In Search of Discovery: Results from the Tevatron

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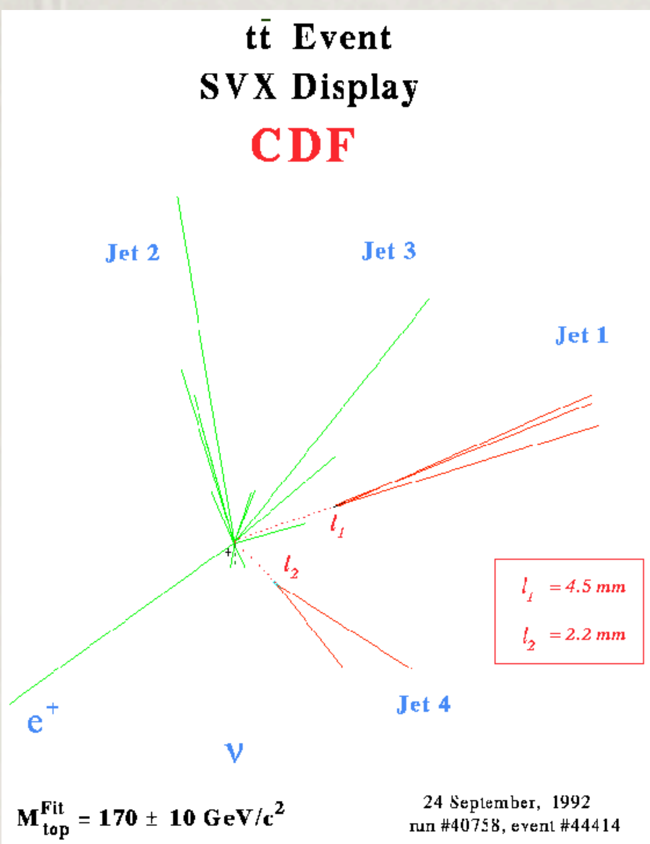
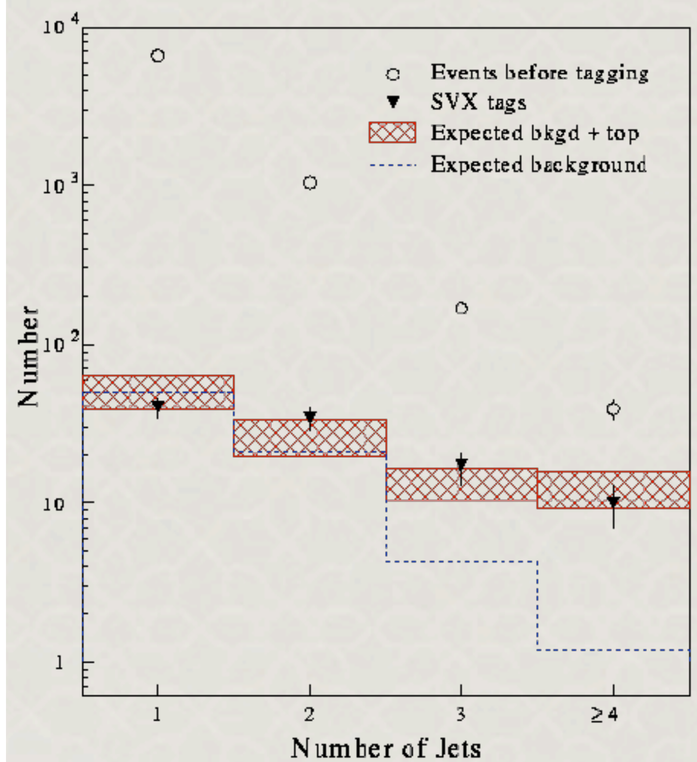
UK HEP Forum, Coseners House, Abingdon

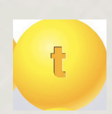
Fundamental Particle Discoveries

- *~ 15 years since last collider particle discovery*

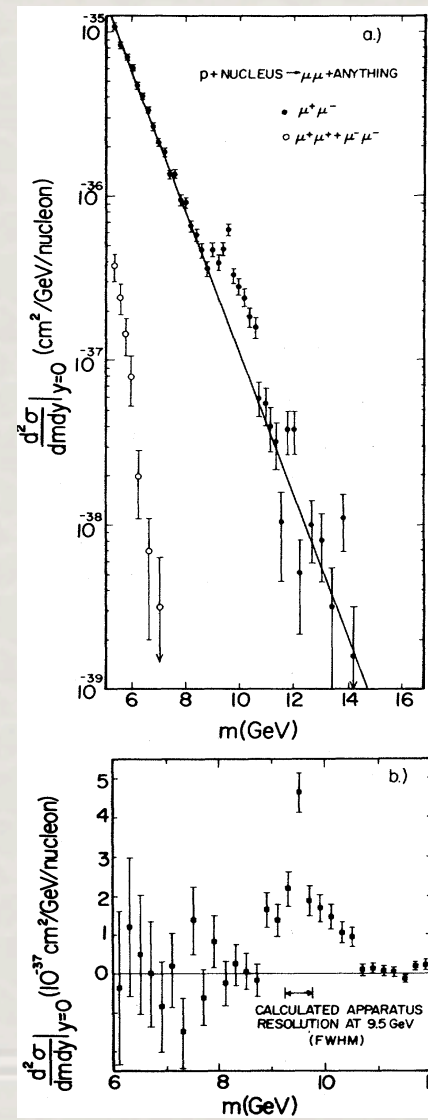




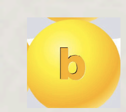
top quark discovered in 1995 through $t\bar{t}$ production



- *> 30 years since last surprise accelerator particle discovery*



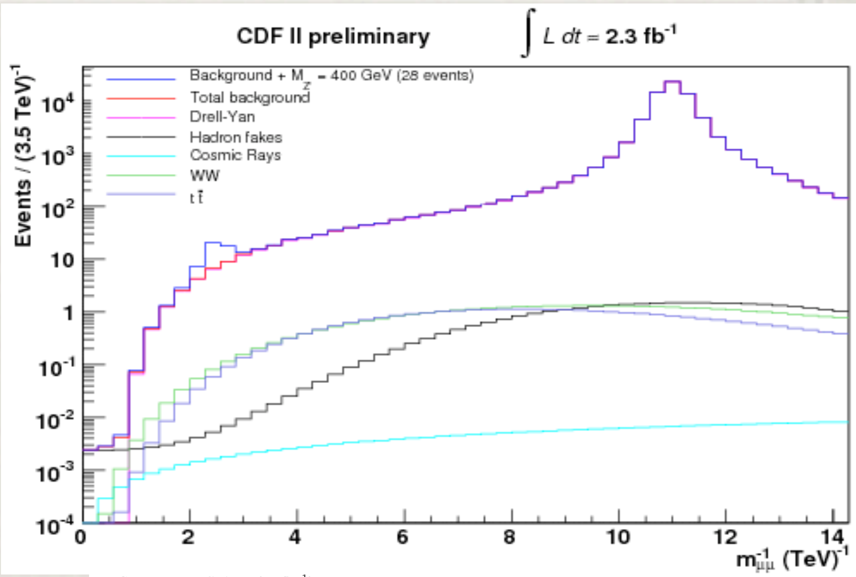
1977 observation of $\Upsilon \rightarrow \mu\mu$ in proton-nucleus collisions demonstrated the existence of a third generation of quarks

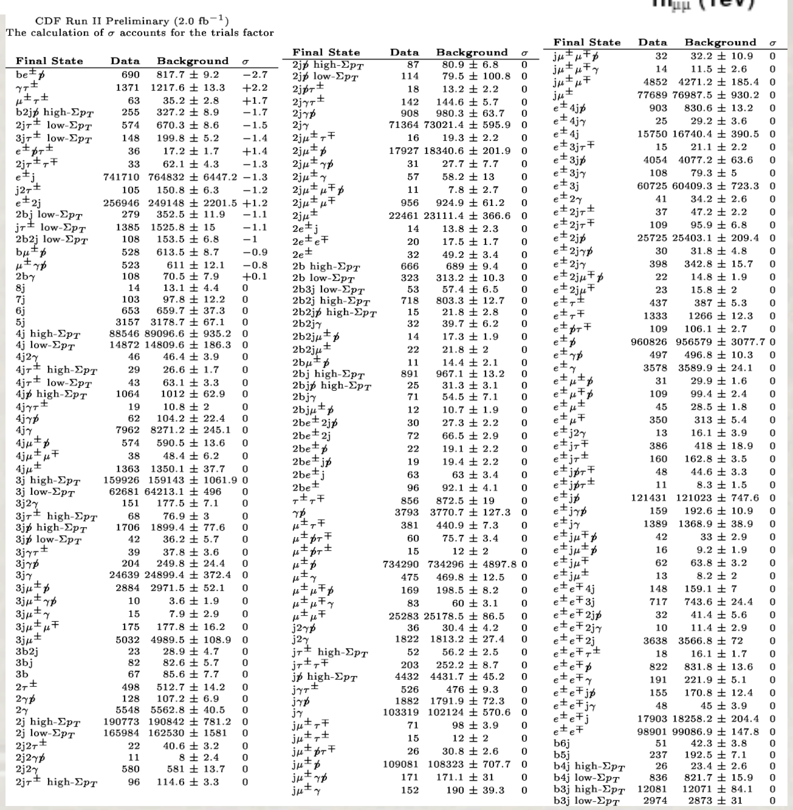


Making a Discovery

- *Strategies*
  - *Probe well-motivated models*
  - *Search for clear indications of new physics*
  - *Study all final states*

- *Issues*
  - *How do you know when it's a discovery?*
  - *How do you know you haven't missed a discovery?*

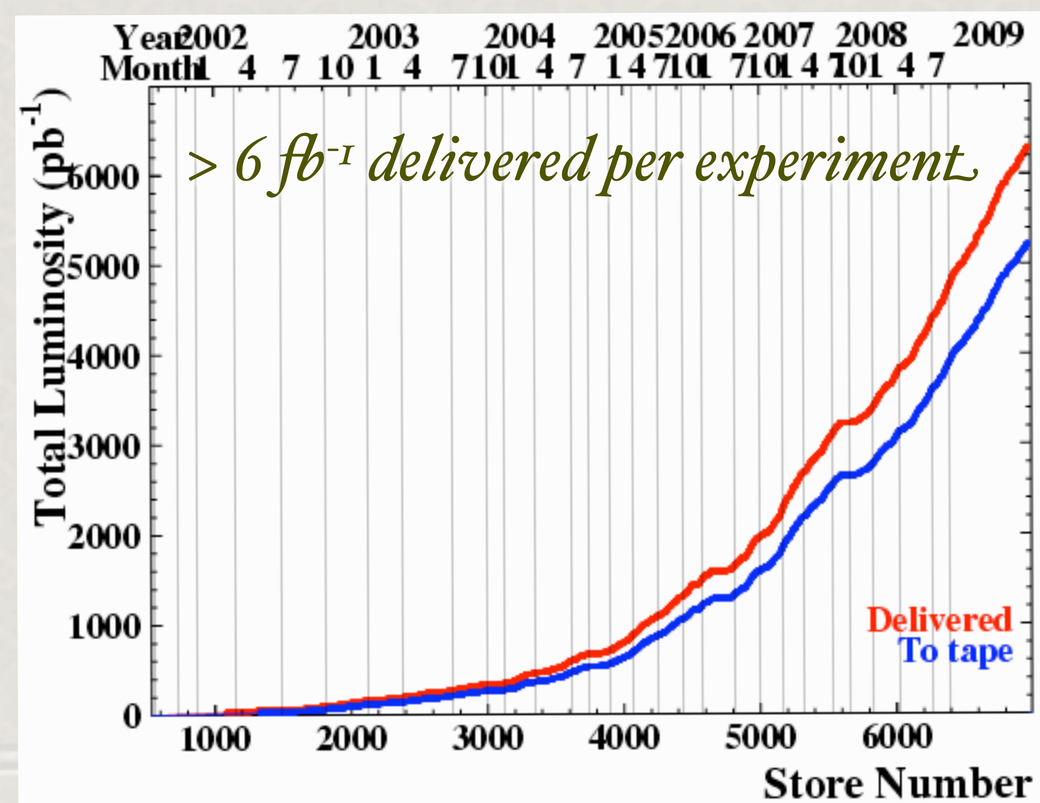



CDF Run II Preliminary (2.0 fb^{-1})
The calculation of σ accounts for the trials factor

Final State	Data	Background	σ
b$e^{\pm}\not{p}$	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
2bγ	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
4j2γ	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
4jγ	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
3j2γ	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
3jγ	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
2j2γ	580	581 ± 13.7	0
2j$\tau^{\pm}$ high-Σp_T	96	114.6 ± 3.3	0
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
2jγ	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
2$e^{\pm}$j	14	13.8 ± 2.3	0
2$e^{\pm}e^{\mp}$	20	17.5 ± 1.7	0
2$e^{\pm}$	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
2b2jγ	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
2bjγ	71	54.5 ± 7.1	0
2bj$\mu^{\pm}\not{p}$	12	10.7 ± 1.9	0
2b$e^{\pm}$2j$\not{p}$	30	27.3 ± 2.2	0
2b$e^{\pm}$2j	72	66.5 ± 2.9	0
2b$e^{\pm}\not{p}$	22	19.1 ± 2.2	0
2b$e^{\pm}$j$\not{p}$	19	19.4 ± 2.2	0
2b$e^{\pm}$j	63	63 ± 3.4	0
2b$e^{\pm}$	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
j2γ	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
jγ	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
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}$4jγ	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}$3jγ	108	79.3 ± 5	0
$e^{\pm}$3j	60725	60409.3 ± 723.3	0
$e^{\pm}$2γ	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}$2jγ	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
$e^{\pm}$j2γ	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
$e^{\pm}$jγ	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}$2jγ	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
$e^{\pm}e^{\mp}$jγ	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

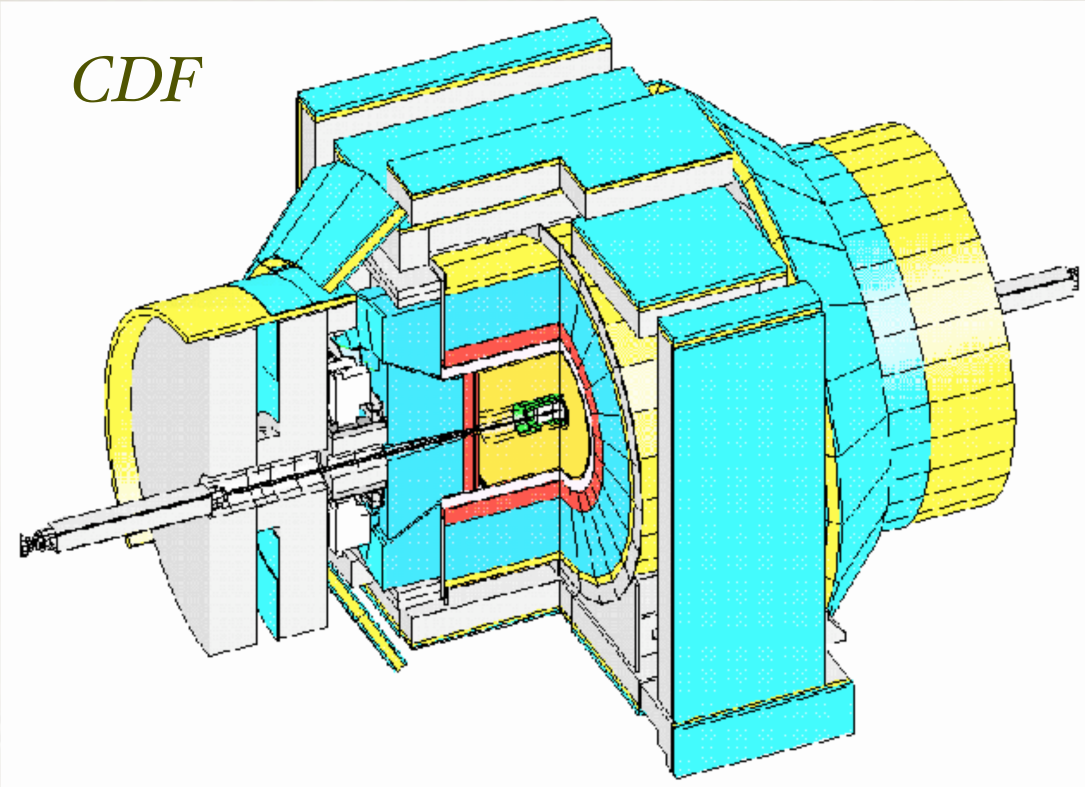
Tevatron Searches

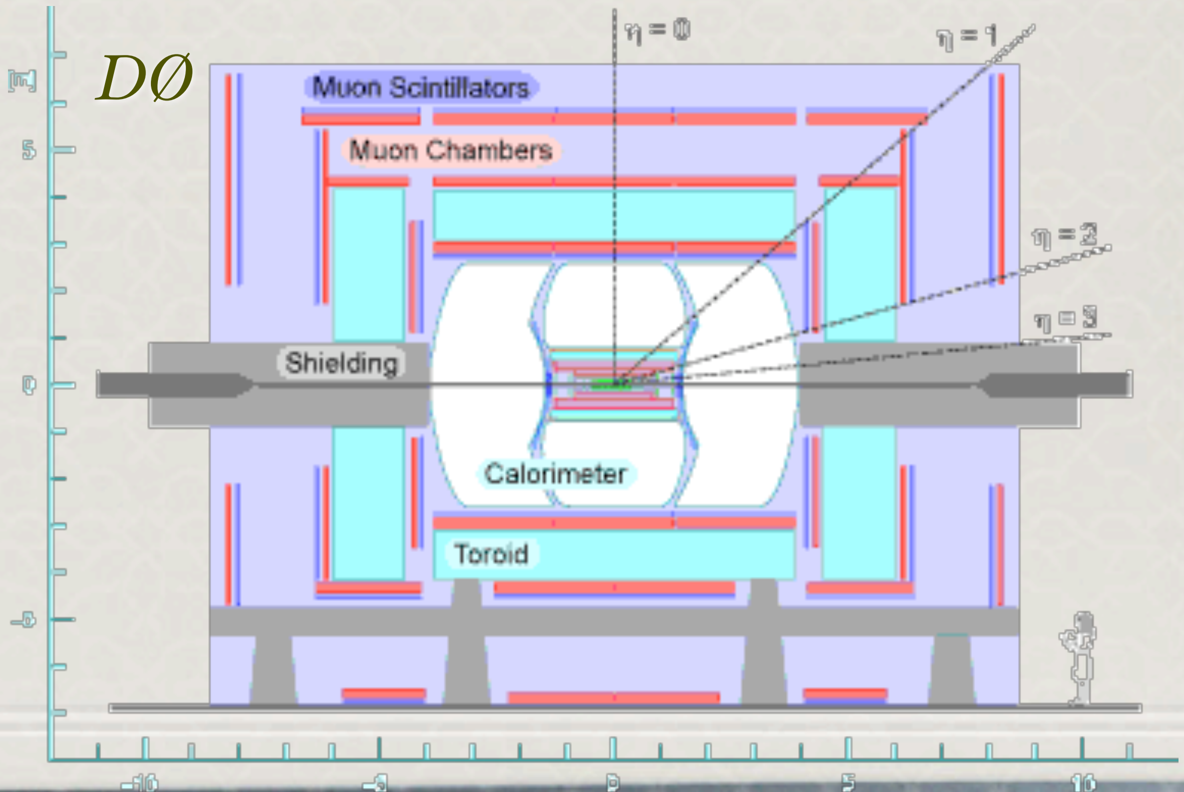
- *World's highest energy collider*
  - *Emphasis on massive particles approaching the kinematic limit*
  - *$p\bar{p}$ collisions complementary to e^+e^-*
    - *High energy & rates, large cross sections for particles with color charge*



Tevatron Detectors

- *Upgraded CDF & DØ detectors have unique capabilities*
  - *CDF: High resolution trackers, time-of-flight chamber*
  - *DØ: Broad muon coverage, finely segmented calorimeter*
- *Complementarity between detectors*





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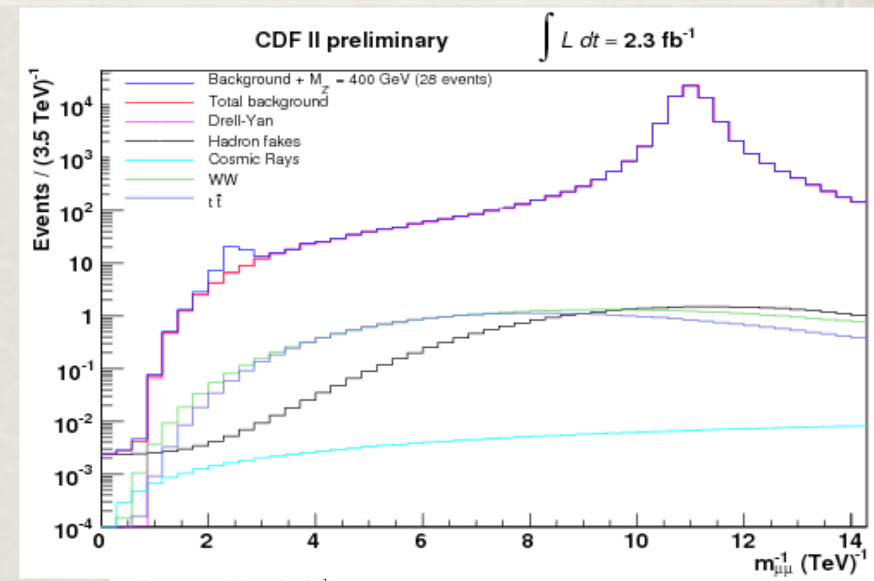

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$2j\tau^{\pm}$ high-Σp_T	96	114.6 ± 3.3	0
$2j\not p$ high-Σp_T	87	80.9 ± 6.8	0
$2j\not p$ low-Σp_T	114	79.5 ± 100.8	0
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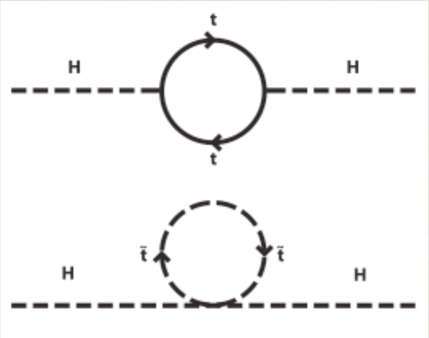
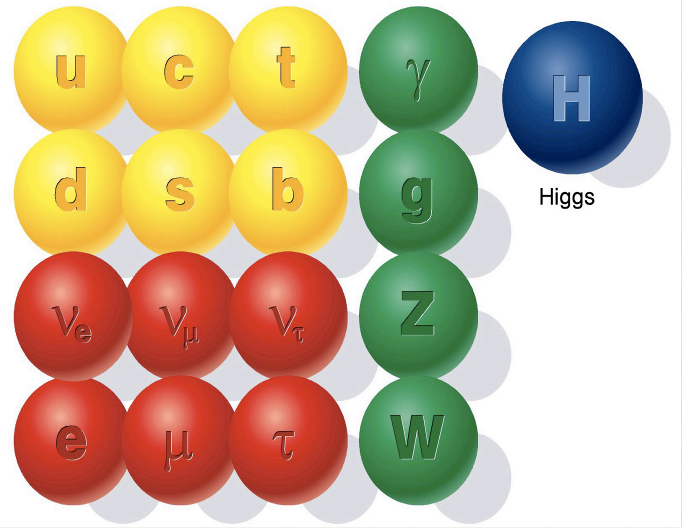
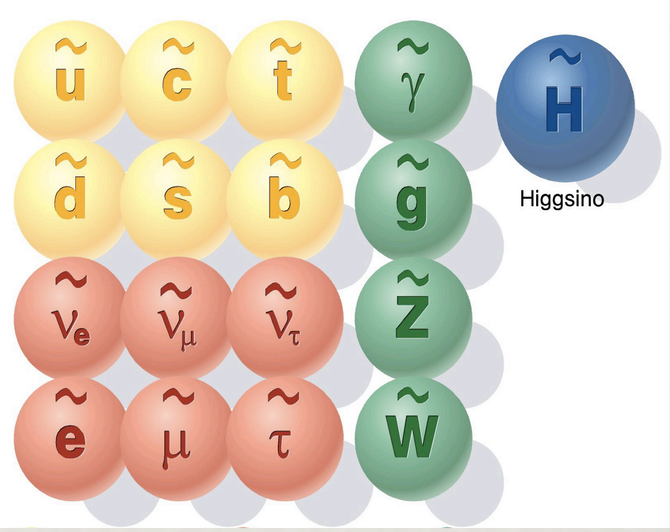
$2be^{\pm}\not p$	22	19.1 ± 2.2	0
$2be^{\pm}j\not p$	19	19.4 ± 2.2	0
$2be^{\pm}j$	63	63 ± 3.4	0
$2be^{\pm}$	96	92.1 ± 4.1	0
$\tau^{\pm}\tau^{\mp}$	856	872.5 ± 19	0
$\gamma\not p$	3793	3770.7 ± 127.3	0
$\mu^{\pm}\tau^{\mp}$	381	440.9 ± 7.3	0
$\mu^{\pm}\not p\tau^{\mp}$	60	75.7 ± 3.4	0
$\mu^{\pm}\not p\tau^{\pm}$	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
$j\mu^{\pm}\mu^{\mp}\not p$	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

A Well-Motivated Model

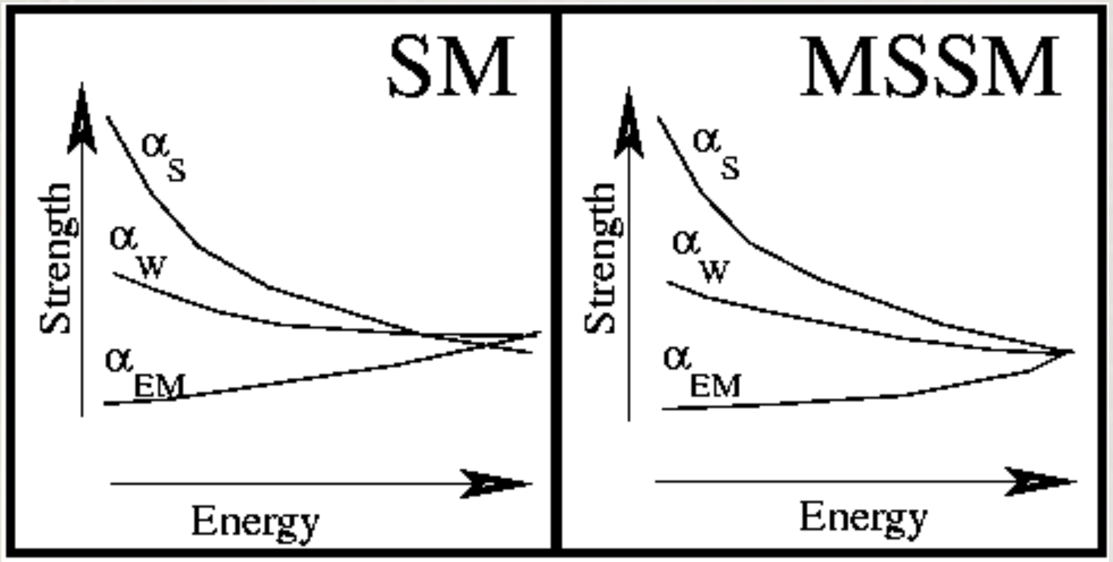
- *Supersymmetry*
  - *Regulates Higgs boson mass*



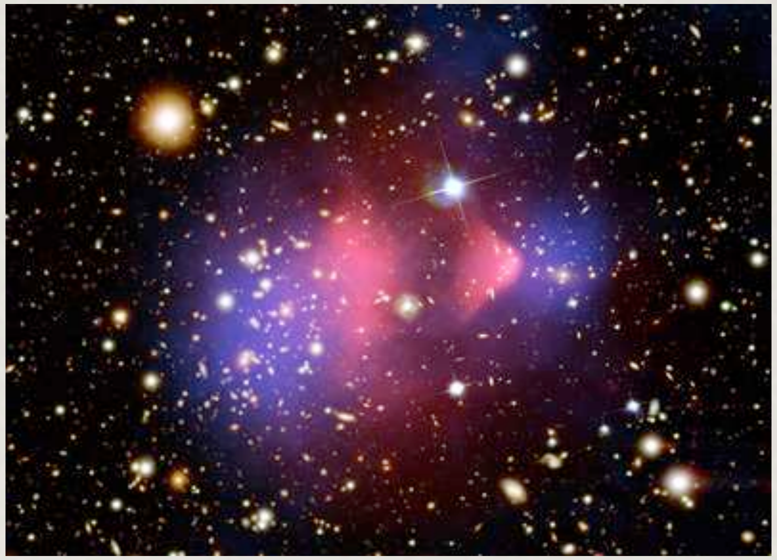


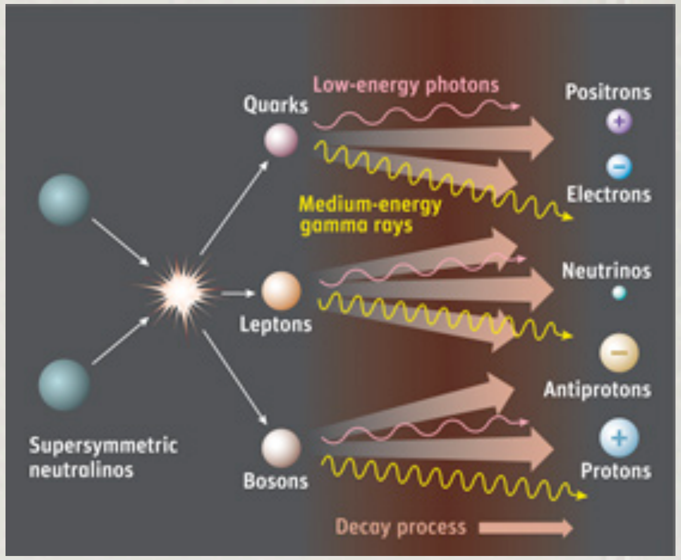


  - *Predicts force unification*



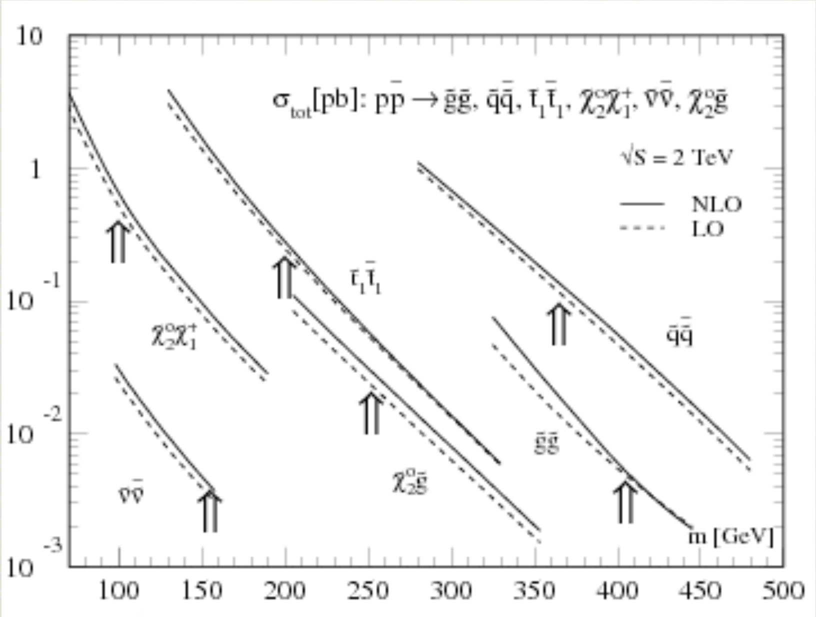
  - *Explains dark matter*

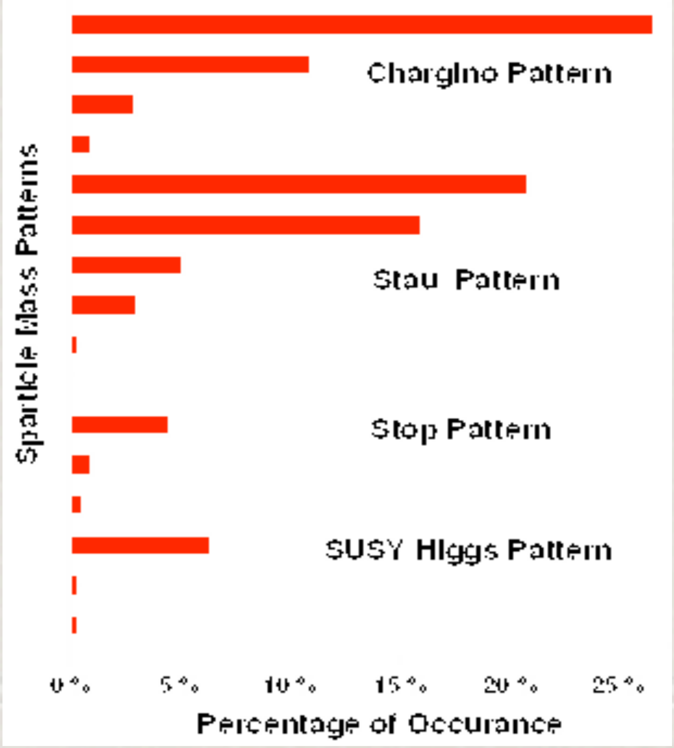




Supersymmetry at the Tevatron

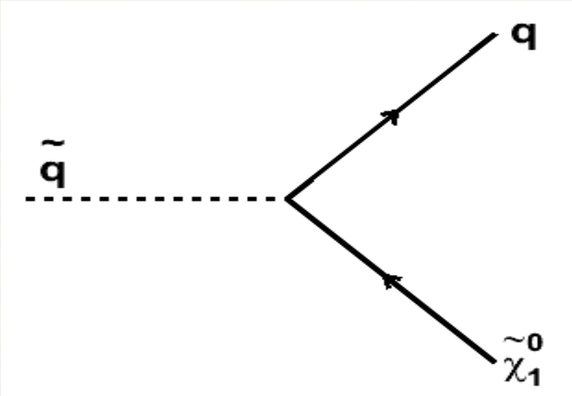
- *Candidates for discovery*
  - *Sparticles with highest cross sections*
    - *Squarks and gluinos*
  - *Sparticles with lowest masses*
    - *Charginos, neutralinos, stop squarks*
- *Final states depend on mass hierarchy*
- *Interpret results using a reference model*
  - *mSUGRA most common (5 parameters)*
    - *Typically assume lightest sparticle stable*

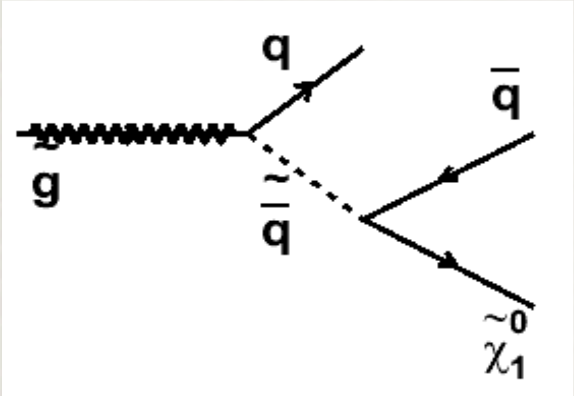




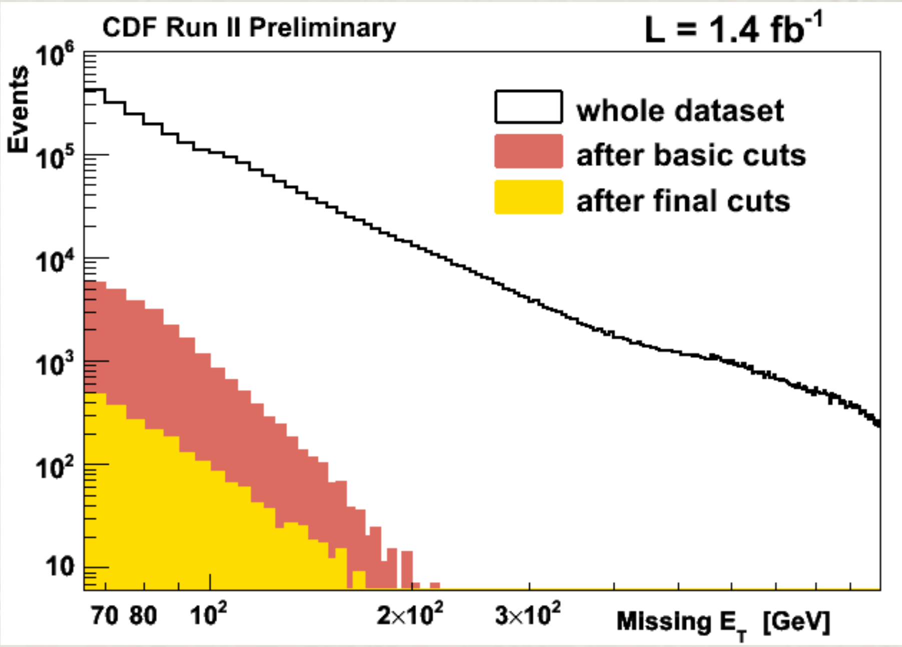
Squark and Gluino Searches

- *Search in final states with 2, 3, or 4 jets plus $\not{E}_T$*
  - *2 jets: $\tilde{q}\tilde{q} \to qq\tilde{\chi}_1^0\tilde{\chi}_1^0$ ($m_{\tilde{q}} < m_{\tilde{g}}$)*
  - *3 jets: $\tilde{q}\tilde{g} \to qqq\tilde{\chi}_1^0\tilde{\chi}_1^0$ ($m_{\tilde{q}} \approx m_{\tilde{g}}$)*
  - *4 jets: $\tilde{g}\tilde{g} \to qqqq\tilde{\chi}_1^0\tilde{\chi}_1^0$ ($m_{\tilde{q}} > m_{\tilde{g}}$)*





- *Challenging backgrounds*
  - *Need to understand $\not{E}_T$ tails in multijet events*
  - *At large $\not{E}_T$ $t\bar{t}$ and W/Z + jets dominate*

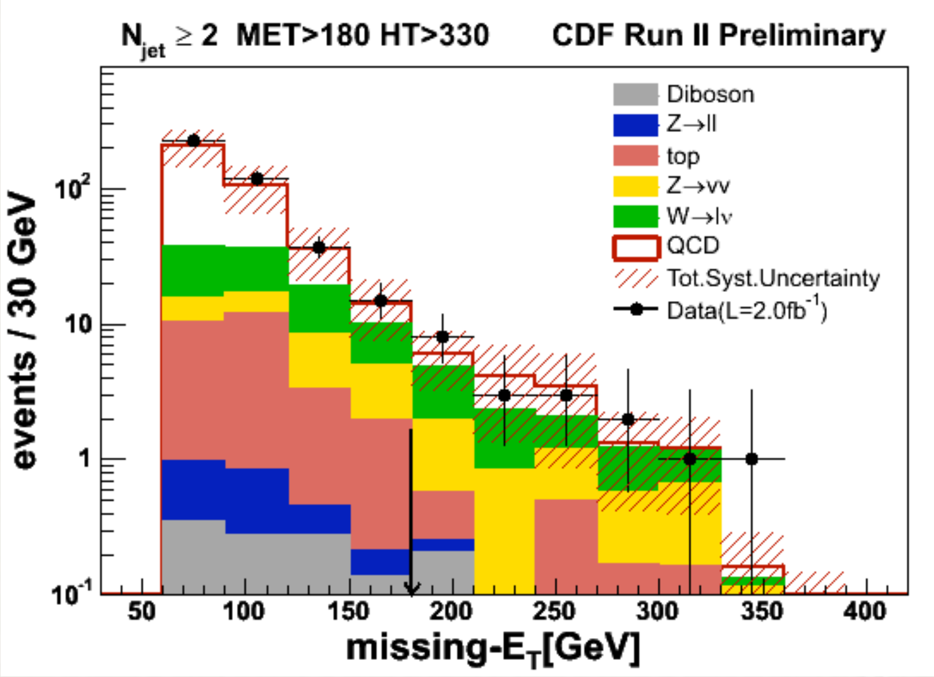


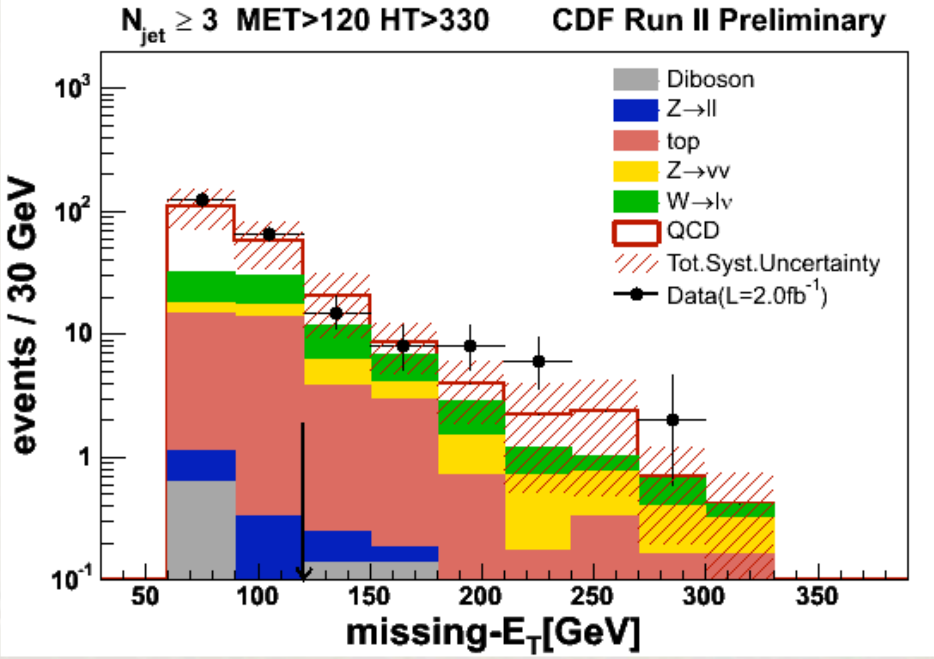
Squark and Gluino Background

- *Various methods to estimate background*
  - *MC-based prediction*
    - *Reduce QCD background with selection*
      - *$\not{E}_T$ not aligned with a reconstructed jet*
    - *Background predicted entirely with MC*

samples	2-jets	3-jets	4-jets
QCD	4.37±2.01	13.34±4.67	15.26±7.60
top	1.35±1.22	7.56±3.85	22.14±7.29
Z→ $\nu\nu$+jets	3.95±1.09	5.39±1.74	2.74±0.95
Z→ ll+jets	0.09±0.04	0.16±0.11	0.14±0.08
W→ $l\nu$+jets	6.08±2.15	10.69±3.84	7.68±2.85
WW/WZ/ZZ	0.21±0.19	0.35±0.17	0.49±0.34
tot SM	16±5	37±12	48±17

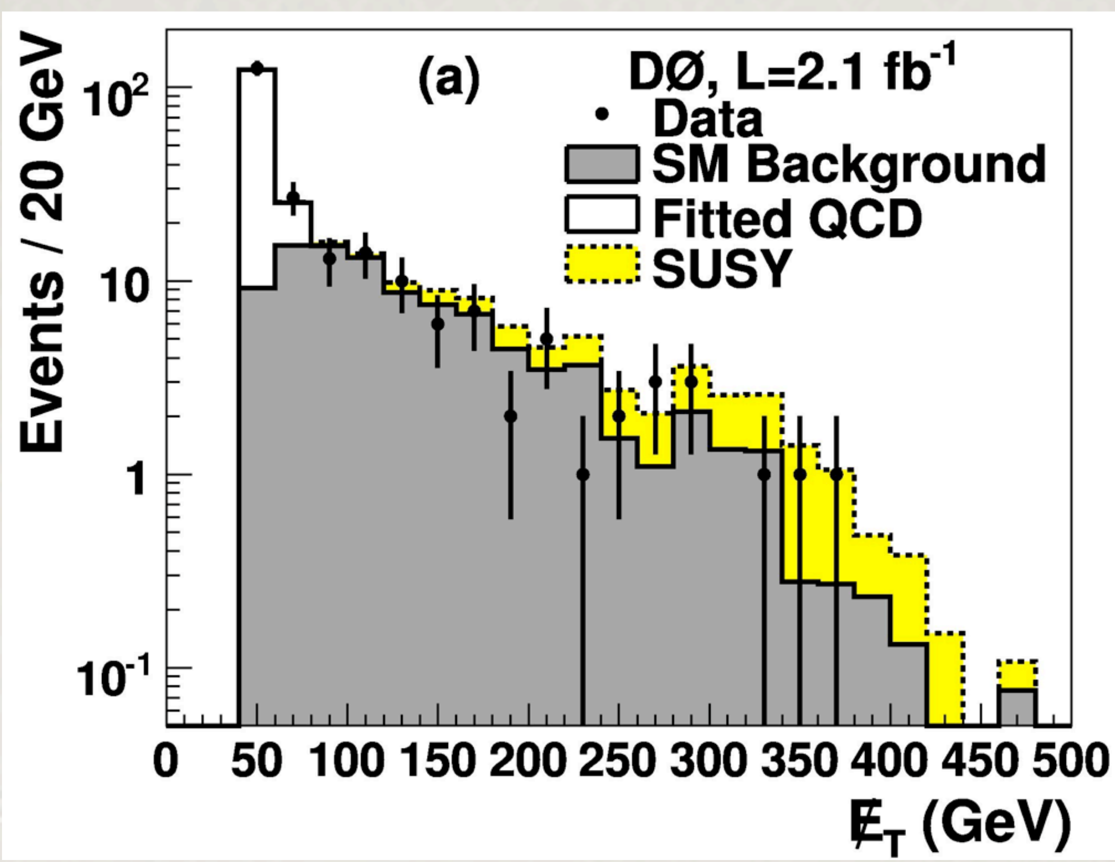
Region	Observed data
4-jets	45
3-jets	38
2-jets	18

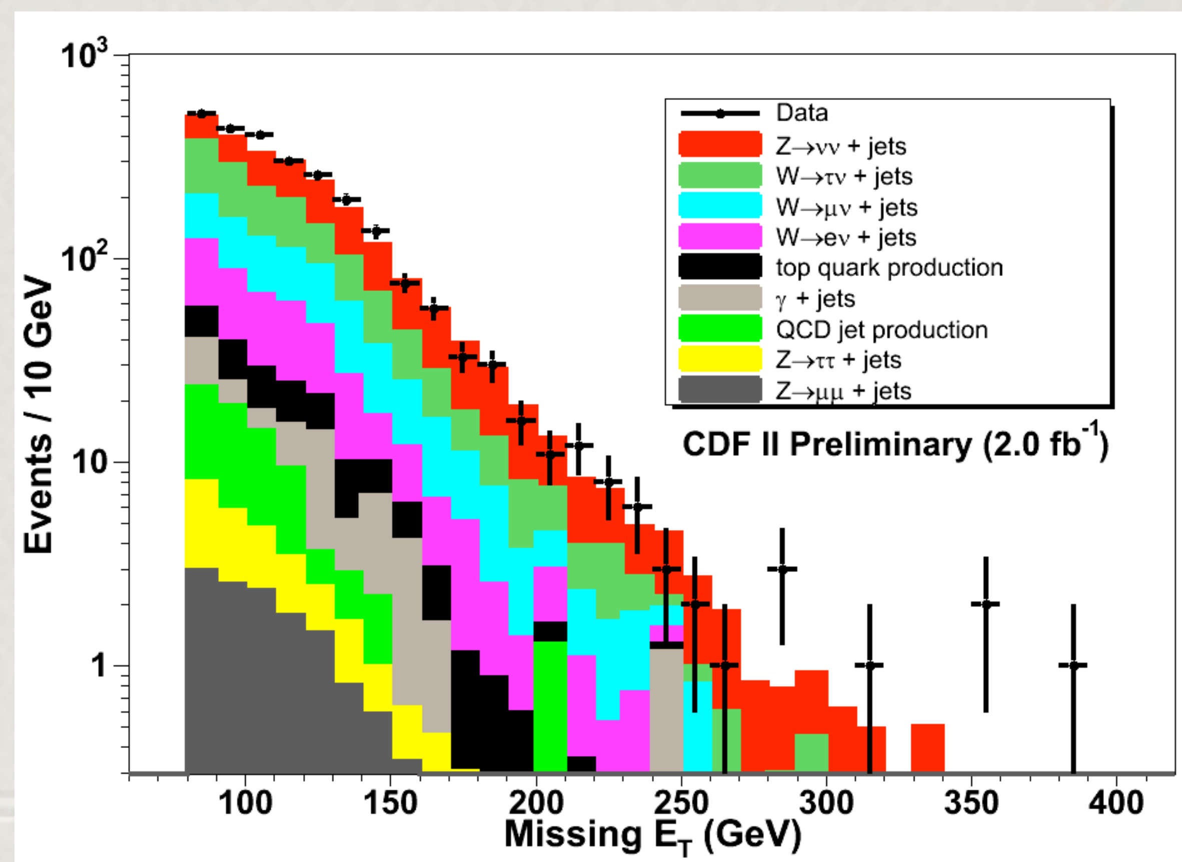




Squark and Gluino Background

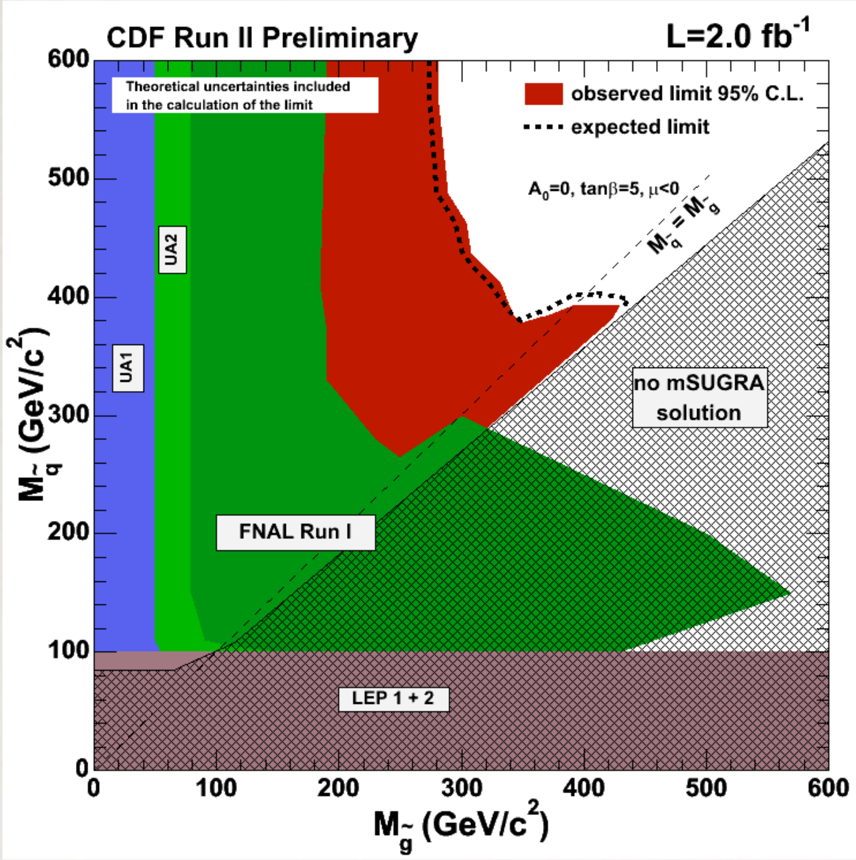
- *Data + MC prediction*
  - *Assume exponentially falling $\not\!\!E_T$ spectrum in QCD events*
    - *Negligible after selection*
- *Data-based prediction*
  - *Normalize W/Z + jets prediction to measurement*
    - *Background uncertainty: 6%*

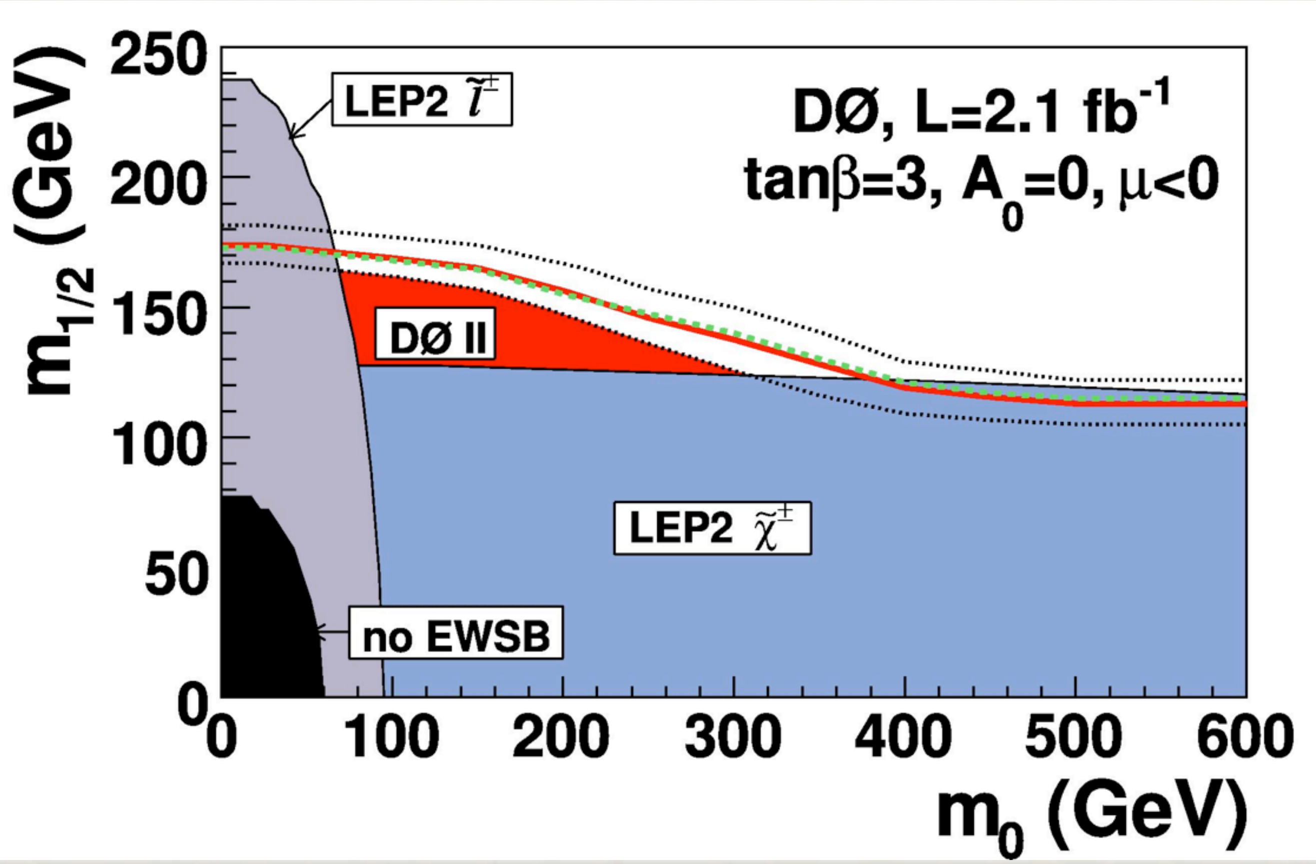




Squark and Gluino Limits

- *No significant excess in 2 fb^{-1} of CDF or DØ data*
  - *Limits on squark & gluino production extended to masses of ~400 GeV*
  - *Exclude m_0 below ~300 GeV for $m_{1/2}$ = 150 GeV in mSUGRA*



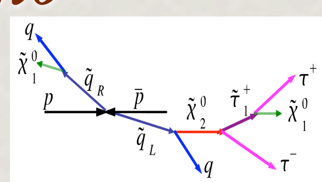
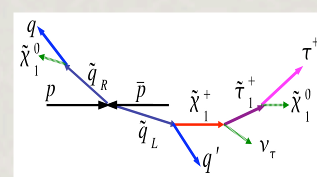


CDF Collaboration, PRL 102, 121801 (2009)

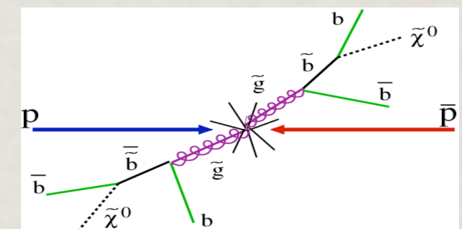
DØ Collaboration, PLB 660, 449 (2008)

Squark and Gluino Searches

- *Other final states possible through cascade decays*
  - *Squark decays to gaugino & quark, gaugino decays to stau & tau / neutrino*
    - *2 jets + τ + $\not\!E_T$*

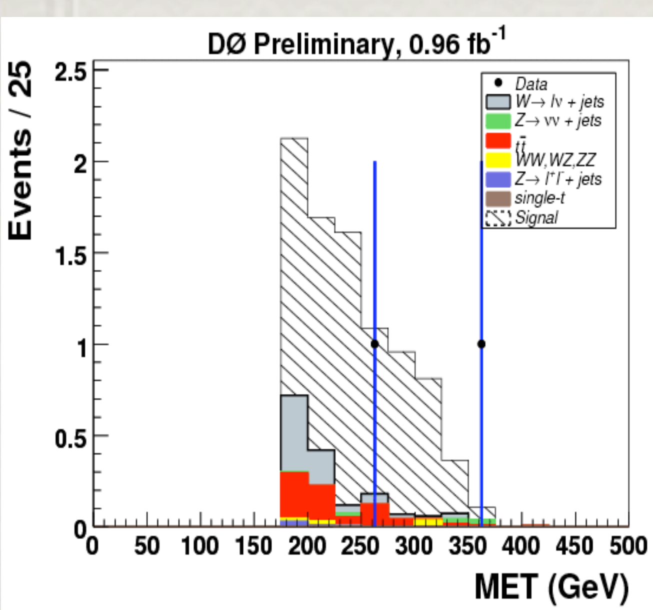
- *Gluino decays to sbottom & bottom*
  - *4 b-jets + $\not\!E_T$*

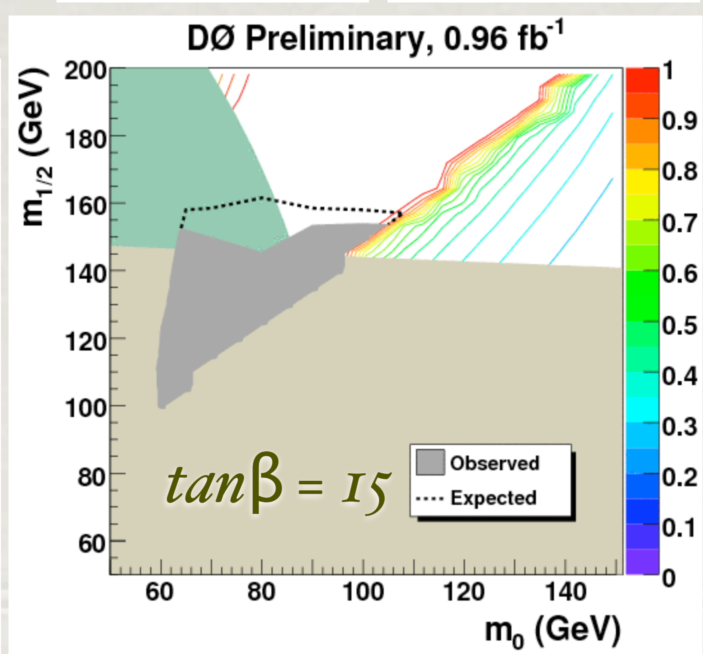


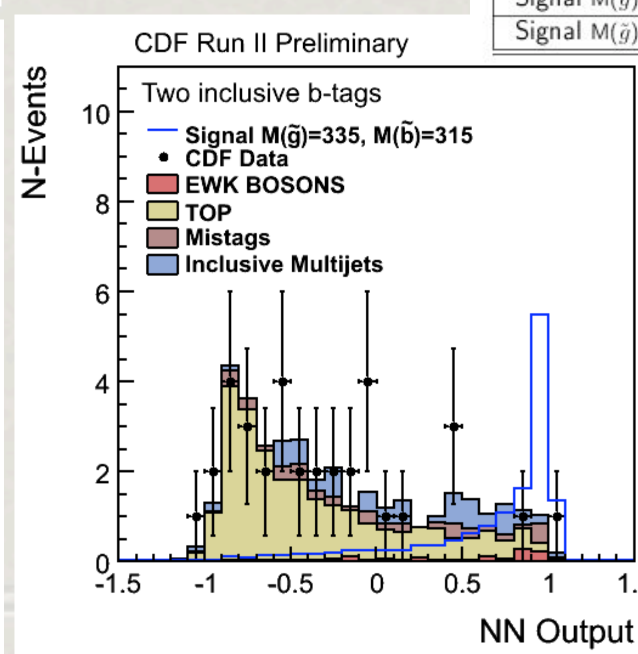
CDF Collaboration, arXiv:0903.2618 (2009)

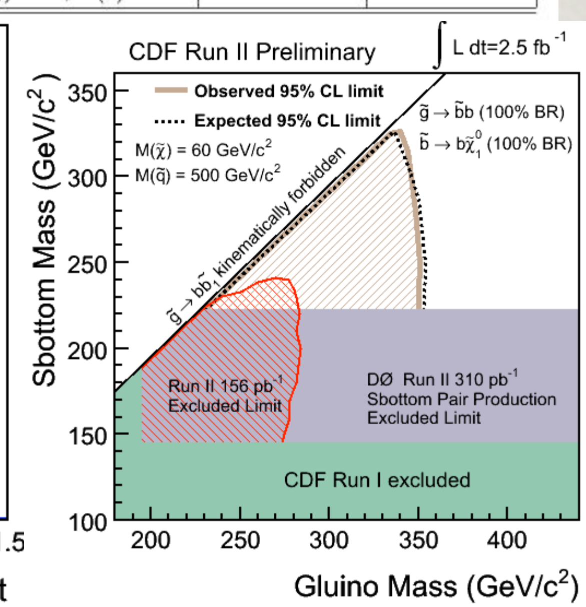
CDF Run II Preliminary 2.5 fb^{-1} (Two Inclusive Tags)

Region	Large Δm Optimization	Small Δm Optimization
W/Z + jets production	0.1 ± 0.05	0.4 ± 0.3
Diboson production	0.07 ± 0.02	0.1 ± 0.03
Top pair production	1.9 ± 1.0	0.6 ± 0.4
Single top production	0.03 ± 0.01	0.04 ± 0.01
HF QCD Multijets	1.5 ± 0.7	0.6 ± 0.3
Light-flavour contamination	0.9 ± 0.3	0.6 ± 0.1
Total expected	4.5 ± 1.4	2.3 ± 0.8
Observed	5	2
Signal M($\tilde{g}$)=335, M($\tilde{b}$)=260	14.9 ± 5.0	-
Signal M($\tilde{g}$)=335, M($\tilde{b}$)=315	-	8.5 ± 2.8

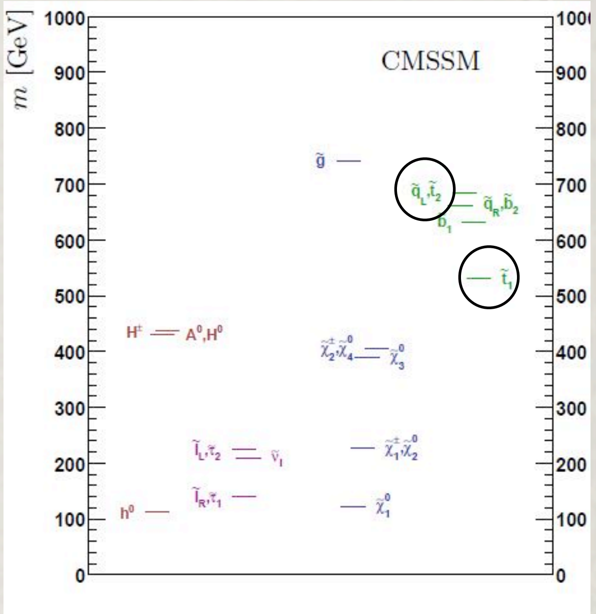




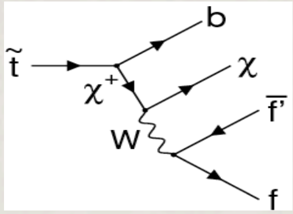


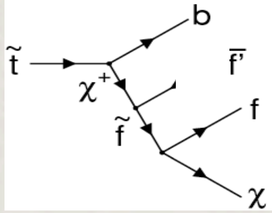


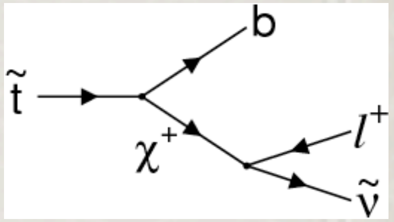
Stop Searches

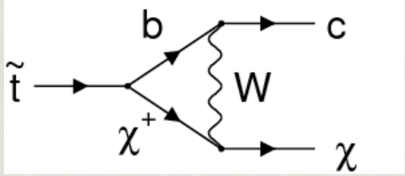


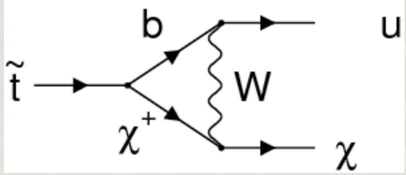
- *Large top mass results in large stop mass splitting*
  - *One stop expected to be light*
- *Final states depend on mass difference* $m_{\tilde{t}} - m_{\tilde{\chi}}$
  - $m_{\tilde{t}} > m_W + m_b$ *or* $m_{\tilde{\chi}^\pm} + m_b$: $l^+l^- + bb + \not{E}_T$
  - $m_{\tilde{t}} > m_{\tilde{\chi}^\pm} + m_{LSP}$: 2 *c-jets* + $\not{E}_T$
  - $m_{\tilde{t}} < m_{\tilde{\chi}^\pm} + m_{LSP}$: *two long-lived charged massive particles*





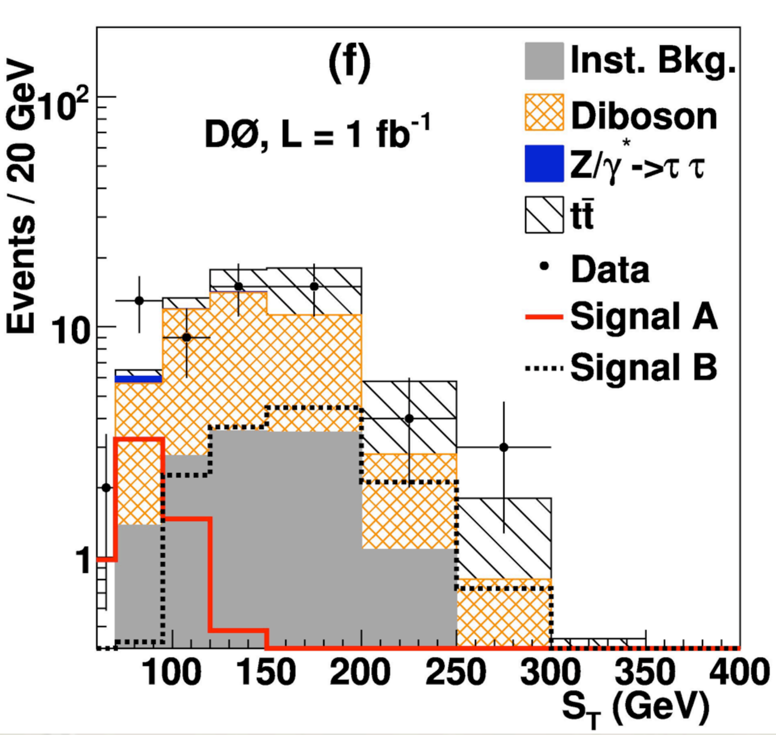


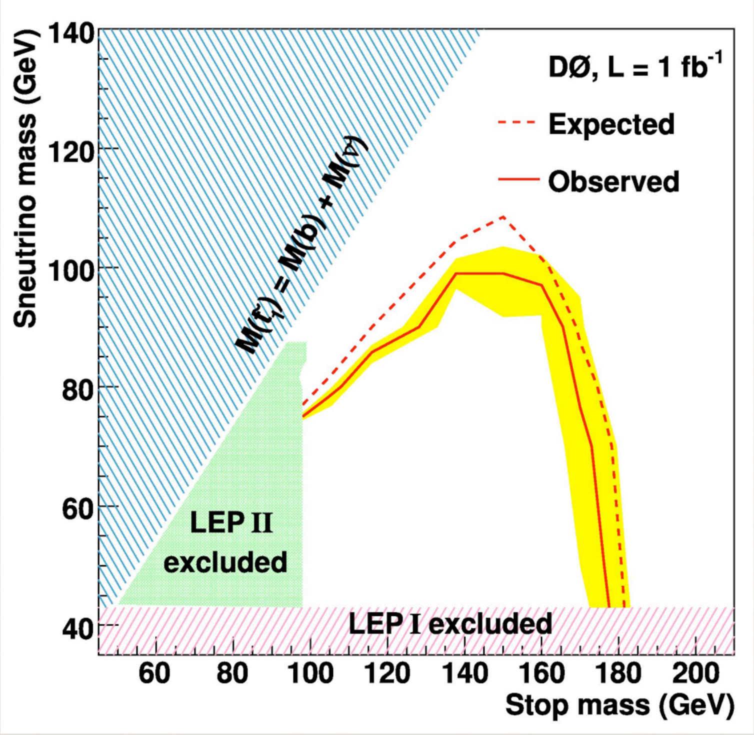


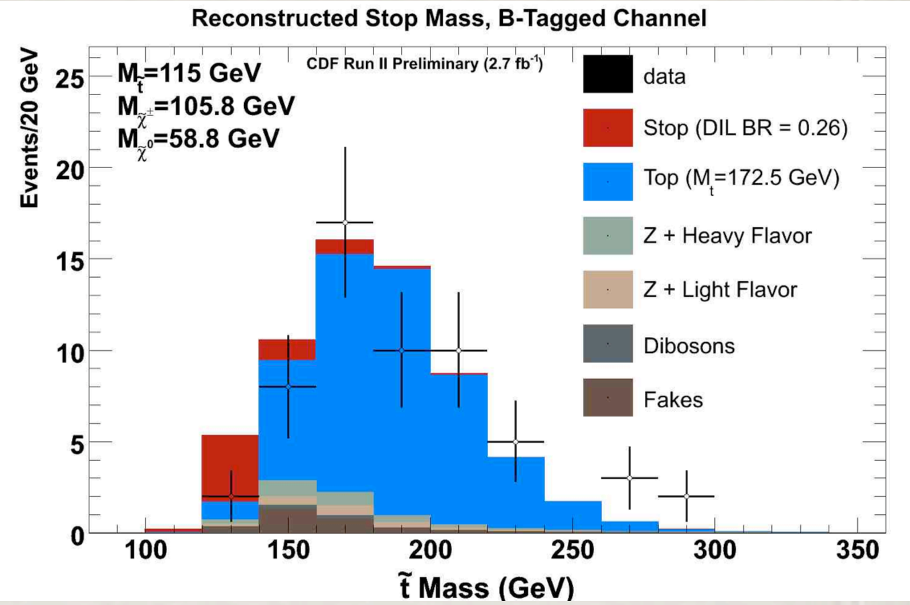


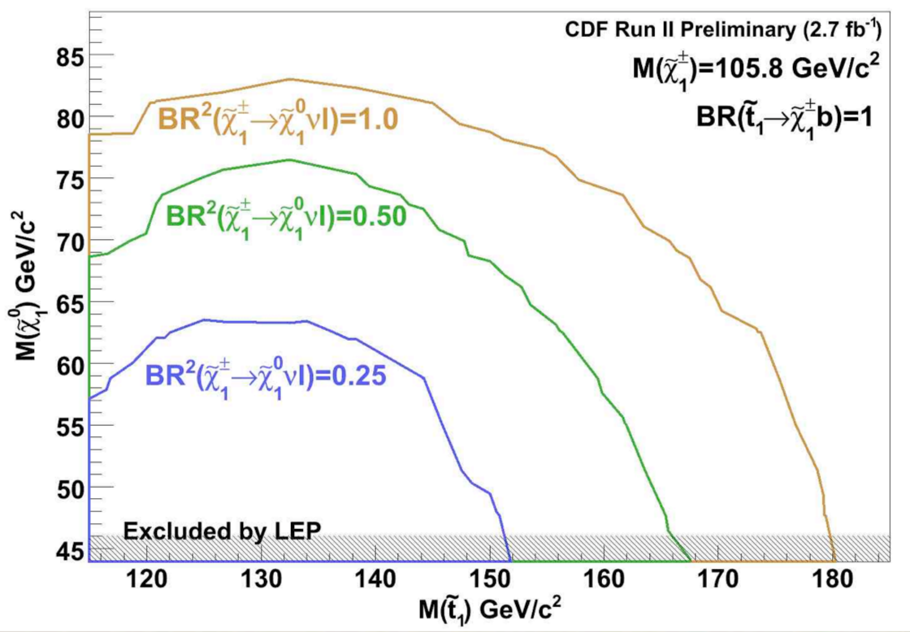
Stop Searches

- *Dilepton + b-jets + $\not\!\!E_T$ final state same as $t\bar{t}$ production*
  - *Search for top-like production at lower mass*









		Total SM	Background contributions					
Selection	Data	Background	$Z/\gamma^* \to \tau^+\tau^-$	$t\bar{t}$	Diboson	Instrumental	Signal A	Signal B
Preselection	735	736 ± 15	458	29.7	60.6	188	34.0 ± 1	26.3 ± 0.7
Emu 1	106	106 ± 5	23	23.5	38.7	21	10.6 ± 0.7	19.4 ± 0.6
Emu 2	71	77 ± 4	5.9	20.0	36.2	15	8.4 ± 0.7	17.6 ± 0.6
Emu 3	61	65 ± 4	0.7	16.4	34.5	13	6.0 ± 0.6	16.1 ± 0.5

DØ Collaboration, PLB 675, 289 (2009)

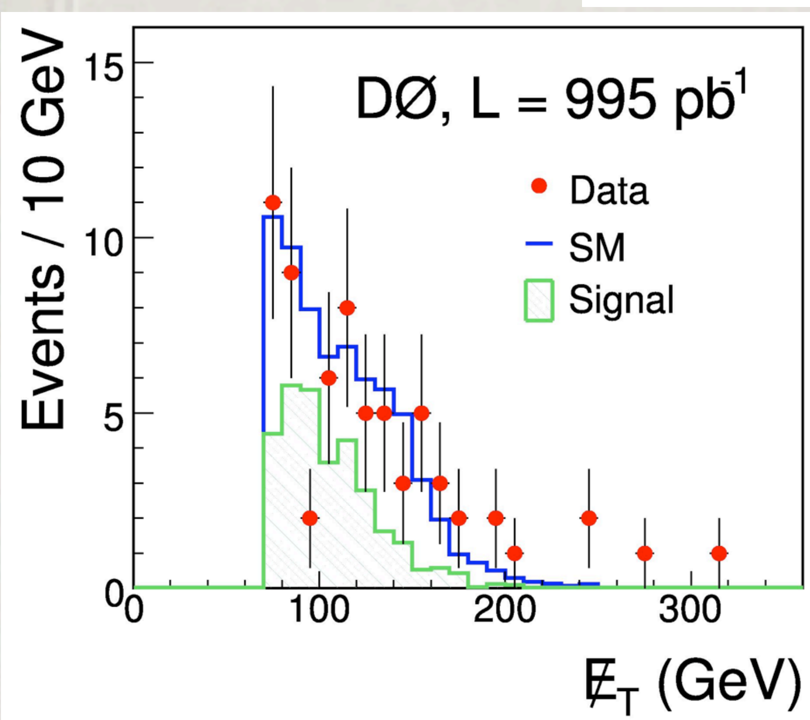
Stop Searches

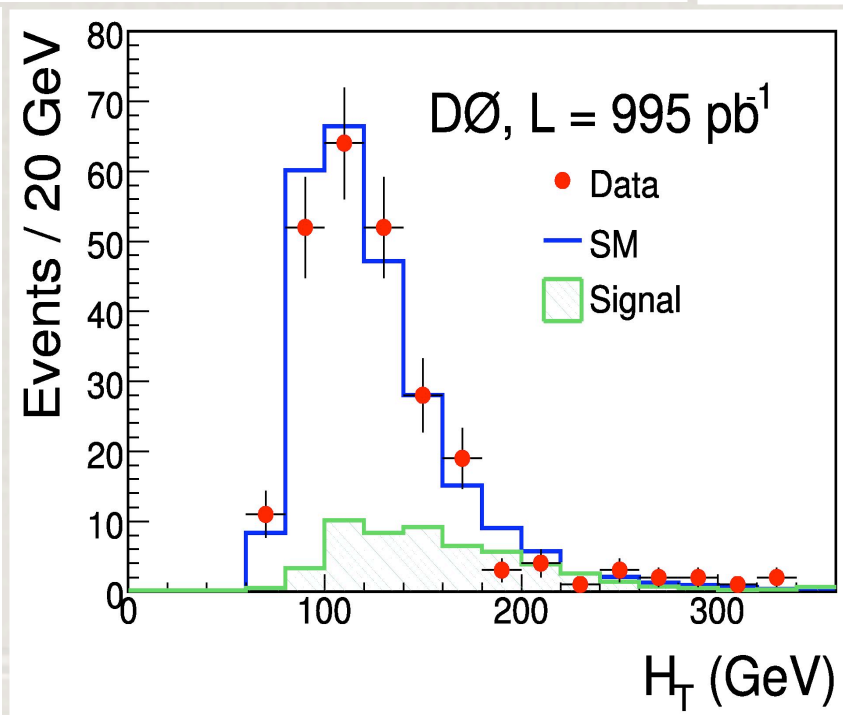
- *Two c-jets + $\not{E}_T$ final state similar to generic squark search*
  - *Charm tagging can reduce background*

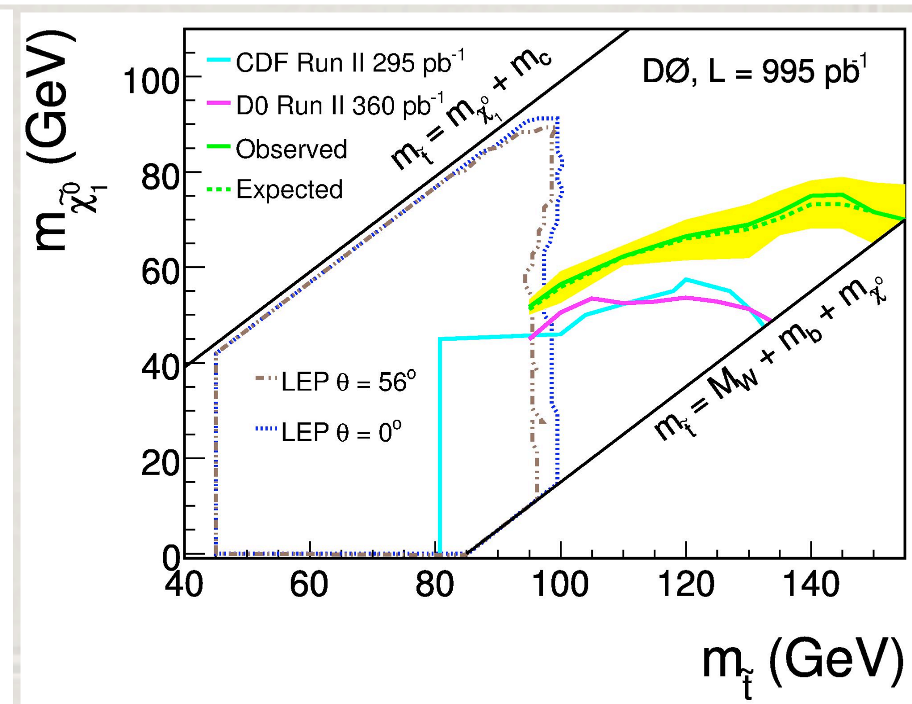
DØ Collaboration, PLB 665, 1 (2008)

$m_{\tilde{t}}$	H_T	S	Observed	Predicted
95 – 130	> 100	< 260	83	$85.3 \pm 1.8^{+12.8}_{-13.0}$
135 – 145	> 140	< 300	57	$59.0 \pm 1.6^{+8.5}_{-8.8}$
150 – 160	> 140	< 320	66	$66.6 \pm 1.1^{+9.6}_{-10.0}$

SM process	Number of events
$W(\to \ell\nu)$ + jets	20.0 ± 0.7
$Z(\to \nu\bar{\nu})$ + jets	15.8 ± 0.5
$W(\to \ell\nu)$ + HF ($b\bar{b}, c\bar{c}$)	12.6 ± 0.5
$Z(\to \nu\bar{\nu})$ + HF ($b\bar{b}, c\bar{c}$)	11.6 ± 0.4
$t\bar{t}$ and single top	3.7 ± 0.1
WW, WZ, ZZ	2.7 ± 0.1
$Z(\to \ell\ell)$ (e, μ, τ) + jets	0.1 ± 0.01
$Z(\to \ell\ell)$ (e, μ, τ) + HF ($b\bar{b}, c\bar{c}$)	0.1 ± 0.01
Total	66.6 ± 1.1

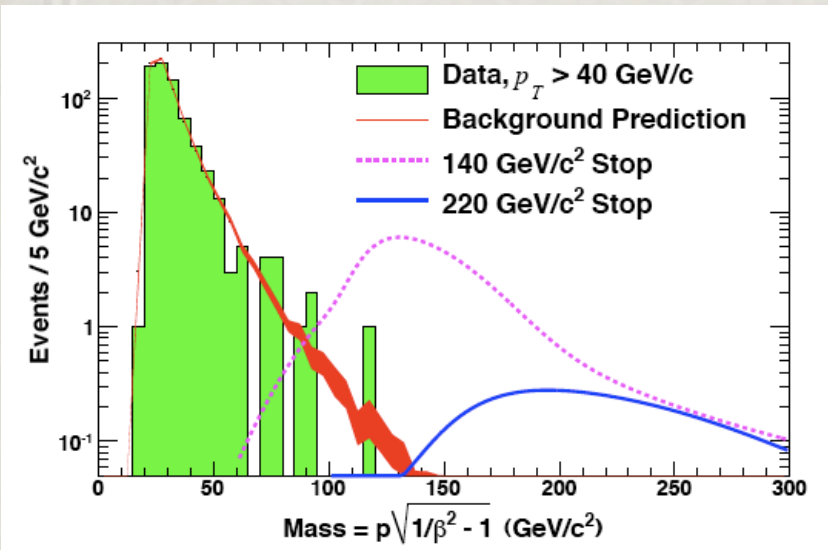


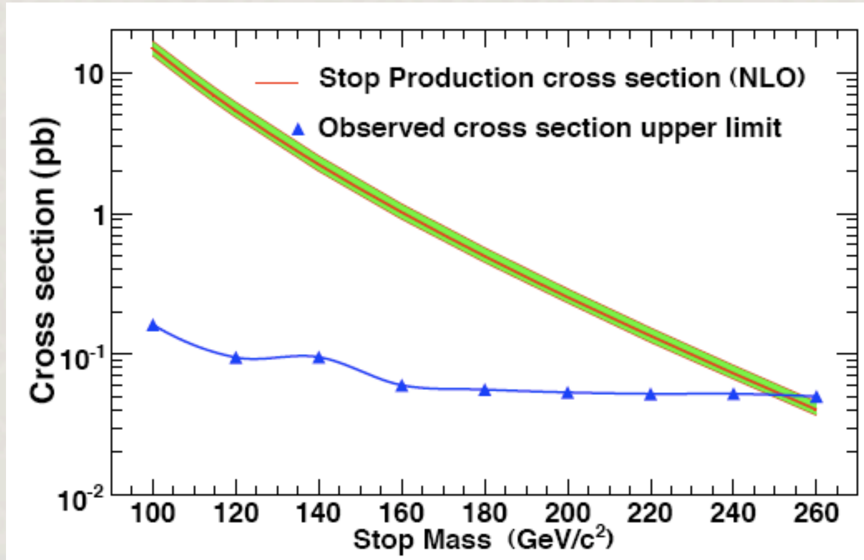




Stop / Gaugino / Stau Search

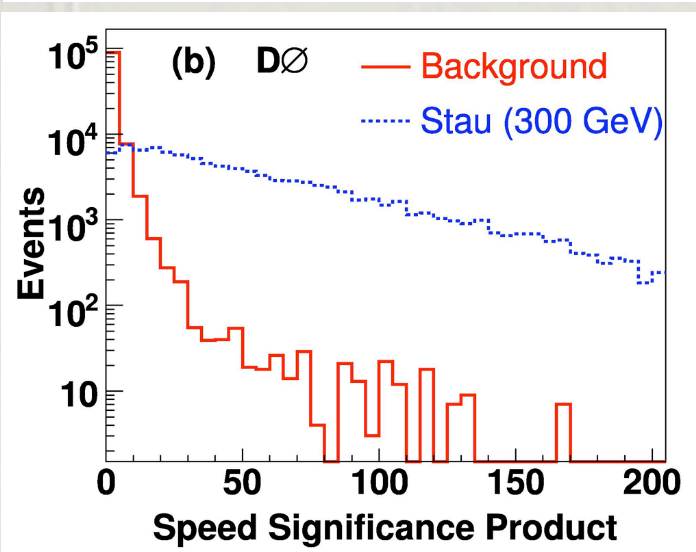
- *Use time-of-flight measurements to search for long-lived particles*
  - ***CDF**: TOF and inner tracking detectors; **DØ**: muon chambers*

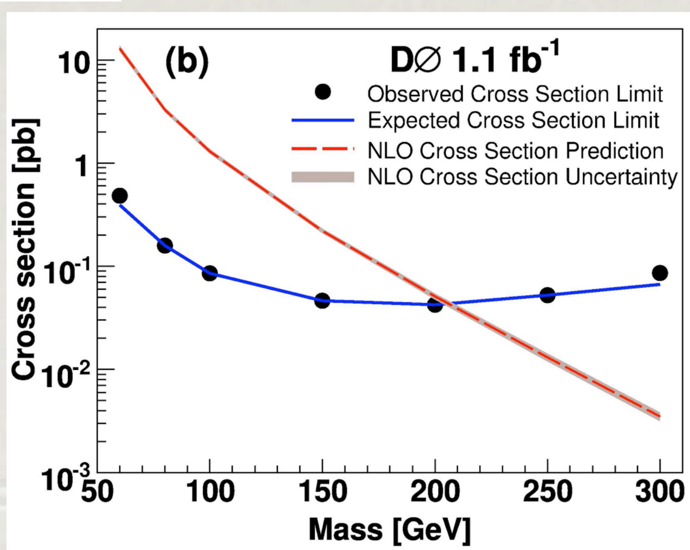




$\tilde{t}$ mass (GeV/c^2)	100	120	140	160
Expected background	4.7±0.3	1.9±0.2	0.8±0.1	0.37±0.05
Observed events	4	1	1	0
Total acceptance (%)	3.6±0.5	4.2±0.5	4.5±0.6	5.1±0.7
Expected limit (fb)	190	120	90	71
95% C.L. limit (fb)	160	90	100	60

CDF Collaboration, arXiv:0902.1266 (2009)





Mass (GeV)	Signal Acceptance	Predicted Background	Observed Events
(b) gaugino-like charginos			
60	$0.032 \pm 0.001 \pm 0.003$	$23.6 \pm 1.9 \pm 1.4$	24
80	$0.024 \pm 0.001 \pm 0.003$	$1.9 \pm 0.5 \pm 0.3$	1
100	$0.046 \pm 0.001 \pm 0.004$	$1.6 \pm 0.5 \pm 0.3$	1
150	$0.085 \pm 0.001 \pm 0.009$	$1.2 \pm 0.4 \pm 0.1$	1
200	$0.089 \pm 0.001 \pm 0.007$	$1.9 \pm 0.5 \pm 0.0$	1
250	$0.074 \pm 0.001 \pm 0.007$	$1.7 \pm 0.5 \pm 0.3$	1
300	$0.059 \pm 0.001 \pm 0.007$	$1.7 \pm 0.5 \pm 0.1$	2

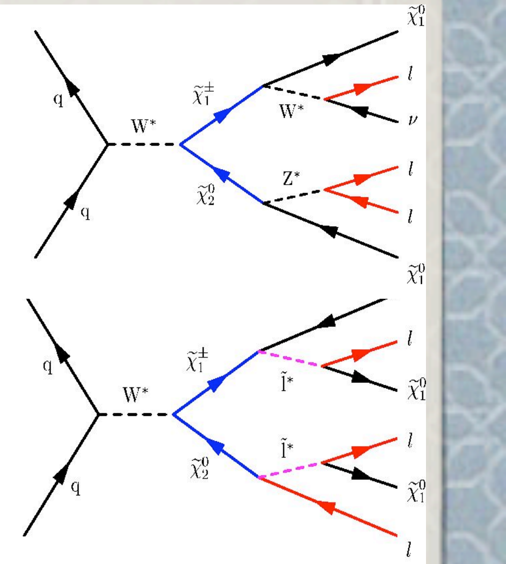
DØ Collaboration, PRL 102, 161802 (2009)

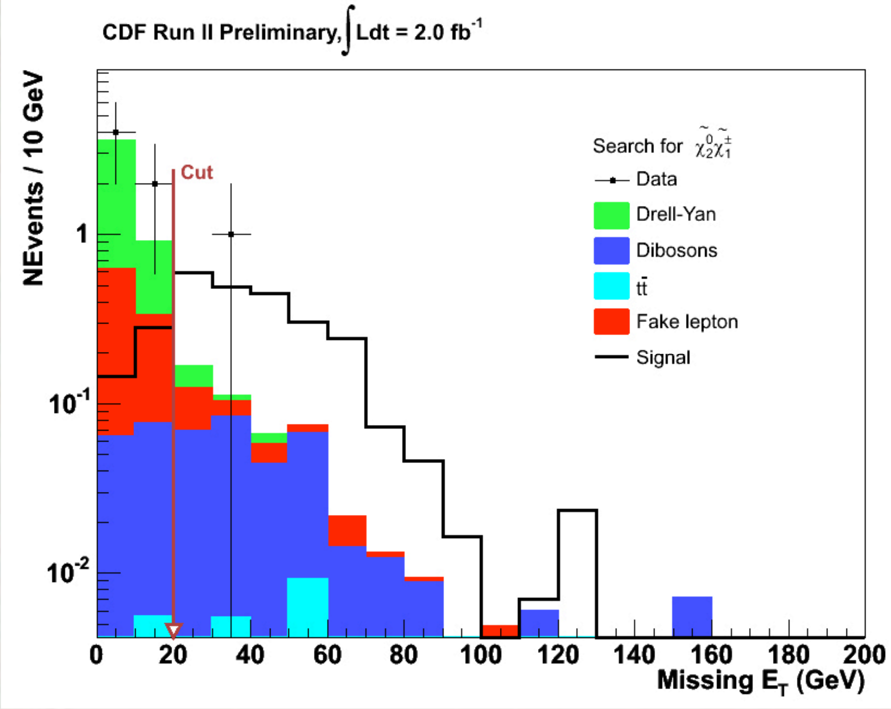
Gaugino-Pair Searches

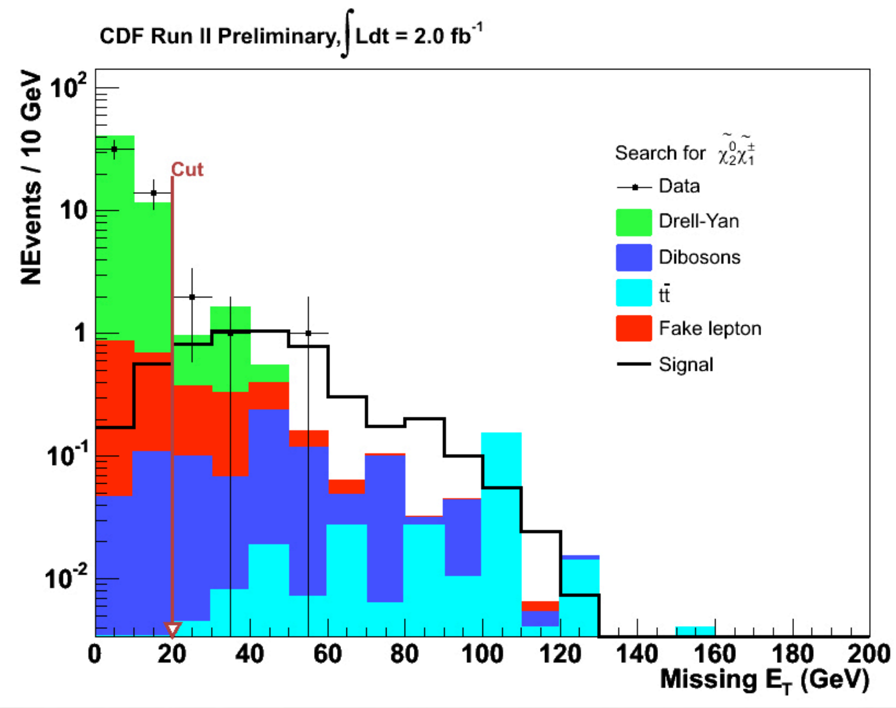
- *Low background to chargino + neutralino production*
  - *Decay through W, Z, or slepton*
  - *Final state: three leptons plus $\not\!\!E_T$*
    - *Separate leptons into high and low purity*

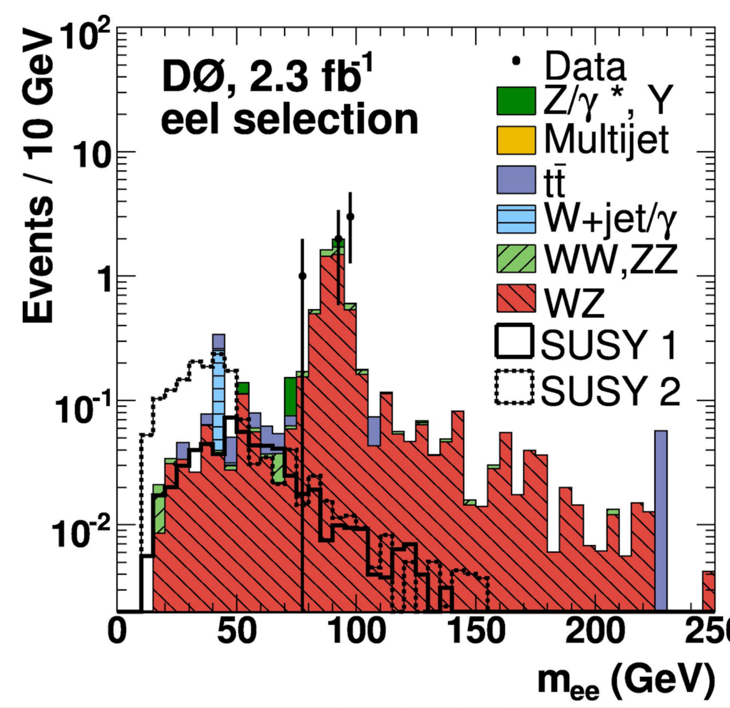
CDF RUN II Preliminary $\int \mathcal{L}dt = 2.0\ \mathrm{fb}^{-1}$: Search for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

Channel	Signal	Background	Observed
3tight	$2.25 \pm 0.13(\mathrm{stat}) \pm 0.29(\mathrm{syst})$	$0.49 \pm 0.04(\mathrm{stat}) \pm 0.08(\mathrm{syst})$	1
2tight,1loose	$1.61 \pm 0.11(\mathrm{stat}) \pm 0.21(\mathrm{syst})$	$0.25 \pm 0.03(\mathrm{stat}) \pm 0.03(\mathrm{syst})$	0
1tight,2loose	$0.68 \pm 0.07(\mathrm{stat}) \pm 0.09(\mathrm{syst})$	$0.14 \pm 0.02(\mathrm{stat}) \pm 0.02(\mathrm{syst})$	0
Total Trilepton	$4.5 \pm 0.2(\mathrm{stat}) \pm 0.6(\mathrm{syst})$	$0.88 \pm 0.05(\mathrm{stat}) \pm 0.13(\mathrm{syst})$	1
2tight,1Track	$4.44 \pm 0.19(\mathrm{stat}) \pm 0.58(\mathrm{syst})$	$3.22 \pm 0.48(\mathrm{stat}) \pm 0.53(\mathrm{syst})$	4
1tight,1loose,1Track	$2.42 \pm 0.14(\mathrm{stat}) \pm 0.32(\mathrm{syst})$	$2.28 \pm 0.47(\mathrm{stat}) \pm 0.42(\mathrm{syst})$	2
Total Dilepton+Track	$6.9 \pm 0.2(\mathrm{stat}) \pm 0.9(\mathrm{syst})$	$5.5 \pm 0.7(\mathrm{stat}) \pm 0.9(\mathrm{syst})$	6







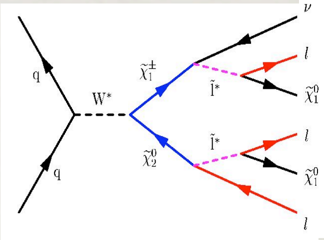


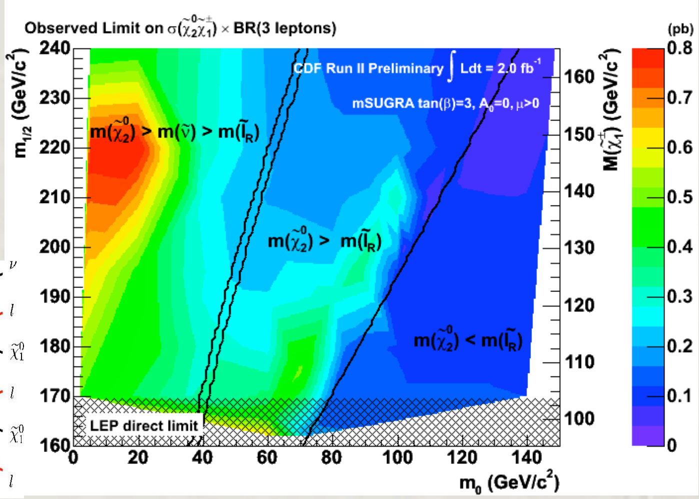
CDF Collaboration, PRL 101, 251801 (2008)

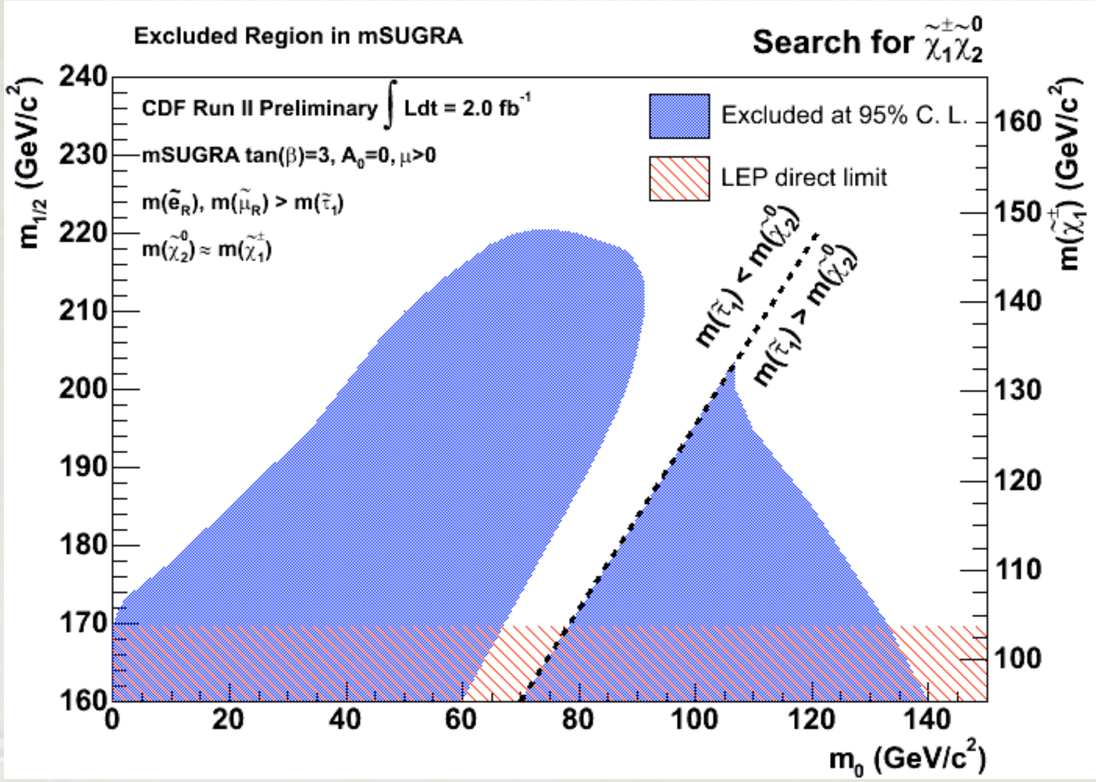
DØ Collaboration, arXiv:0901.0646 (2009)

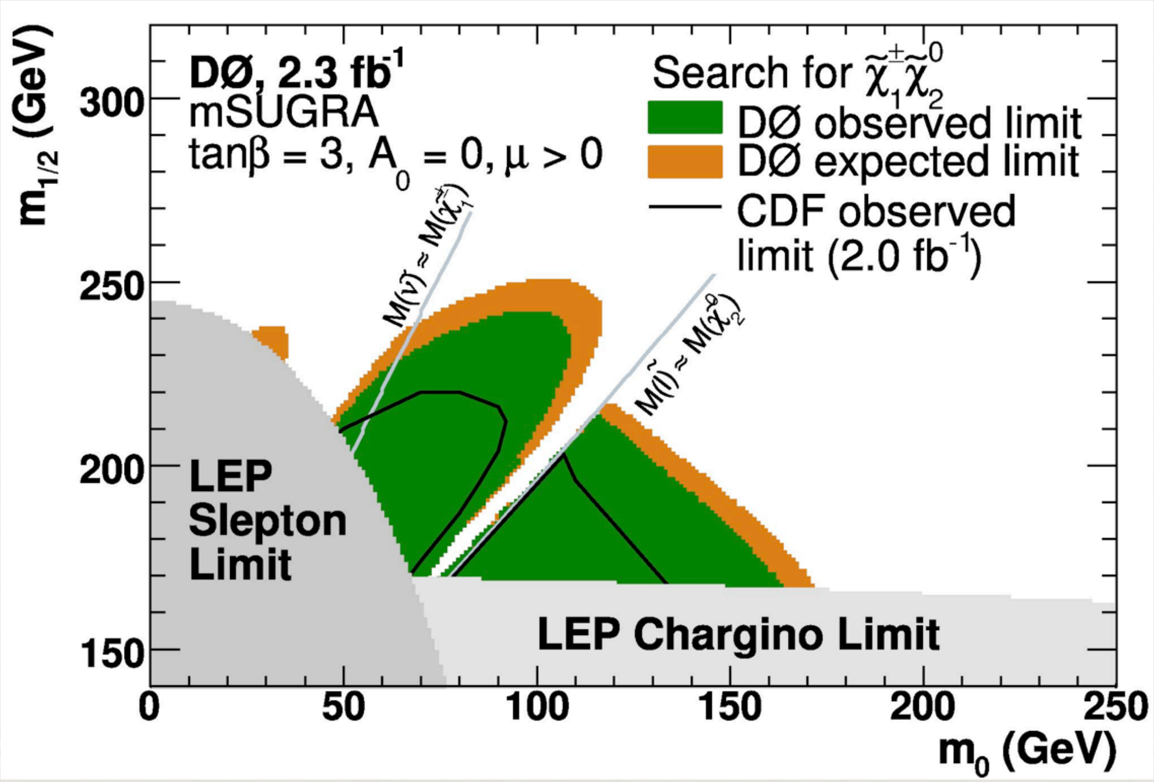
Gaugino-Pair Searches

- *Results interpreted in the context of mSUGRA*
  - *Limits depend on relative neutralino-slepton masses*
    - $m_{\chi_2} > m_{slepton}$ *increases branching ratio to e/μ*
    - $m_{\chi_2} \approx m_{slepton}$ *reduces acceptance to lowest* p_T *lepton*



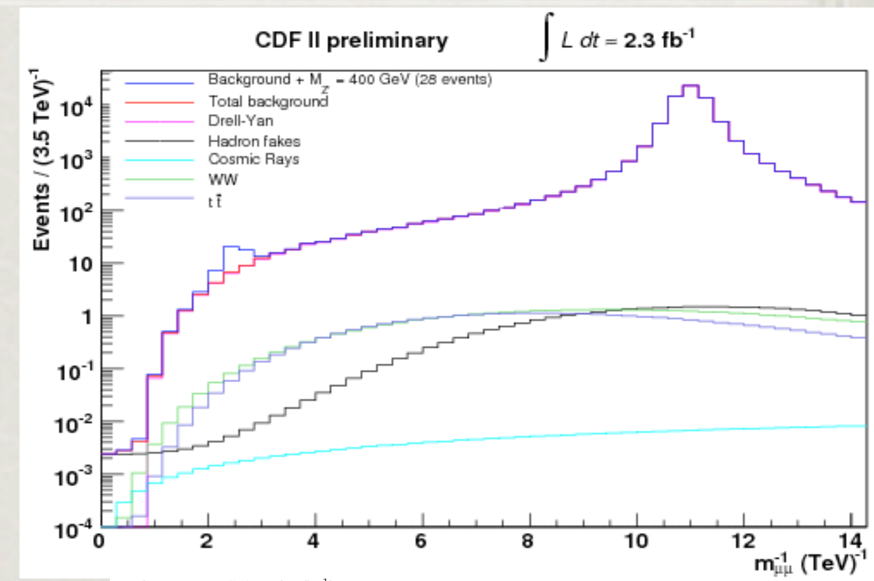






Making a Discovery

- *Strategies*
  - *Probe well-motivated models*
  - *Search for clear indications of new physics*
  - *Study all final states*
- *Issues*
  - *How do you know when it's a discovery?*
  - *How do you know you haven't missed a discovery?*



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

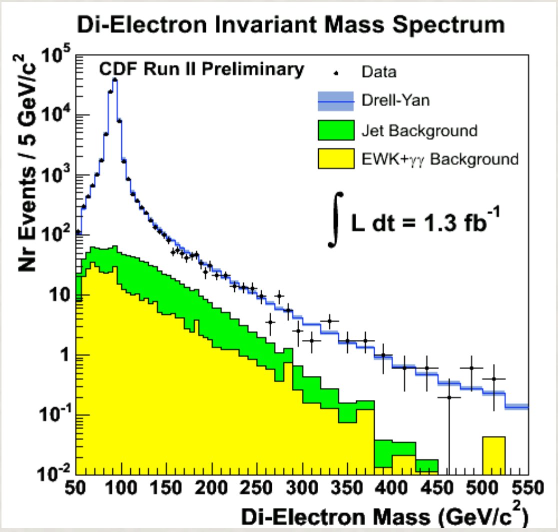
Final State	Data	Background	σ
$be^{\pm}\not{p}$	690	817.7 ± 9.2	−2.7
$\gamma\tau^{\pm}$	1371	1217.6 ± 13.3	+2.2
$\mu^{\pm}\tau^{\pm}$	63	35.2 ± 2.8	+1.7
$b2j\not{p}$ high-Σp_T	255	327.2 ± 8.9	−1.7
$2j\tau^{\pm}$ low-Σp_T	574	670.3 ± 8.6	−1.5
$3j\tau^{\pm}$ low-Σp_T	148	199.8 ± 5.2	−1.4
$e^{\pm}\not{p}\tau^{\pm}$	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

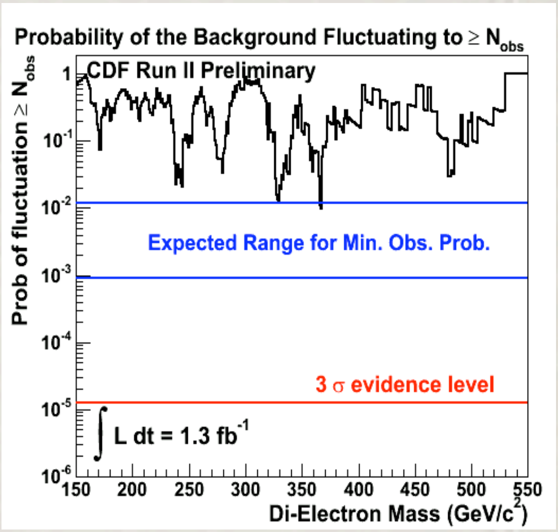
Final State	Data	Background	σ
$j\mu^{\pm}\mu^{\mp}\not{p}$	32	32.2 ± 10.9	0
$j\mu^{\pm}\mu^{\mp}\gamma$	14	11.5 ± 2.6	0
$j\mu^{\pm}\mu^{\mp}$	4852	4271.2 ± 185.4	0
$j\mu^{\pm}$	77689	76987.5 ± 930.2	0
$e^{\pm}4j\not{p}$	903	830.6 ± 13.2	0
$e^{\pm}4j\gamma$	25	29.2 ± 3.6	0
$e^{\pm}4j$	15750	16740.4 ± 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

Indicators of New Physics

- *Mass resonances & final states with low SM background*
  - *Fully reconstructed resonance an unambiguous sign of a new particle*
    - *Wide variety of possible resonances*
      - *Neutral, charged, fractionally & doubly charged*
      - *Decays to fermions and / or gauge bosons*
    - *Strategies for resonance search:*
      - *Calculate significance, accounting for fluctuations over full spectrum*
      - *Judiciously choose binning & variable for mass scan*
  - *Final states with little background offer unique discovery opportunity*
    - *Can convincingly demonstrate new physics and study sample with high purity*

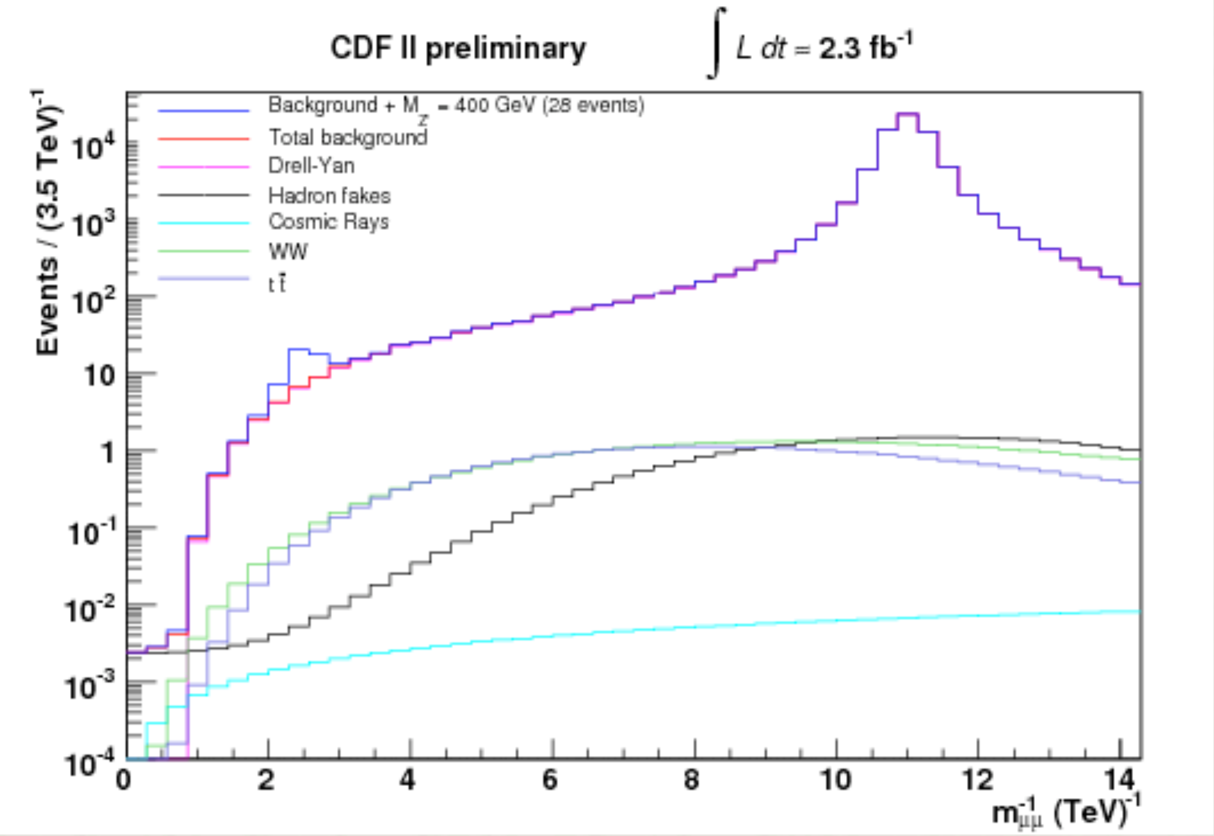


CDF Collaboration, PRL 99, 271802 (2007)



Neutral Resonances

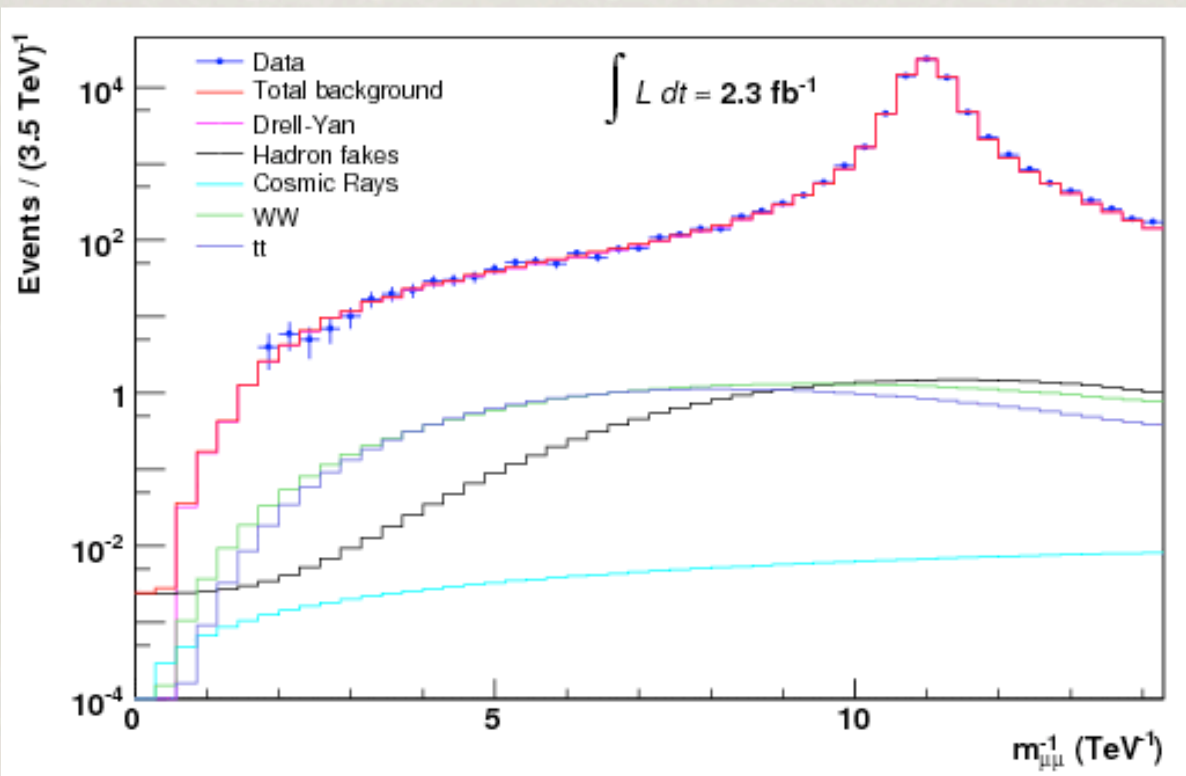
- *Many decays fully reconstructable*
  - *Electrons, muons, light quarks, photons*
- *Constant-resolution variable simplifies narrow-resonance search*

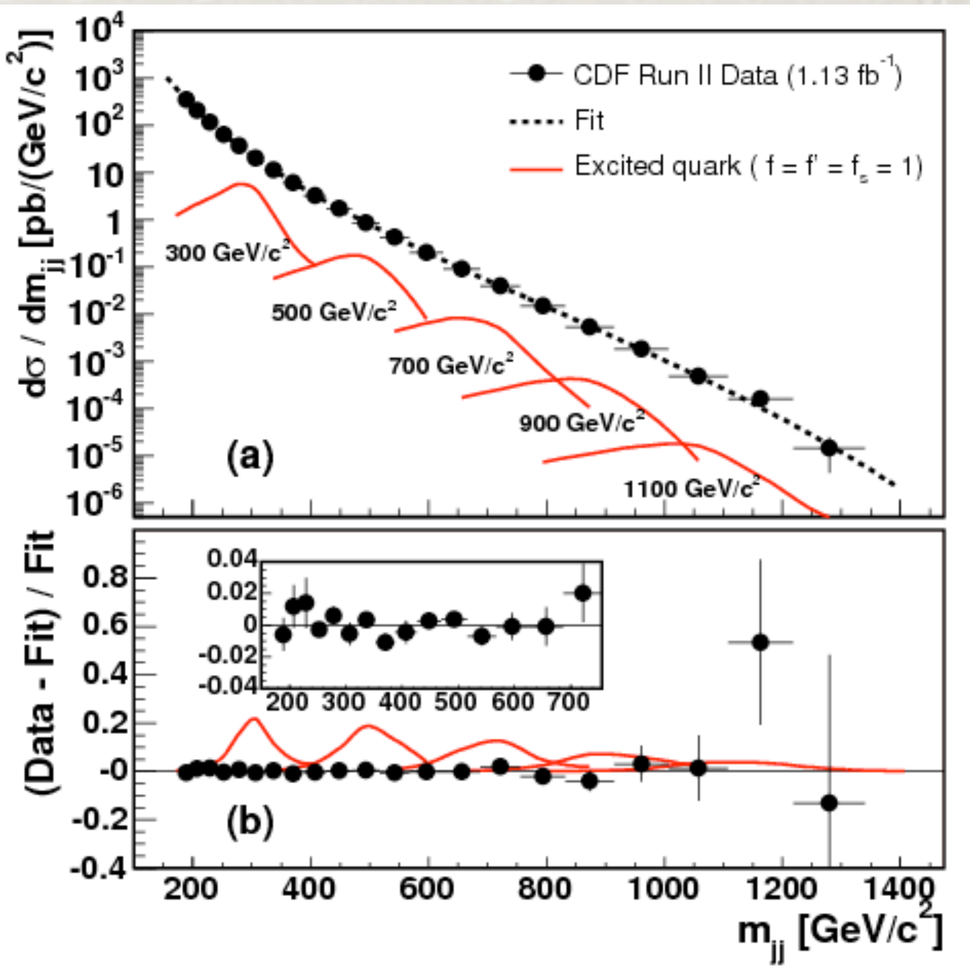


  - **Muons: 1/m**
    - $\sigma_{pT} \propto p_T^2$, $\sigma_{1/pT}$ = *constant*
  - **Electrons & photons: log m**
    - $\sigma_{ET} \propto E_T$, σ_{logET} = *constant*
  - **Jets: $m^{1/2}$**
    - $\sigma_{ET} \propto E_T^{1/2}$, $\sigma_{sqrt(ET)}$ = *constant*

Neutral Resonance Searches

- *Resonances predicted by huge range of new physics*
  - *Supersymmetry, extra dimensions, extra gauge groups and unification*





$\lambda^2 \cdot$ BR	Mass Limit, 95% CL (GeV/c^2
0.01	866
0.005	810
0.002	731
0.001	662
0.0005	541
0.0002	441
0.0001	397

Model	Mass Limits, 95% CL (GeV/c^2)
Z' (SM)	1030
Z' (η)	904
Z' (χ)	892
Z' (ψ)	878
Z' (N)	861
Z' (sec)	821
Z' (ι)	789

Graviton k/M_{Pl}	Mass Limit, 95% CL (GeV/c^2)
0.1	921
0.07	824
0.05	746
0.035	651
0.025	493
0.015	409
0.01	293

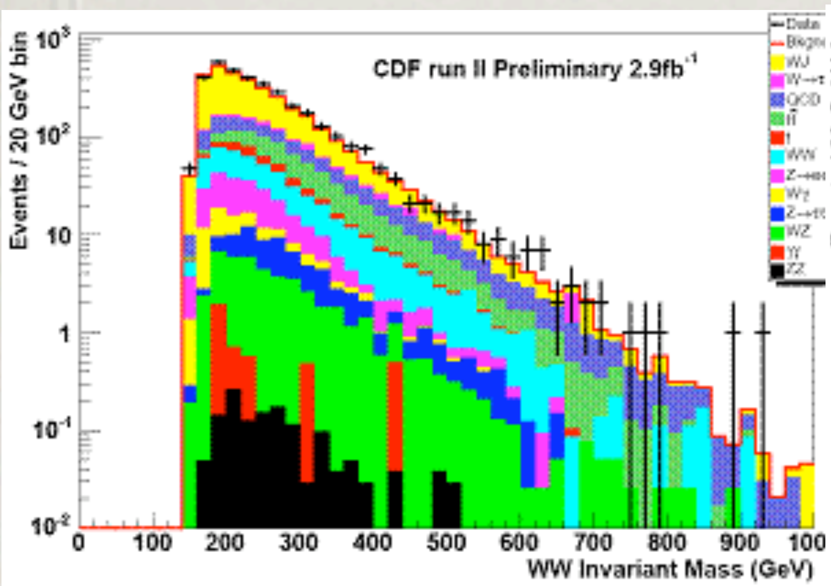
axion / coloron mass > 1250 GeV

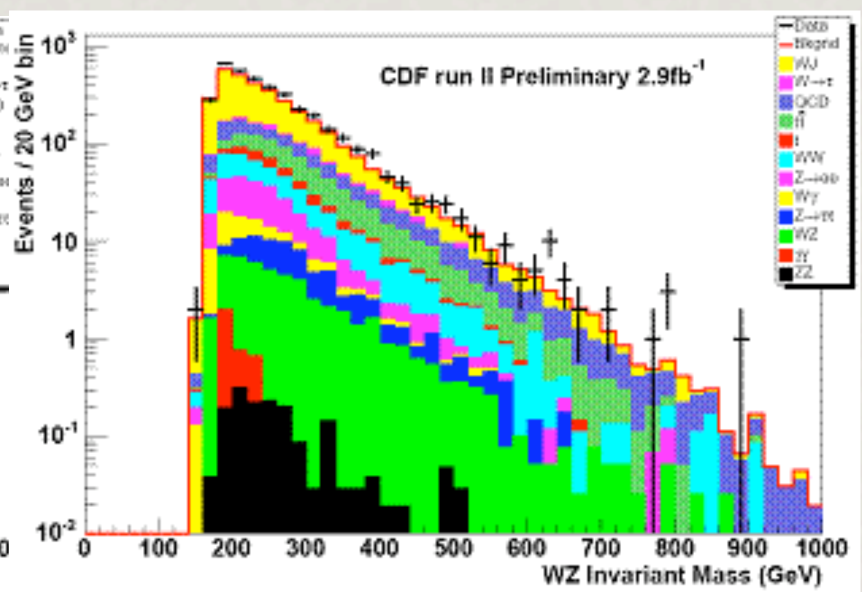
CDF Collaboration, PRL 102, 091805 (2009)

CDF Collaboration, arXiv:0812.4036 (2008)

Neutral Resonances

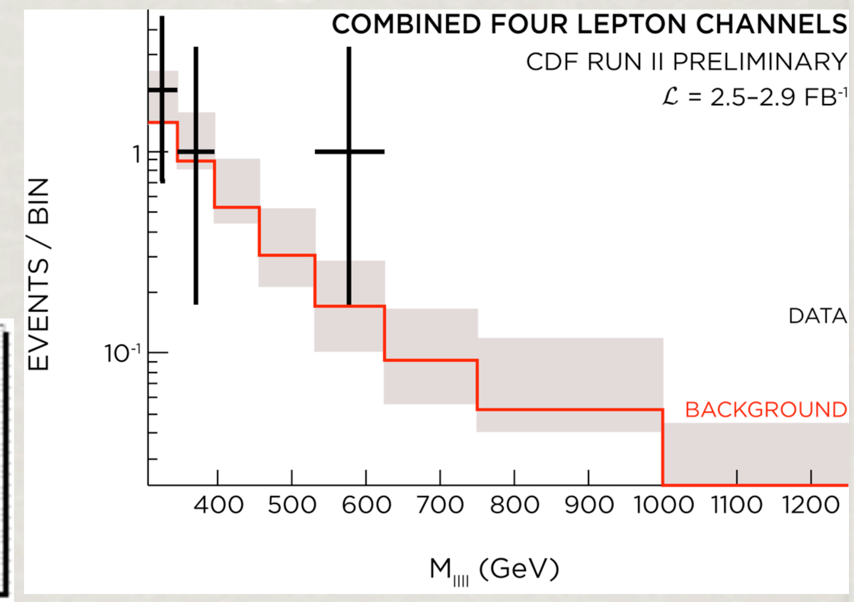
- *Decays to gauge boson pairs*
  - *WW / WZ → lνjj*
    - *Diboson mass: solve for p_z^{ν} with m_W*
- *ZZ → llll, lljj*

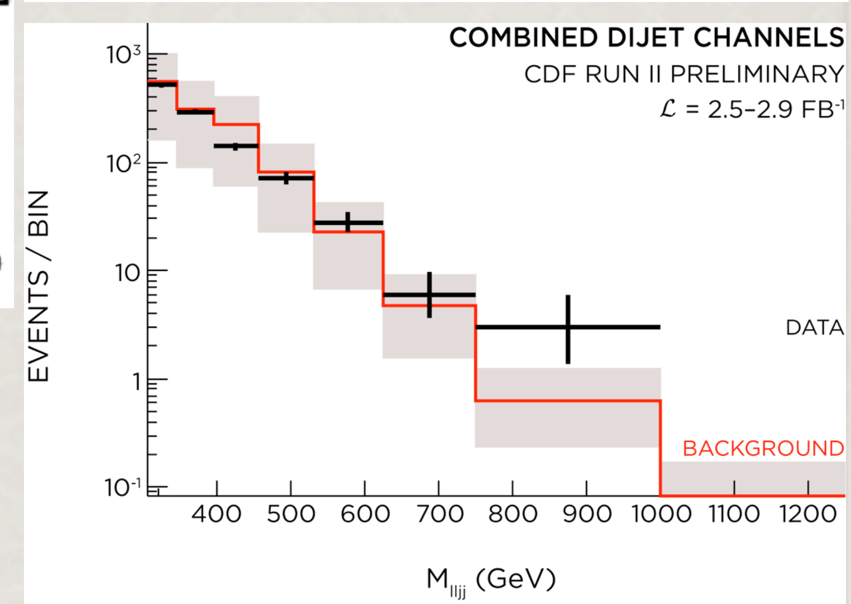




	G*	Z'	W'
Expected exclusion	< 632 GeV	257 – 630 GeV	381 – 420 GeV
Data exclusion	< 607 GeV	247 – 545 GeV	284 – 515 GeV

CDF Run II Preliminary. $\int L\,dt = 2.9\ fb^{-1}$





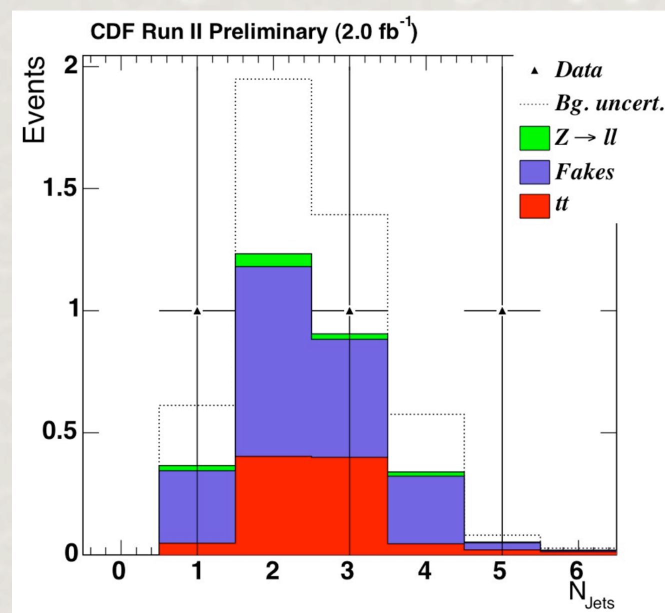
Low-Background Searches

- *Most exciting Tevatron hints have been low-background events*
  - *Look at both signature-based and model-based final states*
    - *lγγ* *scalar resulting in same-sign top quarks* *magnetic monopole*

Multi-Photon + Lepton Events, $\mathcal{L} = 929$ pb^{-1}			
SM Source	$e\gamma\gamma$	$\mu\gamma\gamma$	$(e+\mu)\gamma\gamma$
$W^{\pm}\gamma\gamma$	0.021 ± 0.004	0.015 ± 0.003	0.036 ± 0.006
$Z\gamma\gamma$	0.045 ± 0.005	0.038 ± 0.005	0.083 ± 0.007
ℓee, $\ell\gamma e$, $e \rightarrow \gamma$	0.41 ± 0.12	$0^{+0.03}_{-0.0}$	0.41 ± 0.12
ℓjj, $\ell\gamma j$, $j \rightarrow \gamma$	0.05 ± 0.05	0.05 ± 0.05	0.10 ± 0.09
Total SM Prediction	$\mathbf{0.53 \pm 0.13}$	$\mathbf{0.10 \pm 0.06}$	$\mathbf{0.62 \pm 0.15}$
Observed in Data	**0**	**0**	**0**

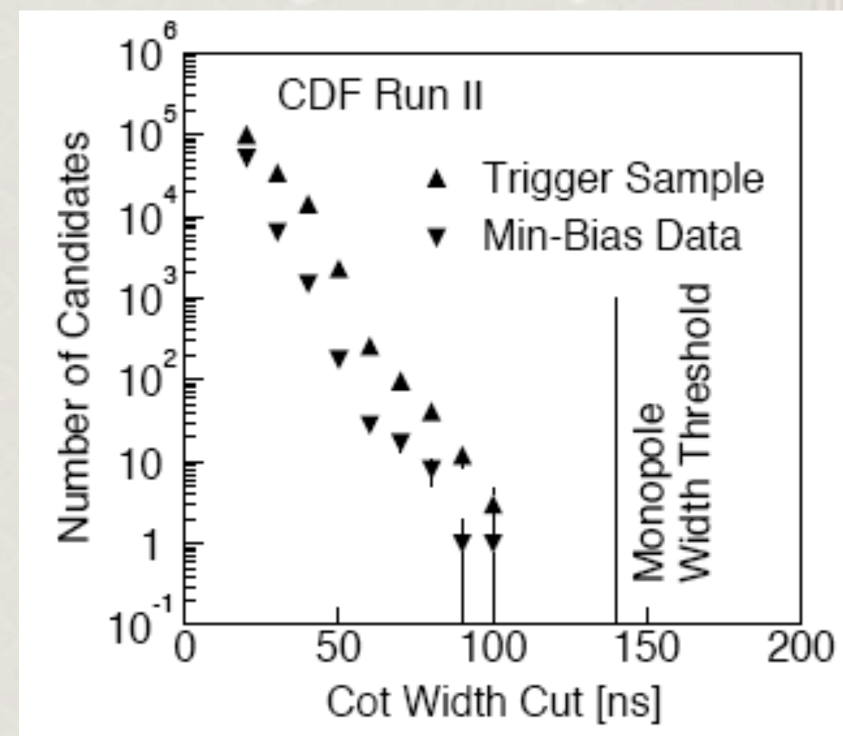
$e\mu$ + Photon Events, $\mathcal{L} = 929$ pb^{-1}	
SM Source	$e\mu\gamma + X$
$Z/\gamma^* + \gamma$	0.66 ± 0.09
$W^{\pm}\gamma$	$0.10^{+0.18}_{-0.10}$
$Z\gamma\gamma$	0.06 ± 0.01
$W\gamma\gamma$	0.011 ± 0.003
$e\mu j$, $j \rightarrow \gamma$	0.05 ± 0.01
$ee\mu$, $e \rightarrow \gamma$	0.06 ± 0.05
$W^{\pm}\gamma$, $Z/\gamma^* + \gamma \rightarrow \tau\gamma$	$0.09^{+0.18}_{-0.09}$
Total SM Prediction	$\mathbf{1.0 \pm 0.3}$
Observed in Data	**0**

CDF Collaboration, PRD 75, 112001 (2007)



Source	ee	$\mu\mu$	$e\mu$	ll
$Z \rightarrow ll$	0.01	0.03	0.04	0.1 ± 0.1
tt	0.27	0.26	0.42	0.9 ± 0.1
$W + jets$	0.60	0.71	0.50	1.8 ± 1.8
Total	0.9	1.0	1.0	2.9 ± 1.8
Data	0	1	2	3

CDF Collaboration, PRL 102, 041801 (2009)



CDF Collaboration, PRL 96, 201801 (2006)

Making a Discovery

- *Strategies*
  - *Probe well-motivated models*
  - *Search for clear indications of new physics*
  - *Study all final states*
- *Issues*
  - *How do you know when it's a discovery?*
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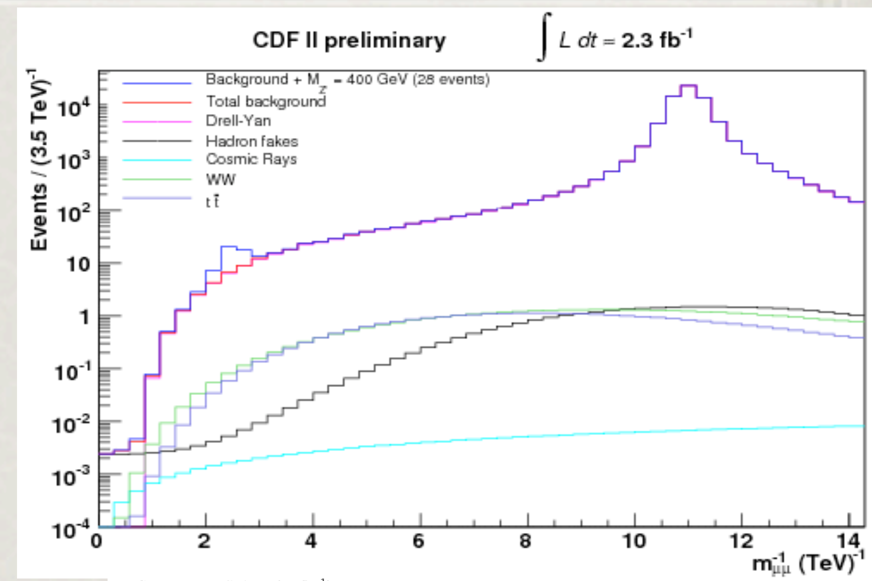


CDF Run II Preliminary (2.0 fb^{-1})
The calculation of σ accounts for the trials factor

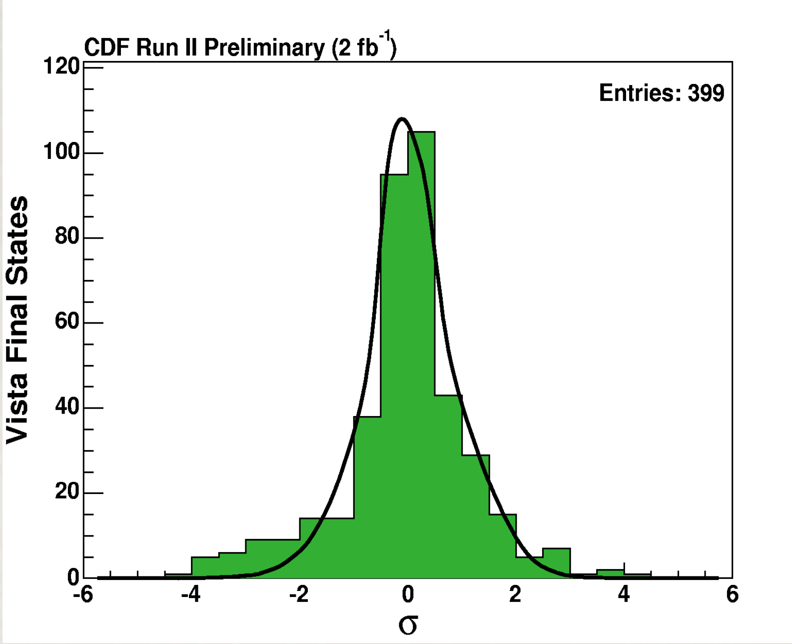
Final State	Data	Background	σ
b$e^\pm\not{p}$	690	817.7 ± 9.2	−2.7
$\gamma\tau^\pm$	1371	1217.6 ± 13.3	+2.2
$\mu^\pm\tau^\pm$	63	35.2 ± 2.8	+1.7
b2j$\not{p}$ high-Σp_T	255	327.2 ± 8.9	−1.7
2j$\tau^\pm$ low-Σp_T	574	670.3 ± 8.6	−1.5
3j$\tau^\pm$ low-Σp_T	148	199.8 ± 5.2	−1.4
$e^\pm\not{p}\tau^\pm$	36	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
2bγ	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
4j2γ	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
4jγ	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
3j2γ	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
3jγ	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
2j2γ	580	581 ± 13.7	0
2j$\tau^\pm$ high-Σp_T	96	114.6 ± 3.3	0

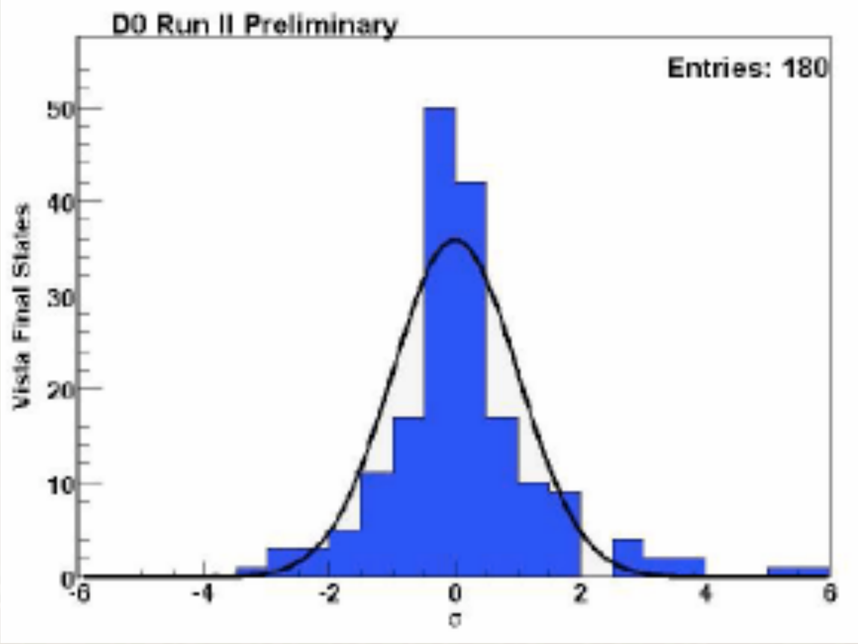
Final State	Data	Background	σ
2j$\not{p}$ high-Σp_T	87	80.9 ± 6.8	0
2j$\not{p}$ low-Σp_T	114	79.5 ± 100.8	0
2j$\not{p}\tau^\pm$	18	13.2 ± 2.2	0
2j$\gamma\tau^\pm$	142	144.6 ± 5.7	0
2j$\gamma\not{p}$	908	980.3 ± 63.7	0
2jγ	71364	73021.4 ± 595.9	0
2j$\mu^\pm\tau^\mp$	16	19.3 ± 2.2	0
2j$\mu^\pm\not{p}$	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
2$e^\pm$j	14	13.8 ± 2.3	0
2$e^\pm e^\mp$	20	17.5 ± 1.7	0
2$e^\pm$	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
2b2jγ	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
2bjγ	71	54.5 ± 7.1	0
2bj$\mu^\pm\not{p}$	12	10.7 ± 1.9	0
2b$e^\pm$2j$\not{p}$	30	27.3 ± 2.2	0
2b$e^\pm$2j	72	66.5 ± 2.9	0
2b$e^\pm\not{p}$	22	19.1 ± 2.2	0
2b$e^\pm$j$\not{p}$	19	19.4 ± 2.2	0
2b$e^\pm$j	63	63 ± 3.4	0
2b$e^\pm$	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
j2γ	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
jγ	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

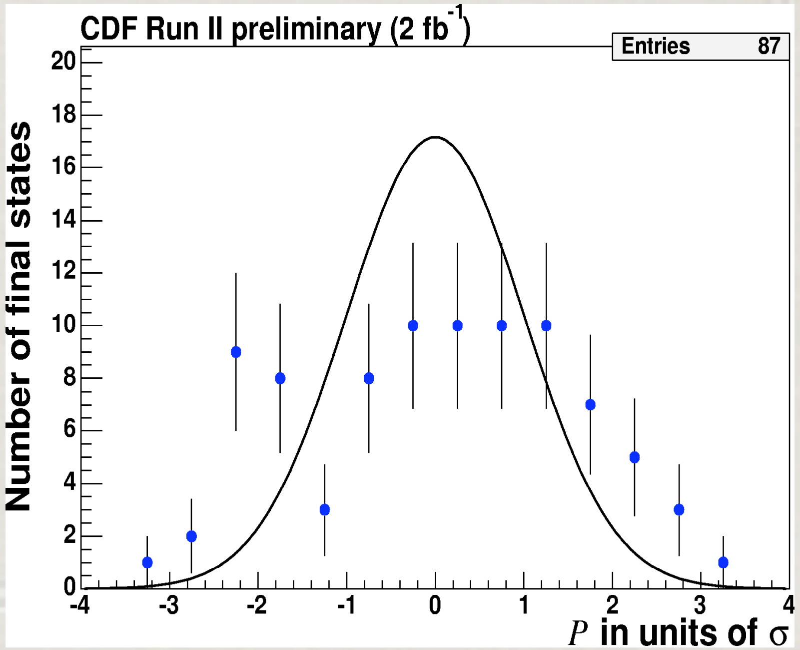
Final State	Data	Background	σ
j$\mu^\pm\mu^\mp\not{p}$	32	32.2 ± 10.9	0
j$\mu^\pm\mu^\mp\gamma$	14	11.5 ± 2.6	0
j$\mu^\pm\mu^\mp$	4852	4271.2 ± 185.4	0
j$\mu^\pm$	77689	76987.5 ± 930.2	0
$e^\pm$4j$\not{p}$	903	830.6 ± 13.2	0
$e^\pm$4jγ	25	29.2 ± 3.6	0
$e^\pm$4j	15750	16740.4 ± 390.5	0
$e^\pm$3j$\tau^\mp$	15	21.1 ± 2.2	0
$e^\pm$3j$\not{p}$	4054	4077.2 ± 63.6	0
$e^\pm$3jγ	108	79.3 ± 5	0
$e^\pm$3j	60725	60409.3 ± 723.3	0
$e^\pm$2γ	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$2jγ	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
$e^\pm$j2γ	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
$e^\pm$jγ	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$2jγ	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
$e^\pm e^\mp$jγ	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

Global Search

- *Cover all final states with global data search*
  - *Develop global SM prediction using MC, simulation, corrections*
  - *Compare normalization and shapes of data-populated final states*
  - *Search final states for mass resonances*
  - *Combine final states and search for excesses at large total p_T*

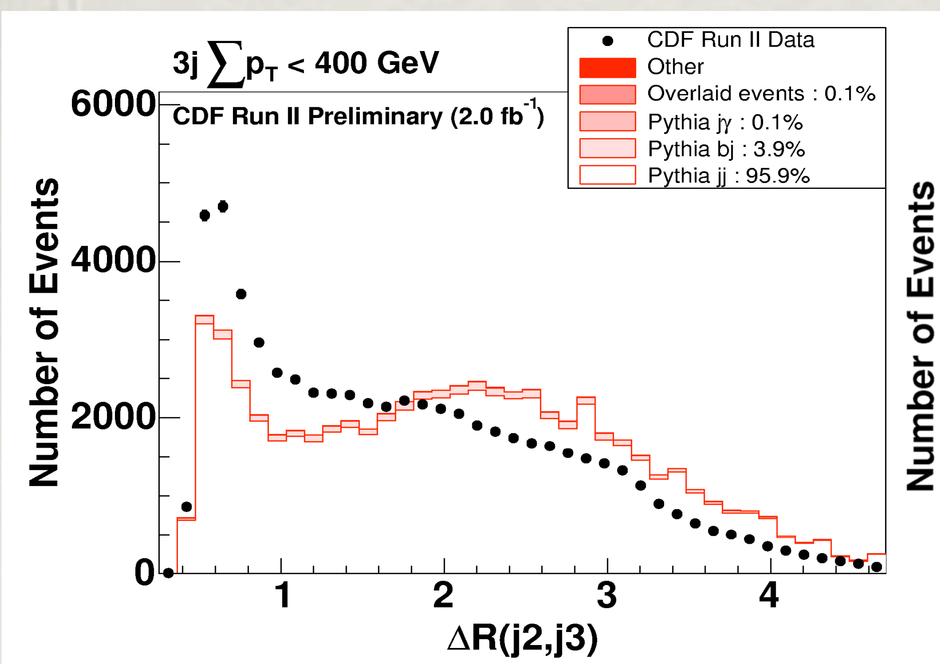


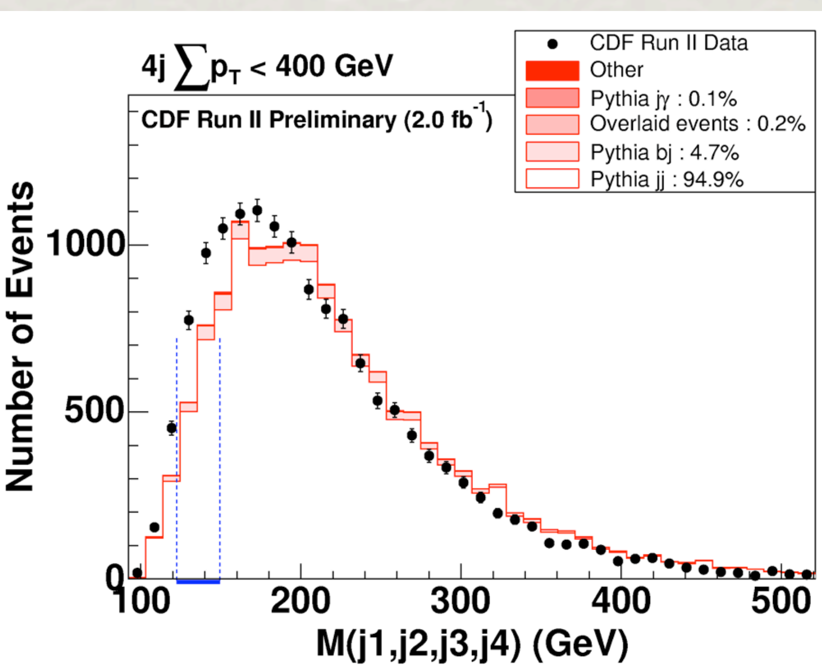


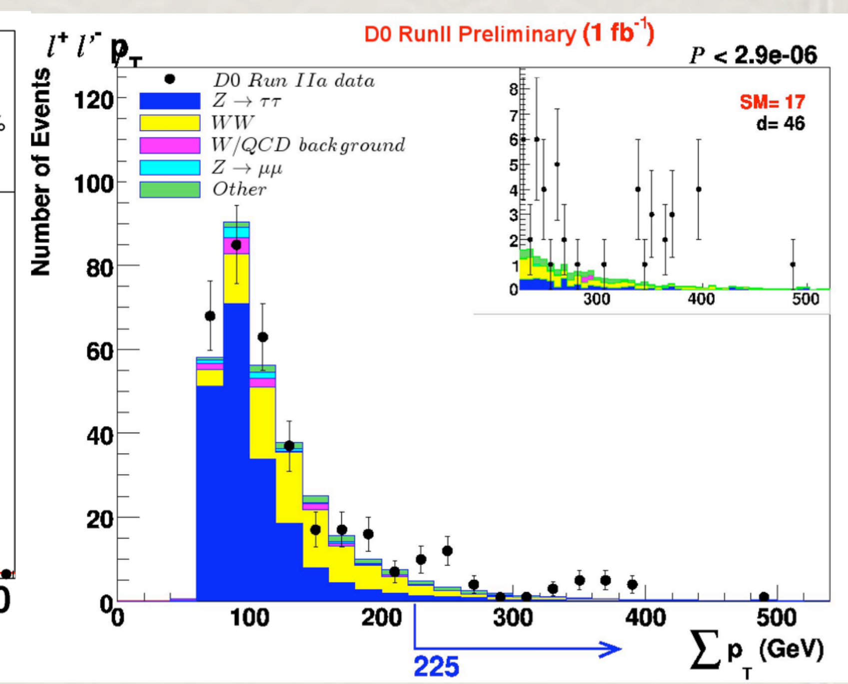


Global Search Results

- *Statistically significant shape and mass discrepancies observed*
  - *CDF: Interpreted as mismodelling of radiative jet events*
    - *No excess at high total p_T (expect 8% of experiments to observe more significant excess)*
  - *DØ: Interpreted as mismodelling of muon resolution tails*







CDF Collaboration, PRD 79, 011101 (2009)

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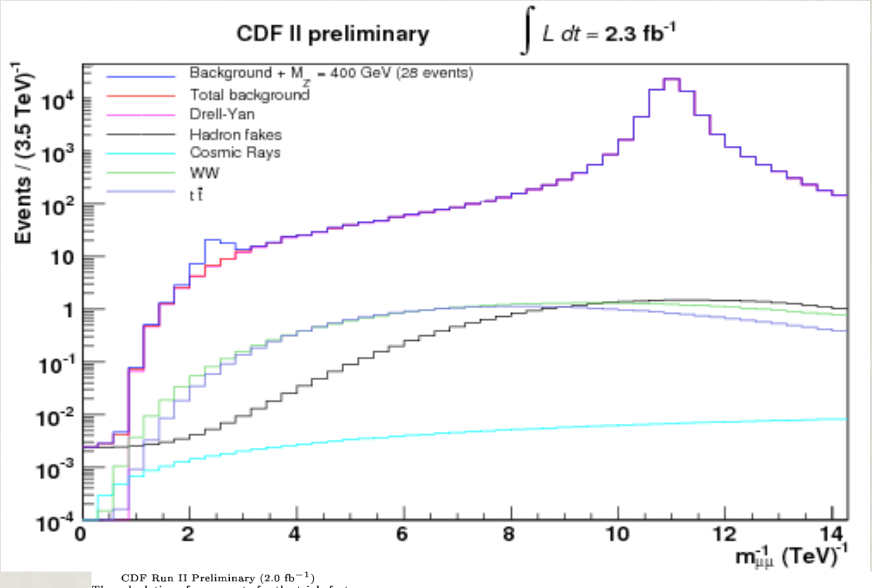

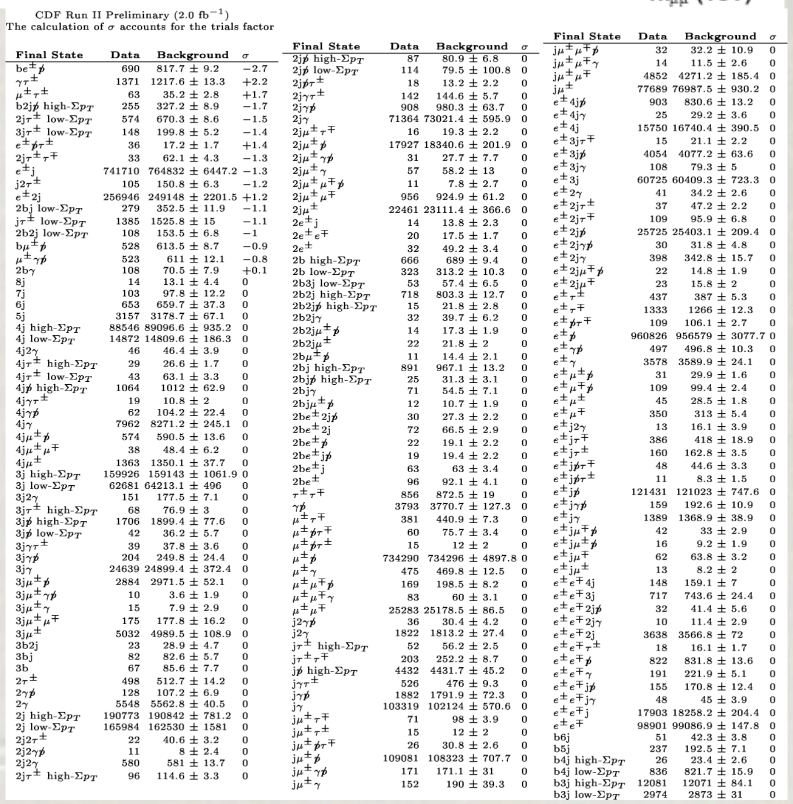

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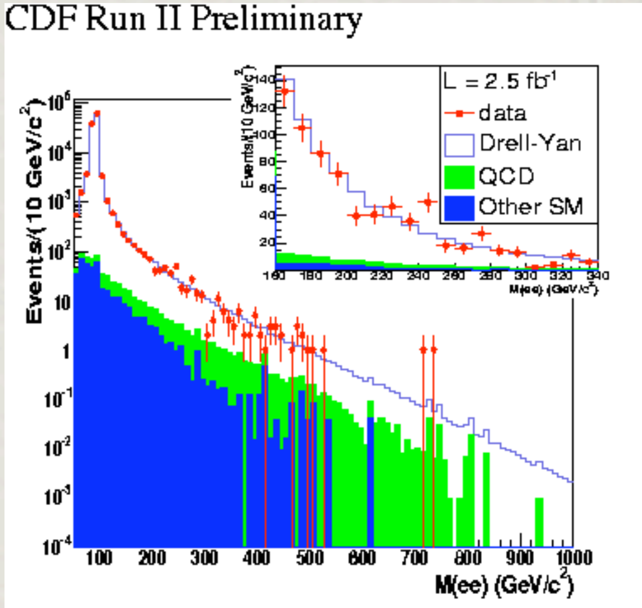
4j2γ	46	46.4 ± 3.9	0
4j$\tau^\pm$ high-Σp_T	29	26.6 ± 1.7	0
4j$\tau^\pm$ low-Σp_T	43	63.1 ± 3.3	0
4j$\not p$ high-Σp_T	1064	1012 ± 62.9	0
4j$\gamma\tau^\pm$	19	10.8 ± 2	0
4j$\gamma\not p$	62	104.2 ± 22.4	0
4jγ	7962	8271.2 ± 245.1	0
4j$\mu^\pm\not p$	574	590.5 ± 13.6	0
4j$\mu^\pm\mu^\mp$	38	48.4 ± 6.2	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
3j2γ	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
3jγ	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
2j2γ	580	581 ± 13.7	0
2j$\tau^\pm$ high-Σp_T	96	114.6 ± 3.3	0
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
2jγ	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
2$e^\pm$j	14	13.8 ± 2.3	0
2$e^\pm e^\mp$	20	17.5 ± 1.7	0
2$e^\pm$	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
2b2jγ	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
2bjγ	71	54.5 ± 7.1	0
2bj$\mu^\pm\not p$	12	10.7 ± 1.9	0
2b$e^\pm$2j$\not p$	30	27.3 ± 2.2	0
2b$e^\pm$2j	72	66.5 ± 2.9	0
2b$e^\pm\not p$	22	19.1 ± 2.2	0
2b$e^\pm$j$\not p$	19	19.4 ± 2.2	0
2b$e^\pm$j	63	63 ± 3.4	0
2b$e^\pm$	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
j2γ	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
jγ	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
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$4jγ	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$3jγ	108	79.3 ± 5	0
$e^\pm$3j	60725	60409.3 ± 723.3	0
$e^\pm$2γ	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$2jγ	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
$e^\pm$j2γ	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
$e^\pm$jγ	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$2jγ	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
$e^\pm e^\mp$jγ	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

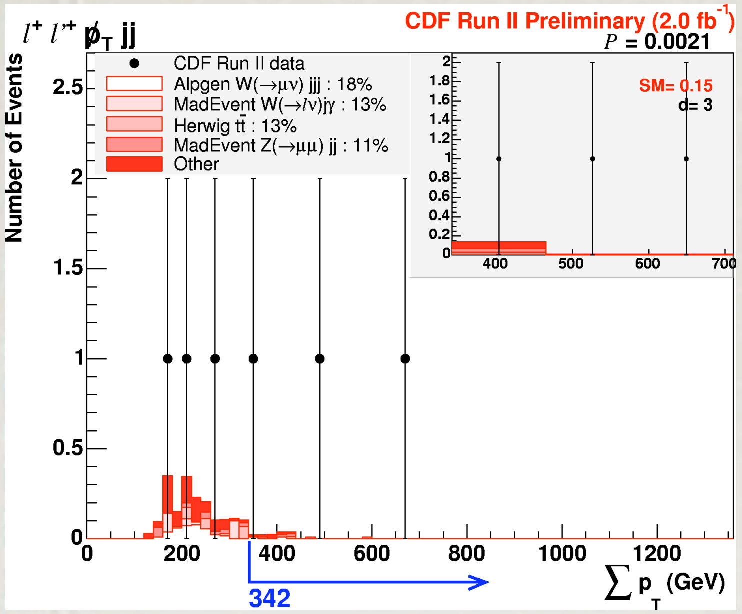
Potential Discoveries

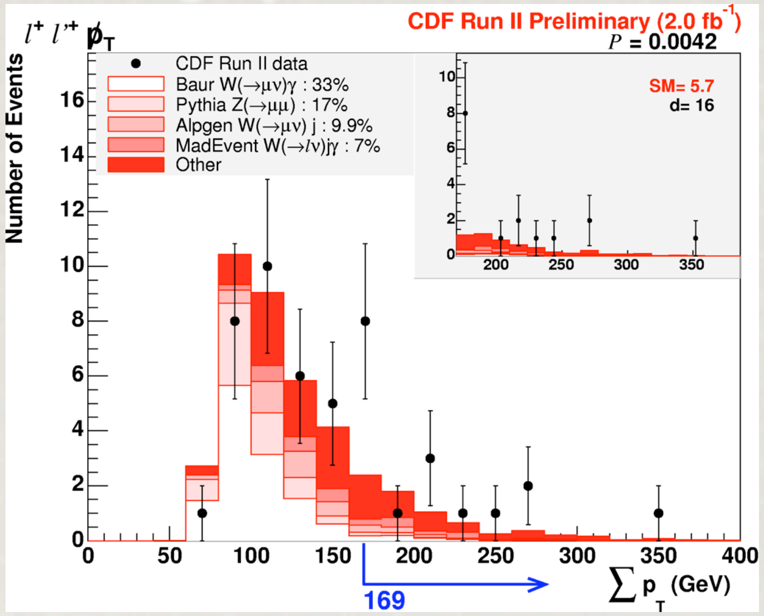
- *Any given data set shows some discrepancies*
  - *Most are statistical fluctuations*
    - *Accounted for in global search*
  - *Can also arise from mismodelled background*
  - *But could also be new physics...*

CDF Collaboration, PRL 102, 031801 (2009)



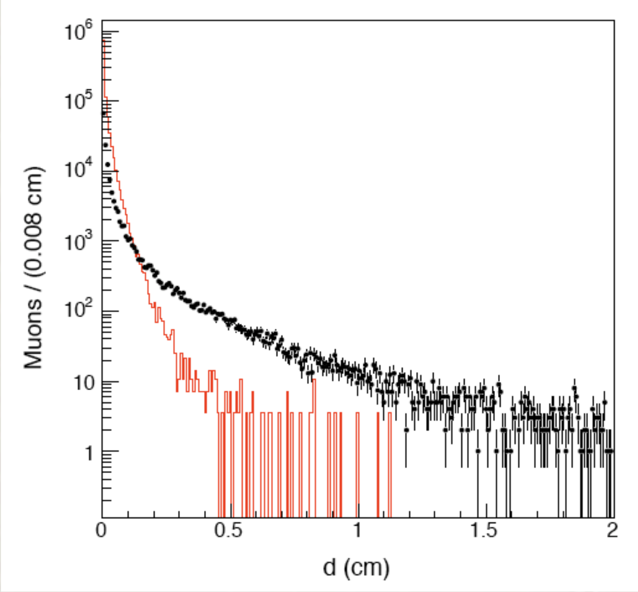
× *Not confirmed by CDF dimuon search*





× *Not confirmed by DØ global search*

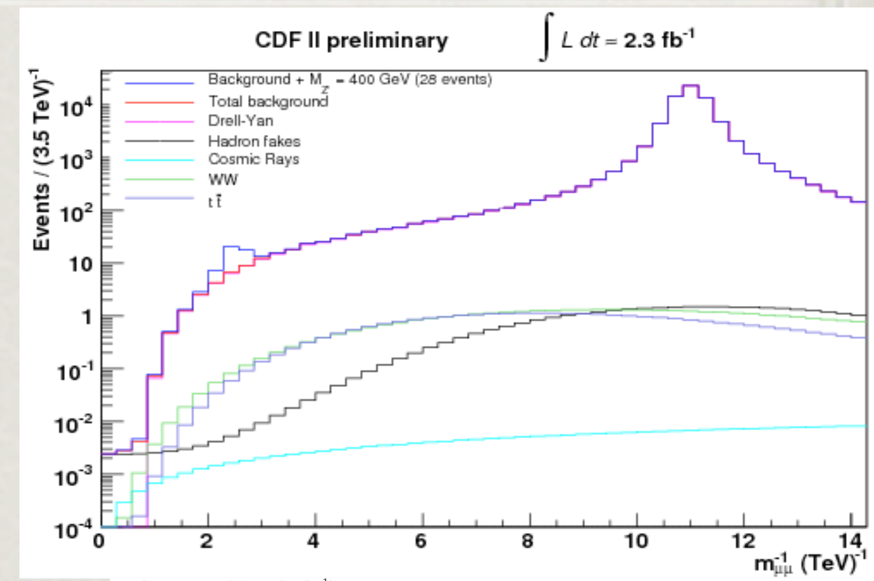
CDF Collaboration, arXiv: 0810.5357 (2008)



× *Not confirmed by DØ dimuon search*

Making a Discovery

- *Strategies*
  - *Probe well-motivated models*
  - *Search for clear indications of new physics*
  - *Study all final states*



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

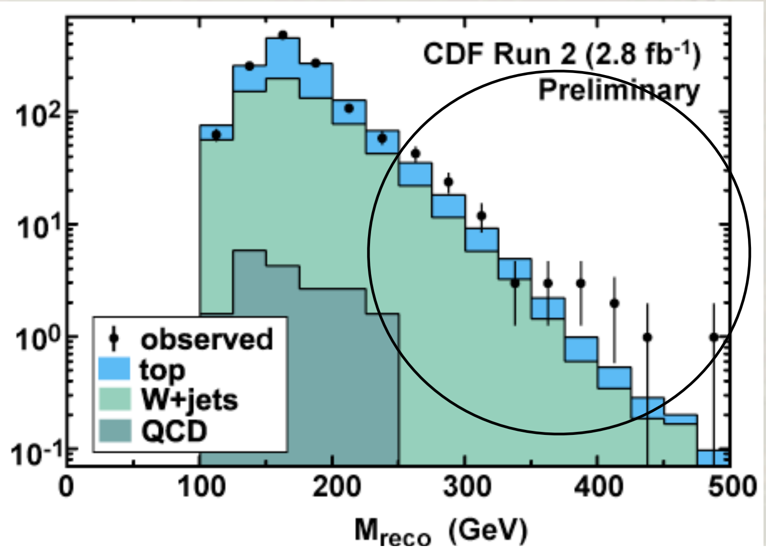
Final State	Data	Background	σ
$2j\not{p}$ high-Σp_T	87	80.9 ± 6.8	0
$2j\not{p}$ low-Σp_T	114	79.5 ± 100.8	0
$2j\not{p}\tau^\pm$	18	13.2 ± 2.2	0
$2j\gamma\tau^\pm$	142	144.6 ± 5.7	0
$2j\gamma\not{p}$	908	980.3 ± 63.7	0
$2j\gamma$	71364	73021.4 ± 595.9	0
$2j\mu^\pm\tau^\mp$	16	19.3 ± 2.2	0
$2j\mu^\pm\not{p}$	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

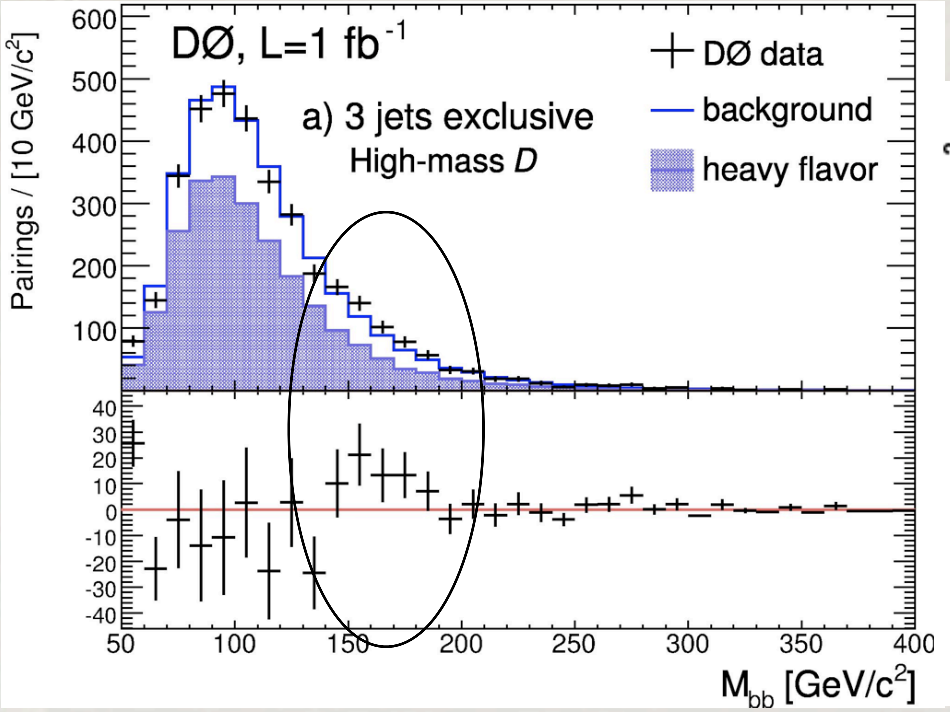
Final State	Data	Background	σ
$j\mu^\pm\mu^\mp\not{p}$	32	32.2 ± 10.9	0
$j\mu^\pm\mu^\mp\gamma$	14	11.5 ± 2.6	0
$j\mu^\pm\mu^\mp$	4852	4271.2 ± 185.4	0
$j\mu^\pm$	77689	76987.5 ± 930.2	0
$e^\pm 4j\not{p}$	903	830.6 ± 13.2	0
$e^\pm 4j\gamma$	25	29.2 ± 3.6	0
$e^\pm 4j$	15750	16740.4 ± 390.5	0
$e^\pm 3j\tau^\mp$	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

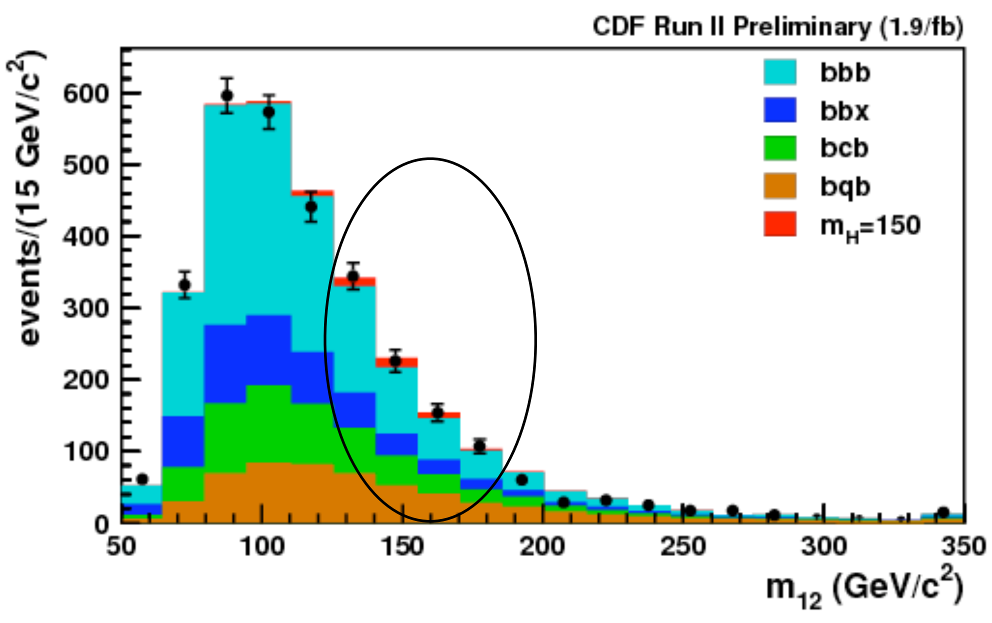
- *Issues*
  - *How do you know when it's a discovery?*
  - *How do you know you haven't missed a discovery?*

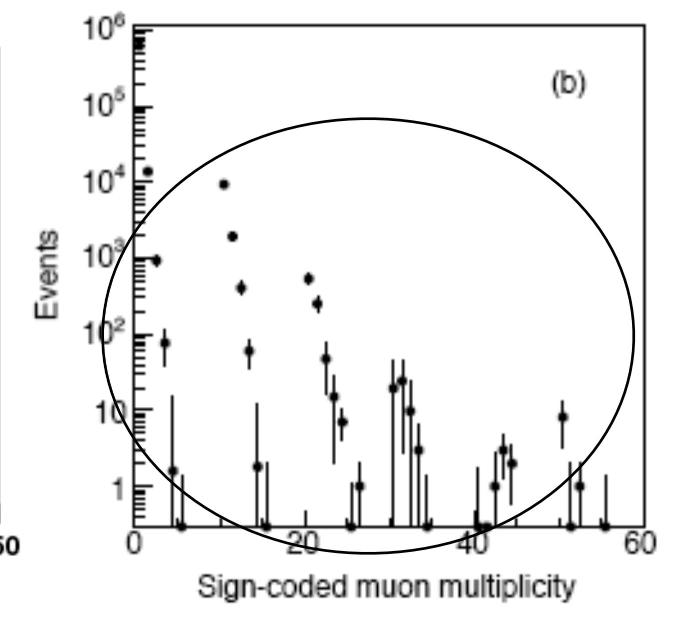
Missing a Discovery

- *Unlikely to find what you aren't looking for*
  - *Global search encompasses all 'standard' final states*
    - *Generally less sensitive than targeted searches*
    - ***Need to follow up all hints***





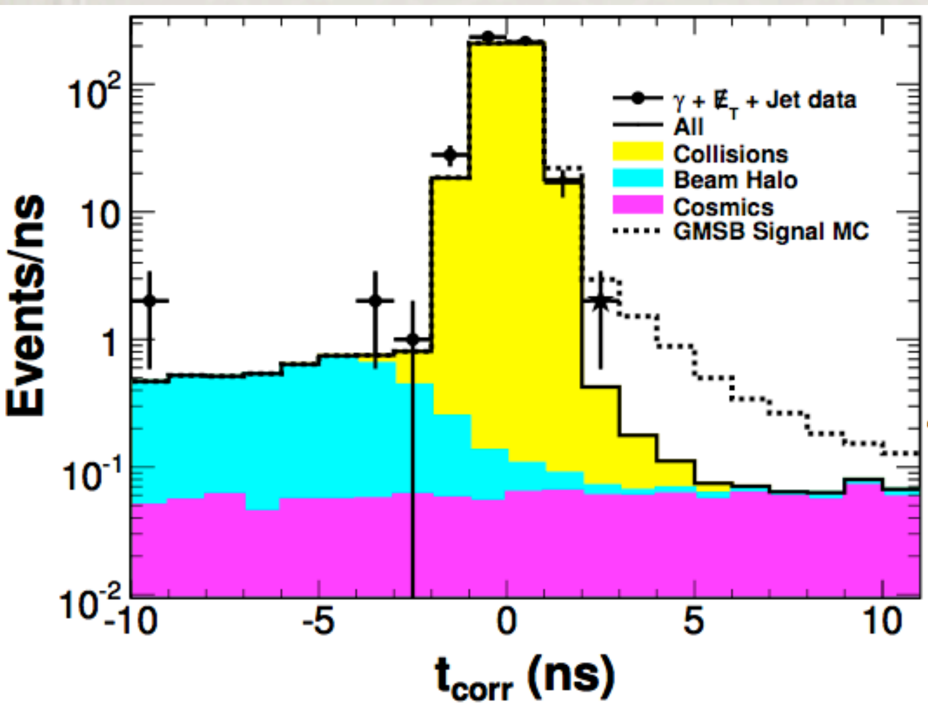


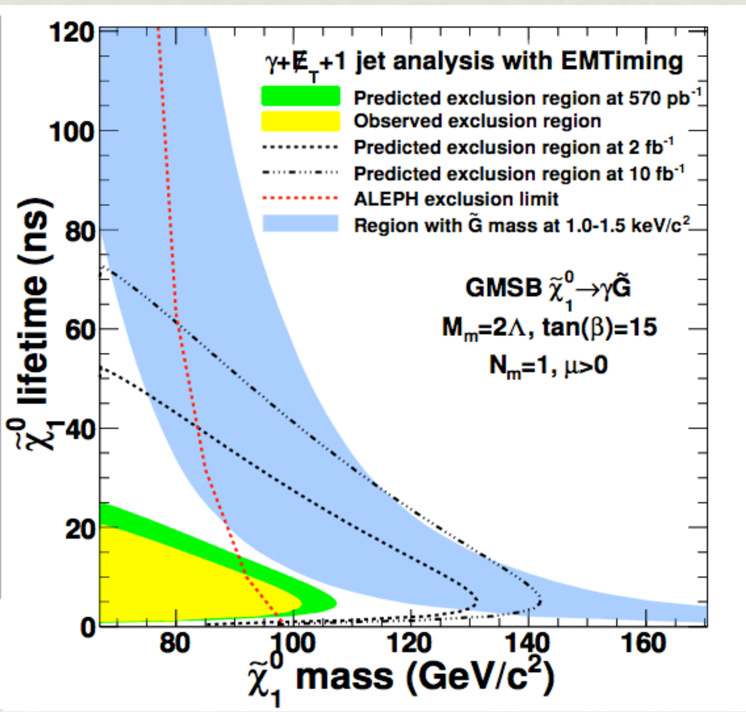


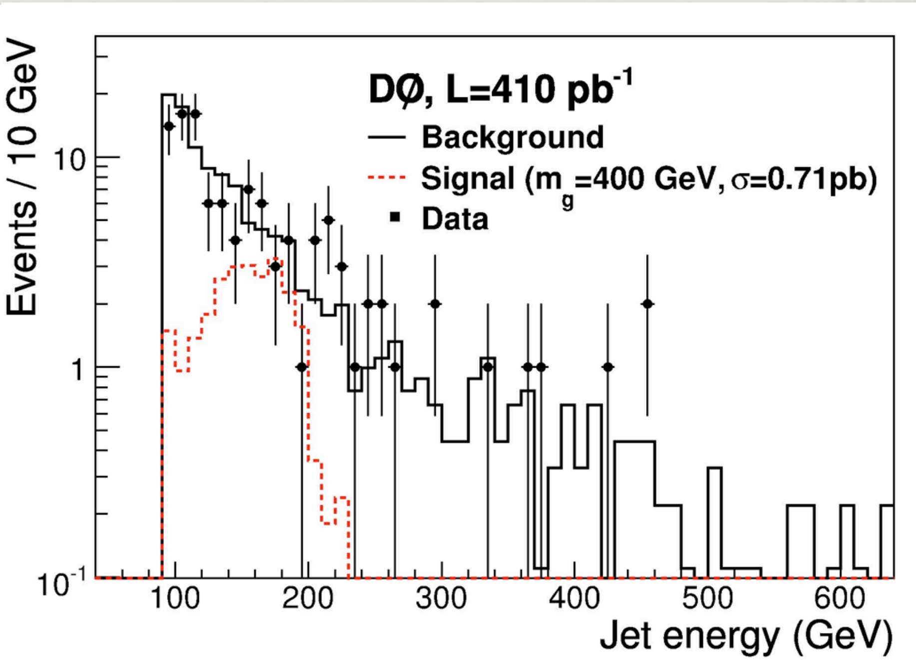
DØ Collaboration, PRL 101, 221802 (2008)

Missing a Discovery

- *More creative final states may not be covered*
  - *Feature of SUSY: large parameter space leads to unusual final states*
    - *Need to know the predictions of these corners of parameter space*
  - *Other theories with non-standard final states?*





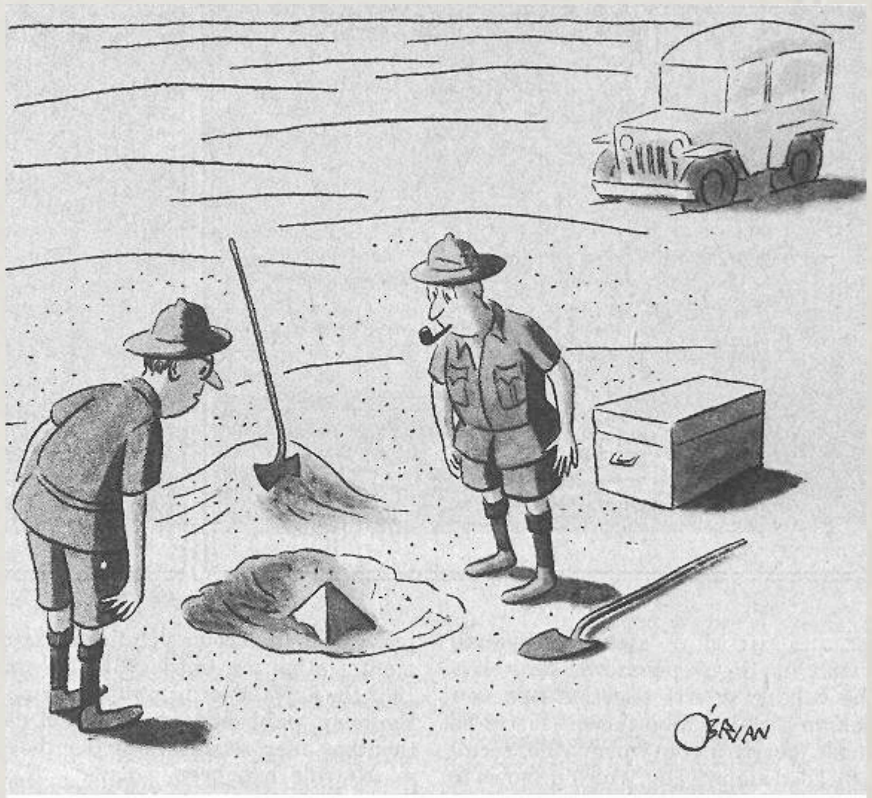


CDF Collaboration, PRL 99, 121801 (2007); PRD 78, 032015 (2008)

DØ Collaboration, PRL 99, 131801 (2007)

Towards the Next Discovery

- *Comprehensive Tevatron search program*
  - *Global, targeted, non-standard searches*
    - *What is missing?*
  - *Constantly pursuing hints*
    - *Suggestions in data could still lead to discovery*



"This could be the discovery of the century. Depending, of course, on how far down it goes."

- *May be many years before first LHC discovery*
  - *Will we know it when we see it?*

Global Search Hints

- *Five most significant excesses different for CDF & DØ*
  - *Most significant common discrepancy in same-sign e-μ*