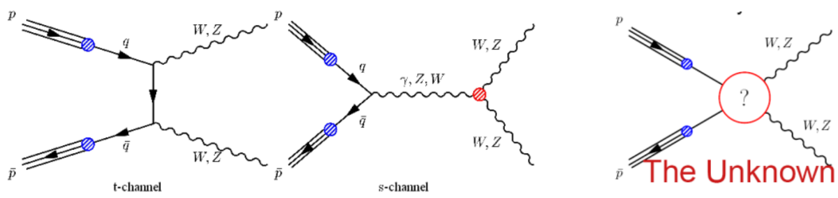

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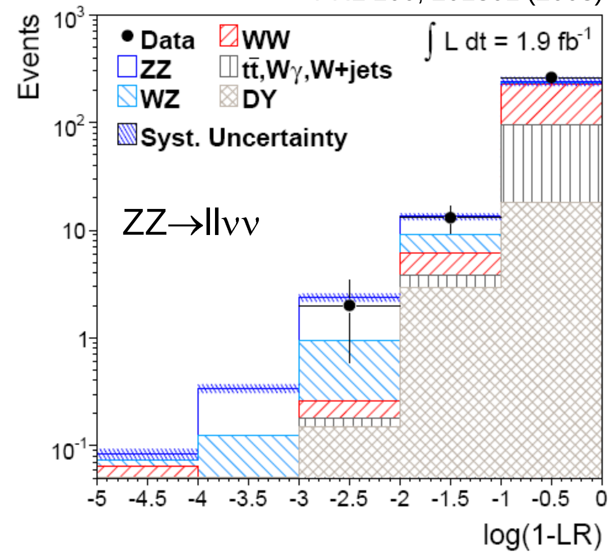
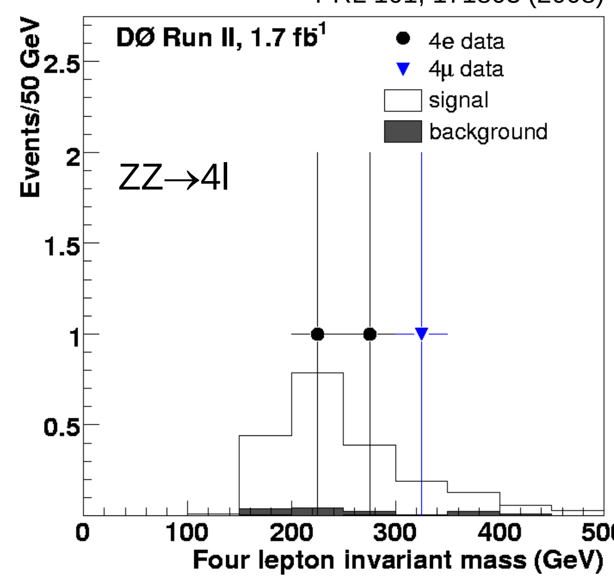
PRL 100, 201801 (2008)



PRL 101, 171803 (2008)



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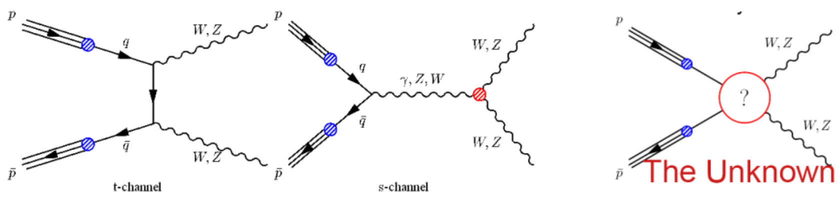

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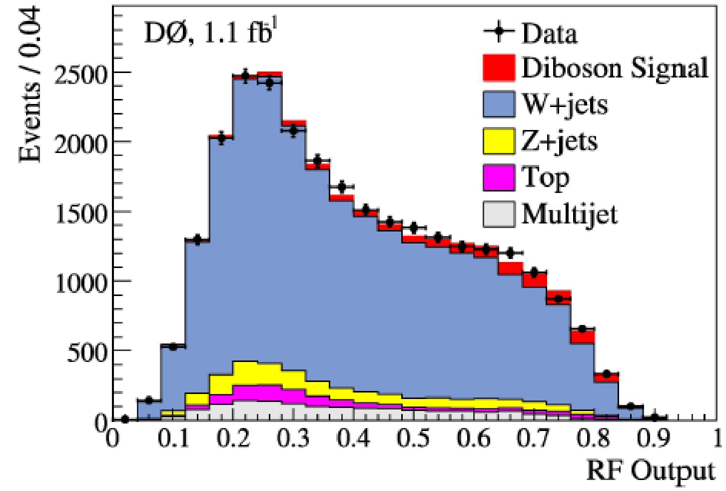
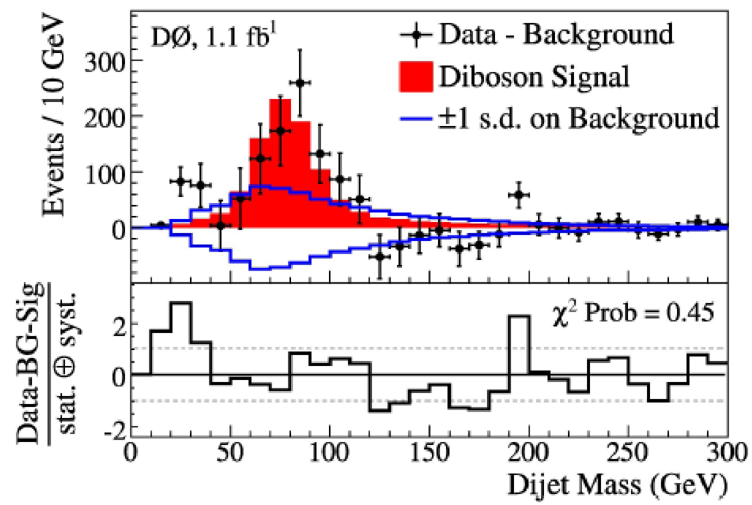
WW/WZ→lνjj

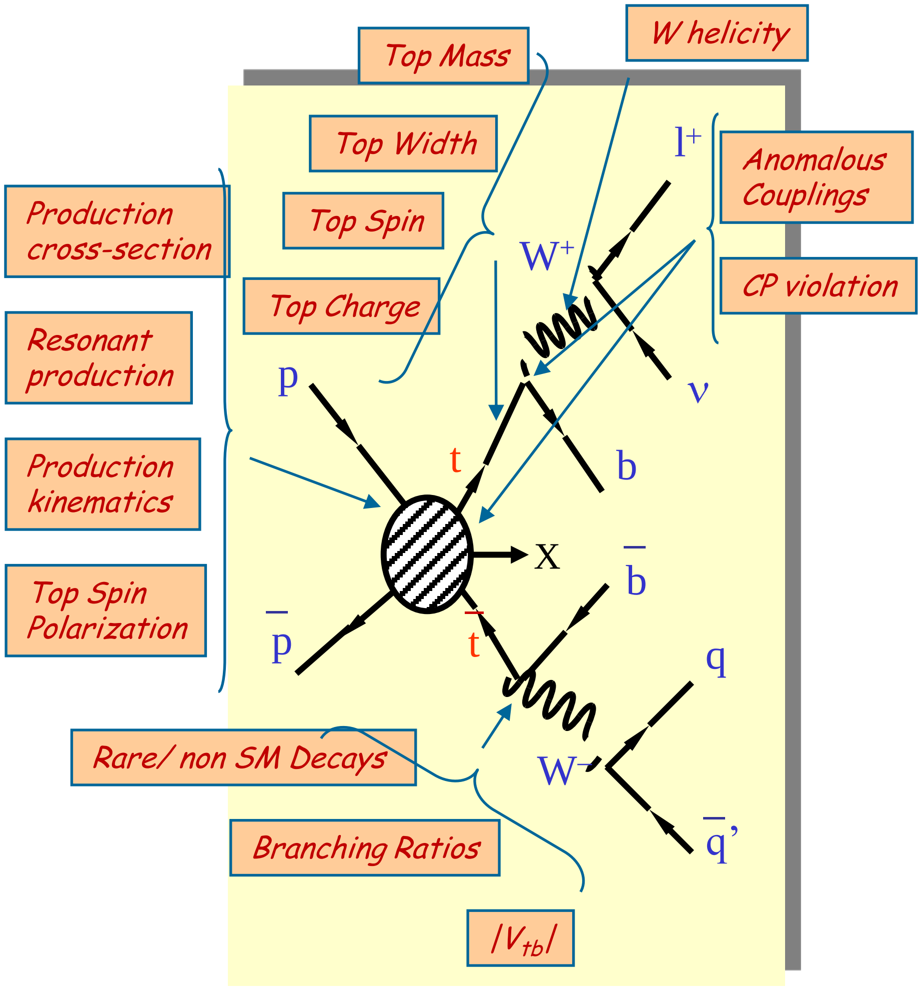
arXiv:0810.3873 [hep-ex]





Top Physics Program

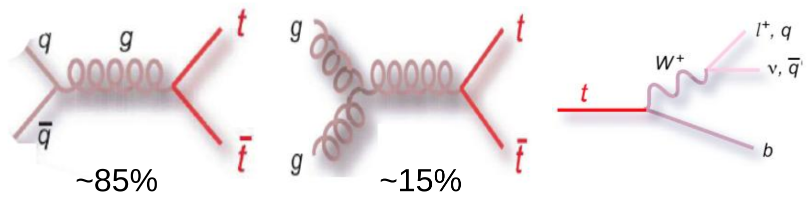
- Precision measurements of top quark properties crucial in order to unveil its true nature: $\lambda_t = \sqrt{2}\, m_t/v = 0.991 \pm 0.007$!!!
- Extremely rich program of measurements.
- Large top samples in Tevatron Run II have allowed to make the transition from the discovery phase to a phase of precision measurements of top quark properties.



Top Quark Production and Decay

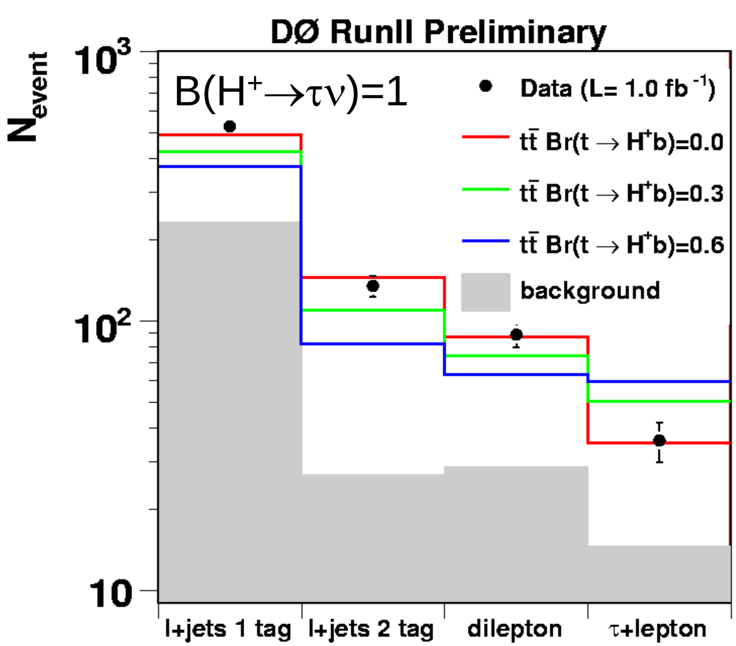
- Top quarks dominantly produced in pairs via the strong interaction.
- Measured cross sections in agreement with SM.

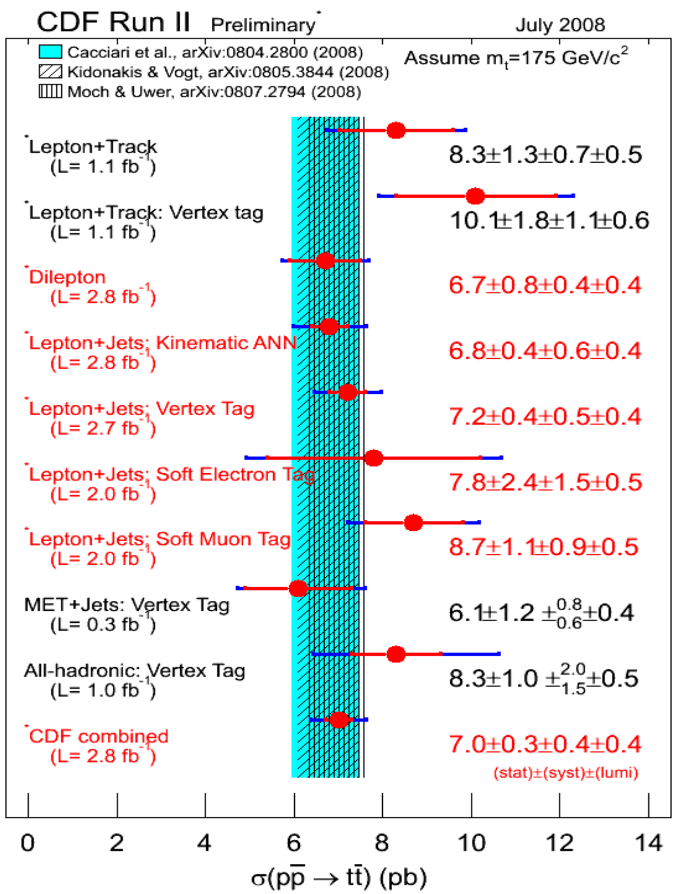
  Experimental precision from combination of channels (~9%) comparable to theoretical error.



- Precise measurements in different channels allows to place constraints on New Physics.

  E.g. $t \to H^+ b$: channels affected differently depending on H^+ decay modes.





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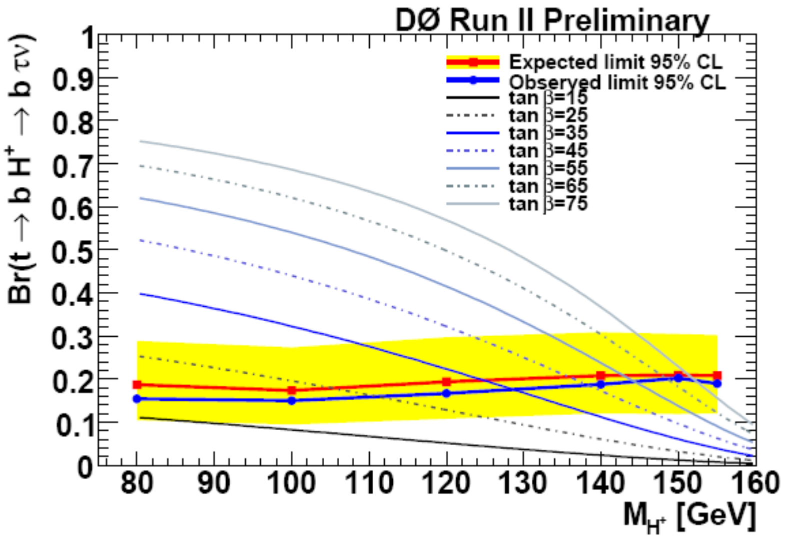

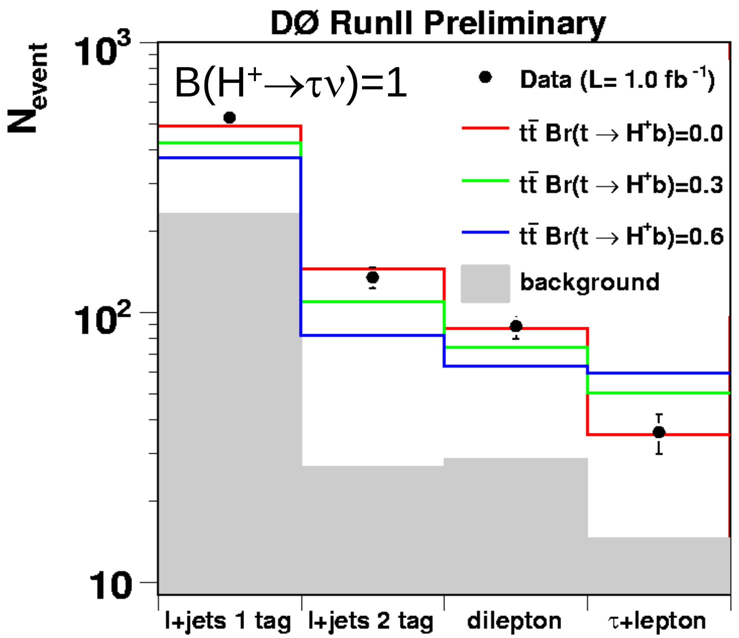

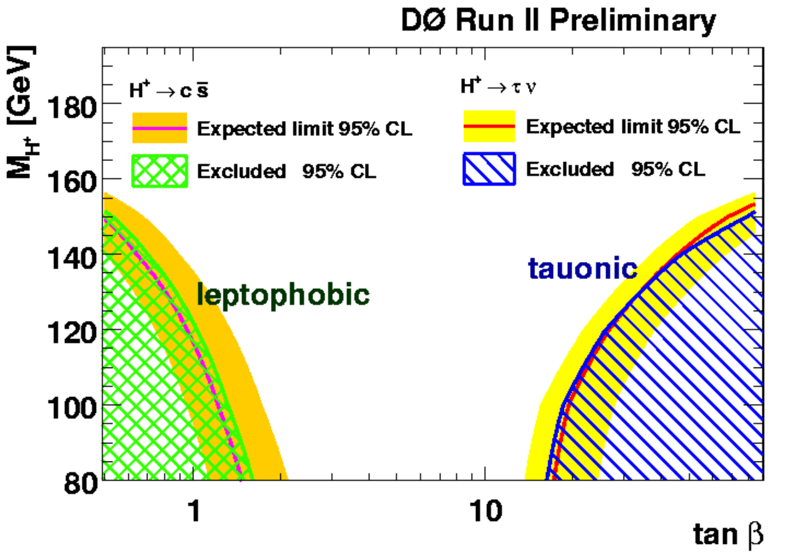

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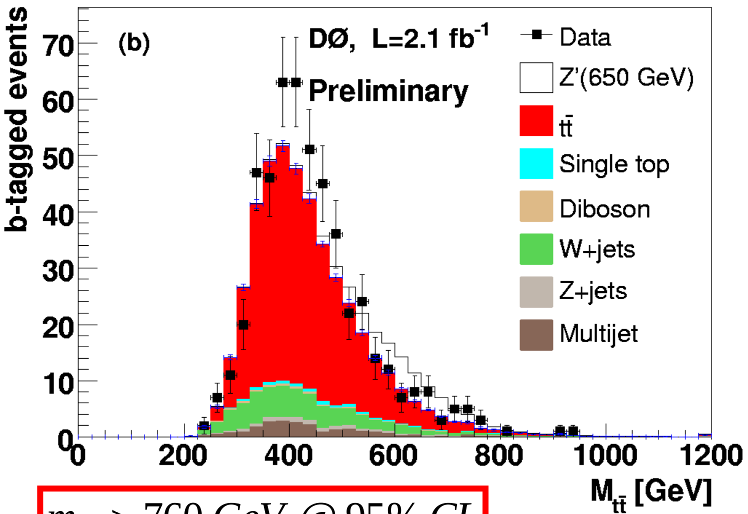
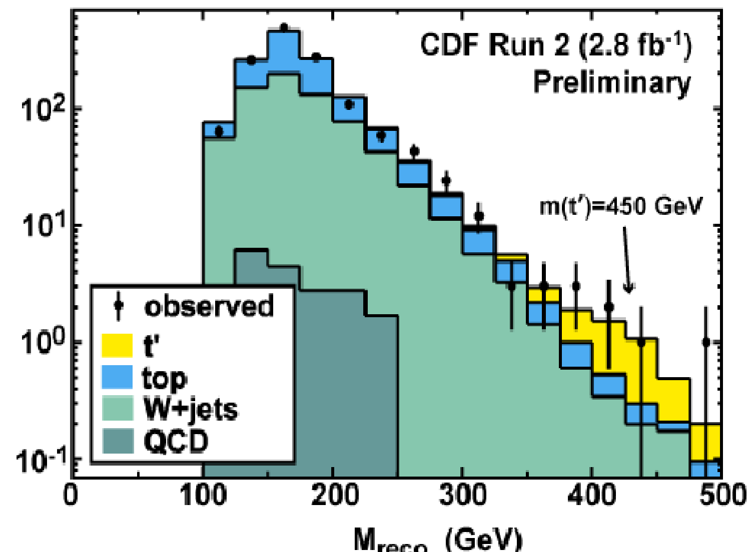
- Precise measurements in different channels allows to place constraints on New Physics.
  E.g. $t \to H^+ b$: channels affected differently depending on H^+ decay modes.
- Also probing for non-SM production mechanisms (e.g. $Z' \to tt$) or New Physics contamination in the top samples (e.g. $t't' \to WqWq$).

Using top as a tool to look for New Physics



$m_{Z'} > 760\ GeV\ @\ 95\%\ CL$

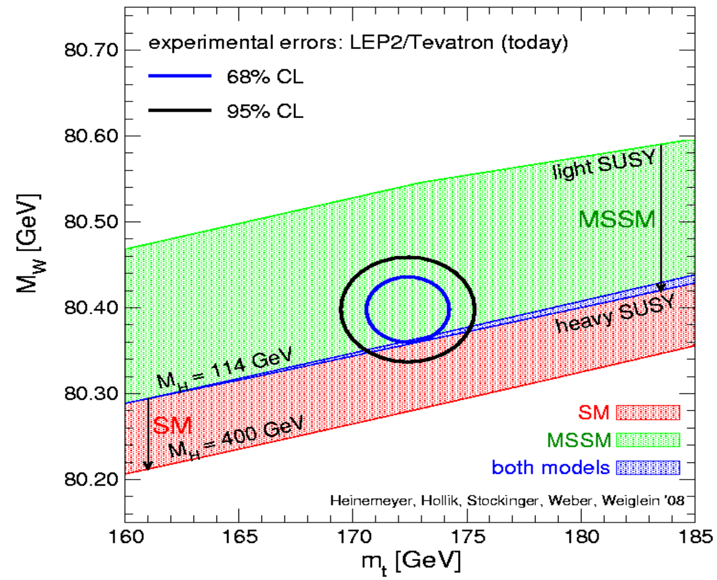
(leptophobic Z' with Γ/M=1.2%)



$m_{t'} > 311\ GeV\ @\ 95\%\ CL$

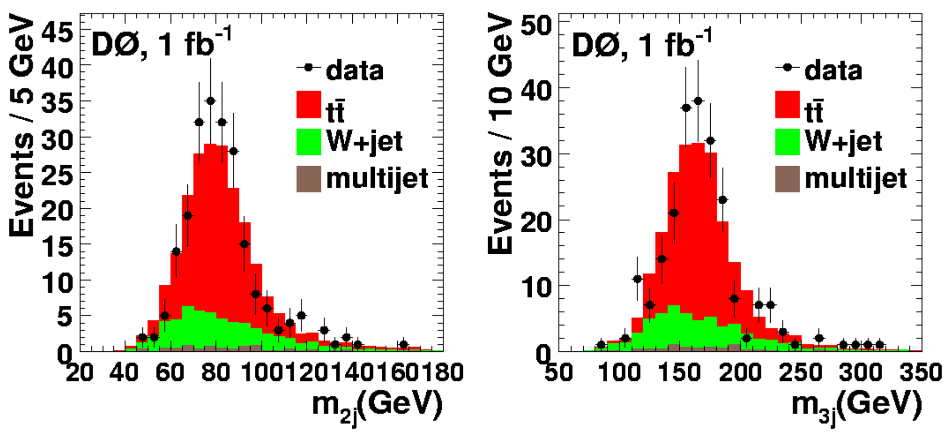
Top Quark Mass

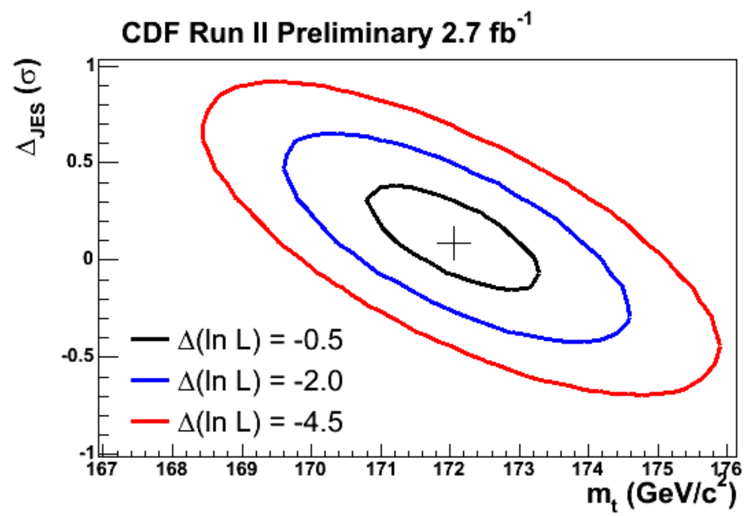
- Fundamental parameter of the Standard Model.
- Important ingredient for EW precision analyses at the quantum level.
  ⇒ incisive consistency checks
  ⇒ constrain/rule out models of New Physics
  ⇒ provide valuable information on the parameters of the Lagrangian



- Sophisticated techniques to minimize statistical and dominant systematic uncertainties (JES via in-situ calibration to M_W in lepton+jets).

PRL 101, 182001 (2008)





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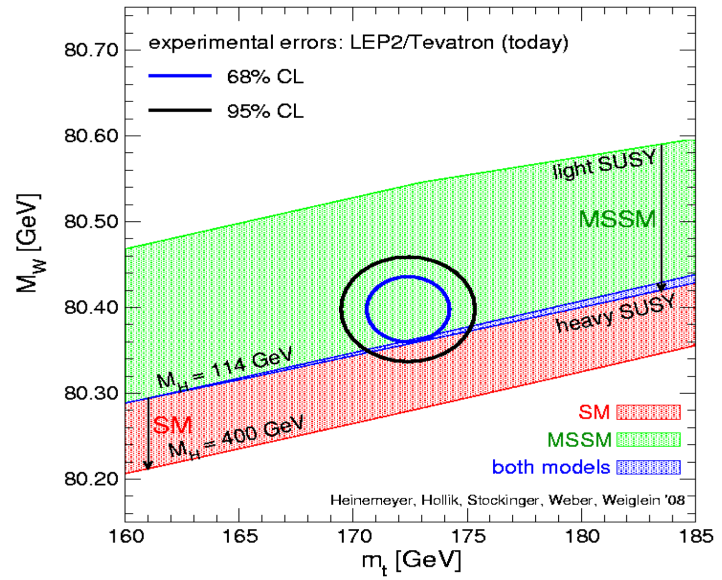
- Sophisticated techniques to minimize statistical and dominant systematic uncertainties (JES via in-situ calibration to M_W in lepton+jets).

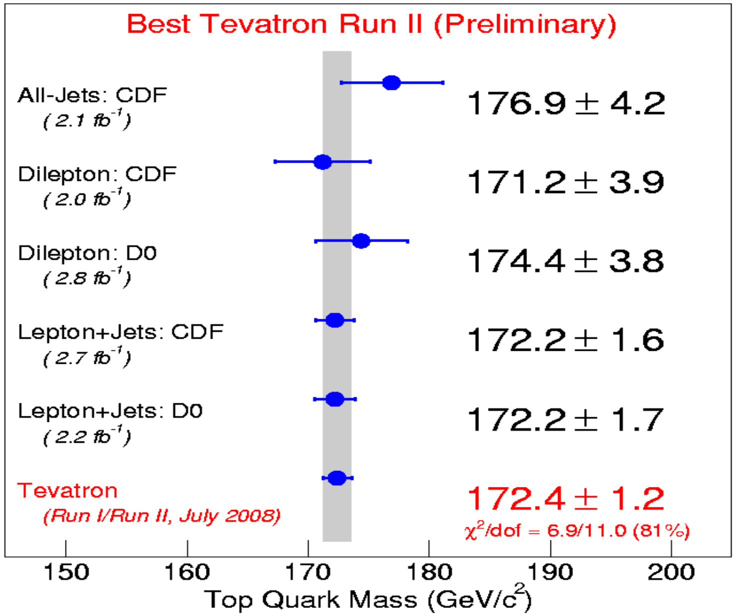
- Current world-average (most sensitive channels use up to 2.7 fb^{-1}):

$$m_t = 172.4 \pm 0.7 \pm 1.0\ GeV$$

Measurement will be limited by systematic uncertainties (signal modeling, b-jet response), some of which can be constrained by data.

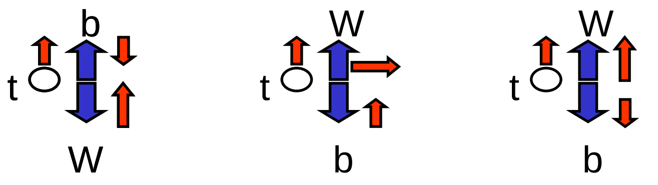
Estimate ultimate precision ≤1 GeV





Probing the *tbW* Interaction

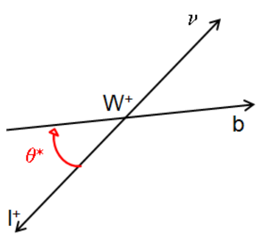
W helicity in top quark decays

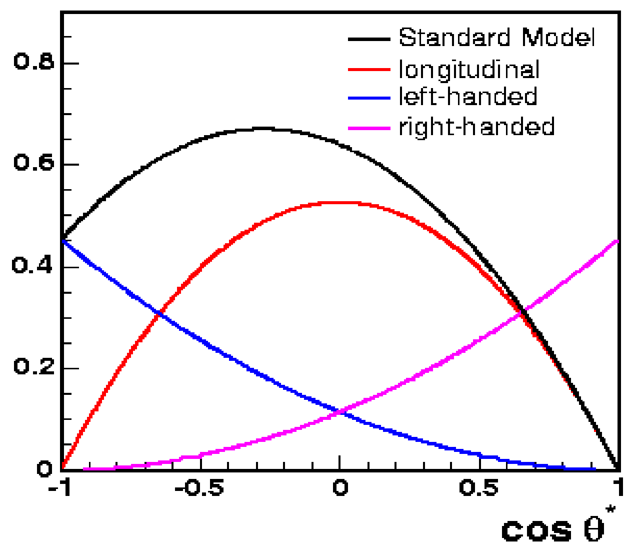


$\lambda_W = -1$ $\lambda_W = 0$ $\lambda_W = +1$

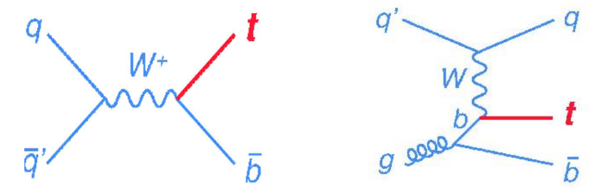
SM: $F_{-} \approx \frac{2M_W^2}{m_t^2 + 2M_W^2} = 0.30$ $F_0 \approx \frac{m_t^2}{m_t^2 + 2M_W^2} = 0.70$ $F_{+} = 0$

- Reconstruct helicity angle of lepton in top quark pair events.

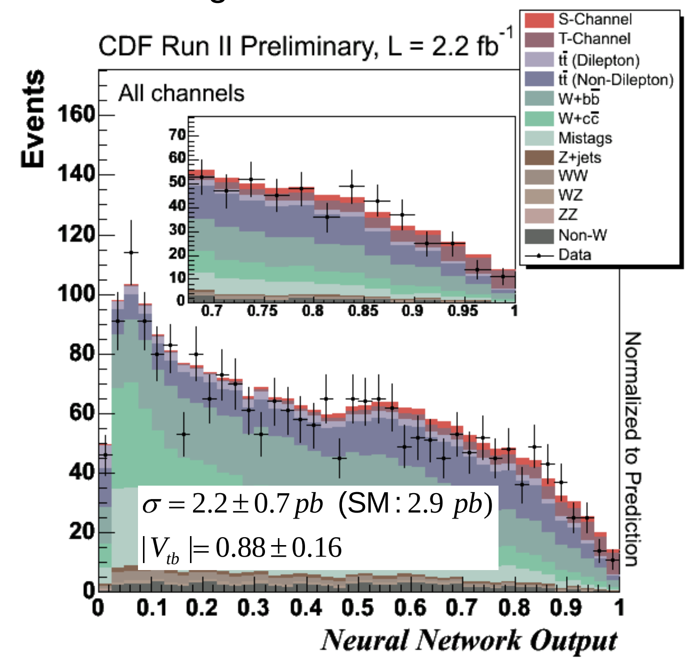




Electroweak single top production



- σ and kinematics sensitive to *tbW* interaction
- σ~1/2 σ(tt) but very large W+jets background
- Both experiments have evidence for single top via sophisticated multivariate techniques to extract the signal.



Expect observation with ~3 fb^{-1}

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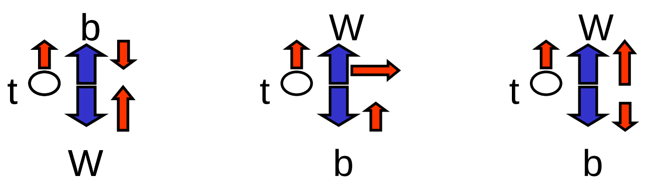
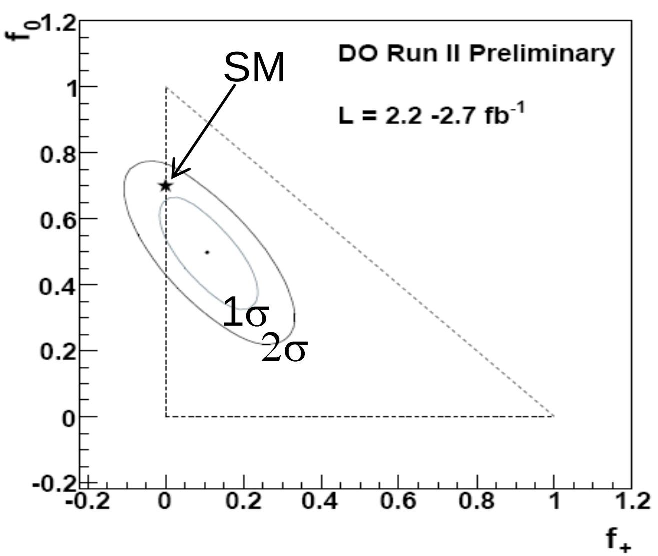


$\lambda_W = -1$ $\lambda_W = 0$ $\lambda_W = +1$

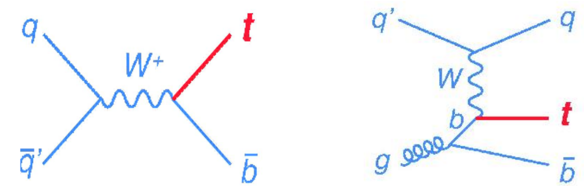
SM: $F_- \approx \dfrac{2M_W^2}{m_t^2 + 2M_W^2} = 0.30$ $F_0 \approx \dfrac{m_t^2}{m_t^2 + 2M_W^2} = 0.70$ $F_+ = 0$

- Model-independent measurement of W helicity fractions

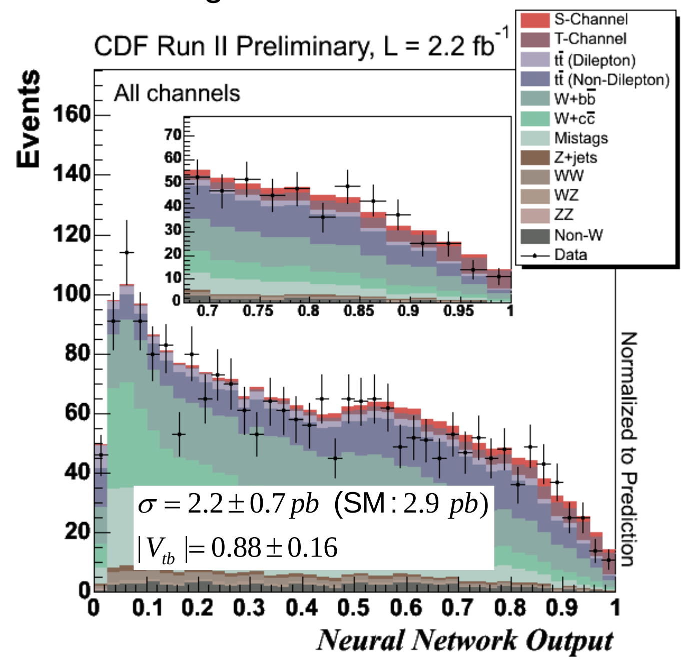


Sensitive to ratio of anomalous couplings

Electroweak single top production



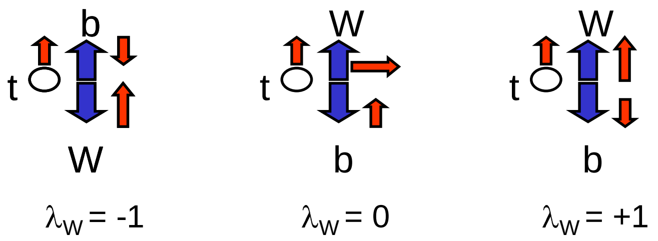
- σ and kinematics sensitive to *tbW* interaction
- σ~1/2 σ(tt) but very large W+jets background
- Both experiments have evidence for single top via sophisticated multivariate techniques to extract the signal.



Expect observation with ~3 fb^{-1}

Probing the *tbW* Interaction

W helicity in top quark decays



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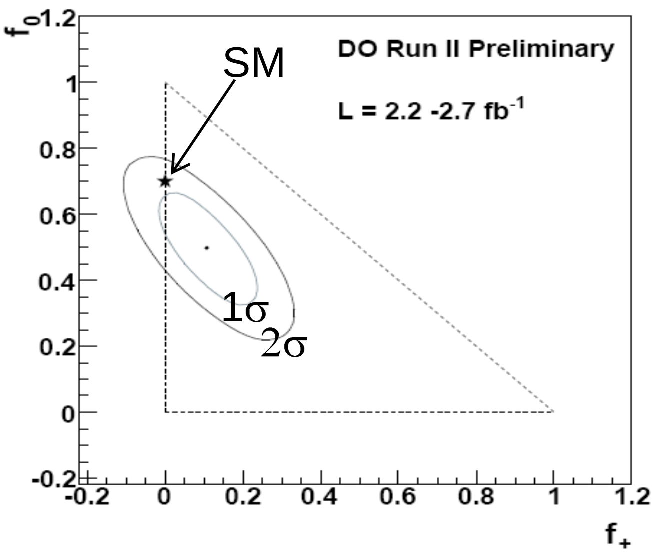


Sensitive to ratio of anomalous couplings

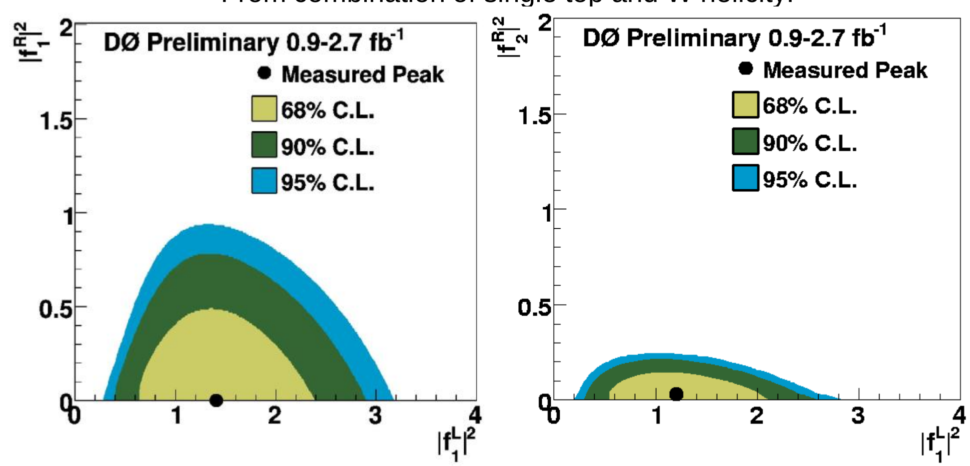
Electroweak single top production

With full dataset:

- $\Delta V_{tb}/V_{tb}$~8%
- Simultaneous measurement of s- and t-channel cross sections
- Searches for anomalous production (W', H^+, FCNC)
- Measurement of *tbW* couplings

$$\mathcal{L} = \frac{g}{\sqrt{2}} W_\mu^- \bar{b} \gamma^\mu \left(f_1^L P_L + f_1^R P_R \right) t - \frac{g}{\sqrt{2} M_W} \partial_\nu W_\mu^- \bar{b} \sigma^{\mu\nu} \left(f_2^L P_L + f_2^R P_R \right) t + h.c.$$

From combination of single top and W helicity:



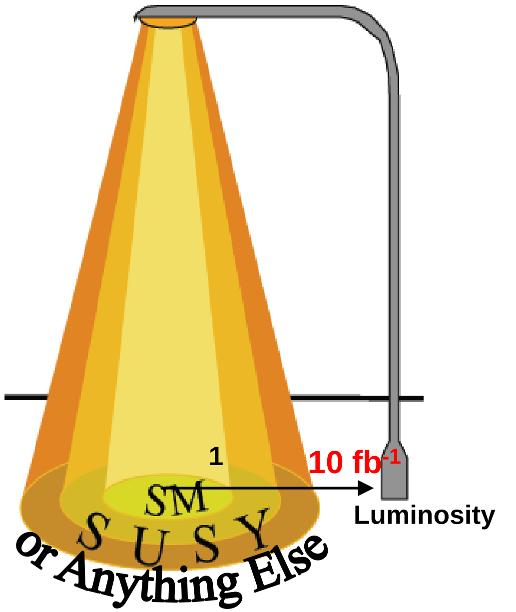
Results available on all these topics with <2 fb^{-1}

New Phenomena Searches

Model-inspired searches: theory-driven

➔ optimized analyses to extract well-defined signals.

- SUSY: (heavy-quark)jets + MET, multi-leptons + MET, multi-photons+MET, long-lived massive particles, rare B decays, etc
- Extra Dimensions: mono-jets, di-lepton/di-photon resonances
- Extra gauge bosons: W', Z'
- Leptoquarks
- Compositeness: excited leptons,..
- …



Signature-based searches: final-state driven

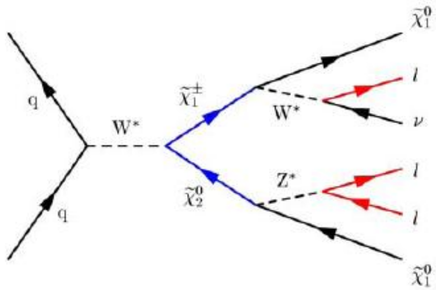
➔ Looking for deviations from the SM anywhere.

Prospects for discoveries remain open:

1. Tevatron is "still" the energy frontier.
2. High luminosity: significant signals may quickly develop as luminosity grows and analyses mature.
3. Well understood detector, refined experimental techniques and experienced collaborations. Data makes you smarter…

SUSY Searches

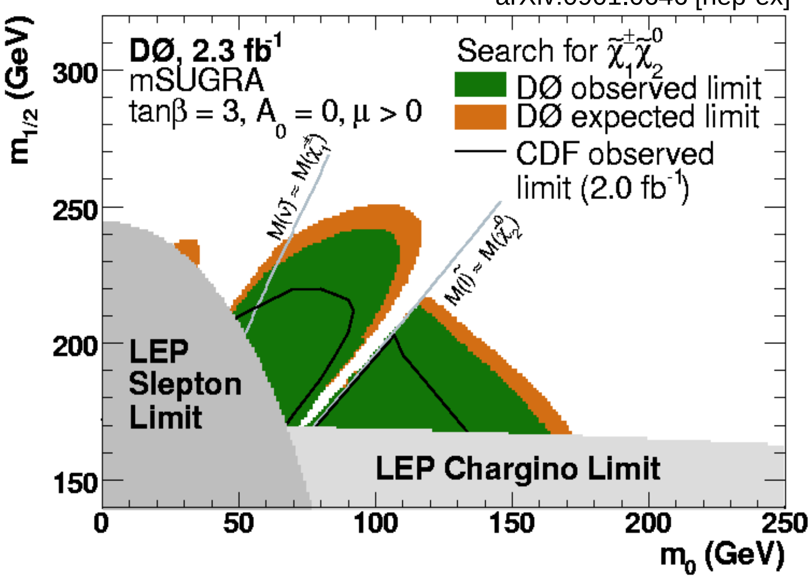
Chargino/Neutralino



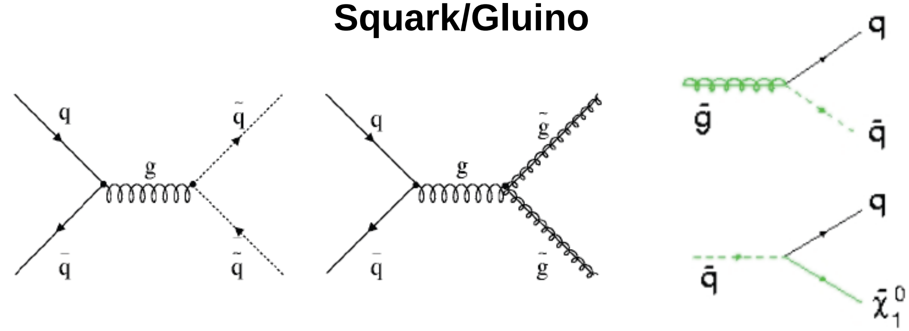
- Clean multi-lepton+MET signature, but:
  - low σxBR (<0.1 pb)
  - low p_T leptons (<10 GeV)
- Challenges: lepton ID at low p_T.

  ➔ use e.g. dilepton+track selections.

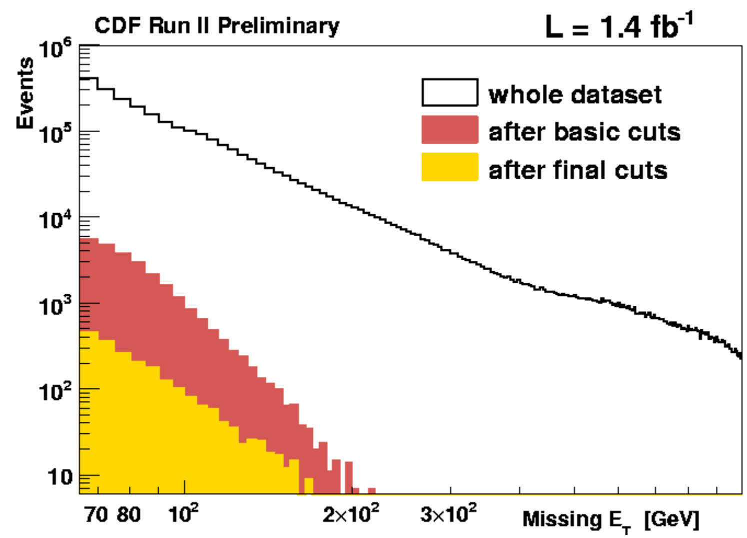
arXiv:0901.0646 [hep-ex]



Squark/Gluino



- Pair production of $\tilde{q}$,$\tilde{g}$ with decays involving multi-jets + MET.
- Critical to understand tail of MET distribution.



SUSY Searches

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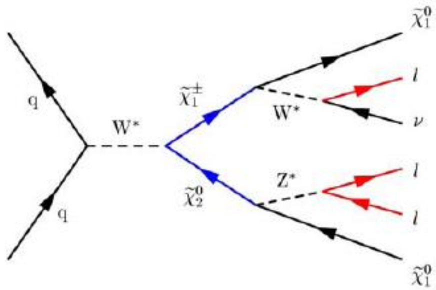

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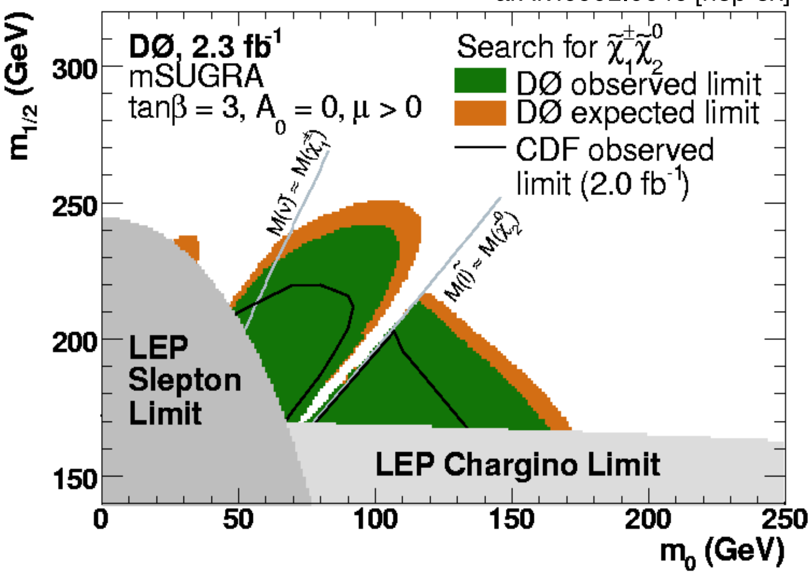

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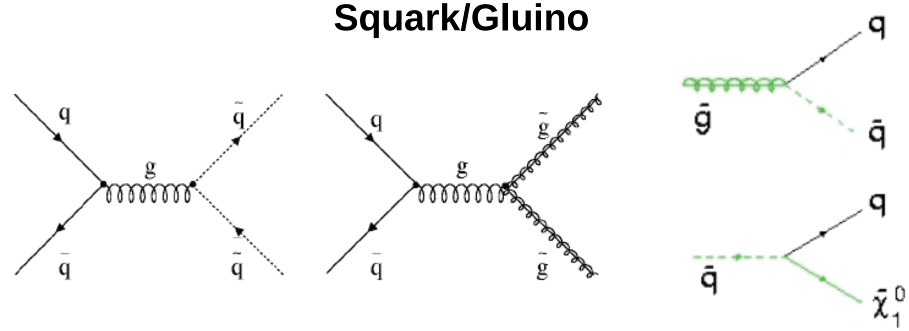

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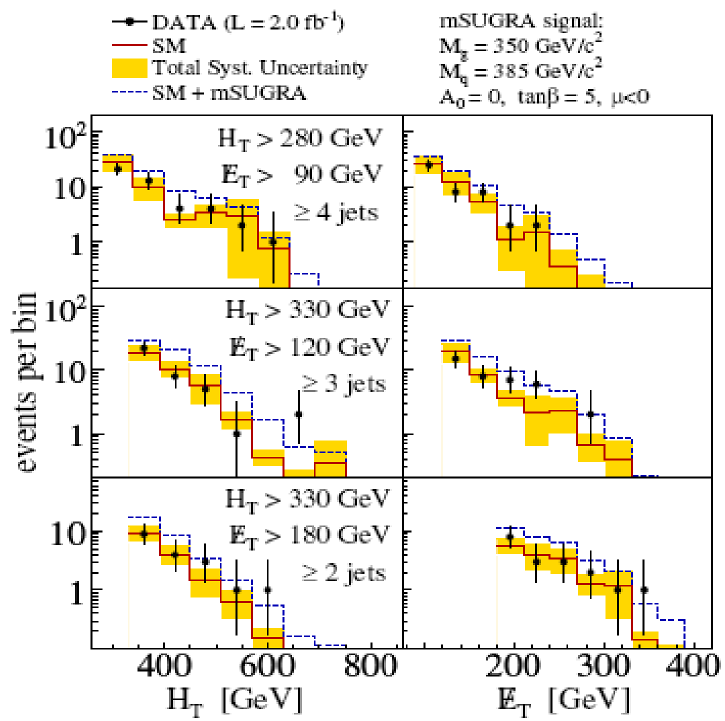
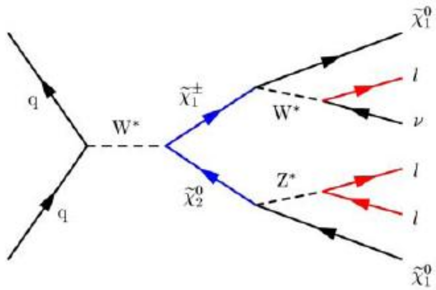
arXiv:0811.2512 [hep-ex]



SUSY Searches

Chargino/Neutralino



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➔ use e.g. dilepton+track selections.

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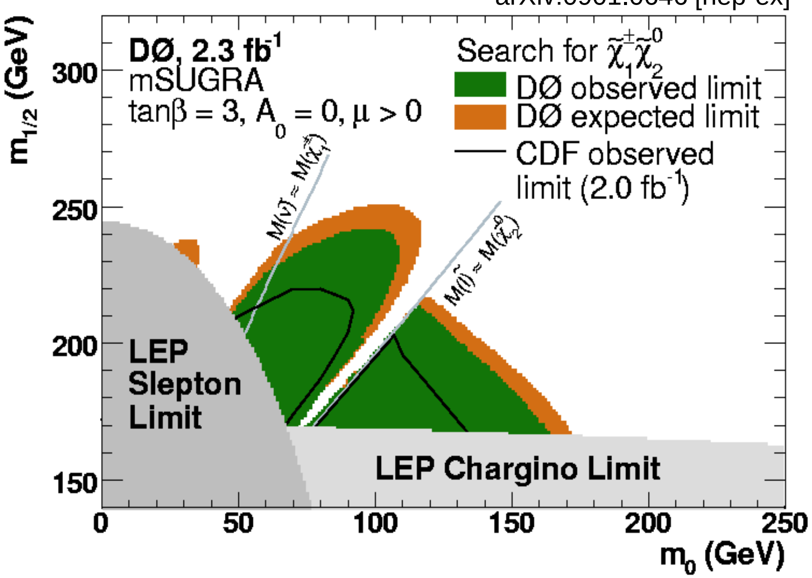

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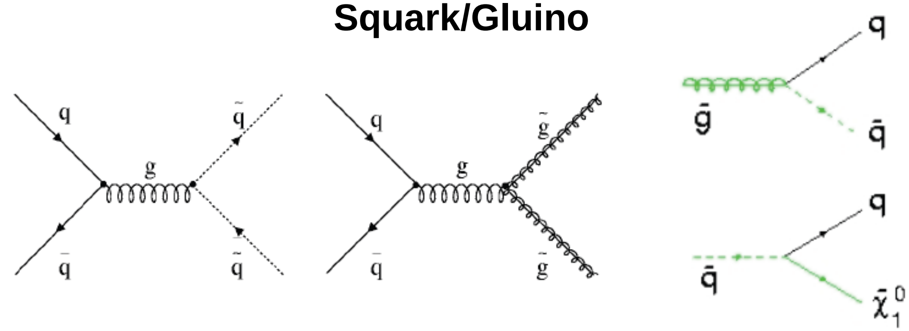

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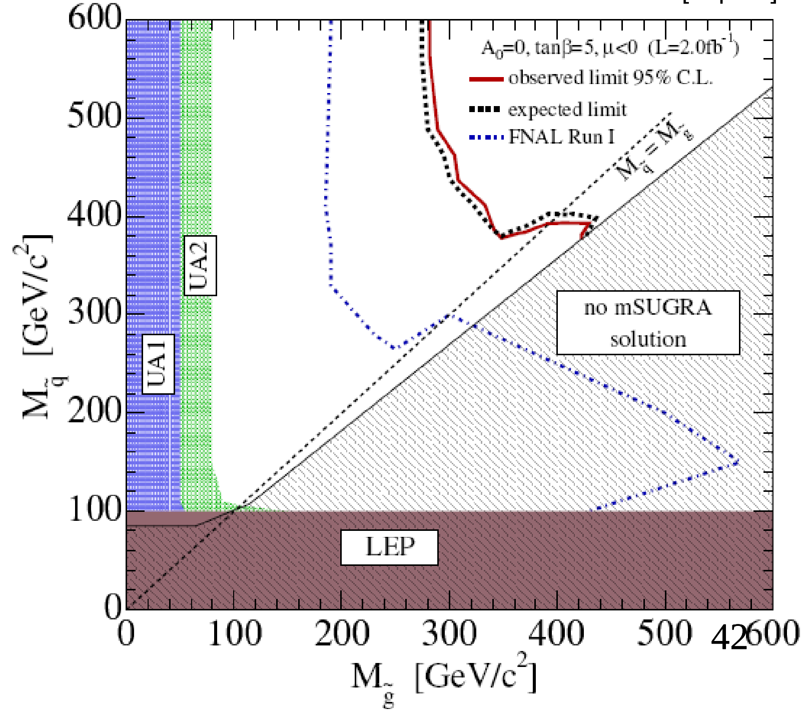
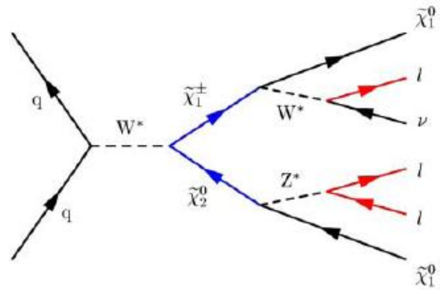


SUSY Searches

Chargino/Neutralino



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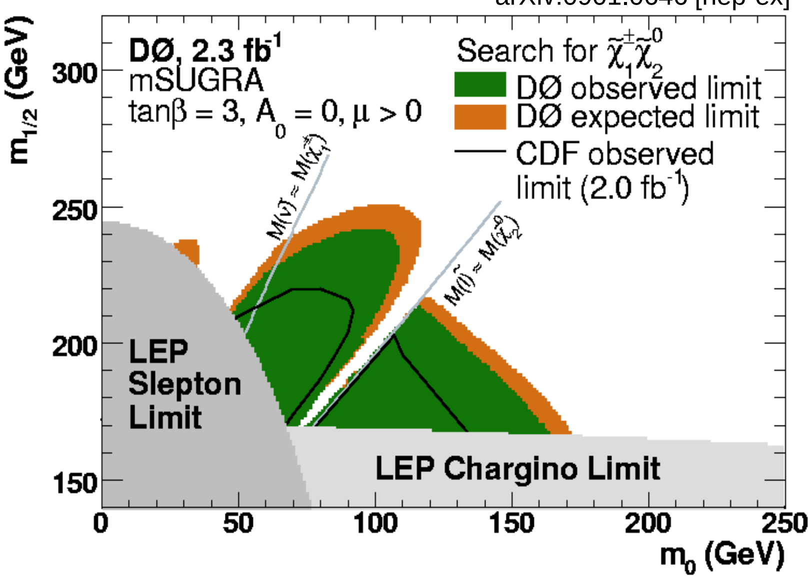

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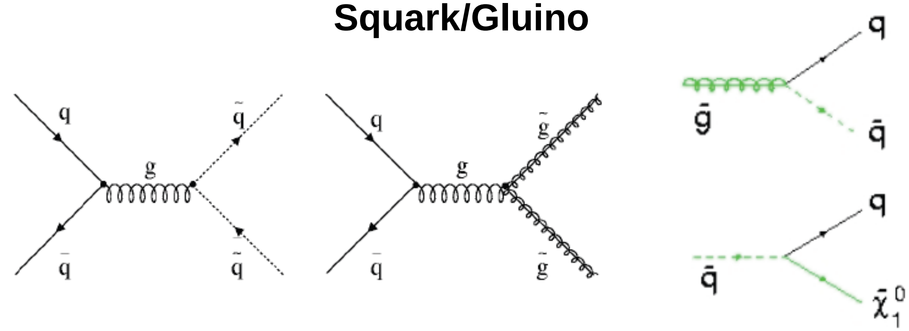
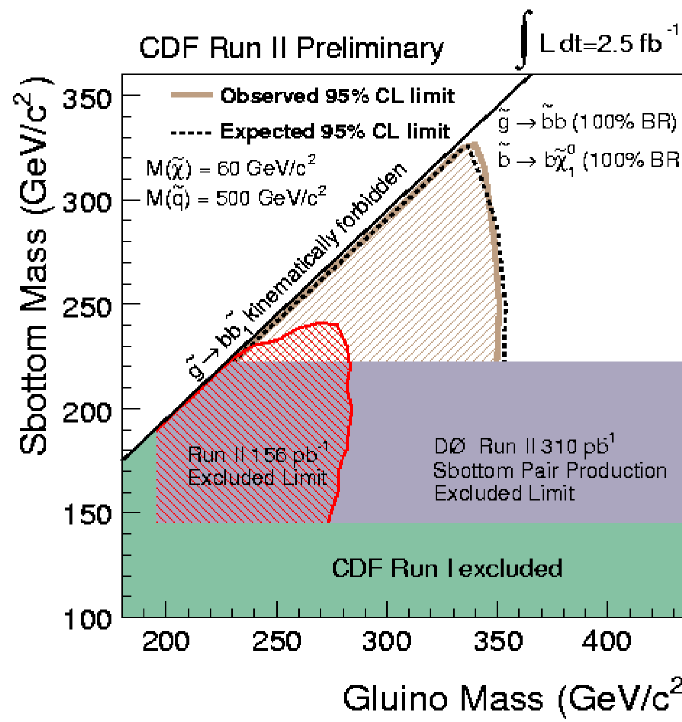
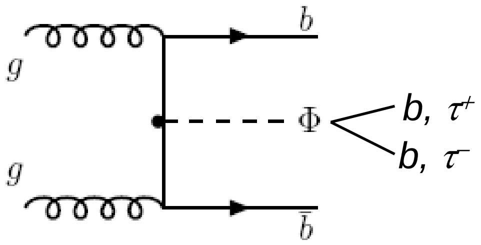


- Pair production of q̃,g̃ with decays involving multi-jets + MET.
- Stop/sbottom: include b/c in the final state.



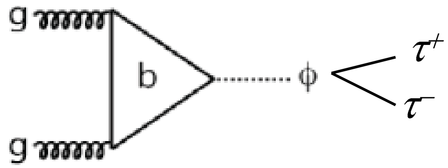
SUSY Higgs

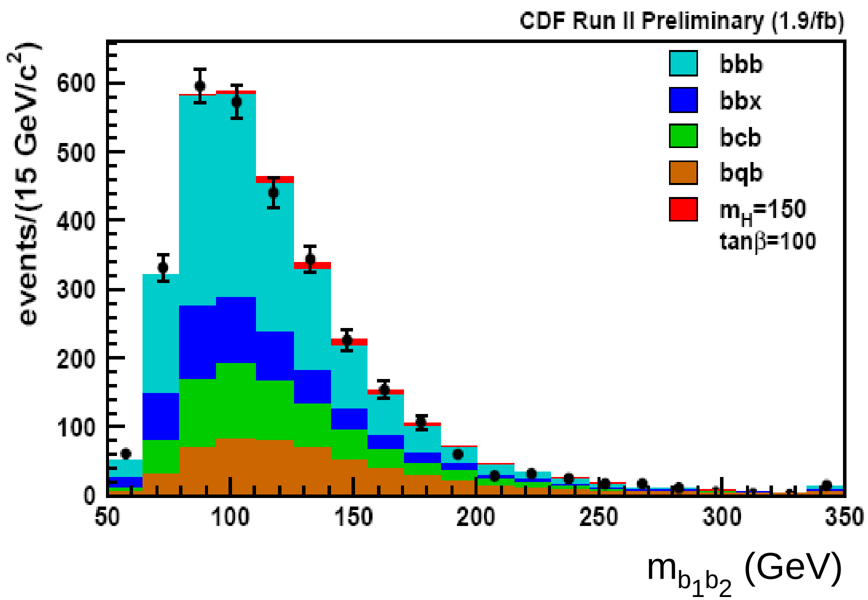
- MSSM at large tanβ:
  - $\Phi^0=\{h^0/H^0,A^0\}$ nearly degenerated in mass
  - Coupling to b, τ enhanced (∝tanβ) ➔ $\sigma_{\Phi+X} \propto 2 \times \tan^2\beta$
  - $BR(\Phi^0\to bb)\sim 90\%$, $BR(\Phi^0\to\tau^+\tau^-)\sim 10\%$

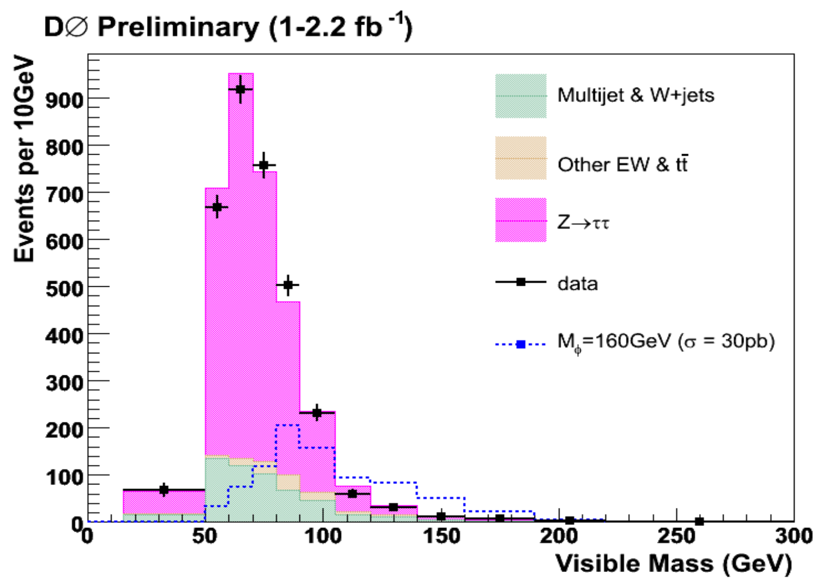


- Three complementary channels:
  - $b(b)+\Phi^0\to bbb(b)$
  - $b(b)+\Phi^0\to \tau^+\tau^-\, b(b)$
  - $\Phi^0\to\tau^+\tau^-$

  (typically require ≥1 τ→e,μ)







$$M^{vis} = \sqrt{(p_\ell^\mu + p_\tau^\mu + p_T^\mu)^2}$$

SUSY Higgs

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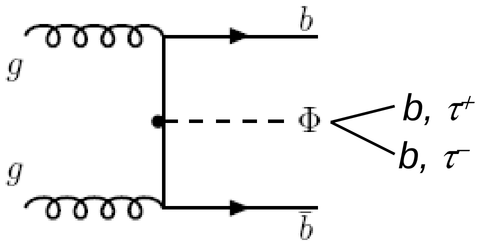

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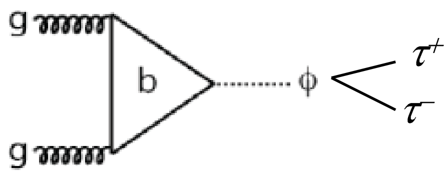
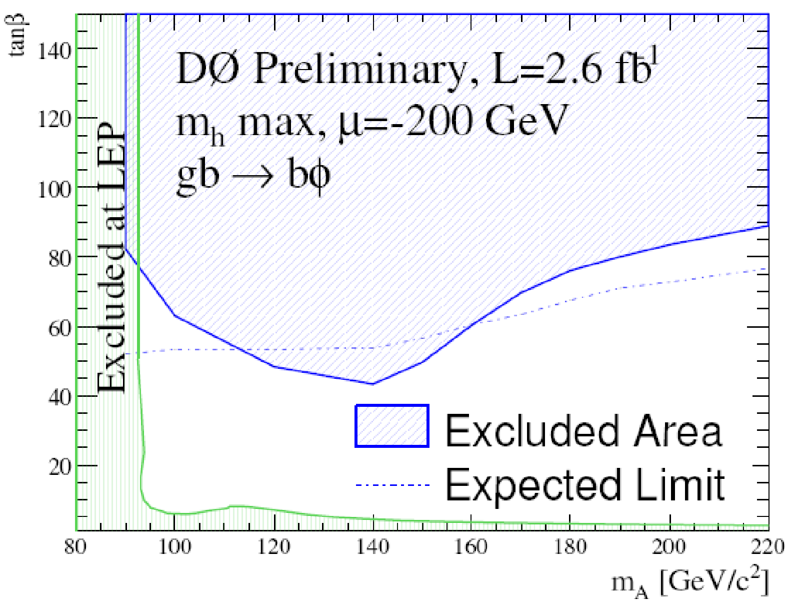
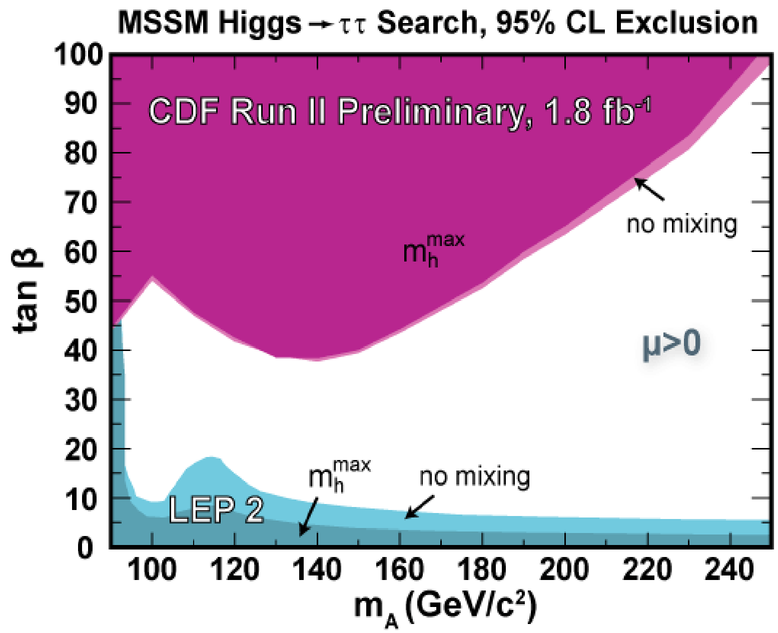




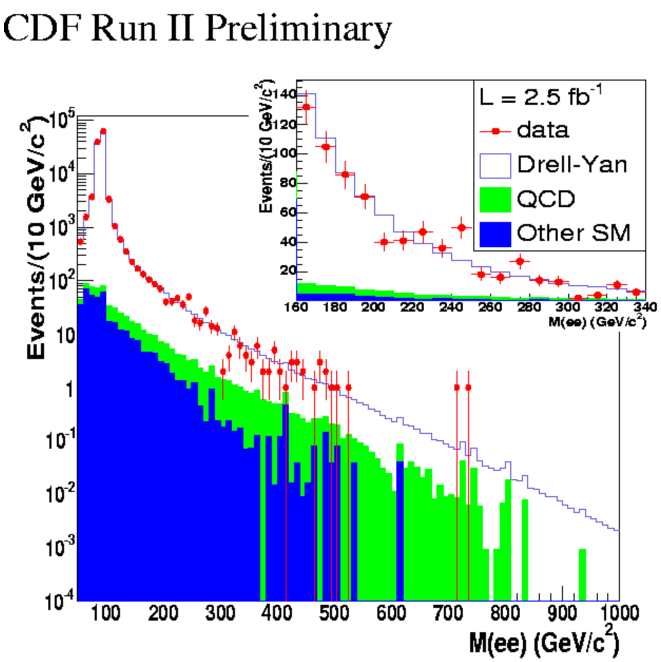


Individual searches approaching "interesting" range $\tan\beta < m_t/m_b$~35.
Combination underway.

Non-SUSY Searches

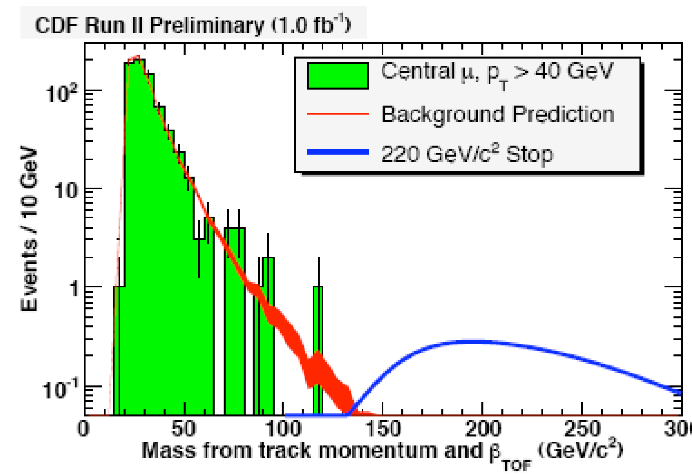
Di-lepton invariant mass distributions probes:

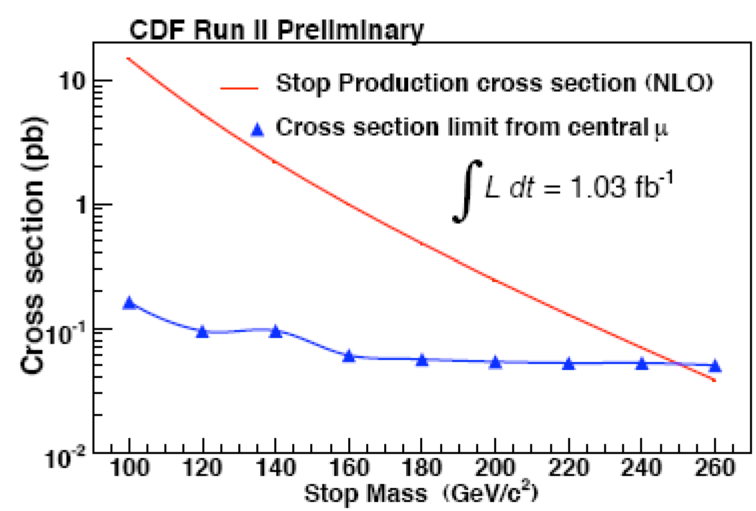
- New Z' gauge bosons: expected in many beyond-SM scenarios (GUTs, etc).
- Extra-dimensions (large, Randall-Sundrum gravitons, etc)



- Most significant excess at M(ee)~240 GeV (3.8σ). Probability for fluctuation in 150-1000 GeV range 0.6% (2.5σ).
- Observed limits ~840-966 GeV depending on Z' model.

- Quasi-model independent searches for long-lived or "stable" particles:
  - Using Time-of-Flight system (CDF) or muon timing (DØ).





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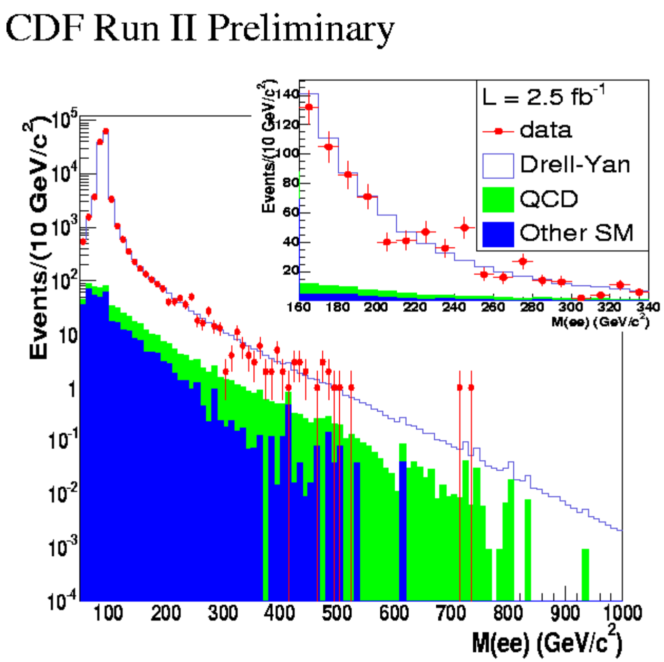

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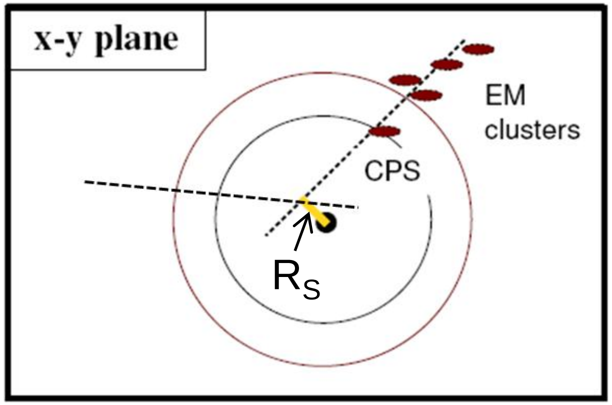
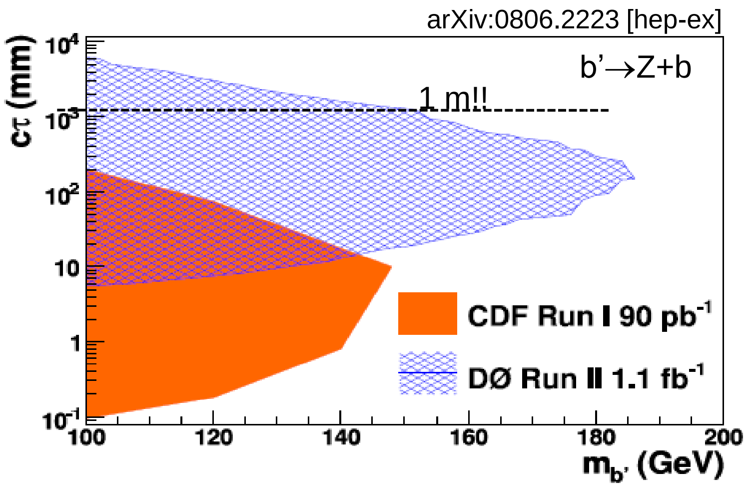
- Quasi-model independent searches for long-lived or "stable" particles:
  - Reconstructing displaced vertices with the tracking system (CDF) or the calorimeter and preshower (DØ).





SM Higgs at the Tevatron

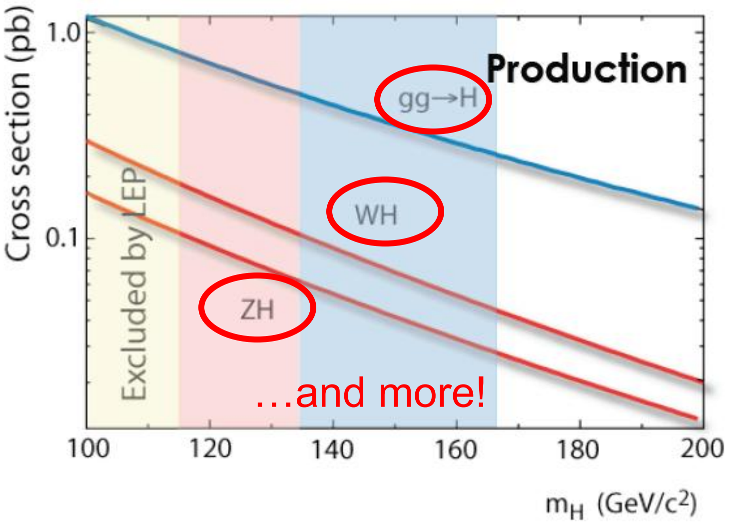
- Current experimental information (limits @ 95% CL):
  - SM LEP direct search: m_H>114.4 GeV
  - SM indirect constraint: m_H<154 GeV
    + LEP direct search: m_H<185 GeV

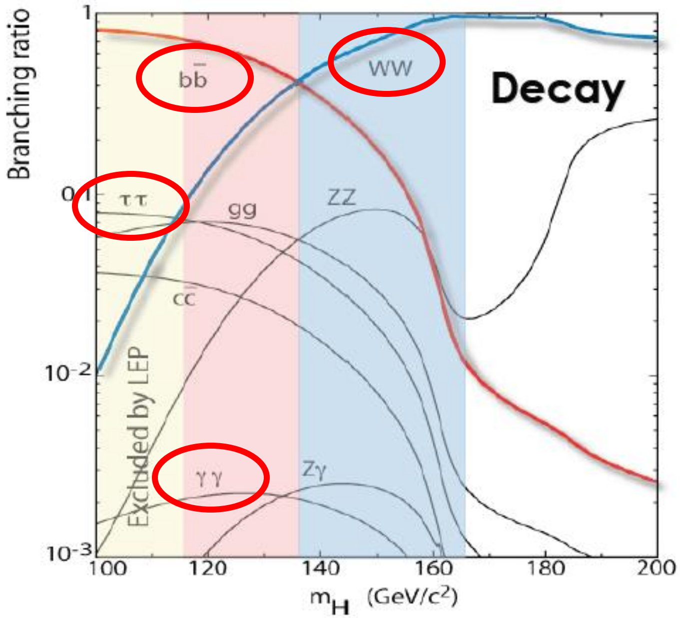
➔ Tevatron is sensitive over whole "interesting" mass range.

- Main production mechanisms (115<m_H<180 GeV):
  - Gluon fusion (gg→H): σ~0.8-0.2 pb
  - Associated production (VH, V=W,Z): σ~0.2-0.03 pb

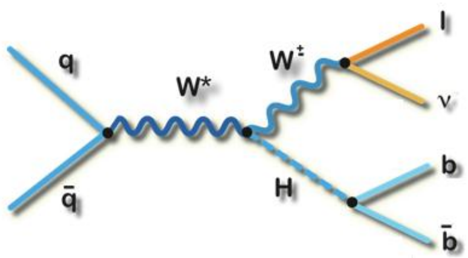
- Dominant decay channels:
  - m_H<135 GeV: H→bb
  - m_H>135 GeV: H→WW$^{(*)}$

- Search strategy:
  - Low mass region:
    dominated by WH→lνbb, ZH →l^+l^-bb, ZH→ννbb
  - High mass region:
    dominated by gg→H→WW$^{(*)}$→ l^+νl'$^-$ν
  - Complement with many other channels:
    VBF production, VH→qqbb, H→ττ(with 2jets), H→γγ, WH->WWW, ttH,…





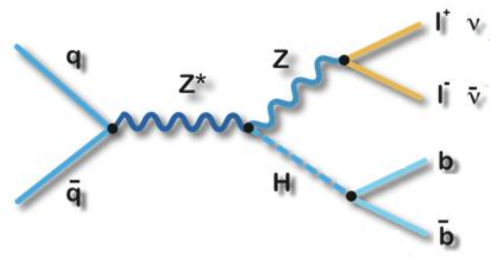
SM Low Mass Higgs



1 high p_T lepton

MET

2 b-jets



2 high p_T leptons / High MET

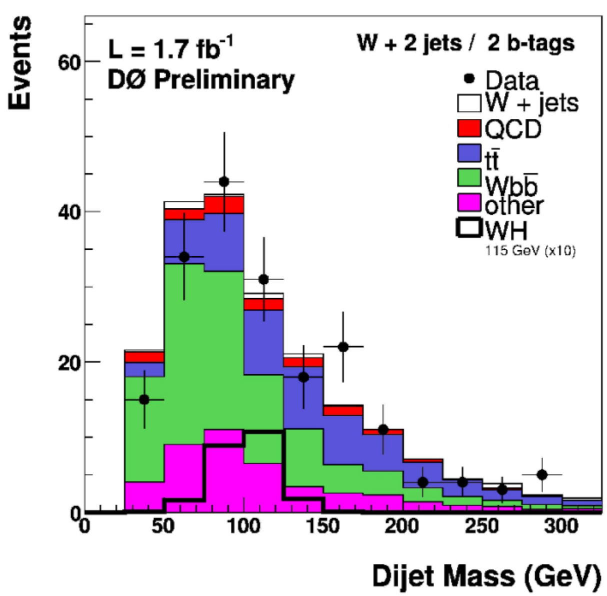
2 b-jets / 2 b-jets

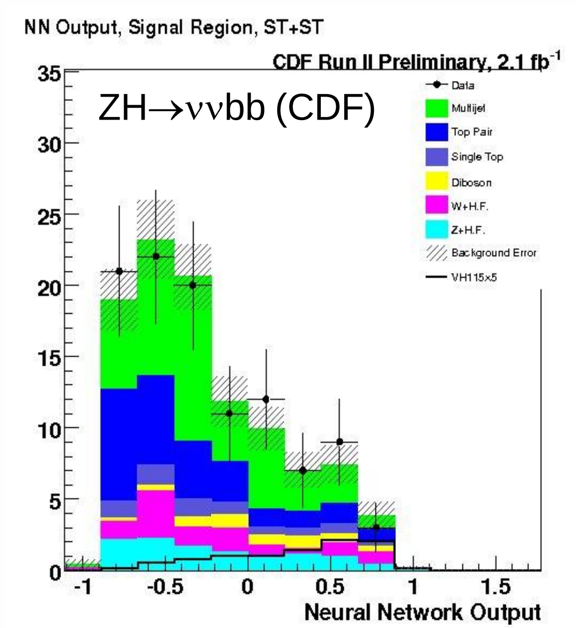
Key issues:

- Lepton identification
- B-tagging performance
- Dijet mass resolution
- Background modeling
  - W/Z+heavy-flavor jets
  - Multijets ($ZH \to \nu\nu bb$)
- All analyses use multivariate techniques for signal-to-bckg discrimination.

95%CL Limits at m_H = 115 GeV

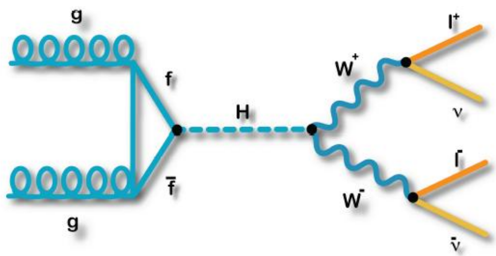
Analysis	Lum (fb^{-1})	Limit (σ/SM) Exp.	Limit (σ/SM) Obs.
$WH \to l\nu bb$ (CDF)	2.7	4.8	5.6
$WH \to l\nu bb$ (DØ)	2.7	6.4	6.7
$ZH \to \nu\nu bb$ (CDF)	2.1	5.6	6.9
$ZH \to \nu\nu bb$ (DØ)	2.1	8.4	7.5
$ZH \to l^+l^-bb$ (CDF)	2.7	9.9	7.1
$ZH \to l^+l^-bb$ (DØ)	2.3	12.3	11.0





Best individual channels have expected limits ~5-6xSM

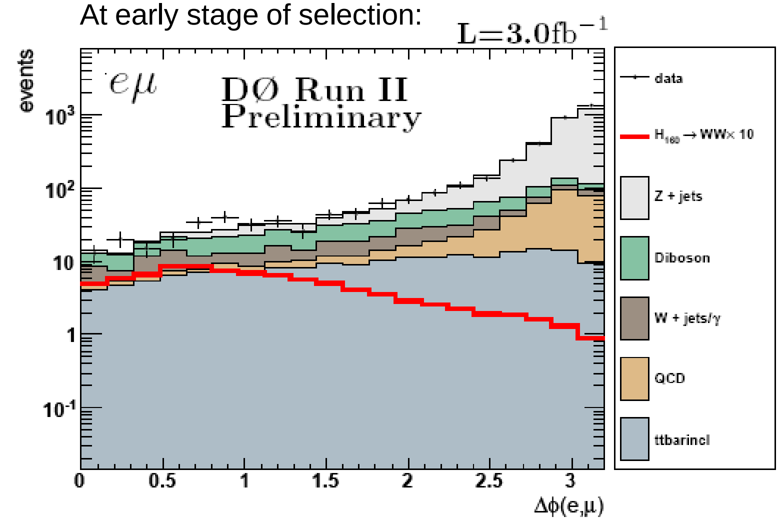
SM High Mass Higgs



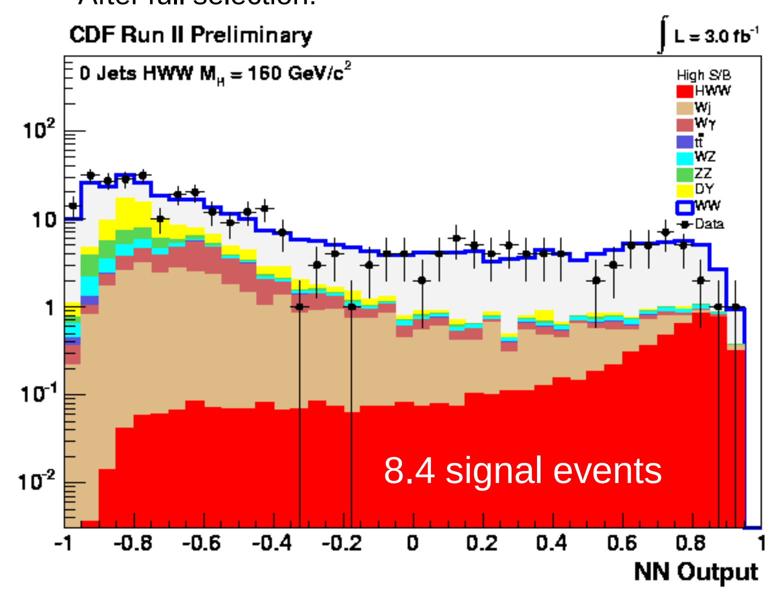
ee, μμ, eμ

- Highest sensitivity channel for m_H>130 GeV.
- Main backgrounds:
  - m_H~160 GeV: WW
  - m_H~130 GeV: W+jets
- Low $\Delta\phi$(l,l) because of spin-0 Higgs.
- Capitalize on improvements in lepton identification and multivariate techniques.

At early stage of selection:



After full selection:

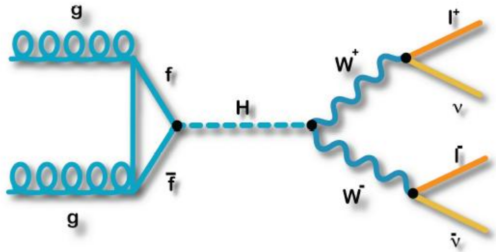


95%CL Limits at m_H = 165 GeV

Analysis	Lum (fb^{-1})	Higgs Events	Limit (σ/SM)	
			Exp.	Obs.
CDF	3.0	17.2	1.6	1.7
DØ	3.0	15.6	1.9	2.0

Both experiments approaching SM sensitivity!

SM High Mass Higgs



ee, μμ, eμ

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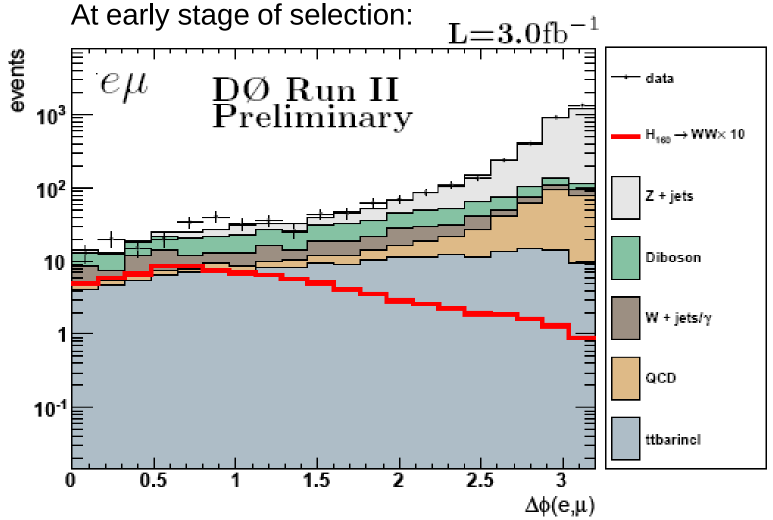

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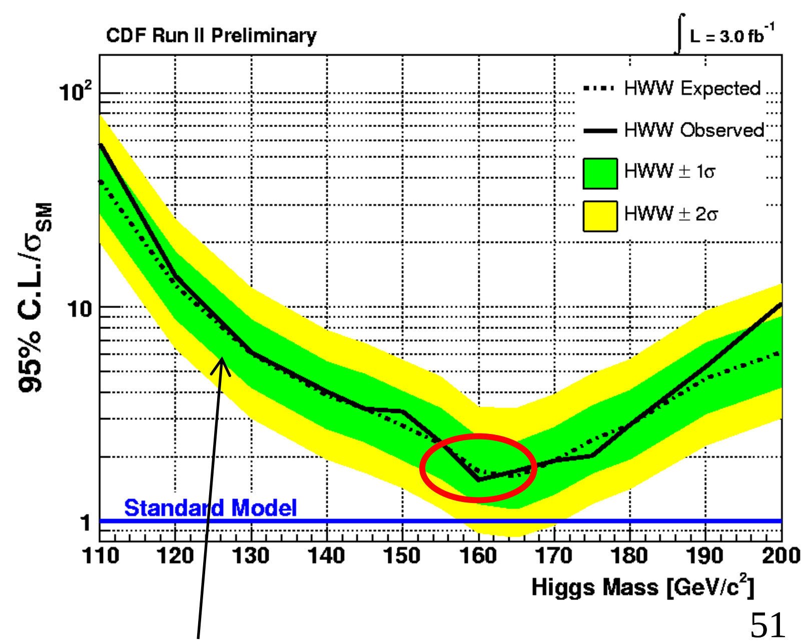
- Low $\Delta\phi$(l,l) because of spin-0 Higgs.
- Capitalize on improvements in lepton identification and multivariate techniques



95%CL Limits at m_H = 165 GeV

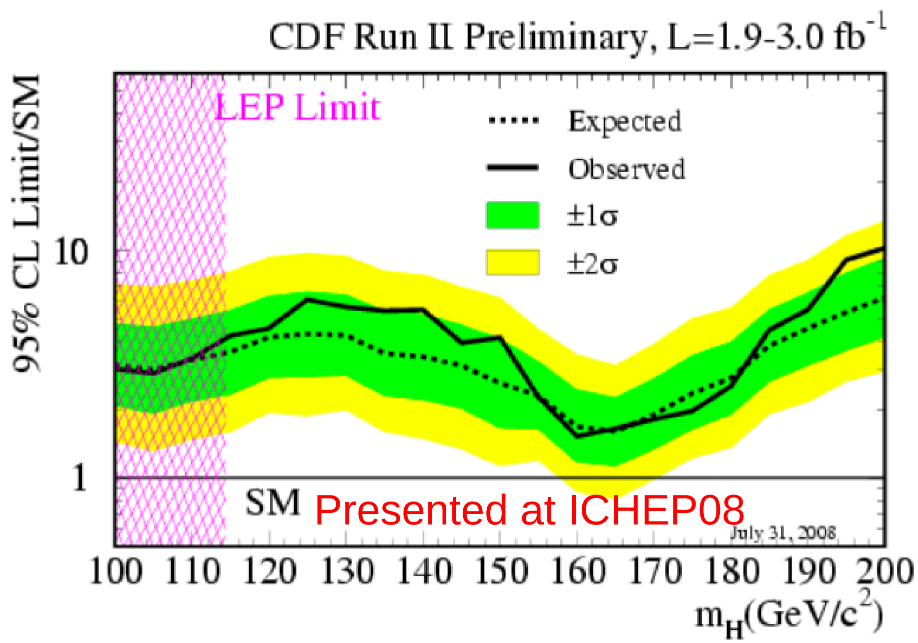
Analysis	Lum (fb^{-1})	Higgs Events	Limit (σ/SM)	
			Exp.	Obs.
CDF	3.0	17.2	1.6	1.6
DØ	3.0	15.6	1.9	2.0

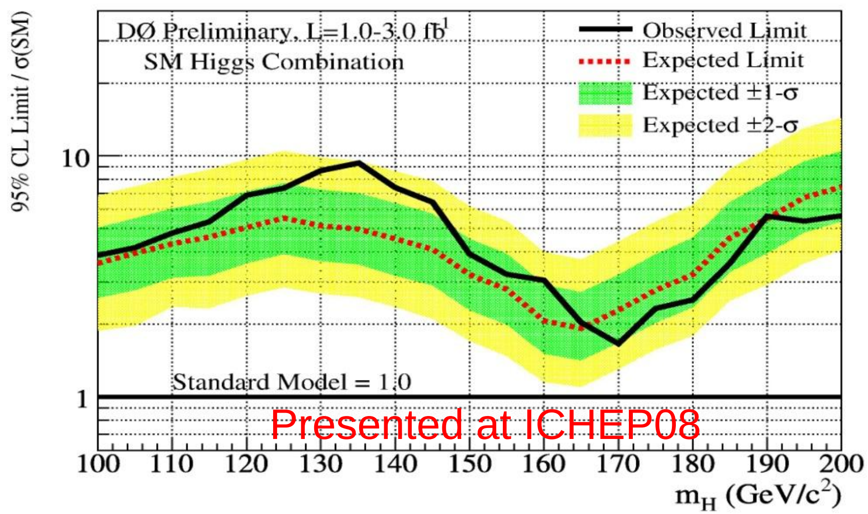
Both experiments approaching SM sensitivity!

Significant sensitivity at low mass as well!

SM Higgs Combined Limits

- Calculation of limits and combination:
  - Using Bayesian and CLs approaches.
  - Incorporate systematic uncertainties (including correlations) using pseudo-experiments.
  - Some uncertainties are effectively constrained by data.





At m_H = 115 GeV:

Exp. limit: 3.6 x SM
Obs. limit: 4.2 x SM

At m_H = 165 GeV:

Exp. limit: 1.6 x SM
Obs. limit: 1.6 x SM

At m_H = 115 GeV:

Exp. limit: 4.6 x SM
Obs. limit: 5.3 x SM

At m_H = 165 GeV:

Exp. limit: 1.9 x SM
Obs. limit: 2.0 x SM

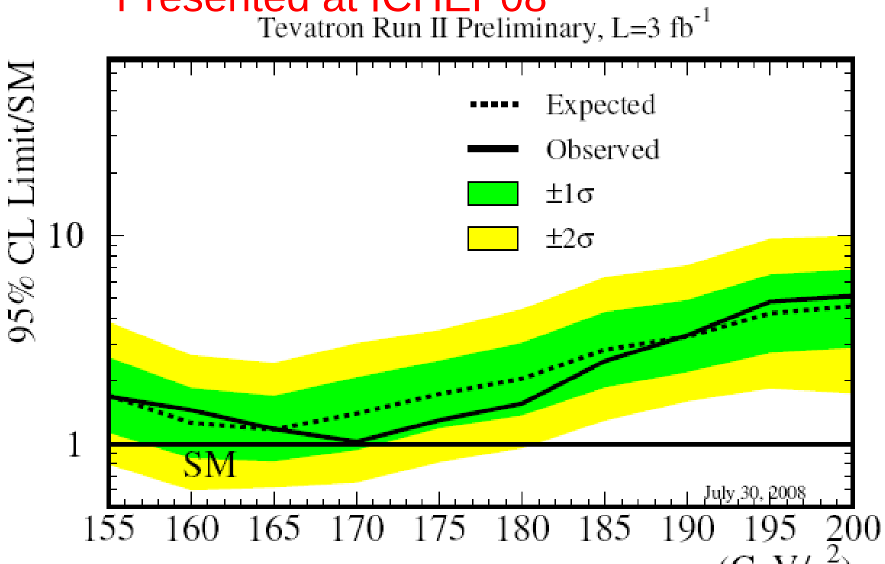
Tevatron SM Higgs Combination

Excluded m_H = 170 GeV @ 95% CL

95%CL Limits/SM

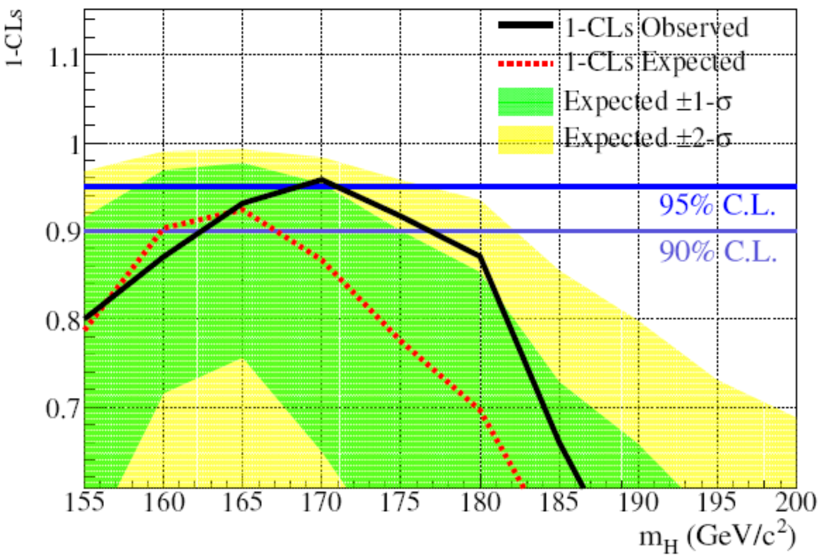
M_Higgs(GeV)	160	165	**170**	175
Method 1: Exp	1.3	1.2	1.4	1.7
Method 1: Obs	1.4	1.2	**1.0**	1.3
Method 2: Exp	1.2	1.1	1.3	1.7
Method 2: Obs	1.3	1.1	**0.95**	1.2

Presented at ICHEP08



arXiv:0808.0534 [hep-ex]

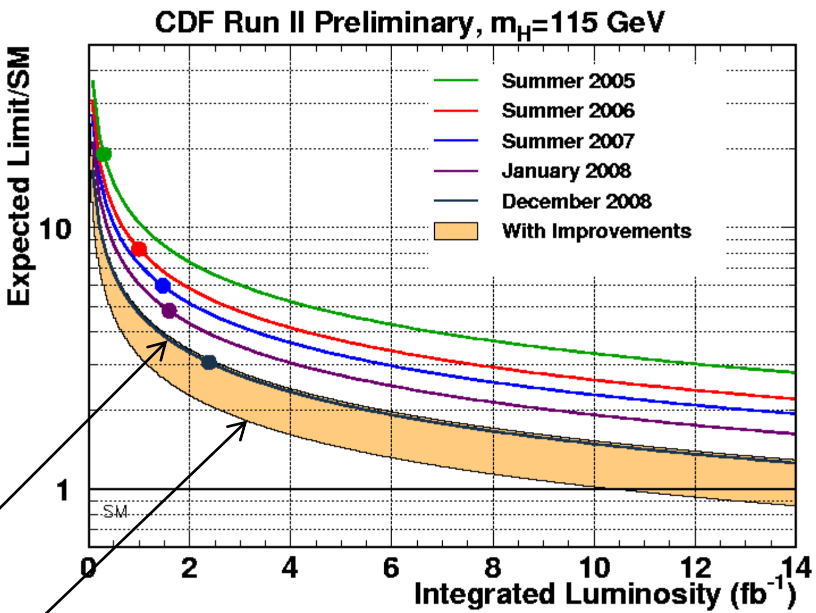
Presented at ICHEP08



- First direct exclusion since LEP II.
- Verified using two independent methods (CLs, Bayesian).
- Low mass Tevatron combination not available as of ICHEP08:
  - Challenging owing to the large number of channels (~70).
  - Expected sensitivity: < 3.0xSM @ m_H=115 GeV.
- Tevatron combination by Moriond 2009: stay tuned!

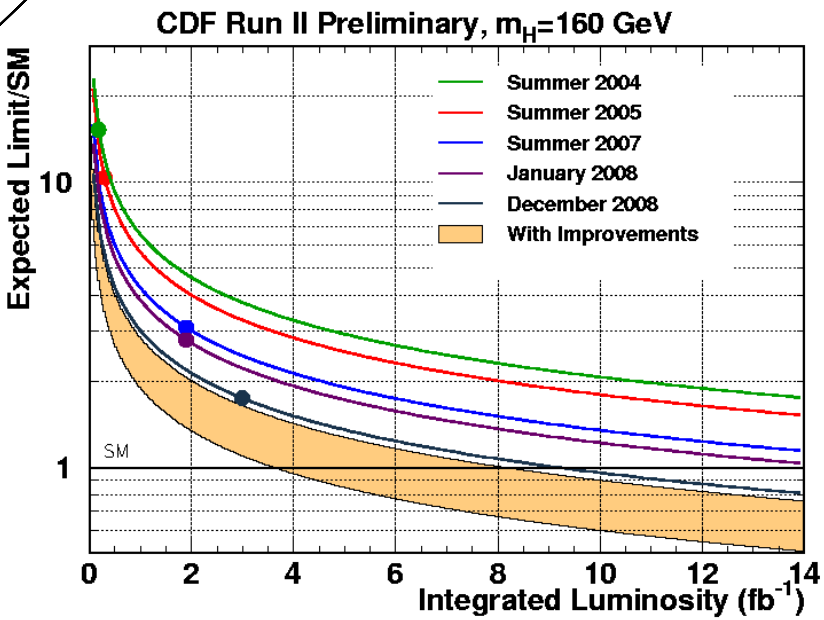
SM Higgs Prospects

- Limits have improved faster than 1/√L due to analysis improvements.
- Major effort underway to continue to improve sensitivity:
  - Optimized object identification/resolution
  - Optimized selections and signal-to-bckg discrimination
  - Reduced systematic uncertainties
  - Adding new channels
  - Adding more data!



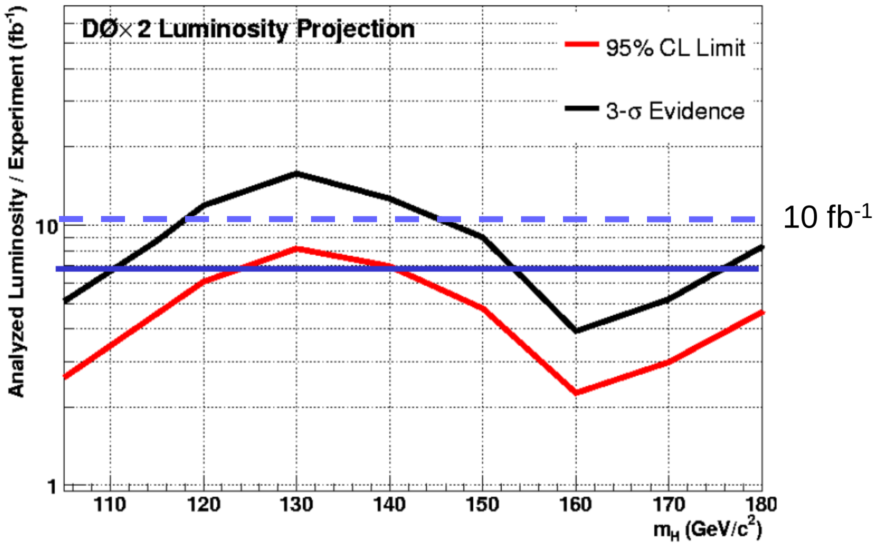
x1.5 improvement relative to Summer 2007

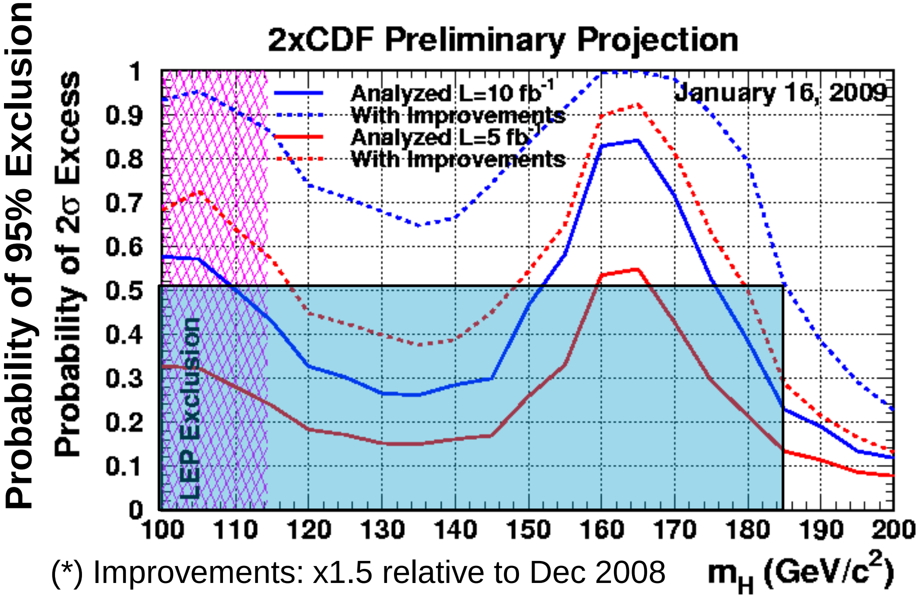
x2.25 improvement relative to Summer 2007



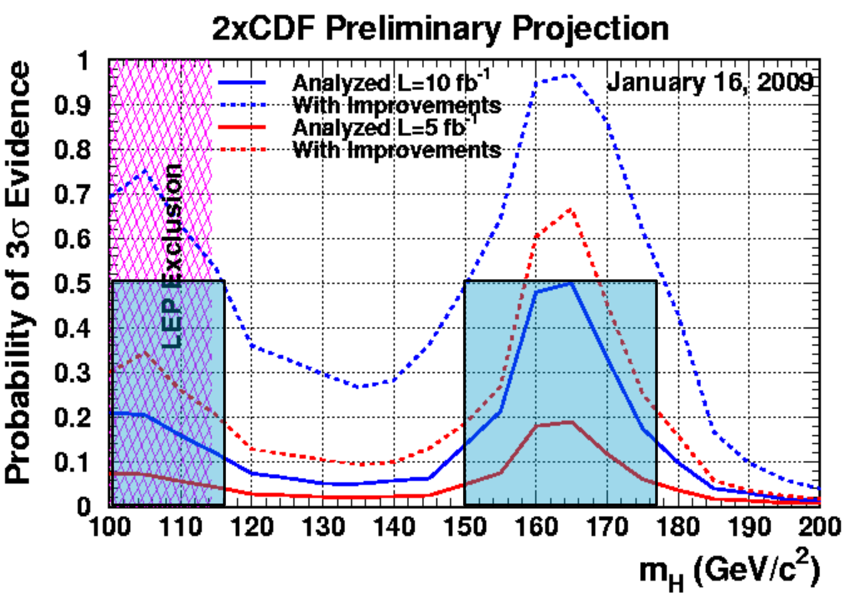
SM Higgs Prospects

- Median projected reach as a function of analyzed (=0.8 x delivered) integrated luminosity:
  ** Does NOT include current observed limit **
  With 10 fb^{-1} /experiment:
  - Exclude at 95% CL for m_H<185 GeV.
  - 3σ evidence at low and high mass.
  - There is a band of possibilities around these lines.





(*) Improvements: x1.5 relative to Dec 2008

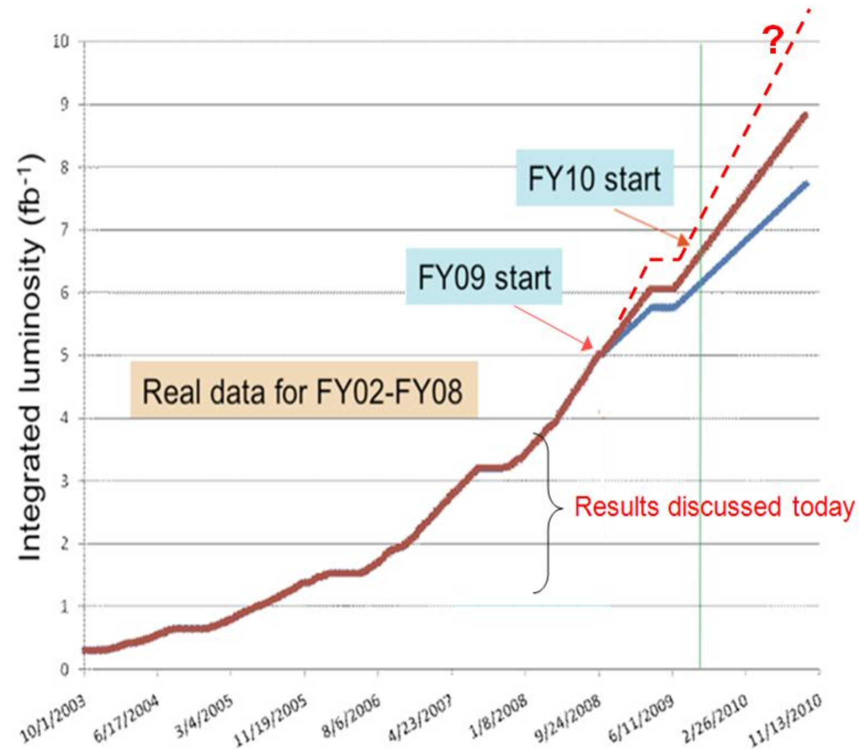


➔ Tevatron complements LHC at low mass.

Conclusions

- Run II physics program in full swing.
- Excellent performance of the accelerator and CDF and DØ detectors. Collaboration strengths sufficient to carry out program.
- Expect >10 fb^{-1} by the end of the run. Analyzed luminosity will increase by a factor of ~2.5-10.
  Physics reach further expanded by analysis improvements.
- Expect significant statements from the Tevatron on precision measurements and the Higgs search.
  Prospects for discoveries remain open.
- Continue to establish benchmarks in analysis techniques for the LHC era.

In a way we are “just getting started”…



For more information:

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

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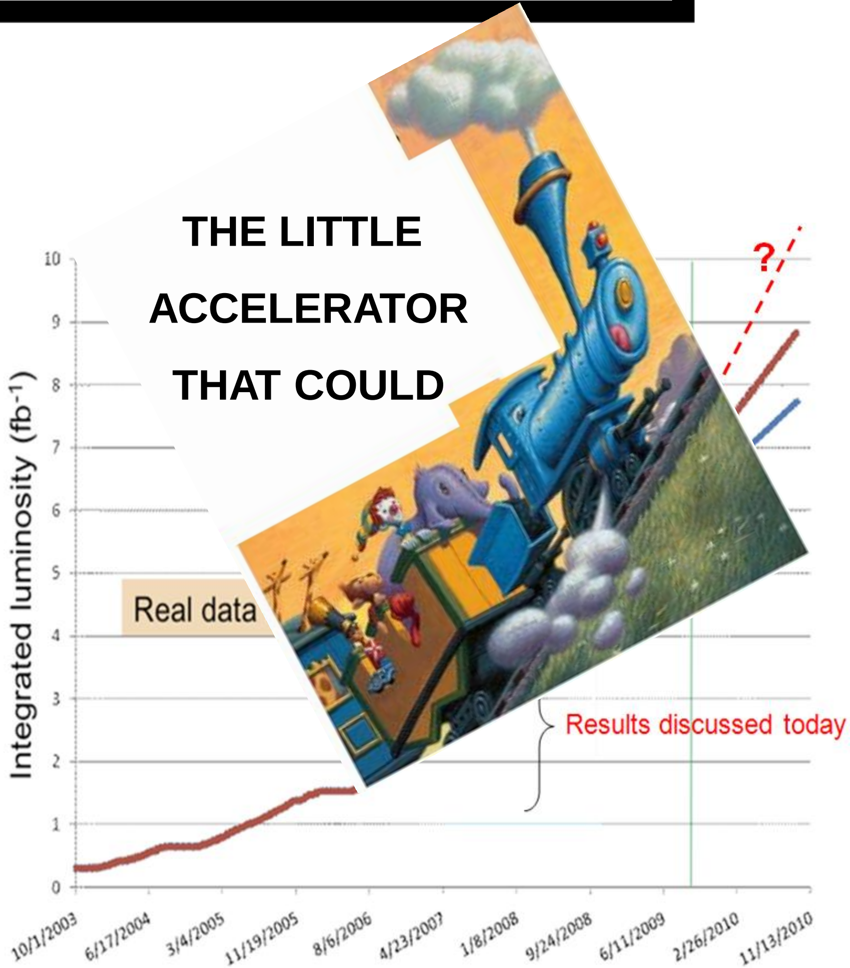
- Expect significant statements from the Tevatron on precision measurements and the Higgs search.
  Prospects for discoveries remain open.
- Continue to establish benchmarks in analysis techniques for the LHC era.
- Exciting prospects for concurrent analysis of Tevatron and LHC data!



For more information:

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Backup

Multi-Muon Events at CDF

- Observe a larger-than-expected yield of muons with large impact parameter (outside the 1.5 cm radius beam pipe) in a sample collected with a dimuon trigger.
- These events are referred to as "ghost events", and disappear when making tight requirements on silicon tracking.
- Only ~50% of events can be explained based on standard sources (long-lived particles, punch-through, in-flight decays, interactions with material, etc).
- A significant fraction of "ghost events" contain more additional muons (and tracks) in a cone around the trigger muon than predicted:
  - Impact parameter of muons consistent with originating from decay of a particle with τ~20 ps.
  - Also different kinematic properties than expected from standard sources.

- The source of this excess is currently not understood.

FERMILAB-PUB-08-046-E

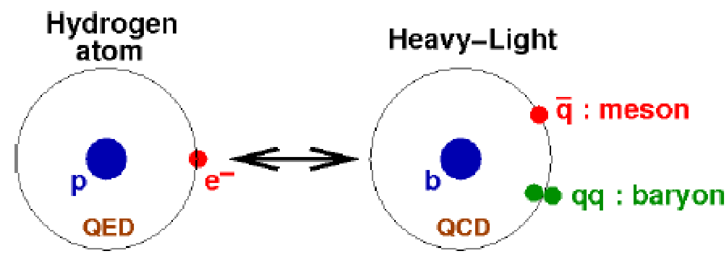
Study of multi-muon events produced in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV

T. Aaltonen,[21] J. Adelman,[11] B. Álvarez González,[9] S. Amerio[z],[35] D. Amidei,[28] A. Anastassov,[31] J. Antos,[12] G. Apollinari,[15] A. Apresyan,[39] T. Arisawa,[44] A. Artikov,[13] W. Ashmanskas,[15] P. Azzurri[aa],[37] W. Badgett,[15] B.A. Barnett,[23] V. Bartsch,[25] D. Beecher,[25] S. Behari,[23] G. Bellettini[y],[37] D. Benjamin,[14] I. Bizjak[dd],[25] C. Blocker,[6] B. Blumenfeld,[23] A. Bocci,[14] V. Boisvert,[40] G. Bolla,[39] D. Bortoletto,[39] J. Boudreau,[38] A. Bridgeman,[22] L. Brigliadori,[35] C. Bromberg,[29] E. Brubaker,[11] J. Budagov,[13] H.S. Budd,[40] S. Budd,[22] S. Burke,[15] K. Burkett,[15] G. Busetto[z],[35] P. Bussey[k],[19] K. L. Byrum,[2] S. Cabrera[u],[14] C. Calancha,[26] M. Campanelli,[29] F. Canelli,[15] B. Carls,[22] R. Carosi,[37] S. Carrillo[m],[16] B. Casal,[9] M. Casarsa,[15] A. Castro[w],[5] P. Catastini[z],[37] D. Cauz[cc],[42] V. Cavaliere[z],[37] S.H. Chang,[24] Y.C. Chen,[1] M. Chertok,[7] G. Chiarelli,[37] G. Chlachidze,[15] K. Cho,[24] D. Chokheli,[13] J.P. Chou,[20] K. Chung,[10] Y.S. Chung,[40] C.I. Ciobanu,[36] M.A. Ciocci[z],[37] A. Clark,[18] D. Clark,[6] G. Compostella,[35] M.E. Convery,[15] J. Conway,[7] M. Cordelli,[17] G. Cortiana[z],[35] C.A. Cox,[7] D.J. Cox,[7] F. Crescioli[y],[37] C. Cuenca Almenar[u],[7] J. Cuevas[r],[9] J.C. Cully,[28] D. Dagenhart,[15] M. Datta,[15] T. Davies,[19] P. de Barbaro,[40] M. Dell'Orso[y],[37] L. Demortier,[41] J. Deng,[14] M. Deninno,[5] G.P. di Giovanni,[36] B. Di Ruzza[cc],[42] J.R. Dittmann,[4] S. Donati[y],[37] J. Donini,[35] T. Dorigo,[35] J. Efron,[32] R. Erbacher,[7] D. Errede,[22] S. Errede,[22] R. Eusebi,[15] W.T. Fedorko,[11] J.P. Fernandez,[26] R. Field,[16] G. Flanagan,[39] R. Forrest,[7] M.J. Frank,[4] M. Franklin,[20] J.C. Freeman,[15] I. Furic,[16] M. Gallinaro,[41]

- Investigations continue at CDF.
- Check at DØ underway.

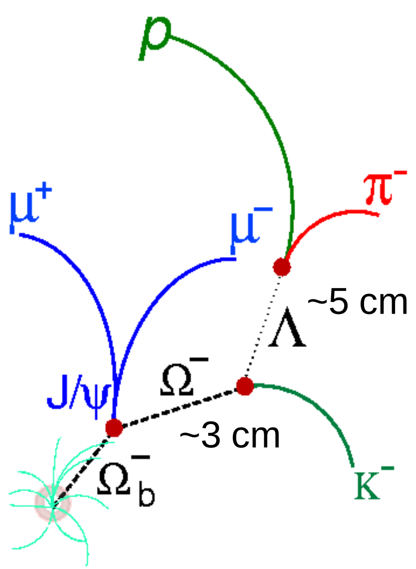
Study of New Heavy b-Baryons

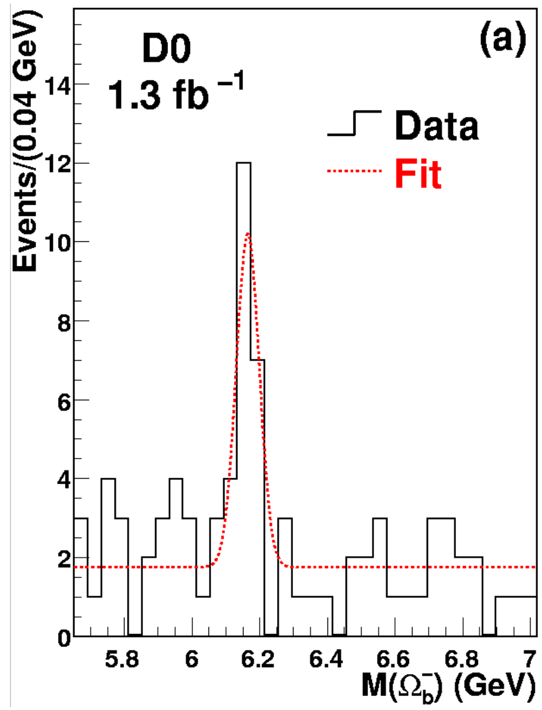
- Heavy quark hadrons are the "hydrogen atom" of QCD and b hadrons offer the heavier quarks in bound systems
  ➔ Very sensitive tests of potential models, HQET, lattice gauge calculations…
- Have added to Λ_b(udb) (seen in UA1):
  $\Sigma_b^{\pm}$, $\Sigma_b^{*\pm}$ (uub,ddb), Ξ_b^-(dsb), Ω_b^-(ssb).



Observation of the Ω_b^-

PRL 101, 232002 (2008)





17.8 ± 4.9 (stat) ± 0.8 (syst) events

Mass: 6.165 ± 0.010(stat) ± 0.013(syst) GeV

Significance: 5.4σ

$$\frac{f(b\to\Omega_b^-)Br(\Omega_b^-\to J/\psi\,\Omega^-)}{f(b\to\Xi_b^-)Br(\Xi_b^-\to J/\psi\,\Xi^-)} = 0.80 \pm 0.32(stat)^{+0.14}_{-0.22}(syst)$$

What will be the next discovery?

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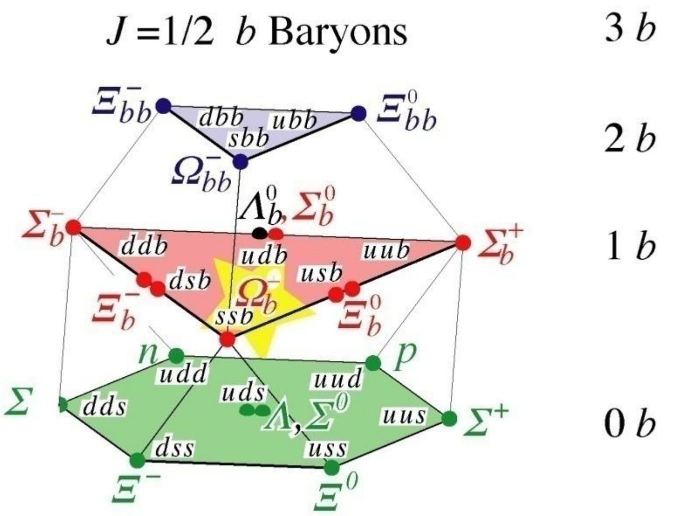

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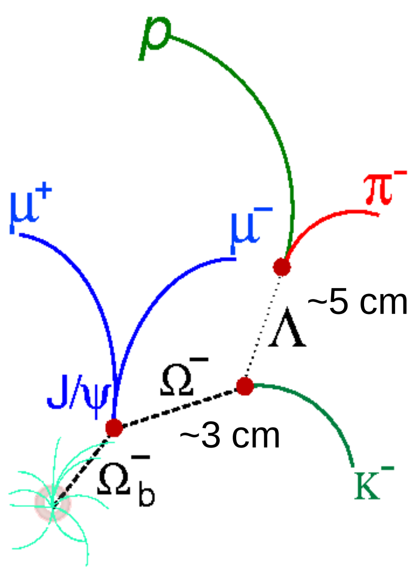

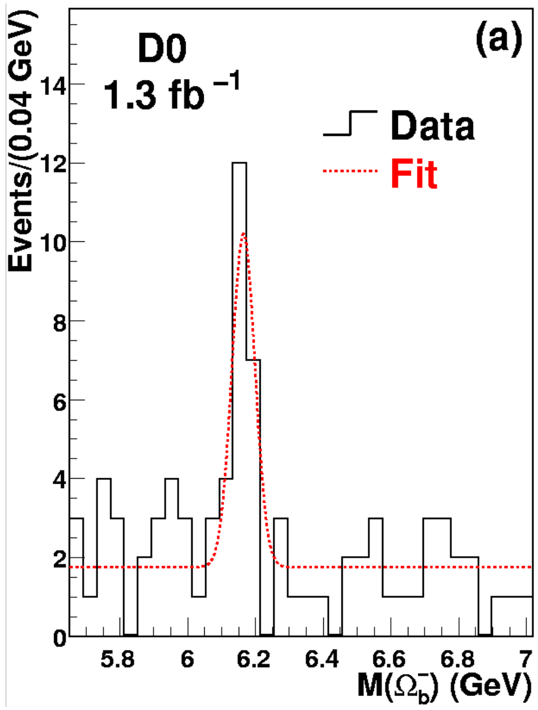

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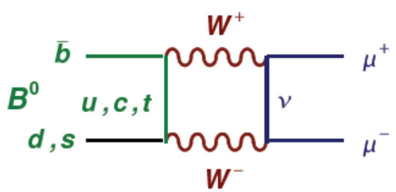
What will be the next discovery?

Rare Decays

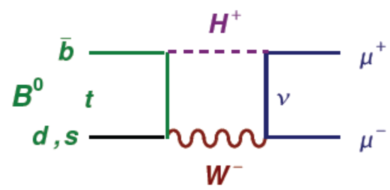
- Rare decays very sensitive to New Physics. Large b production rate and high luminosity open a window of opportunity at the Tevatron.

- **FCNC $B_{s/d}$ decays**:

SM



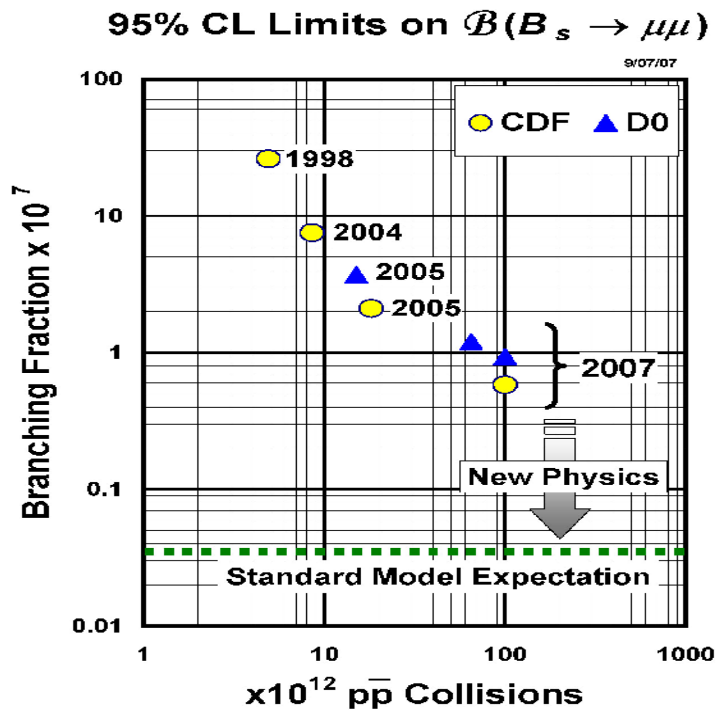
NP



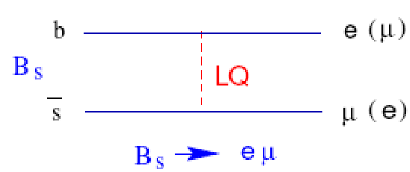
SM: BR($B_s \to \mu\mu$) ~3.8×10^{-9}

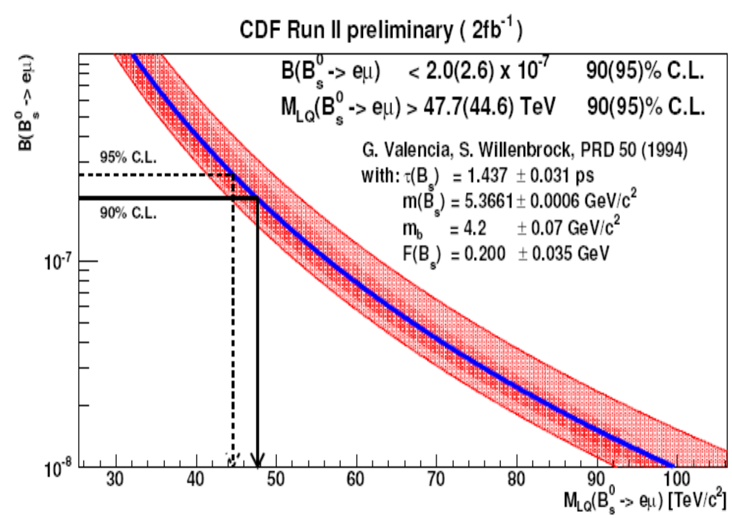
MSSM/2HDM: SM x $\tan^N\beta$ (N=6,4)!!

CDF (2 fb^{-1}): <5.8×10^{-8} (~15xSM) @ 95% CL



- **Flavor-violating $B_s \to e\mu$ decays:**
  - Forbidden in the SM.
  - Sensitivity to very large mass scales.





Limits on B_d competitive with B factories.

Unique limits on B_s.