Searches for Physics Beyond the Standard Model at the Tevatron

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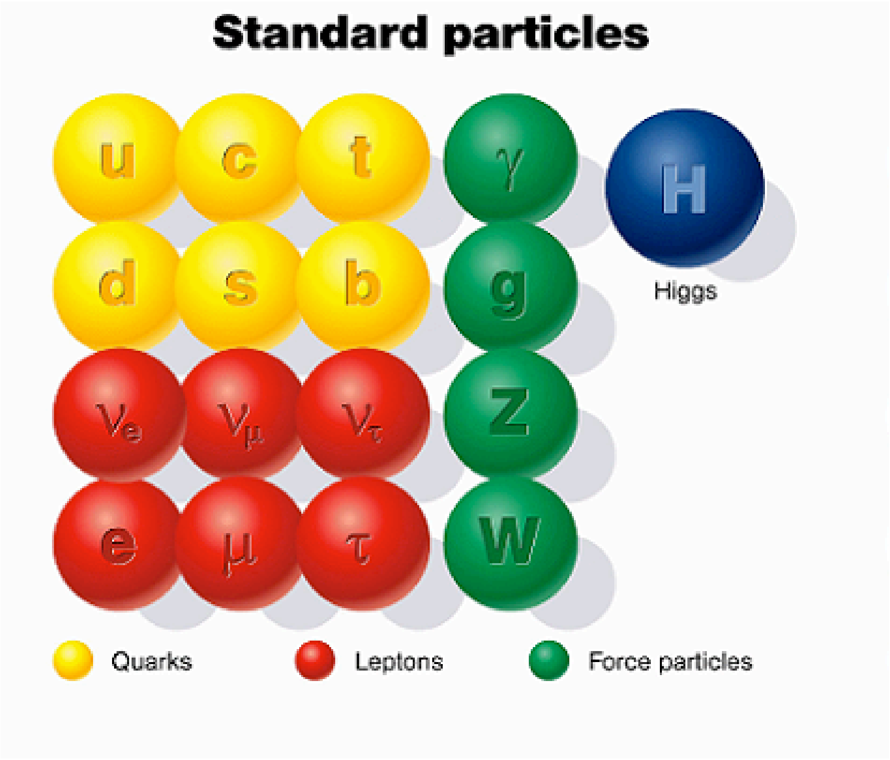
Oxford University

NExT Meeting

Rutherford Appleton Laboratory

26 January 2011

What We Search For



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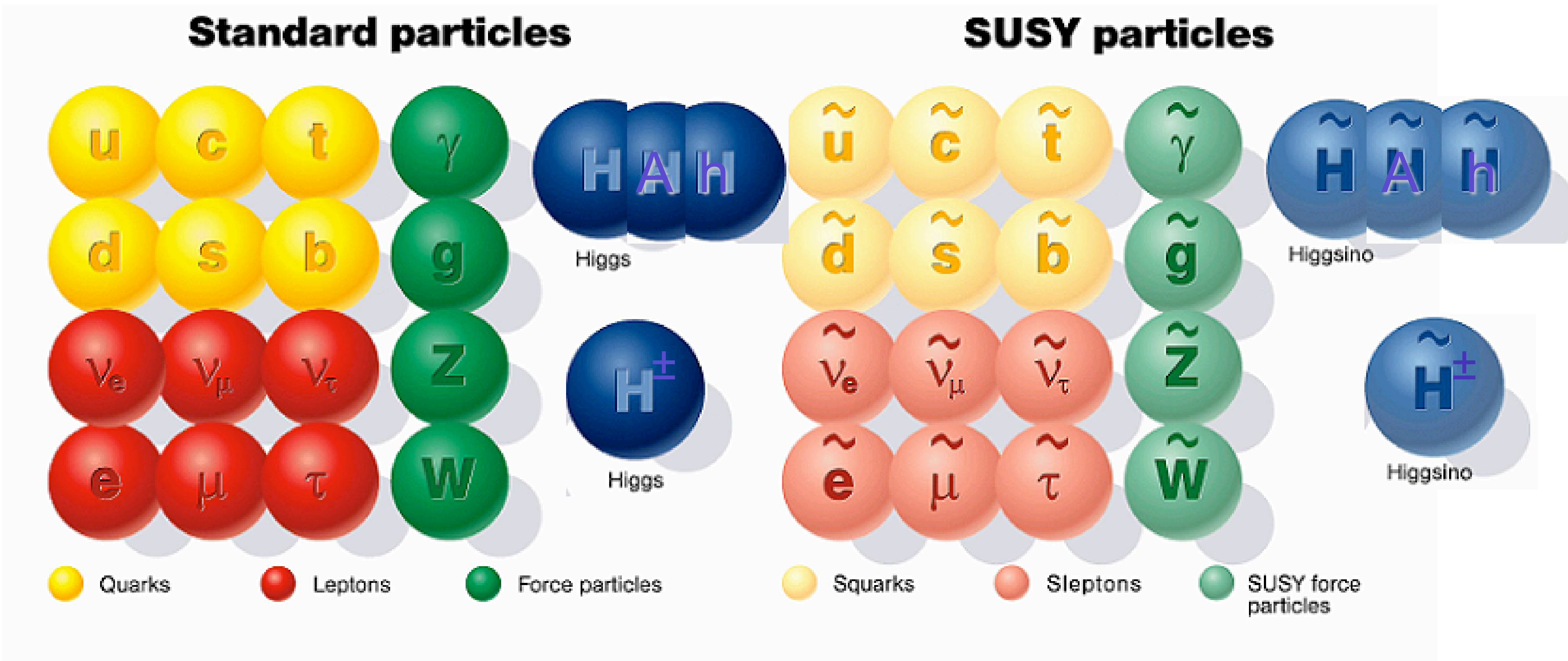
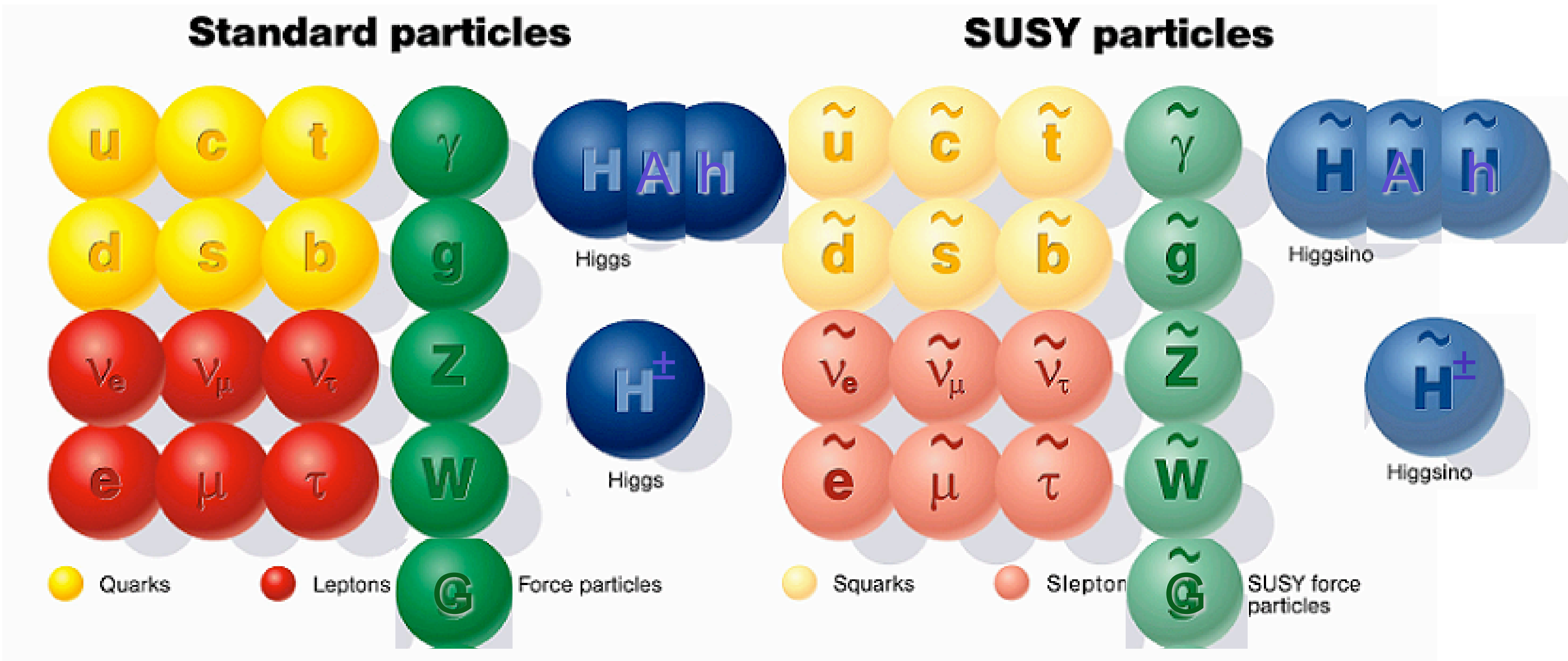


Supersymmetry

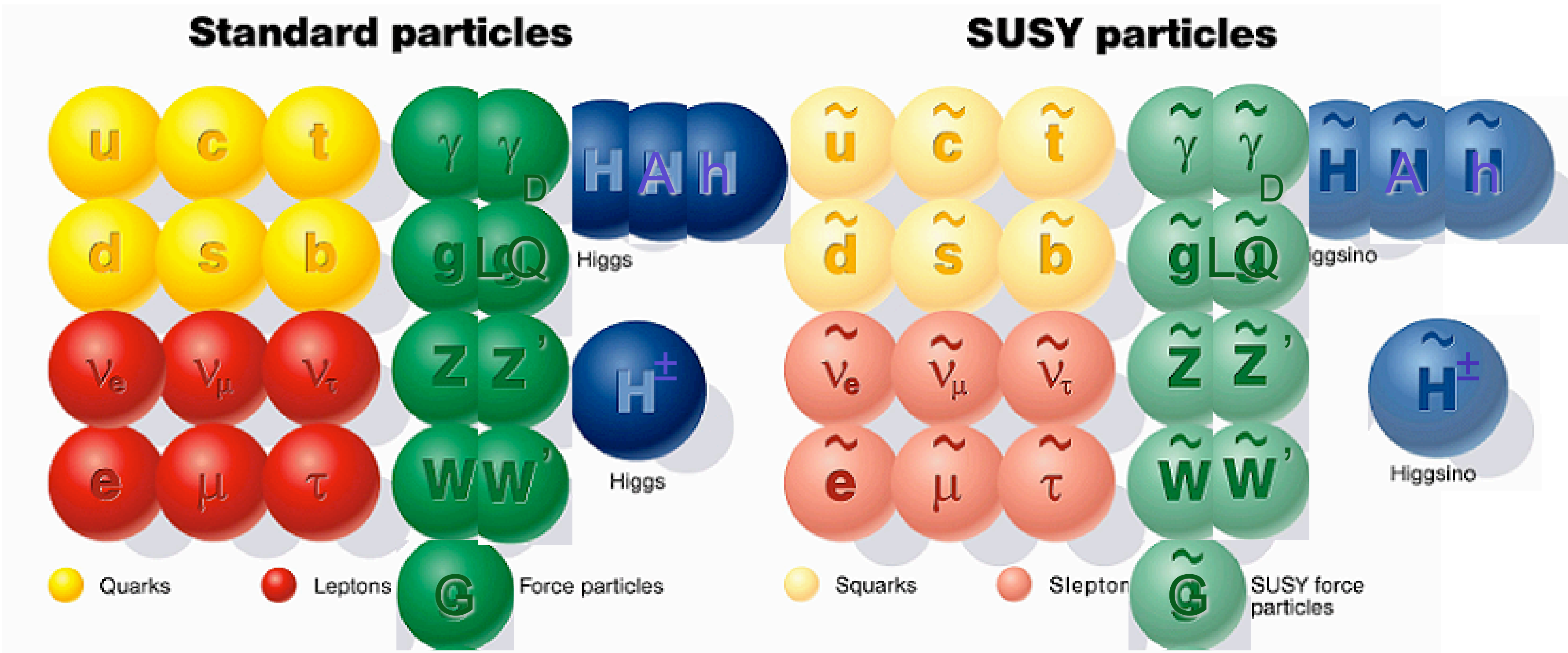
What We Search For



Supersymmetry

Gravitons and extra dimensions

What We Search For

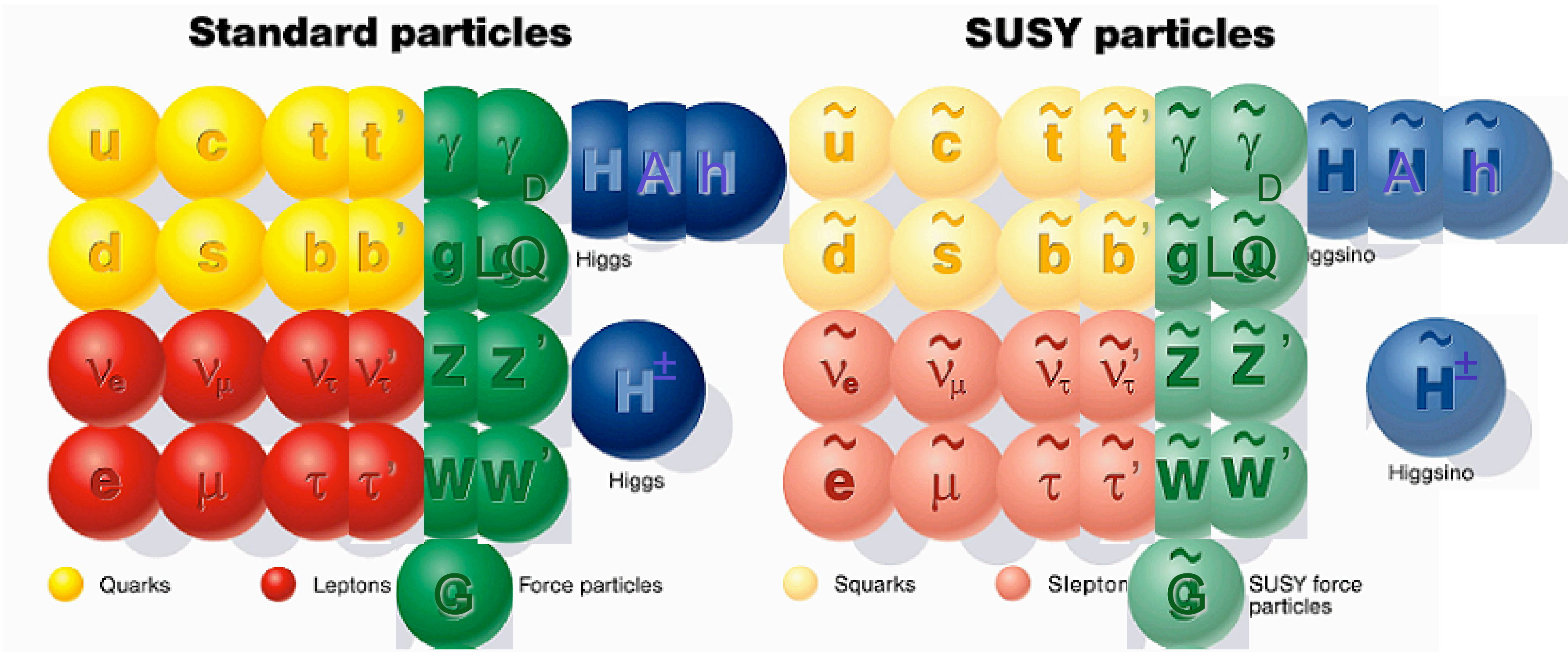


Supersymmetry

Gravitons and extra dimensions

New gauge bosons

What We Search For



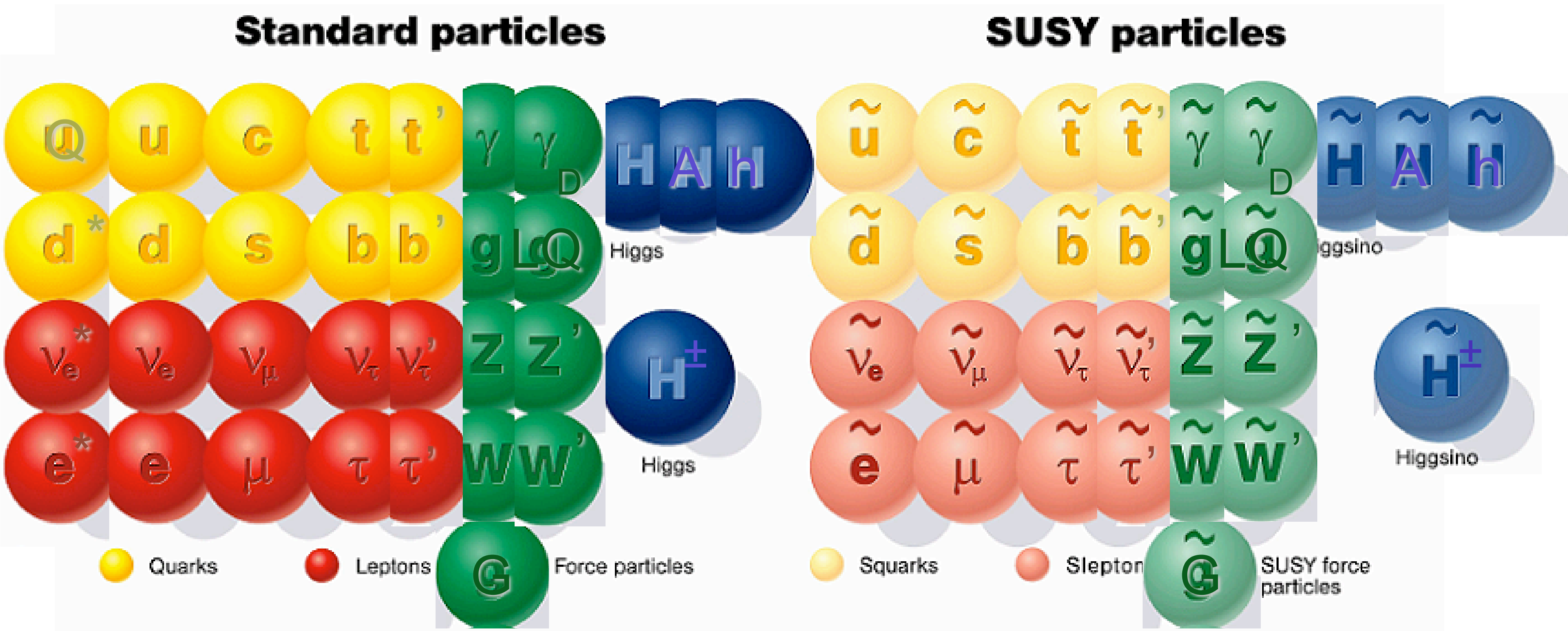
Fourth generation

Supersymmetry

Gravitons and extra dimensions

New gauge bosons

What We Search For



Fourth generation

Supersymmetry

Gravitons and extra dimensions

Exotic fermions

New gauge bosons

Where We Search

CDF Run II Preliminary (2.0 fb^{-1})
The calculation of σ accounts for the trials factor

Final State	Data	Background	σ
$be^{\pm}\not{p}$	690	817.7 ± 9.2	−2.7
$\gamma\tau^{\pm}$	1371	1217.6 ± 13.3	+2.2
$\mu^{\pm}\tau^{\pm}$	63	35.2 ± 2.8	+1.7
$b2j\not{p}$ high-Σp_T	255	327.2 ± 8.9	−1.7
$2j\tau^{\pm}$ low-Σp_T	574	670.3 ± 8.6	−1.5
$3j\tau^{\pm}$ low-Σp_T	148	199.8 ± 5.2	−1.4
$e^{\pm}\not{p}\tau^{\pm}$	36	17.2 ± 1.7	+1.4
$2j\tau^{\pm}\tau^{\mp}$	33	62.1 ± 4.3	−1.3
$e^{\pm}j$	741710	764832 ± 6447.2	−1.3
$j2\tau^{\pm}$	105	150.8 ± 6.3	−1.2
$e^{\pm}2j$	256946	249148 ± 2201.5	+1.2
$2bj$ low-Σp_T	279	352.5 ± 11.9	−1.1
$j\tau^{\pm}$ low-Σp_T	1385	1525.8 ± 15	−1.1
$2b2j$ low-Σp_T	108	153.5 ± 6.8	−1
$b\mu^{\pm}\not{p}$	528	613.5 ± 8.7	−0.9
$\mu^{\pm}\gamma\not{p}$	523	611 ± 12.1	−0.8
$2b\gamma$	108	70.5 ± 7.9	+0.1
$8j$	14	13.1 ± 4.4	0
$7j$	103	97.8 ± 12.2	0
$6j$	653	659.7 ± 37.3	0
$5j$	3157	3178.7 ± 67.1	0
$4j$ high-Σp_T	88546	89096.6 ± 935.2	0
$4j$ low-Σp_T	14872	14809.6 ± 186.3	0
$4j2\gamma$	46	46.4 ± 3.9	0
$4j\tau^{\pm}$ high-Σp_T	29	26.6 ± 1.7	0
$4j\tau^{\pm}$ low-Σp_T	43	63.1 ± 3.3	0
$4j\not{p}$ high-Σp_T	1064	1012 ± 62.9	0
$4j\gamma\tau^{\pm}$	19	10.8 ± 2	0
$4j\gamma\not{p}$	62	104.2 ± 22.4	0
$4j\gamma$	7962	8271.2 ± 245.1	0
$4j\mu^{\pm}\not{p}$	574	590.5 ± 13.6	0
$4j\mu^{\pm}\mu^{\mp}$	38	48.4 ± 6.2	0
$4j\mu^{\pm}$	1363	1350.1 ± 37.7	0
$3j$ high-Σp_T	159926	159143 ± 1061.9	0
$3j$ low-Σp_T	62681	64213.1 ± 496	0
$3j2\gamma$	151	177.5 ± 7.1	0
$3j\tau^{\pm}$ high-Σp_T	68	76.9 ± 3	0
$3j\not{p}$ high-Σp_T	1706	1899.4 ± 77.6	0
$3j\not{p}$ low-Σp_T	42	36.2 ± 5.7	0
$3j\gamma\tau^{\pm}$	39	37.8 ± 3.6	0
$3j\gamma\not{p}$	204	249.8 ± 24.4	0
$3j\gamma$	24639	24899.4 ± 372.4	0
$3j\mu^{\pm}\not{p}$	2884	2971.5 ± 52.1	0
$3j\mu^{\pm}\gamma\not{p}$	10	3.6 ± 1.9	0
$3j\mu^{\pm}\gamma$	15	7.9 ± 2.9	0
$3j\mu^{\pm}\mu^{\mp}$	175	177.8 ± 16.2	0
$3j\mu^{\pm}$	5032	4989.5 ± 108.9	0
$3b2j$	23	28.9 ± 4.7	0
$3bj$	82	82.6 ± 5.7	0
$3b$	67	85.6 ± 7.7	0
$2\tau^{\pm}$	498	512.7 ± 14.2	0
$2\gamma\not{p}$	128	107.2 ± 6.9	0
2γ	5548	5562.8 ± 40.5	0
$2j$ high-Σp_T	190773	190842 ± 781.2	0
$2j$ low-Σp_T	165984	162530 ± 1581	0
$2j2\tau^{\pm}$	22	40.6 ± 3.2	0
$2j2\gamma\not{p}$	11	8 ± 2.4	0
$2j2\gamma$	580	581 ± 13.7	0
$2j\tau^{\pm}$ high-Σp_T	96	114.6 ± 3.3	0

Final State	Data	Background	σ
$2j\not{p}$ high-Σp_T	87	80.9 ± 6.8	0
$2j\not{p}$ low-Σp_T	114	79.5 ± 100.8	0
$2j\not{p}\tau^{\pm}$	18	13.2 ± 2.2	0
$2j\gamma\tau^{\pm}$	142	144.6 ± 5.7	0
$2j\gamma\not{p}$	908	980.3 ± 63.7	0
$2j\gamma$	71364	73021.4 ± 595.9	0
$2j\mu^{\pm}\tau^{\mp}$	16	19.3 ± 2.2	0
$2j\mu^{\pm}\not{p}$	17927	18340.6 ± 201.9	0
$2j\mu^{\pm}\gamma\not{p}$	31	27.7 ± 7.7	0
$2j\mu^{\pm}\gamma$	57	58.2 ± 13	0
$2j\mu^{\pm}\mu^{\mp}\not{p}$	11	7.8 ± 2.7	0
$2j\mu^{\pm}\mu^{\mp}$	956	924.9 ± 61.2	0
$2j\mu^{\pm}$	22461	23111.4 ± 366.6	0
$2e^{\pm}j$	14	13.8 ± 2.3	0
$2e^{\pm}e^{\mp}$	20	17.5 ± 1.7	0
$2e^{\pm}$	32	49.2 ± 3.4	0
$2b$ high-Σp_T	666	689 ± 9.4	0
$2b$ low-Σp_T	323	313.2 ± 10.3	0
$2b3j$ low-Σp_T	53	57.4 ± 6.5	0
$2b2j$ high-Σp_T	718	803.3 ± 12.7	0
$2b2j\not{p}$ high-Σp_T	15	21.8 ± 2.8	0
$2b2j\gamma$	32	39.7 ± 6.2	0
$2b2j\mu^{\pm}\not{p}$	14	17.3 ± 1.9	0
$2b2j\mu^{\pm}$	22	21.8 ± 2	0
$2b\mu^{\pm}\not{p}$	11	14.4 ± 2.1	0
$2bj$ high-Σp_T	891	967.1 ± 13.2	0
$2bj\not{p}$ high-Σp_T	25	31.3 ± 3.1	0
$2bj\gamma$	71	54.5 ± 7.1	0
$2bj\mu^{\pm}\not{p}$	12	10.7 ± 1.9	0
$2be^{\pm}2j\not{p}$	30	27.3 ± 2.2	0
$2be^{\pm}2j$	72	66.5 ± 2.9	0
$2be^{\pm}\not{p}$	22	19.1 ± 2.2	0
$2be^{\pm}j\not{p}$	19	19.4 ± 2.2	0
$2be^{\pm}j$	63	63 ± 3.4	0
$2be^{\pm}$	96	92.1 ± 4.1	0
$\tau^{\pm}\tau^{\mp}$	856	872.5 ± 19	0
$\gamma\not{p}$	3793	3770.7 ± 127.3	0
$\mu^{\pm}\tau^{\mp}$	381	440.9 ± 7.3	0
$\mu^{\pm}\not{p}\tau^{\mp}$	60	75.7 ± 3.4	0
$\mu^{\pm}\not{p}\tau^{\pm}$	15	12 ± 2	0
$\mu^{\pm}\not{p}$	734290	734296 ± 4897.8	0
$\mu^{\pm}\gamma$	475	469.8 ± 12.5	0
$\mu^{\pm}\mu^{\mp}\not{p}$	169	198.5 ± 8.2	0
$\mu^{\pm}\mu^{\mp}\gamma$	83	60 ± 3.1	0
$\mu^{\pm}\mu^{\mp}$	25283	25178.5 ± 86.5	0
$j2\gamma\not{p}$	36	30.4 ± 4.2	0
$j2\gamma$	1822	1813.2 ± 27.4	0
$j\tau^{\pm}$ high-Σp_T	52	56.2 ± 2.5	0
$j\tau^{\pm}\tau^{\mp}$	203	252.2 ± 8.7	0
$j\not{p}$ high-Σp_T	4432	4431.7 ± 45.2	0
$j\gamma\tau^{\pm}$	526	476 ± 9.3	0
$j\gamma\not{p}$	1882	1791.9 ± 72.3	0
$j\gamma$	103319	102124 ± 570.6	0
$j\mu^{\pm}\tau^{\mp}$	71	98 ± 3.9	0
$j\mu^{\pm}\tau^{\pm}$	15	12 ± 2	0
$j\mu^{\pm}\not{p}\tau^{\mp}$	26	30.8 ± 2.6	0
$j\mu^{\pm}\not{p}$	109081	108323 ± 707.7	0
$j\mu^{\pm}\gamma\not{p}$	171	171.1 ± 31	0
$j\mu^{\pm}\gamma$	152	190 ± 39.3	0

Final State	Data	Background	σ
$j\mu^{\pm}\mu^{\mp}\not{p}$	32	32.2 ± 10.9	0
$j\mu^{\pm}\mu^{\mp}\gamma$	14	11.5 ± 2.6	0
$j\mu^{\pm}\mu^{\mp}$	4852	4271.2 ± 185.4	0
$j\mu^{\pm}$	77689	76987.5 ± 930.2	0
$e^{\pm}4j\not{p}$	903	830.6 ± 13.2	0
$e^{\pm}4j\gamma$	25	29.2 ± 3.6	0
$e^{\pm}4j$	15750	16740.4 ± 390.5	0
$e^{\pm}3j\tau^{\mp}$	15	21.1 ± 2.2	0
$e^{\pm}3j\not{p}$	4054	4077.2 ± 63.6	0
$e^{\pm}3j\gamma$	108	79.3 ± 5	0
$e^{\pm}3j$	60725	60409.3 ± 723.3	0
$e^{\pm}2\gamma$	41	34.2 ± 2.6	0
$e^{\pm}2j\tau^{\pm}$	37	47.2 ± 2.2	0
$e^{\pm}2j\tau^{\mp}$	109	95.9 ± 6.8	0
$e^{\pm}2j\not{p}$	25725	25403.1 ± 209.4	0
$e^{\pm}2j\gamma\not{p}$	30	31.8 ± 4.8	0
$e^{\pm}2j\gamma$	398	342.8 ± 15.7	0
$e^{\pm}2j\mu^{\mp}\not{p}$	22	14.8 ± 1.9	0
$e^{\pm}2j\mu^{\mp}$	23	15.8 ± 2	0
$e^{\pm}\tau^{\pm}$	437	387 ± 5.3	0
$e^{\pm}\tau^{\mp}$	1333	1266 ± 12.3	0
$e^{\pm}\not{p}\tau^{\mp}$	109	106.1 ± 2.7	0
$e^{\pm}\not{p}$	960826	956579 ± 3077.7	0
$e^{\pm}\gamma\not{p}$	497	496.8 ± 10.3	0
$e^{\pm}\gamma$	3578	3589.9 ± 24.1	0
$e^{\pm}\mu^{\pm}\not{p}$	31	29.9 ± 1.6	0
$e^{\pm}\mu^{\mp}\not{p}$	109	99.4 ± 2.4	0
$e^{\pm}\mu^{\pm}$	45	28.5 ± 1.8	0
$e^{\pm}\mu^{\mp}$	350	313 ± 5.4	0
$e^{\pm}j2\gamma$	13	16.1 ± 3.9	0
$e^{\pm}j\tau^{\mp}$	386	418 ± 18.9	0
$e^{\pm}j\tau^{\pm}$	160	162.8 ± 3.5	0
$e^{\pm}j\not{p}\tau^{\mp}$	48	44.6 ± 3.3	0
$e^{\pm}j\not{p}\tau^{\pm}$	11	8.3 ± 1.5	0
$e^{\pm}j\not{p}$	121431	121023 ± 747.6	0
$e^{\pm}j\gamma\not{p}$	159	192.6 ± 10.9	0
$e^{\pm}j\gamma$	1389	1368.9 ± 38.9	0
$e^{\pm}j\mu^{\mp}\not{p}$	42	33 ± 2.9	0
$e^{\pm}j\mu^{\pm}\not{p}$	16	9.2 ± 1.9	0
$e^{\pm}j\mu^{\mp}$	62	63.8 ± 3.2	0
$e^{\pm}j\mu^{\pm}$	13	8.2 ± 2	0
$e^{\pm}e^{\mp}4j$	148	159.1 ± 7	0
$e^{\pm}e^{\mp}3j$	717	743.6 ± 24.4	0
$e^{\pm}e^{\mp}2j\not{p}$	32	41.4 ± 5.6	0
$e^{\pm}e^{\mp}2j\gamma$	10	11.4 ± 2.9	0
$e^{\pm}e^{\mp}2j$	3638	3566.8 ± 72	0
$e^{\pm}e^{\mp}\tau^{\pm}$	18	16.1 ± 1.7	0
$e^{\pm}e^{\mp}\not{p}$	822	831.8 ± 13.6	0
$e^{\pm}e^{\mp}\gamma$	191	221.9 ± 5.1	0
$e^{\pm}e^{\mp}j\not{p}$	155	170.8 ± 12.4	0
$e^{\pm}e^{\mp}j\gamma$	48	45 ± 3.9	0
$e^{\pm}e^{\mp}j$	17903	18258.2 ± 204.4	0
$e^{\pm}e^{\mp}$	98901	99086.9 ± 147.8	0
$b6j$	51	42.3 ± 3.8	0
$b5j$	237	192.5 ± 7.1	0
$b4j$ high-Σp_T	26	23.4 ± 2.6	0
$b4j$ low-Σp_T	836	821.7 ± 15.9	0
$b3j$ high-Σp_T	12081	12071 ± 84.1	0
$b3j$ low-Σp_T	2974	2873 ± 31	0

399 “standard” CDF final states
+
180 “standard” D0 leptonic final states
+
many additional standard and non-standard final states

Tools of Discovery

- Tevatron: 1.96 TeV $p\bar{p}$ collisions
  - World's highest energy $p\bar{p}$ collider

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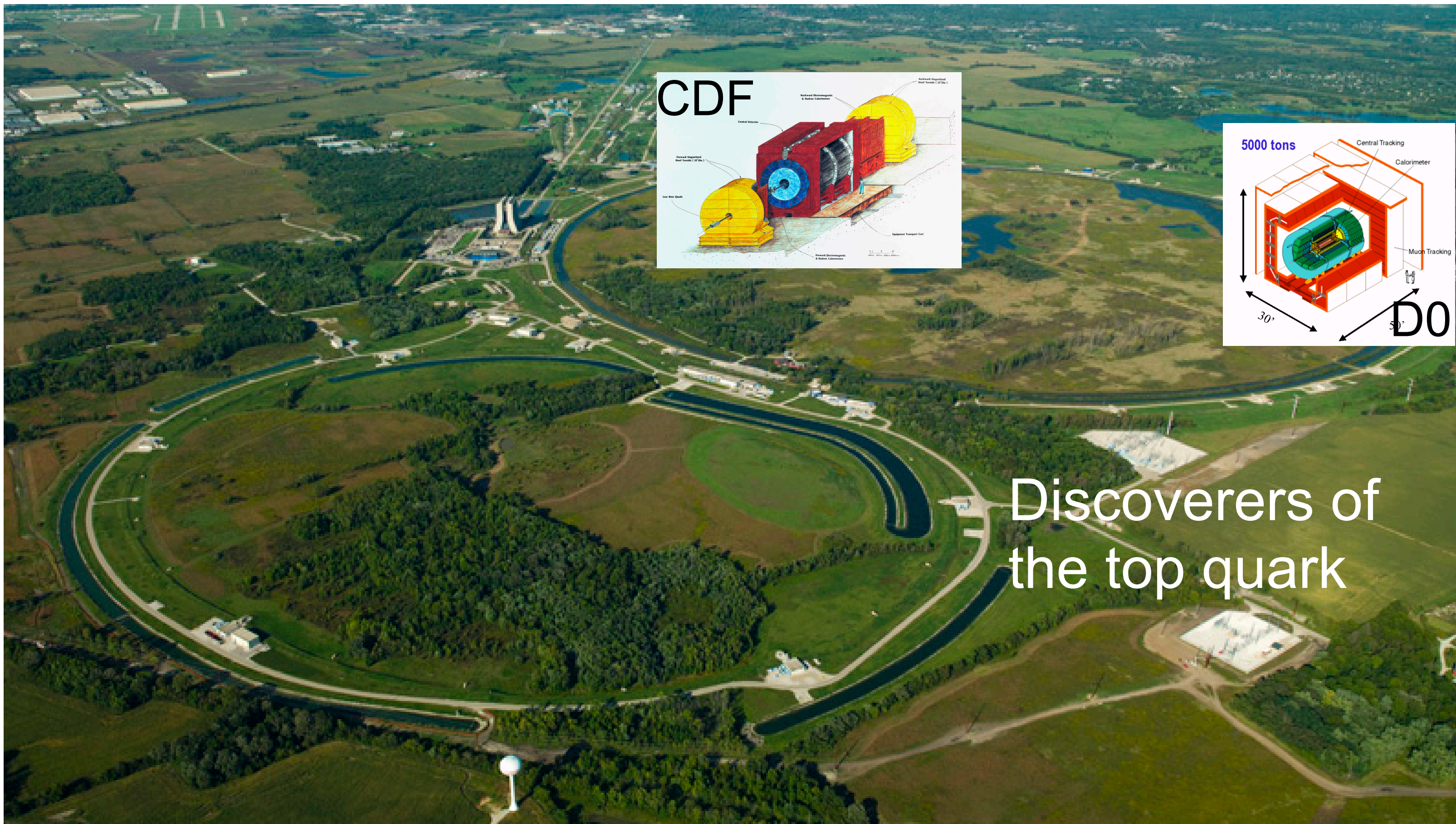
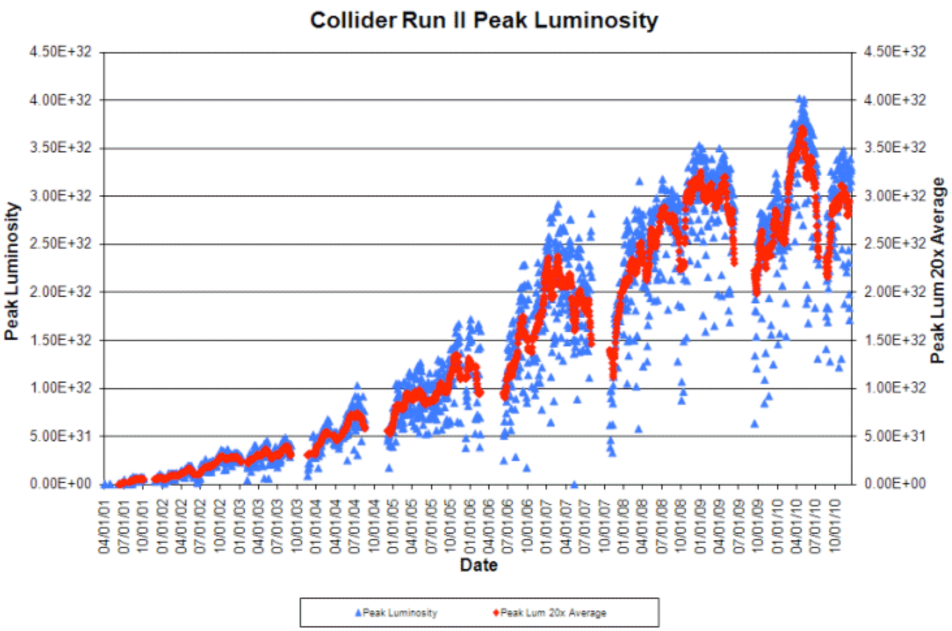


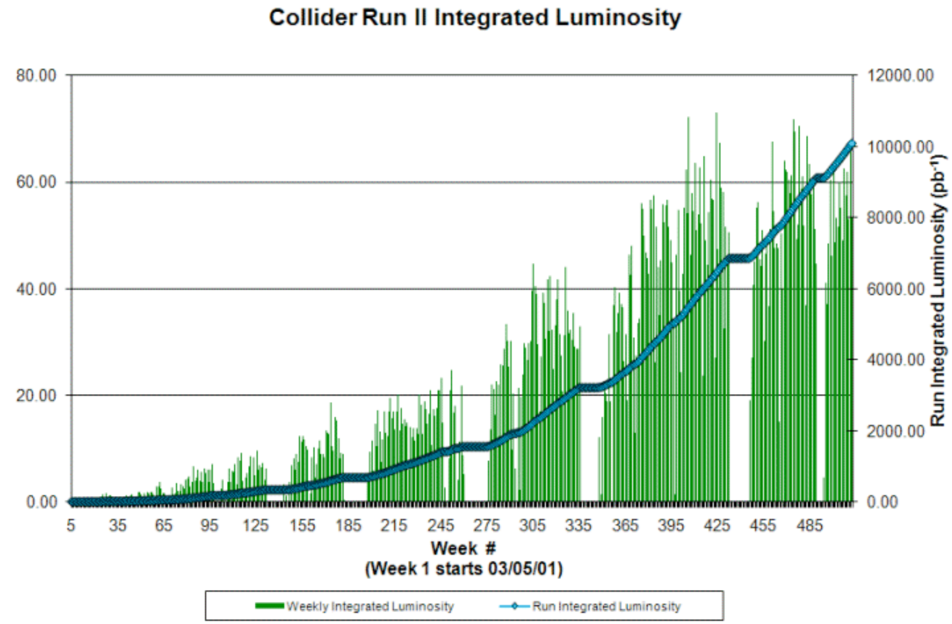
Tools of Discovery

- Tevatron: 1.96 TeV $p\bar{p}$ collisions
  - World's highest energy $p\bar{p}$ collider

Tevatron Luminosity

- World’s highest intensity hadron collider

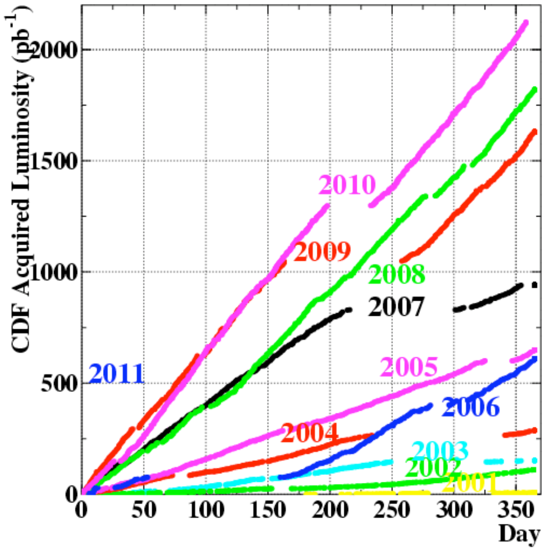




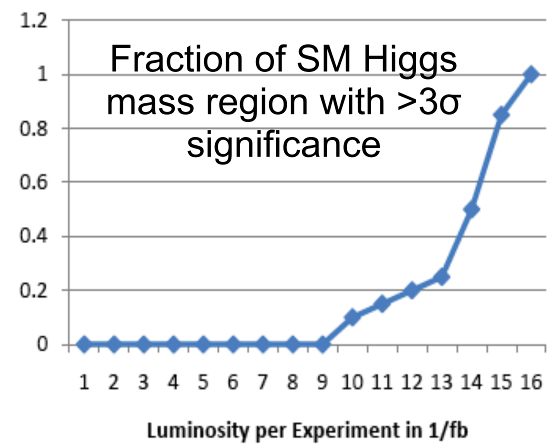
- Peak luminosity: 1.5 pb^{-1} / hour
- Integrated delivered luminosity: 10 fb^{-1} / experiment

The End of the Line

- Tevatron Run II: Mar 2001 - Sep 2011
  - 12 fb^{-1} of delivered luminosity/experiment
  - About 9 fb^{-1} available for analysis

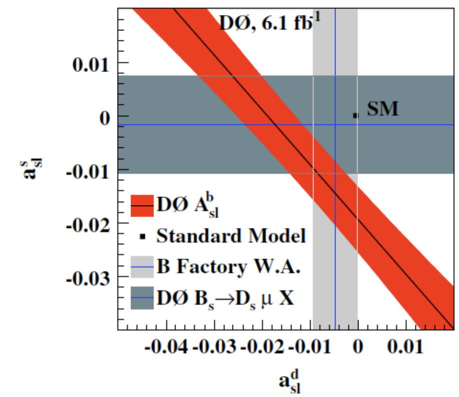


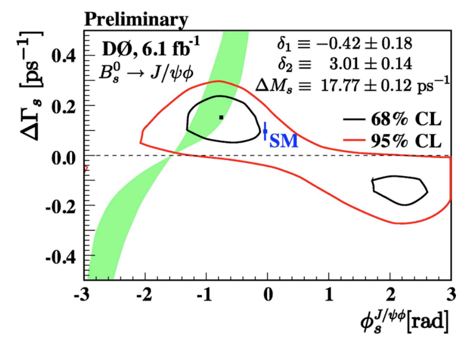
- Tevatron "Run III"
  - Increases delivered luminosity per experiment to 18 fb^{-1}
  - Guarantees 3σ SM Higgs evidence
  - Confirms evidence for new physics
  - Requires additional \$35 million/yr x 3 yrs
  - Department of energy: insufficient funds

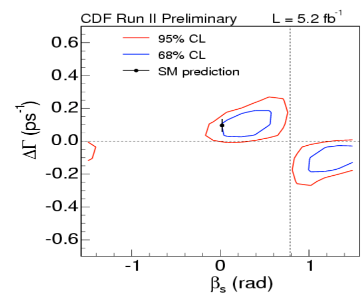


Tevatron Legacy

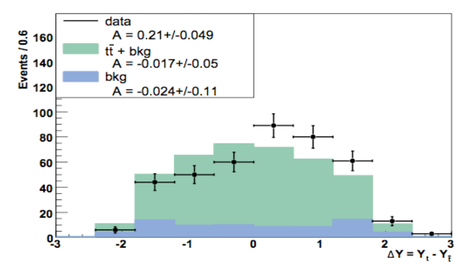
- First evidence of new physics (?)
  - Dimuon charge asymmetry
  - sin $2\beta_s$
  - $t\bar{t}$ forward-backward asymmetry
  - SM Higgs + m_t + m_W

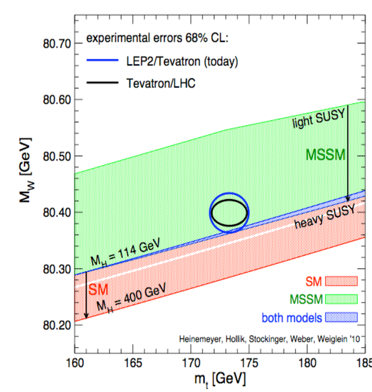






- Benchmarks for the LHC
  - Supersymmetry
  - New gauge bosons





- Unique sensitivity (?)
  - Corners of SUSY phase space

First Evidence of New Physics?

1) Dimuon Charge Asymmetry

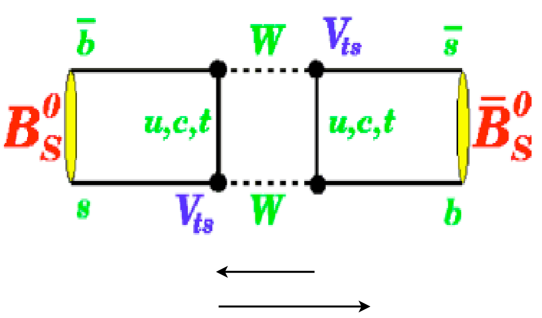
– Measure asymmetry between + and - muon pairs

$$\mathcal{A} = (N^{++} - N^{--}) / (N^{++} + N^{--})$$

Only SM source of asymmetry: semileptonic b decay

– Due to CP violation in B_d and B_s decays ($B^0 \leftrightarrow \bar{B}^0$)

$$\mathcal{A}_b = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}$$



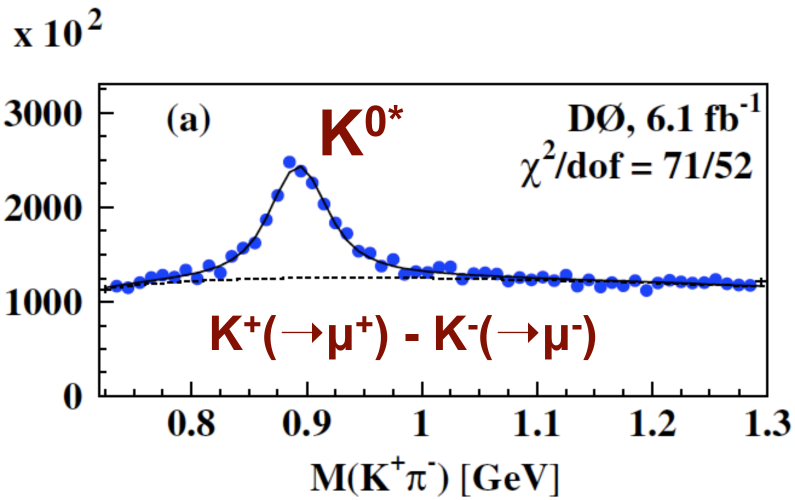
Derived from individual asymmetries:

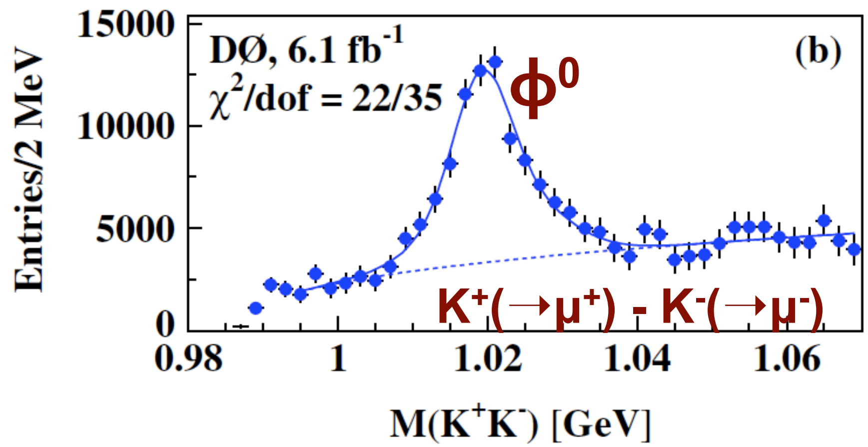
$$a_q = (\Delta\Gamma_q / \Delta M_q) \tan\phi_q$$

$a_d = -4.8^{+1.0}_{-1.2} \times 10^{-4}$ $a_s = (2.1 \pm 0.6) \times 10^{-5}$

Dimuon Charge Asymmetry

- Measurement procedure
  - Reverse magnet polarities to reduce efficiency asymmetry
  - Measure background asymmetries with data



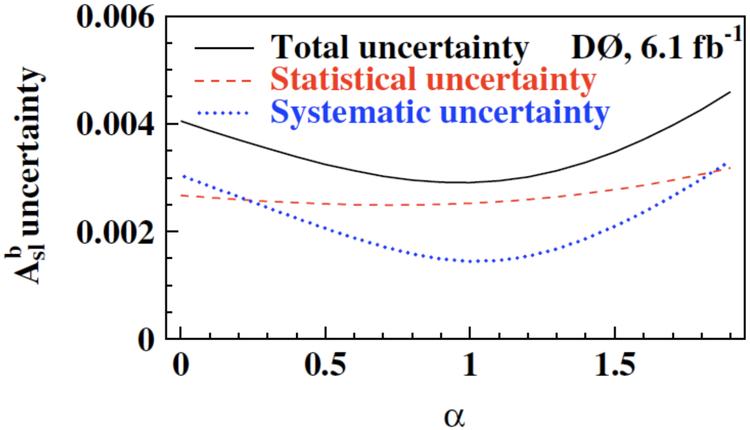


  - Measure inclusive muon asymmetry to exploit common background systematic uncertainties

$$a = (N^+ - N^-) / (N^+ + N^-)$$

Dimuon Charge Asymmetry

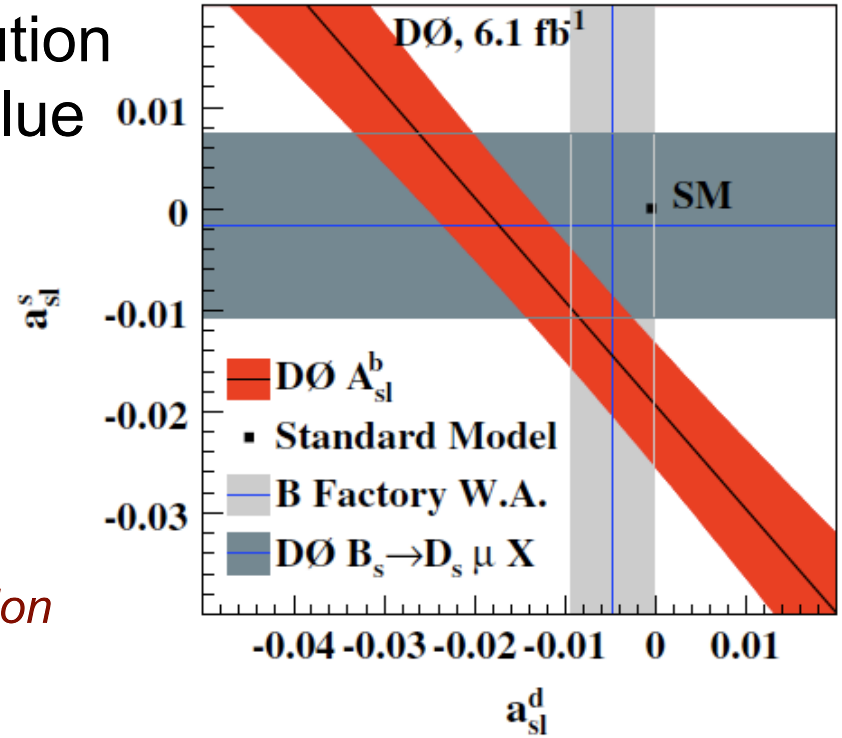
- Individual results
  - Inclusive asymmetry: $\mathcal{A}_b$ = **0.0094 ± 0.0112 ± 0.0214**
  - Dimuon asymmetry: $\mathcal{A}_b$ = **-0.00736 ± 0.00266 ± 0.00305**
- Improve precision by combining uncorrected results
  - A' = A - αa



  - Combined asymmetry: $\mathcal{A}_b$ = **-0.00957 ± 0.00251 ± 0.00146**
    - 3.2σ from SM expectation

Dimuon Charge Asymmetry

- Assuming discrepancy is due to B decays, can compare to existing measurements of a_d and a_s
  - $\mathcal{A}_b$ = **(0.506 ± 0.043)**a_d **+ (0.494 ± 0.043)**a_s
- Can further constrain B_d contribution using combined experimental value a_d**= -0.0047 ± 0.0046**
  - Then a_s **= -0.0146 ± 0.0075**
  - Can use this to extract CP-violating phase ϕ_s (= $-2\beta_s$)



G. Borissov, B. Hoeneisen & D0 Collaboration
Phys. Rev. D82, 032001 (2010);
Phys. Rev. Lett. 105, 081801 (2010)

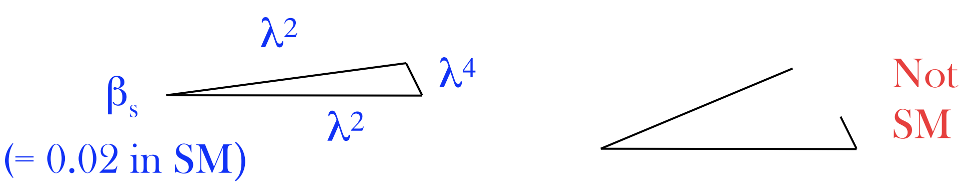
First Evidence of New Physics?

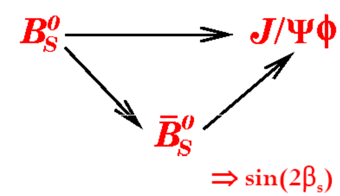
2) sin $2\beta_s$

– CP-violating phase comes from unitarity triangle built from 2nd and 3rd columns of CKM matrix

$$V_{us}V_{ub}^* + V_{cs}V_{cb}^* + V_{ts}V_{tb}^* = 0$$

$$\begin{bmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{bmatrix}$$





Measure using decays to J/ψφ

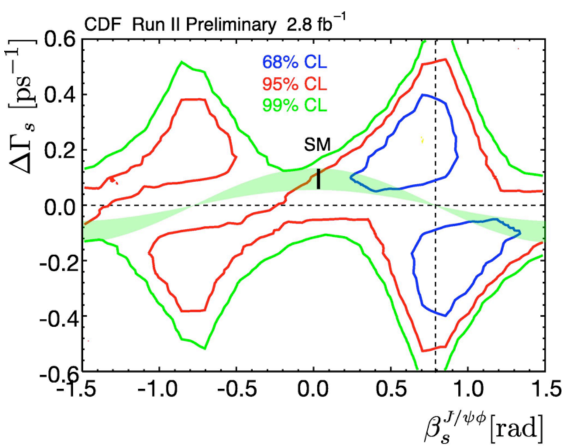
– CP violation due to interference between decays with and without mixing

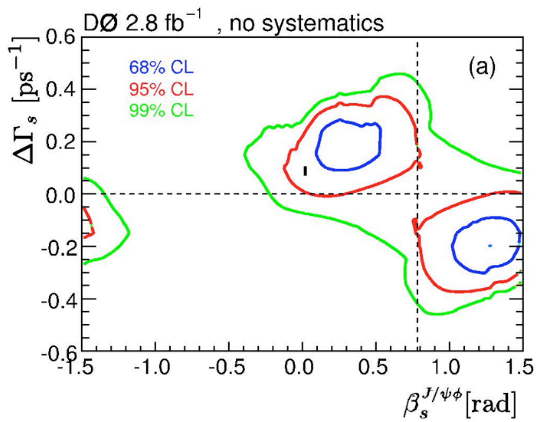
– J/ψφ not a CP eigenstate

– Separate polarizations using angular distributions

sin 2β$_s$

- 2008: CDF & D0 observe nearly 2σ discrepancy with respect to SM
  - UTfit Collaboration combined with other data: “This is a first evidence of physics beyond the Standard Model”

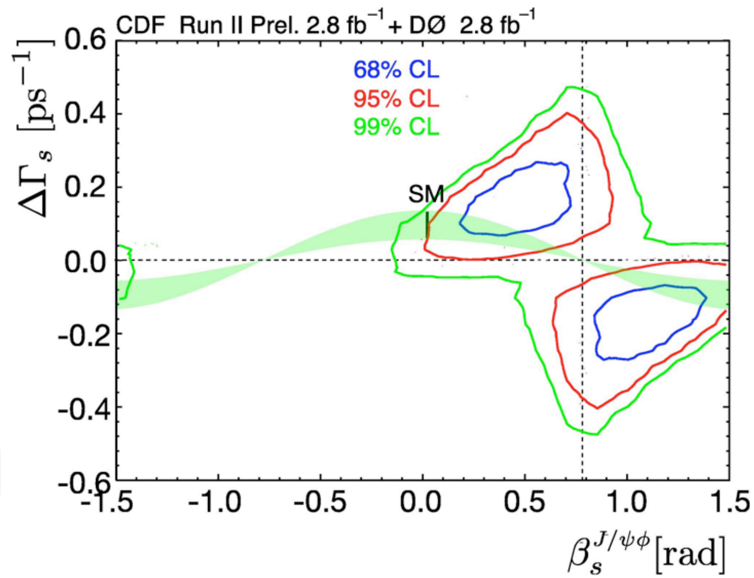




Tevatron combination:

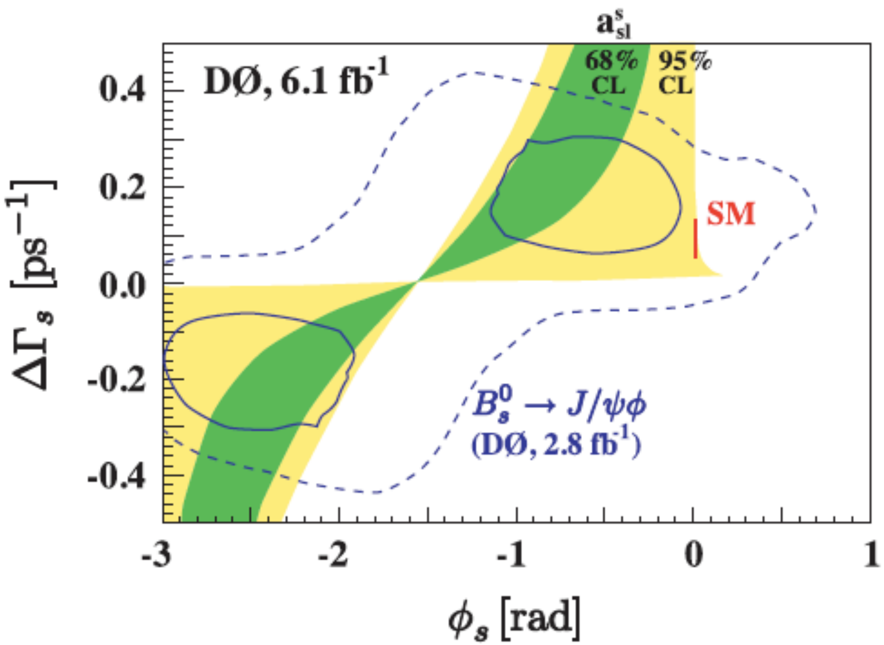
A little more than 2σ deviation from SM

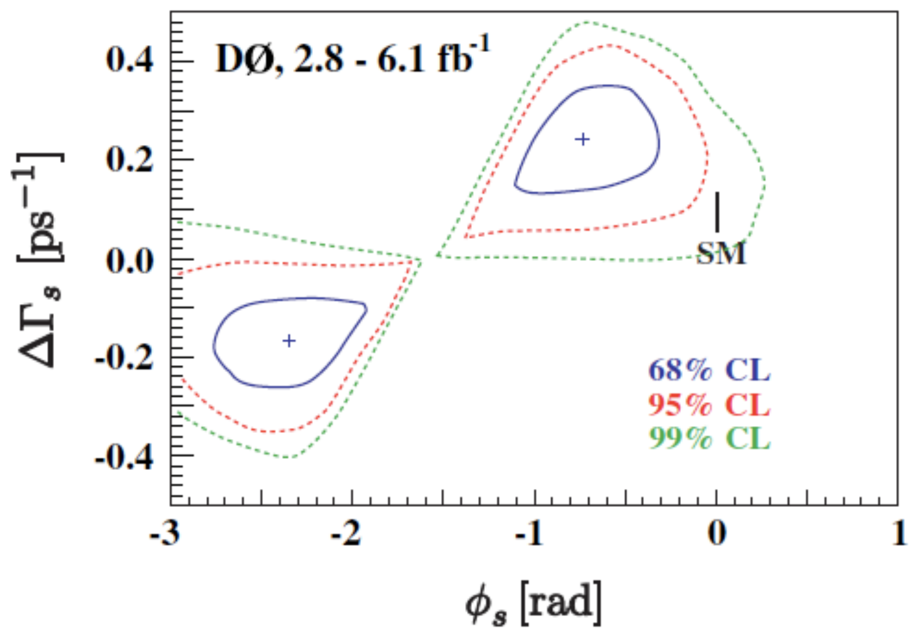
UTfit Collaboration
PMC Physics A3, 6 (2009)



sin 2β_s

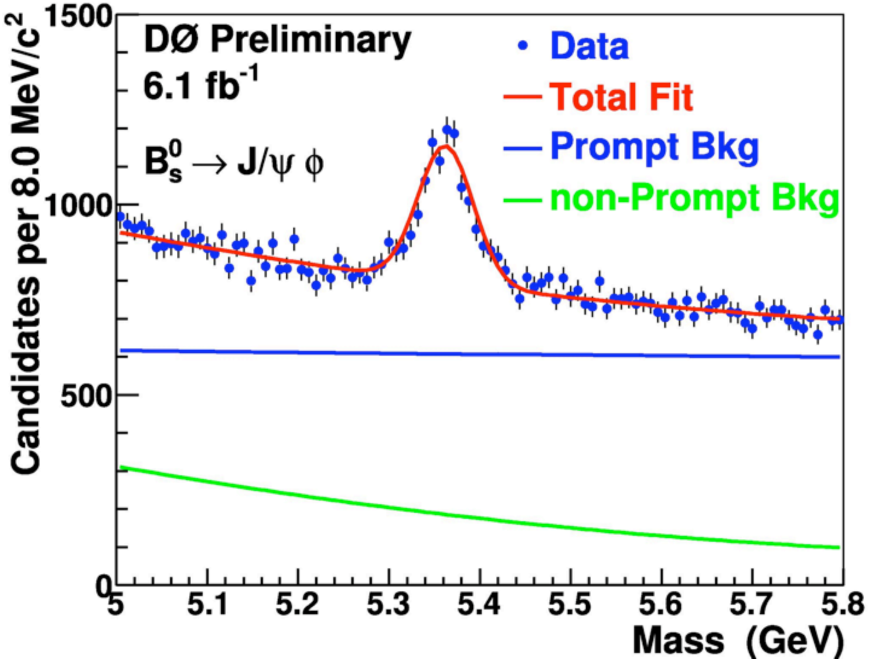
- D0 combined the dimuon asymmetry and the $B_s \rightarrow J/\psi\varphi$ measurements of φ_s
  - Results are consistent & deviate by >2σ from SM

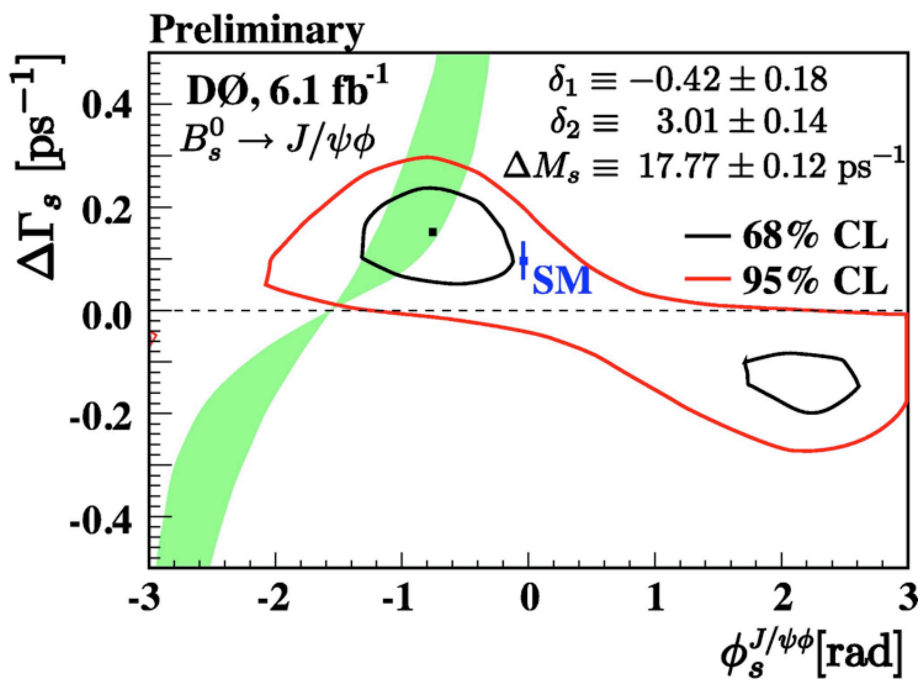




sin 2β_s

- Updated D0 measurement with 6.1 fb^{-1} uses 3435 $B_s \rightarrow J/\psi\varphi$ candidates

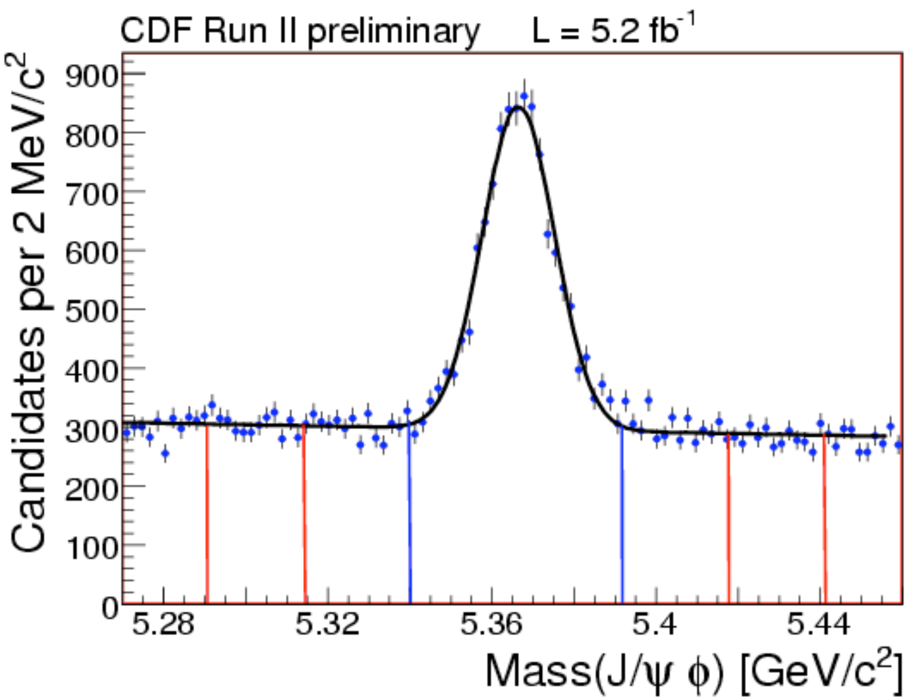


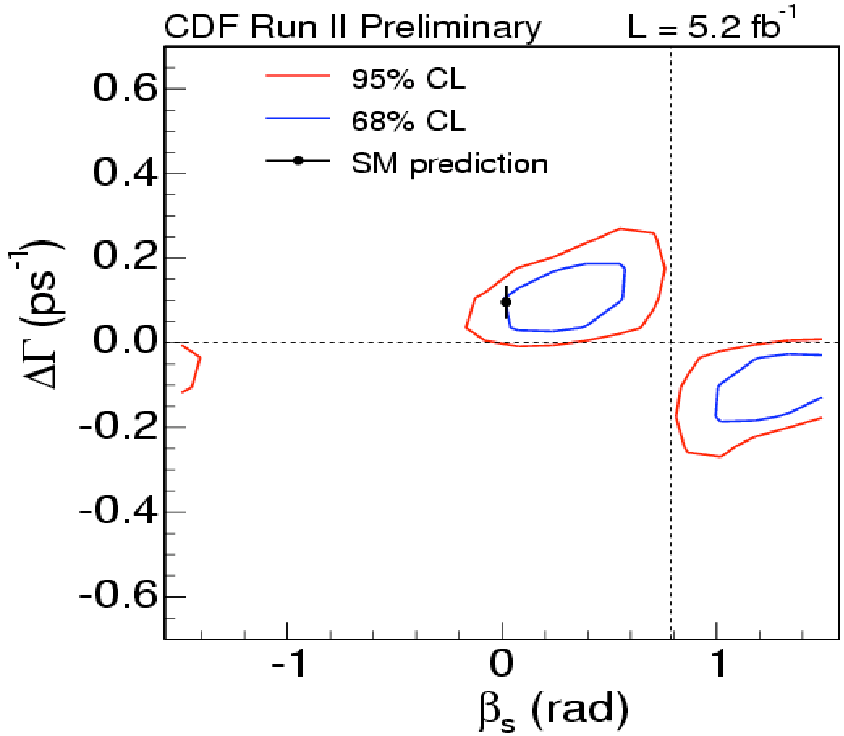


Improved consistency with SM

sin 2β_s

- Updated CDF measurement with 5.2 fb^{-1} uses 6500 $B_s \rightarrow J/\psi\varphi$ candidates





Improved consistency with SM

First Evidence of New Physics?

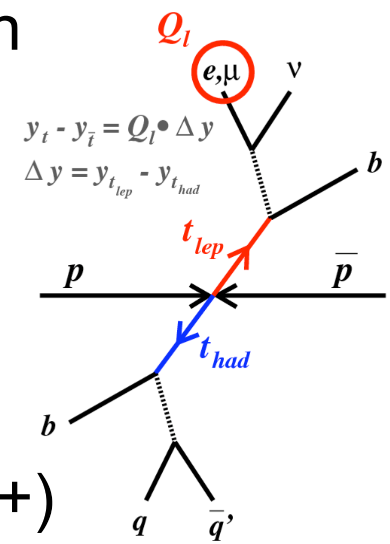
3) $t\bar{t}$ Forward-Backward Asymmetry

– Measure asymmetry between top quarks produced toward and opposite to the proton direction

$\mathcal{A}_{fb}$ **= (N$_f$ - N$_b$) / (N$_f$ + N$_b$)**

$$A^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

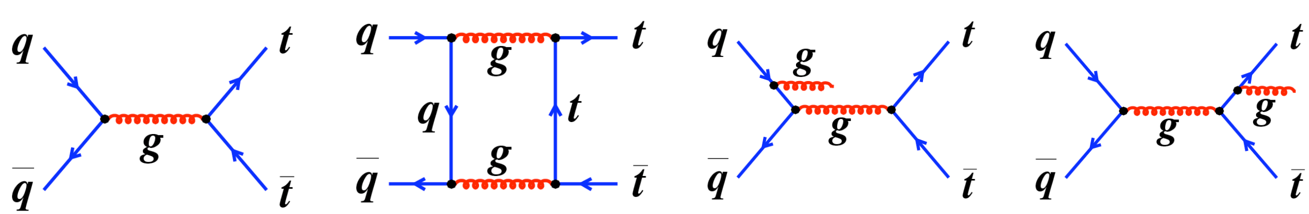
$$= \frac{N(y_t^{t\bar{t}} > 0) - N(y_t^{t\bar{t}} < 0)}{N(y_t^{t\bar{t}} > 0) + N(y_t^{t\bar{t}} < 0)}$$



SM source of asymmetry: higher order interference

– Interference between LO and box diagram (+)

– Interference between ISR & FSR (-)

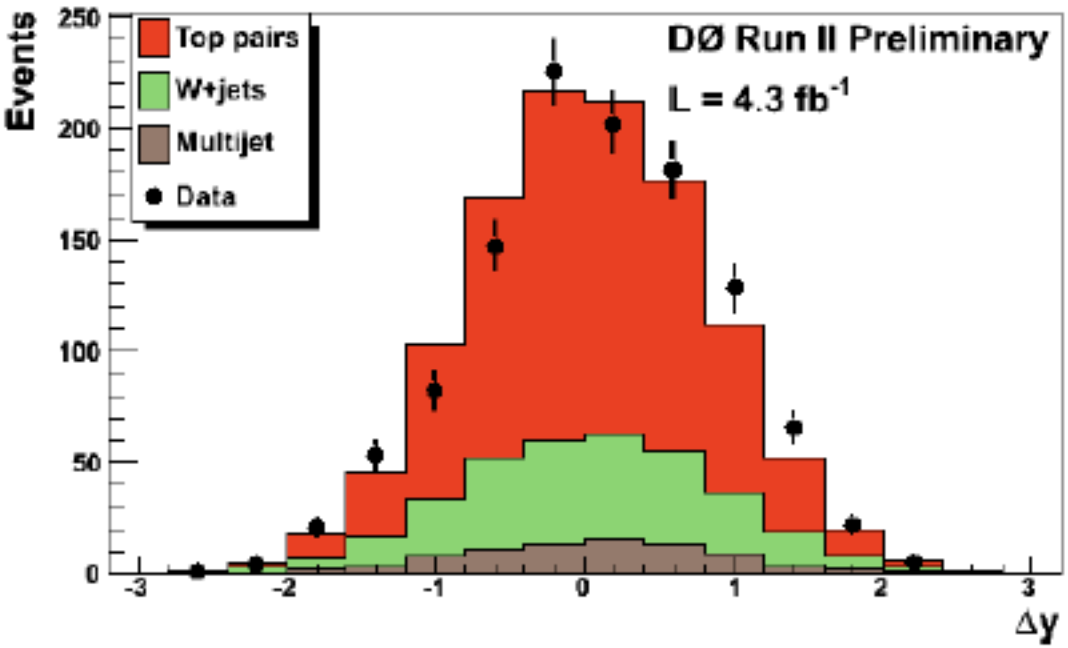


$t\bar{t}$ Forward-Backward Asymmetry

- D0 presents observed Δy distribution and $\mathcal{A}_{fb}$
  - Solve for neutrino rapidity using m_W and m_t
  - Using 1137 candidate events, D0 measures:

$\mathcal{A}_{fb}$ = 0.08 ± 0.04 ± 0.01

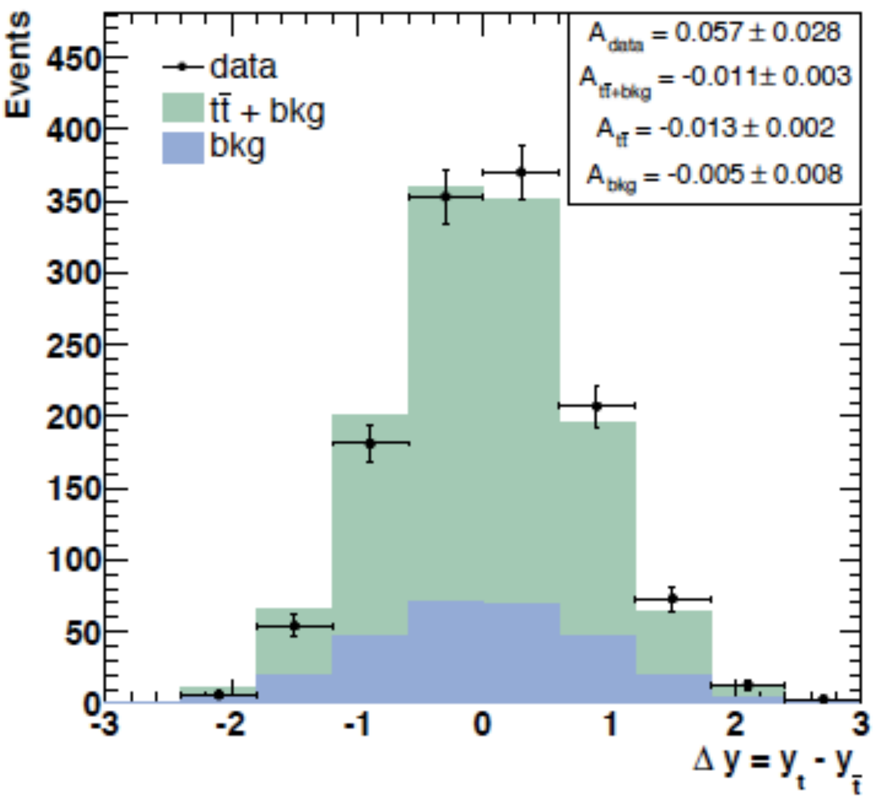
  - Nearly 2σ deviation from SM

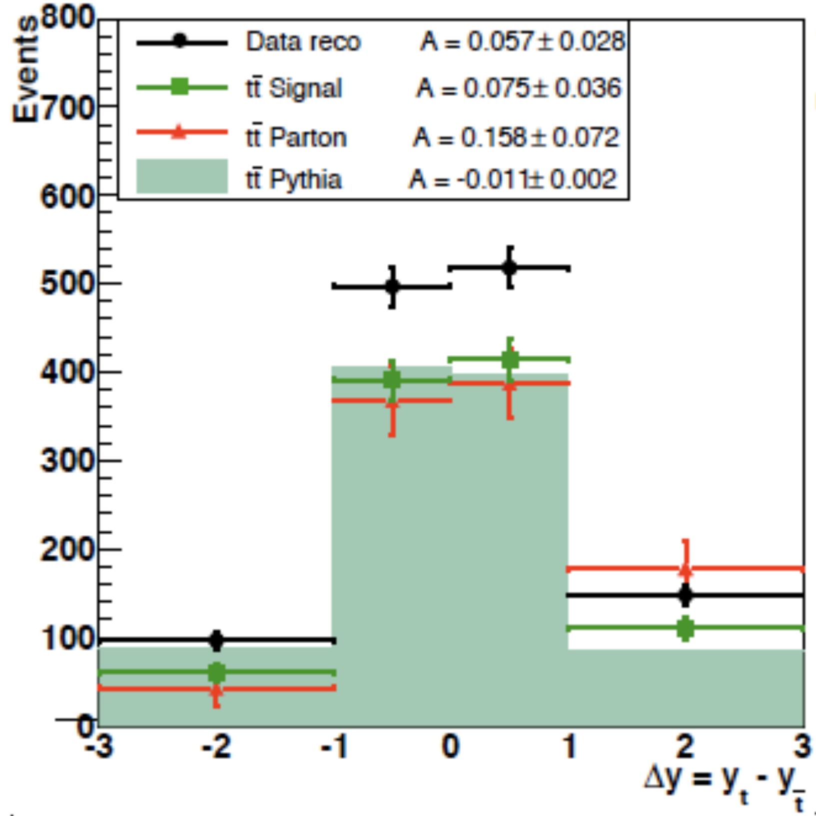


N_{jet}	A_{fb}^{pred} (in %)
≥ 4	$0.8 \pm 0.2(\text{stat}) \pm 1.0(\text{accept}) \pm 0.0(\text{dilution})$
4	$2.3 \pm 0.2(\text{stat}) \pm 1.0(\text{accept}) \pm 0.1(\text{dilution})$
≥ 5	$-4.9 \pm 0.4(\text{stat}) \pm 1.0(\text{accept}) \pm 0.2(\text{dilution})$

$t\bar{t}$ Forward-Backward Asymmetry

- CDF measures the asymmetry in Δy and unfolds to parton level

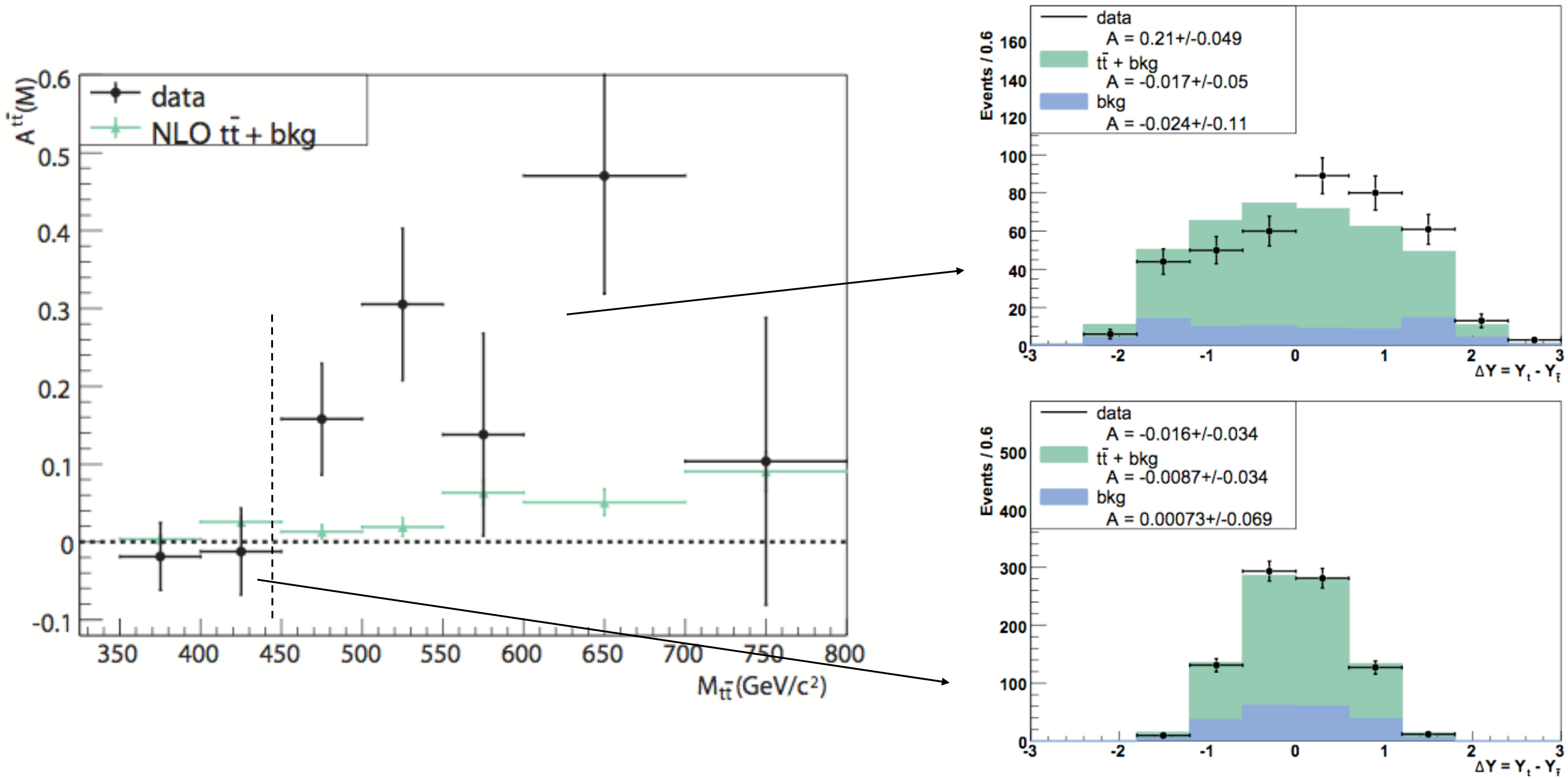




Parton $\mathcal{A}^{tt}{}_{SM}$ **= 0.058 ± 0.009:** Nearly 1.5σ deviation from SM

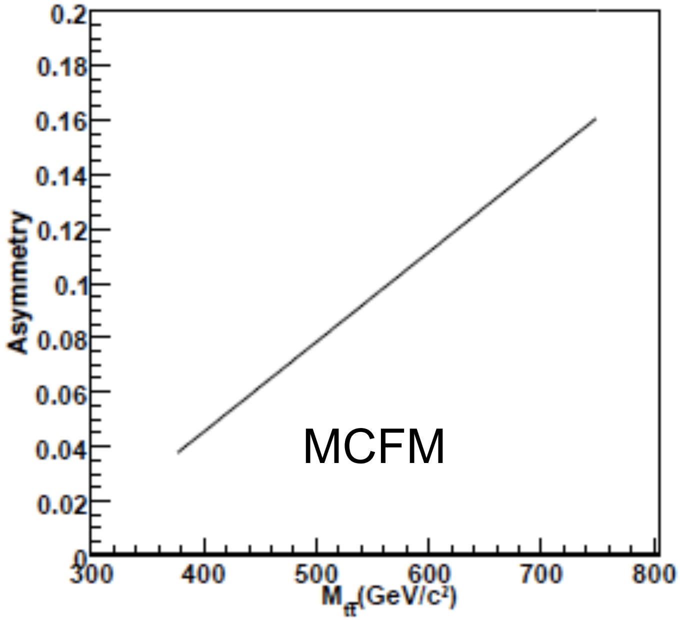
$t\bar{t}$ Forward-Backward Asymmetry

- CDF measures asymmetry as a function of $m_{t\bar{t}}$
  - For m_{tt} > 450 GeV, measured $\mathcal{A}^{tt}$ 3σ larger than SM



$t\bar{t}$ Forward-Backward Asymmetry

- Possible theoretical issues
  - Mass dependence underestimated?
  - LO + box interference effect underestimated?



MC@NLO

selection	all $M_{t\bar{t}}$	$M_{t\bar{t}} < 450$ GeV$/c^2$	$M_{t\bar{t}} \geq 450$ GeV$/c^2$
inclusive	0.024 ± 0.004	0.015 ± 0.005	0.043 ± 0.007
4-jet	0.048 ± 0.005	0.033 ± 0.006	0.078 ± 0.009
5-jet	-0.035 ± 0.007	-0.032 ± 0.009	-0.040 ± 0.012

selection	N events	all $M_{t\bar{t}}$	$M_{t\bar{t}} < 450$ GeV$/c^2$	$M_{t\bar{t}} \geq 450$ GeV$/c^2$
inclusive	1260	0.057 ± 0.028	-0.016 ± 0.034	0.212 ± 0.049
4-jet	939	0.065 ± 0.033	-0.023 ± 0.039	0.26 ± 0.057
5-jet	321	0.034 ± 0.056	0.0049 ± 0.07	0.086 ± 0.093

Data

Data - MC@NLO

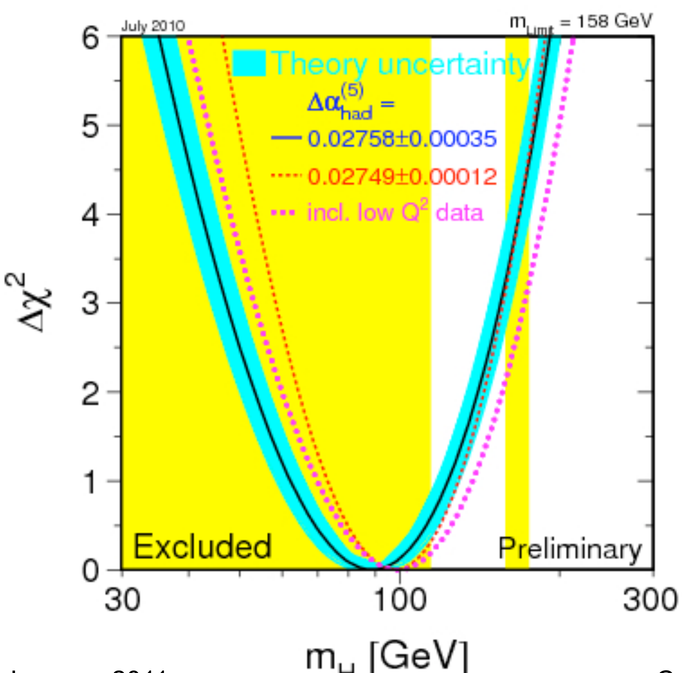
inclusive	0.169 ± 0.049
4-jet	0.182 ± 0.058
5-jet	0.126 ± 0.094

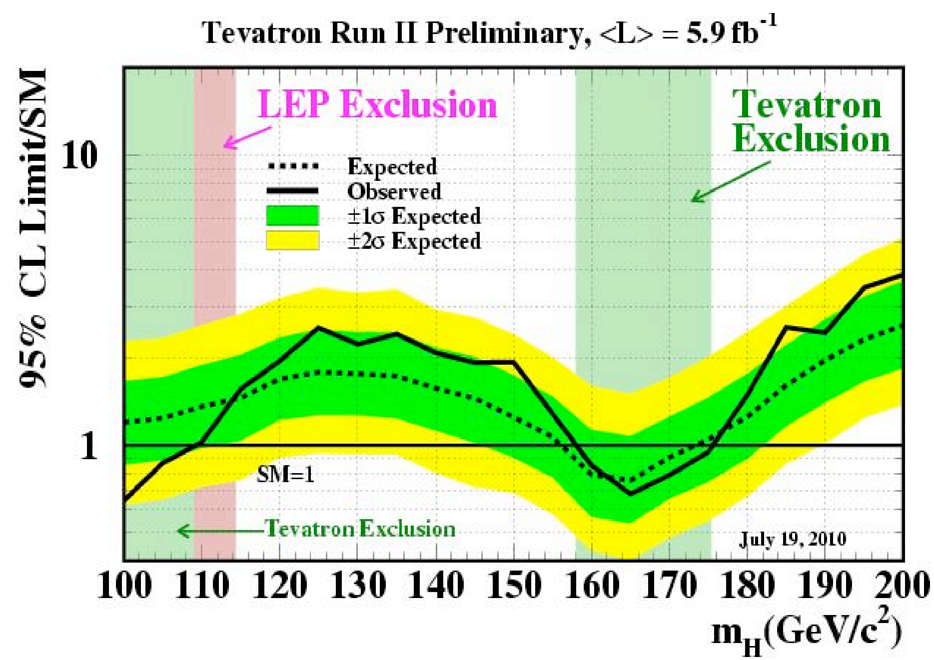
CDF Collaboration, arXiv:1101.0034
submitted to Phys. Rev. D

First Evidence of New Physics?

4) SM Higgs + m_t + m_W

– First evidence might come from an exclusion
  - D0 & CDF will directly exclude the SM Higgs for m_H < 180 GeV if it does not exist
  - Measurements of m_W and m_t (and other electroweak data) exclude m_H > 158 GeV





The LHC Era

- Expect most (all?) new physics searches to be superseded by the LHC
  - Limits provide benchmarks by which to measure LHC progress
  - Strong production:

Search	Tevatron	LHC
Dijets	$m_{q^*} > 0.87$ TeV (CDF)	**$m_{q^*} > 1.58$ TeV (CMS)**
Jets + $\not{p}_T$	$m_{\tilde{g}} > 0.42$ TeV (CDF/D0)	**$m_{\tilde{g}} > 0.65$ TeV (CMS)**
Leptons + jets	$m_{LQ1} > 0.30$ TeV (D0)	**$m_{LQ1} > 0.39$ TeV (CMS)**
Leptons + jets + $\not{p}_T$	$m_{b'} > 0.34$ TeV (CDF)	**$m_{b'} > 0.36$ TeV (CMS)**
c-jets + $\not{p}_T$	**$m_{stop} > 0.18$ TeV (CDF)**	-
b-jets + $\not{p}_T$	**$m_{sbottom} > 0.25$ TeV (D0)**	-
Long-lived particles	**$m_{stop} > 0.25$ TeV (CDF)**	$m_{stop} > 0.20$ TeV (CMS)

The LHC Era

- LHC also superseding Tevatron in weak production
  - Will overtake in all standard searches by long shutdown
  - Weak production:

Search	Tevatron	LHC
Lepton + $\not{p}_T$	$m_{W'}$ > 1.12 TeV (CDF)	**$m_{W'}$ > 1.36 TeV (CMS)**
Dileptons	$m_{Z'}$ > 1.07 TeV (CDF)	**$m_{Z'}$ > 1.14 TeV (CMS)**
Diphotons + $\not{p}_T$	R^{-1} > 0.48 TeV (D0)	**R^{-1} > 0.73 TeV (ATLAS)**
Ditau	**$m_{Z'}$ > 0.40 TeV (CDF)**	-
Trileptons + $\not{p}_T$	**$m_{\chi\pm}$ > 0.13 TeV (D0)**	-
Four leptons	**m_G > 0.49 TeV (CDF)**	-

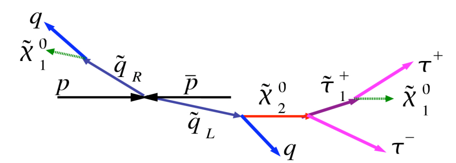
LHC still to demonstrate sensitivity with jet tagging & taus

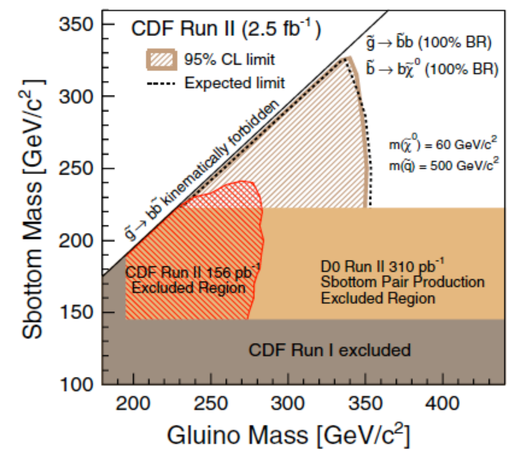
Unique Sensitivity?

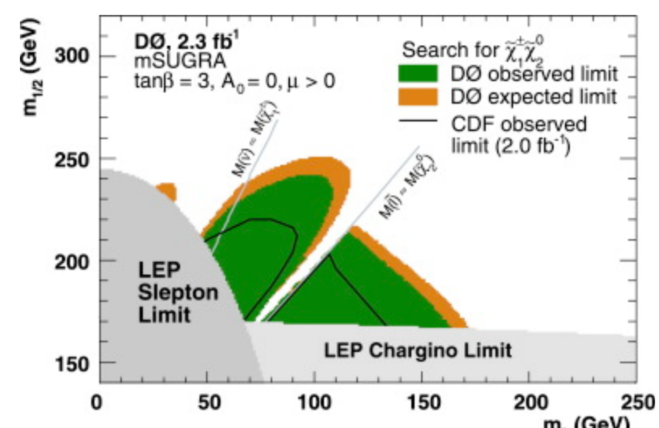
- Are there analyses where the Tevatron still has sensitivity and the LHC might not?
  - LHC might have difficulty identifying soft leptons or jets
    - Experiments have demonstrated ability to identify soft electrons and muons in clean environment
    - Can recover sensitivity with boosted events
  - May motivate Tevatron searches in parameter space of small mass differences between new particles
    - e.g., small difference in stau & neutralino masses resulting in soft tau leptons
    - Still opportunity for discovery?
  - Other processes at low Q^2 and $q\bar{q}$ initial state?

Unique Sensitivity?

- Squark to chargino / NLSP + quark
  - Chargino / NLSP decays dominantly to stau at high tanβ
  - Final state of 2 jets + tau + p_T
- Gluino to sbottom + bottom
  - Optimize for large and small mass differences between gluino and sbottom
- Chargino + Neutralino production
  - Include final states with two taus to allow for decay through staus
  - Gap in sensitivity when leptons are too soft







Summary

Tevatron search legacy will include a sizable chunk of probed parameter space (+ first evidence of new physics?)

Lack of “Run III” a loss for the field

Need Tevatron to work harder to recover sensitivity and fill in the cracks

Need LHC to work harder to maximize overlap with the Tevatron

Eventually: the work will pay off!

Summary

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