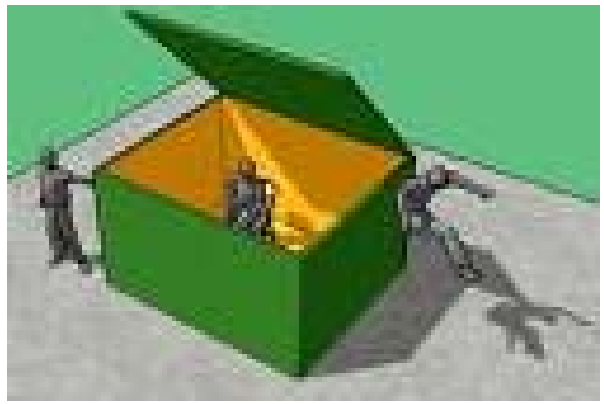
Outside the Box



Tevatron searches for exotic physics

Dave Cutts, for the CDF and D0 collaborations

Brookhaven Forum
November 6, 2008

Fermilab

(Still the energy frontier)

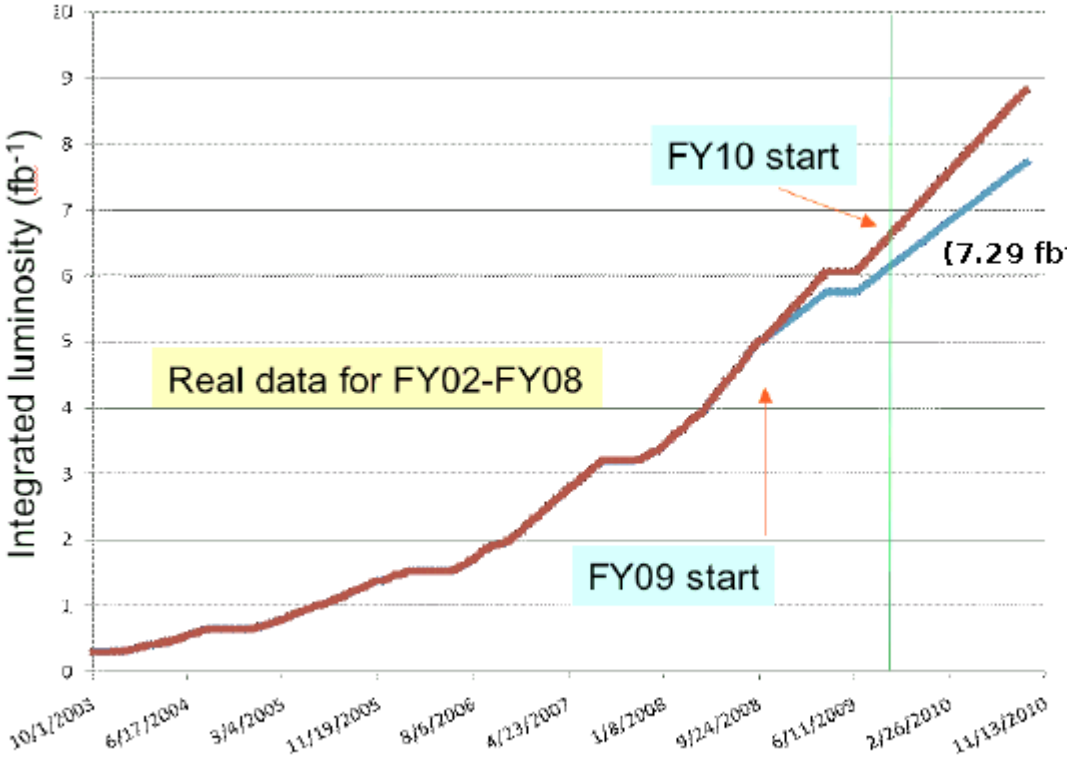
Outline of talk

- status of Tevatron Collider Run 2
- recent results for *some* exotic physics
  - o searches for extra dimensions
  - o searches for long lived particles
  - o model independent searches
- thoughts of the future

For coverage of the vast space *outside the box*, see recent reviews
e.g. presentations at ICHEP08

And,
http://www-d0.fnal.gov
http://www-cdf.fnal.gov

Tevatron



8.82 fb^{-1}

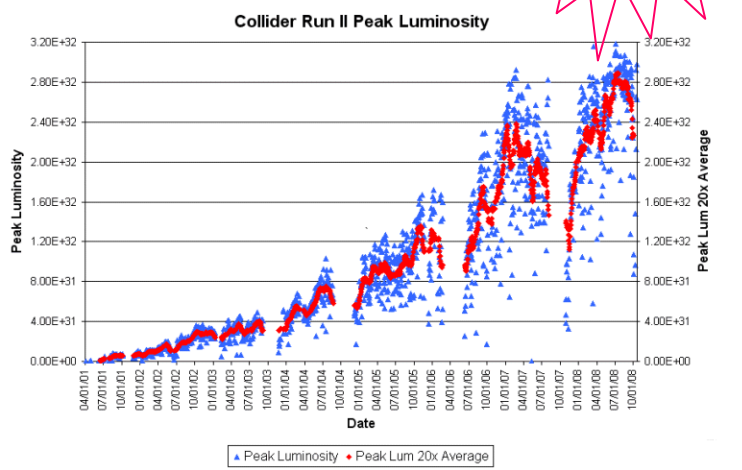
7.72 fb^{-1}

(7.29 fb^{-1} at March PAC)

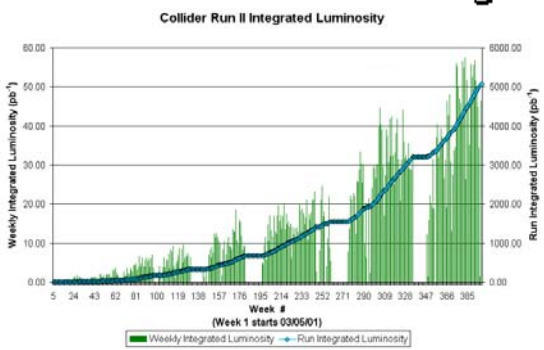
Highest Int. Lum

Lowest Int. Lum

Peak 3.2×10^{32}



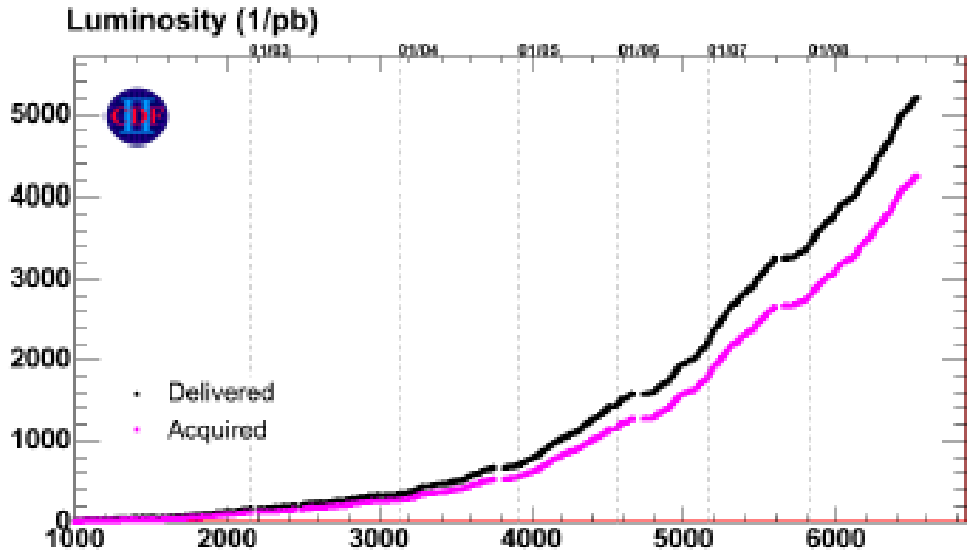
Roger Dixon @ ICFA Seminar – 29

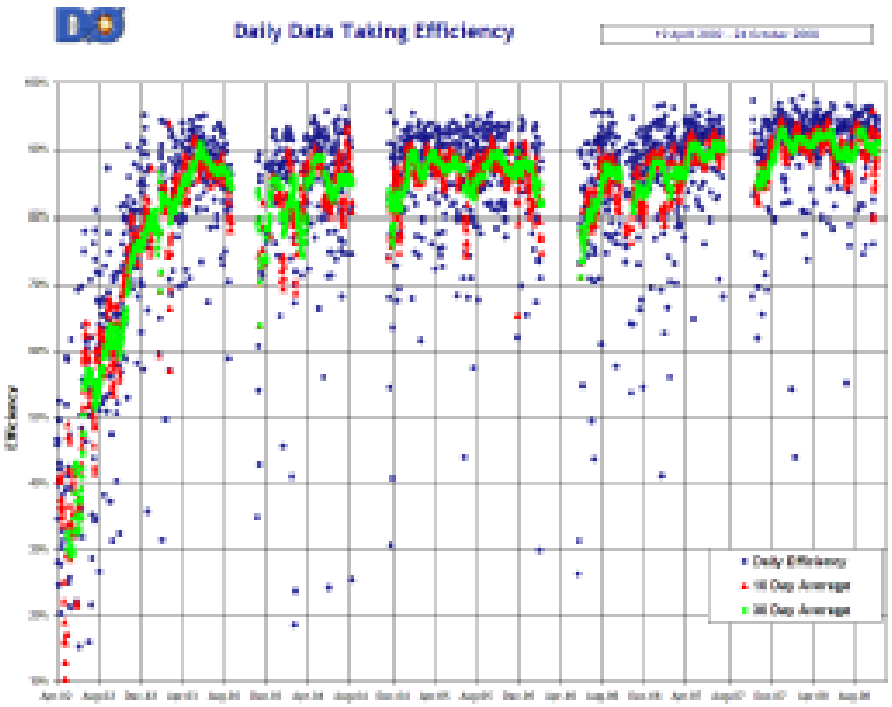


Excellent performance of the collider!

And of the detectors -
…and collaborations!

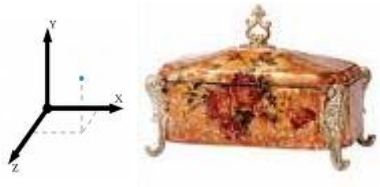
Luminosity to ‘tape’ is what matters



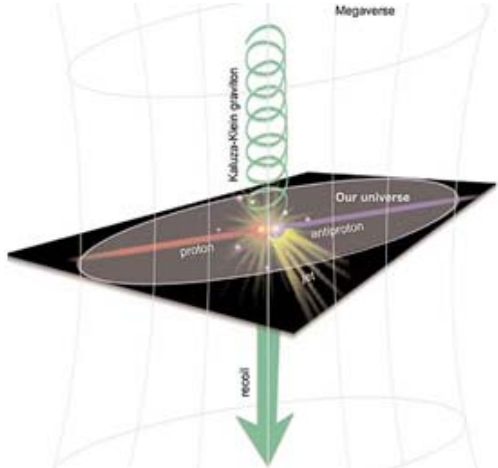


100%

- so high data taking efficiency is crucial



Outside the Box: *Extra Dimensions*



Extra Dimensions can explain why gravity is weak: $1/G \sim M^2_{Pl} \sim M_s^{n+2} R^n$
and can solve the hierarchy problem: $M_s \sim M_W$

First: Large Extra Dimensions (ADD)

Some parameters:

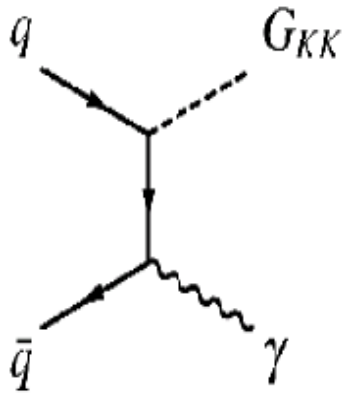
M_{Pl} = 'apparent' Plank scale ~ 2×10^{19} Gev

M_D = fundamental Planck scale (Planck scale in 4+ n dimensions)

~ 1 TeV (?) to solve the hierarchy problem

M_S = 'effective' Planck scale (cutoff in sum over KK excitations)

Large Extra Dimensions I



Real graviton emission as in:

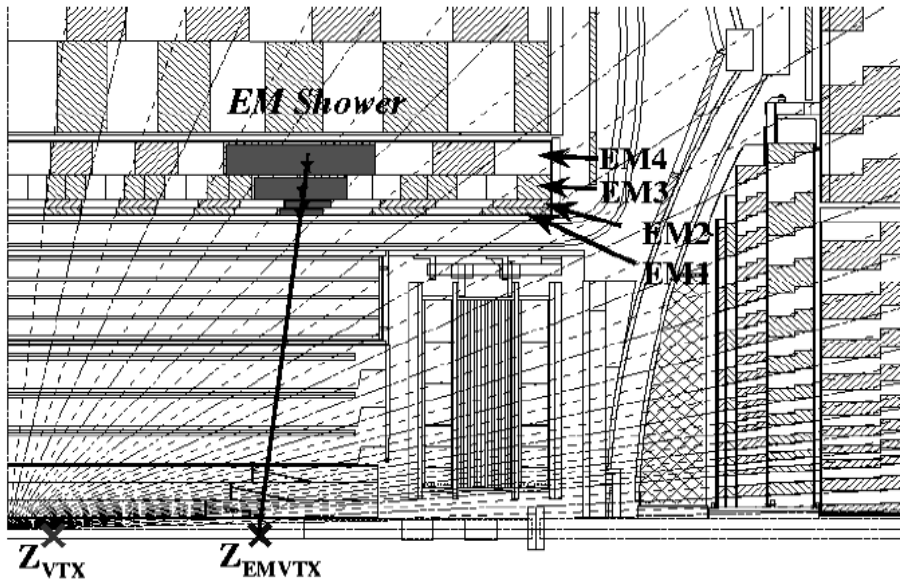
An experimental challenge!

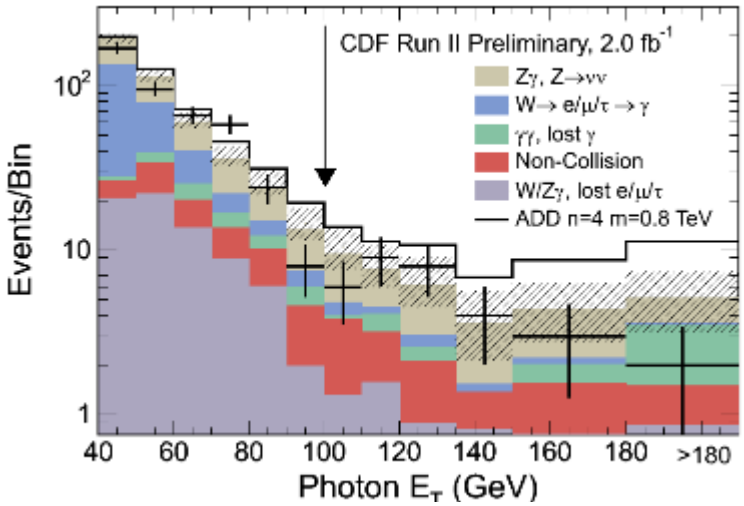
CDF: photon timing
D0: photon pointing

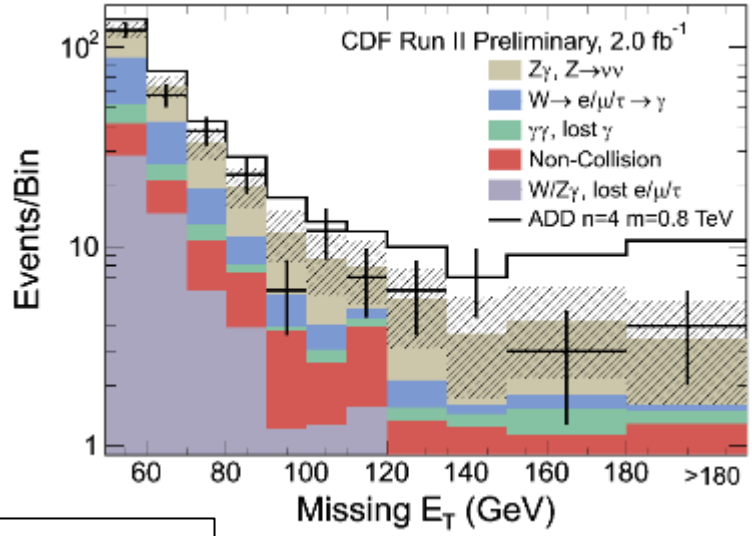
Photon & MET
Electron & MET
Jet & MET

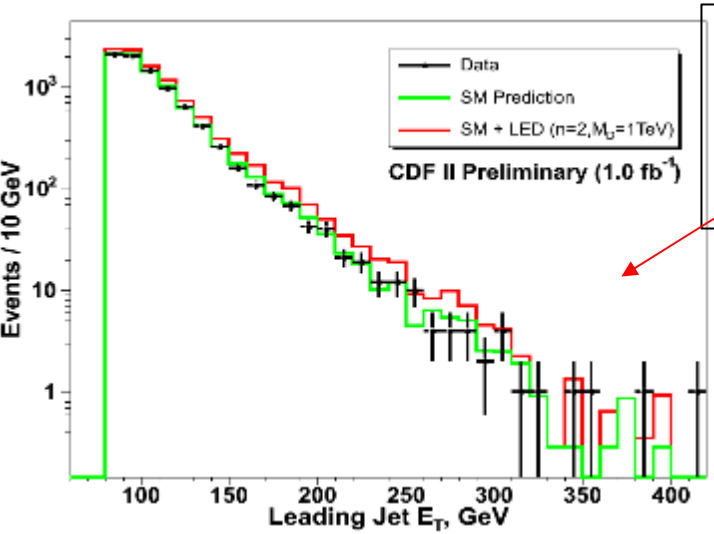
CDF: t < 1 nsec

D0: fine-grained EM calorimetry

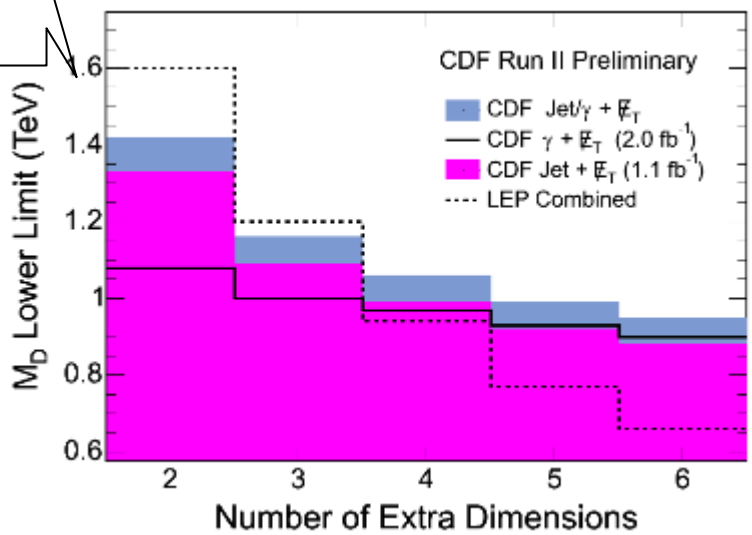




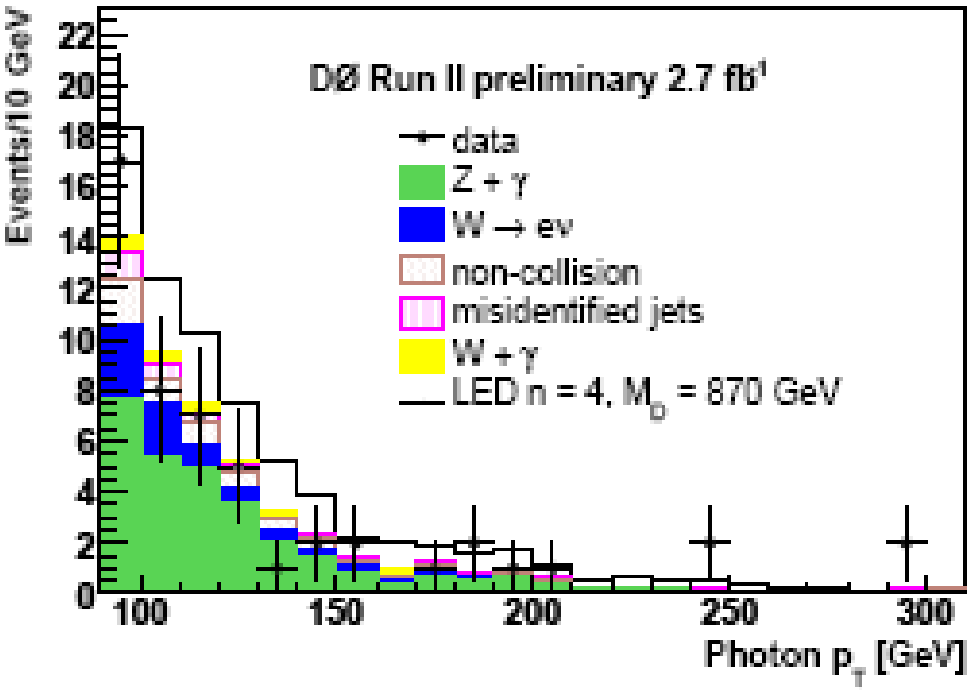




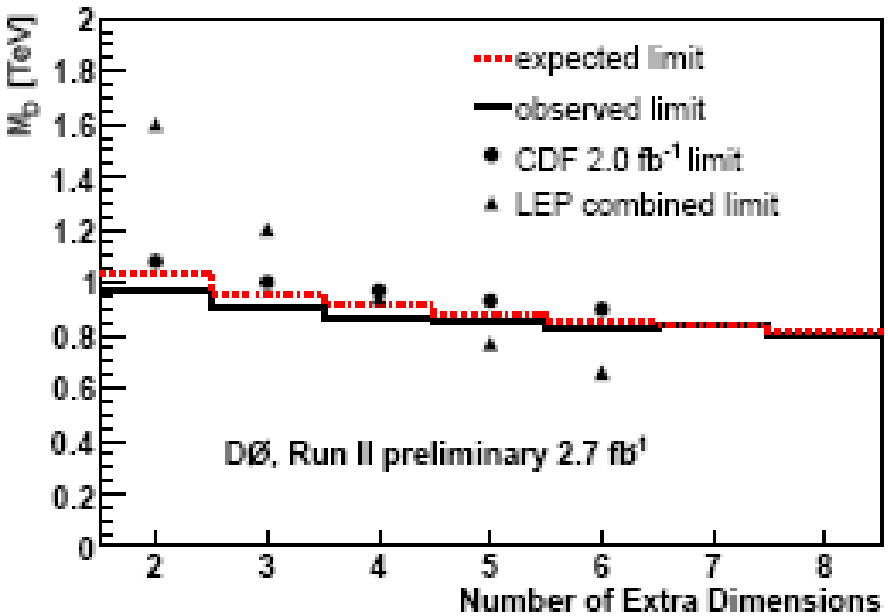
CDF combined: Photon & MET Jet & MET



D0 LED monophoton (2.7 fb^{-1})

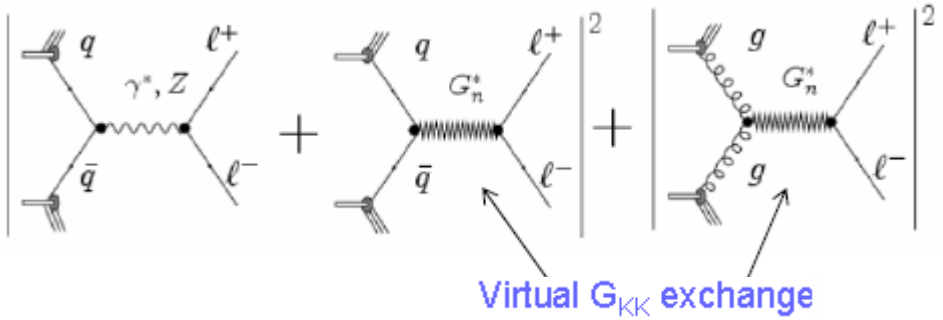


[PRL 101, 011601 (2008)]



Large Extra Dimensions II

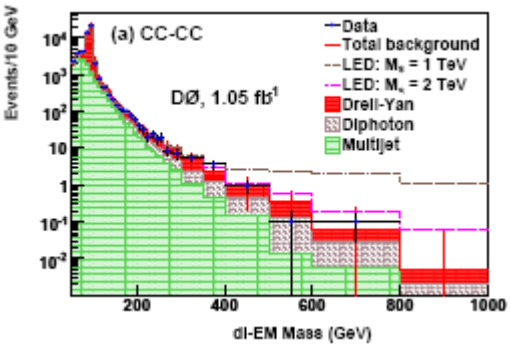
Graviton exchange in LED

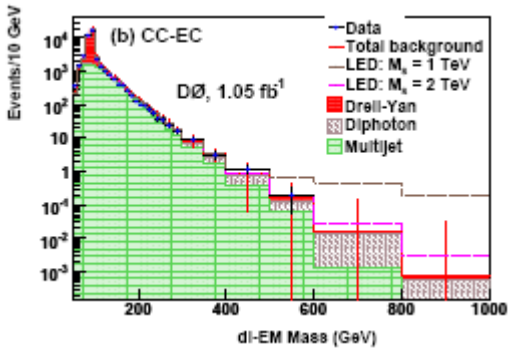


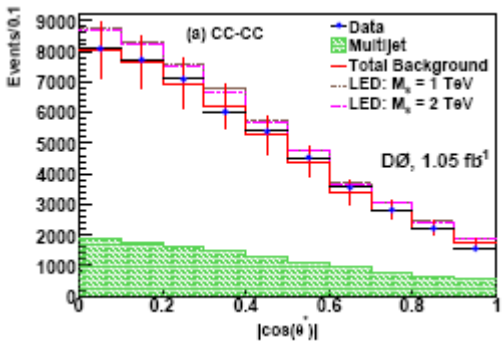
Would modify the cosθ* and ee/γγ mass distributions

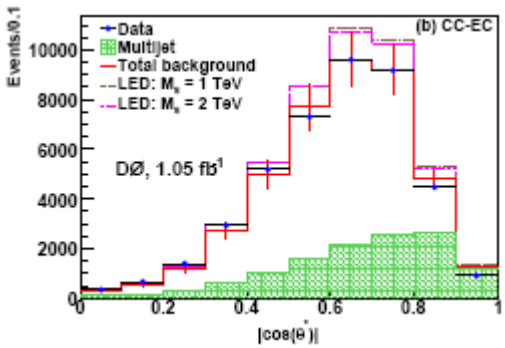
D0 dielectron and diphoton

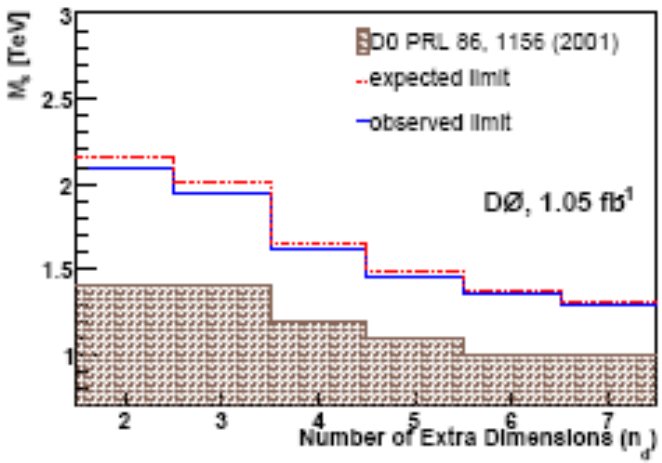
0809.2813 [hep-ex], *Submitted to PRL*









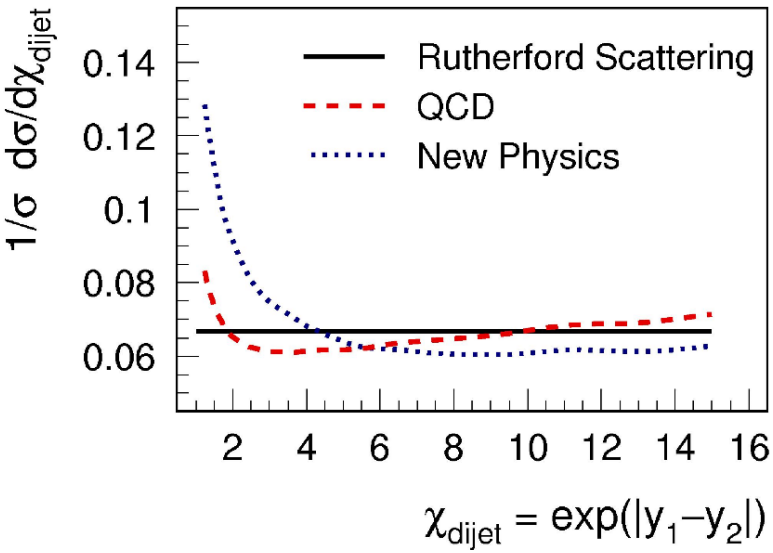


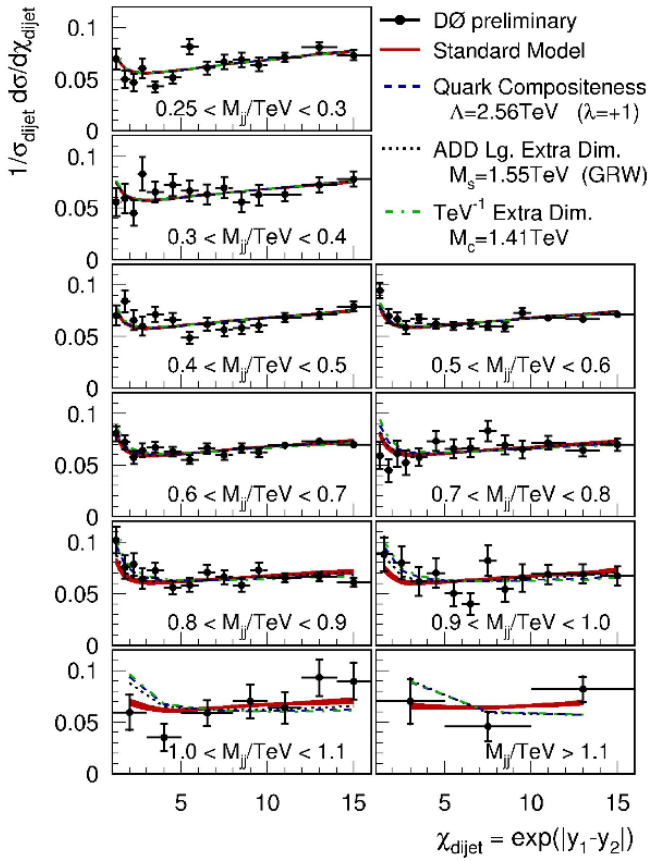
Virtual graviton exchange

D0: dijet angular distributions

$$\chi_{dijet} = \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

Related to CM scattering angle and thus directly sensitive to the dynamics





Summary: results for Large Extra Dimensions

Table 1: Most recent 95% CL lower limits on the fundamental Planck scale M_D (in TeV).

Experiment and channel	$n=2$	$n=3$	$n=4$	$n=5$	$n=6$
LEP Combined [12]	1.60	1.20	0.94	0.77	0.66
CDF monophotons, 2.0 fb^{-1} [18]	1.08	1.00	0.97	0.93	0.90
DØ monophotons, 2.7 fb^{-1} [19]	0.97	0.90	0.87	0.85	0.83
CDF monojets, 1.1 fb^{-1} [20]	1.31	1.08	0.98	0.91	0.88
CDF combined [18]	1.42	1.16	1.06	0.99	0.95

Direct graviton production

Limits on Planck scale ***M_D***

Table 2: Recent 95% CL lower limits on the ultraviolet cutoff M_S (in TeV) from the Tevatron Run 2. NLO QCD effects have been accounted for via a SM K-factor.

DØ Signature	GRW [2]	HLZ [11]					
		$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
$ee+\gamma\gamma$, 1.1 fb^{-1} [21]	1.62	2.09	1.94	1.62	1.46	1.36	1.29
Dijets, 0.7 fb^{-1} [22]	1.56		1.85	1.56	1.41	1.31	1.24

n = # extra dimen.

Virtual graviton exchange
Limits on u-v Cutoff ***M_S***

Landsberg, hep-ex 0808.1867

Search for Randall-Sundrum Gravitons

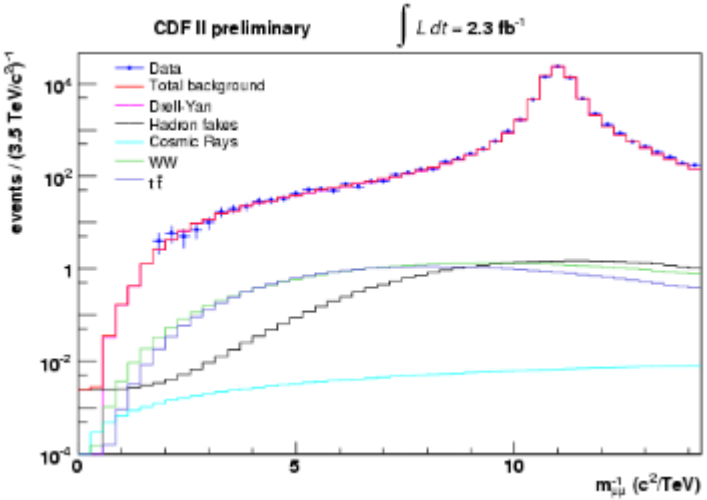
Look for graviton resonances (S=2) decaying into dielectrons, diphotons, dijets

PRL 99, 171802 (2007)
PRL 99, 171801 (2007)

two parameters:

mass of the first KK mode, M_1

dimensionless coupling, k/M_{PL} *(expected range: 0.01 to 0.1)*



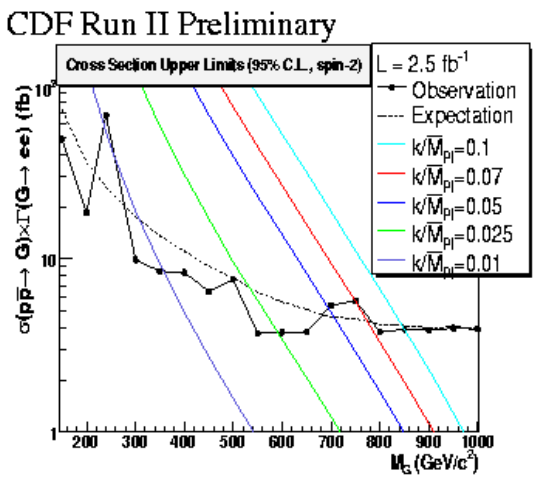
CDF dimuons

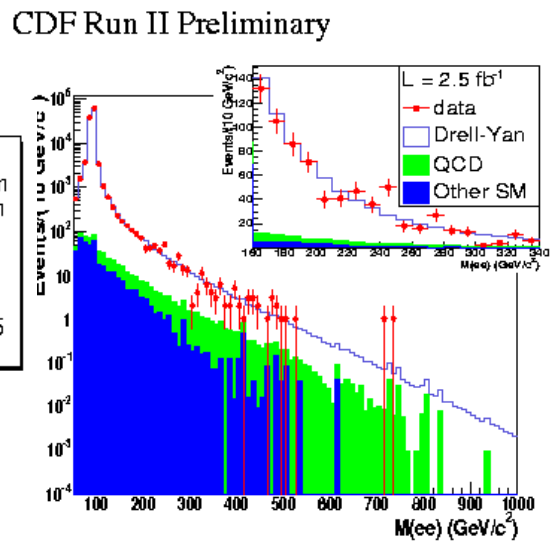
Graviton Mass Limits

CDF II preliminary L = 2.3 fb⁻¹

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

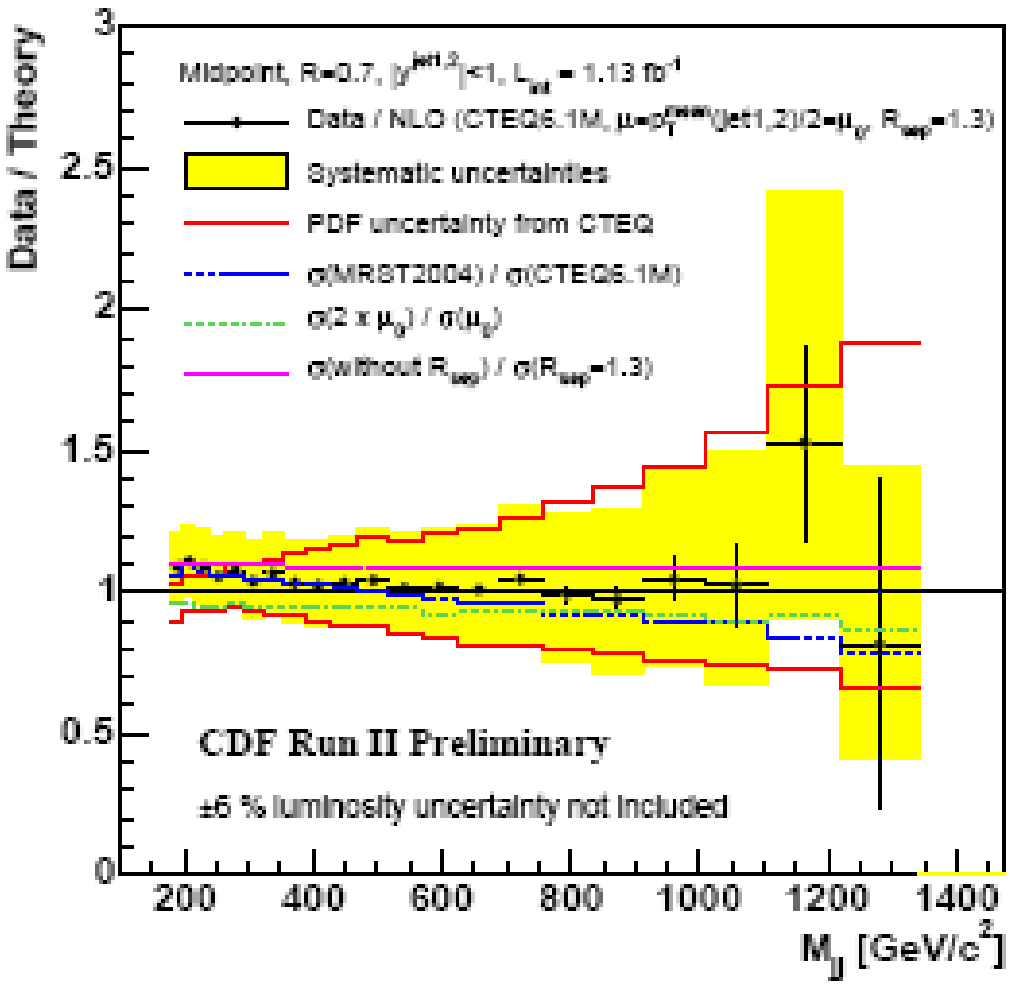
CDF dielectrons

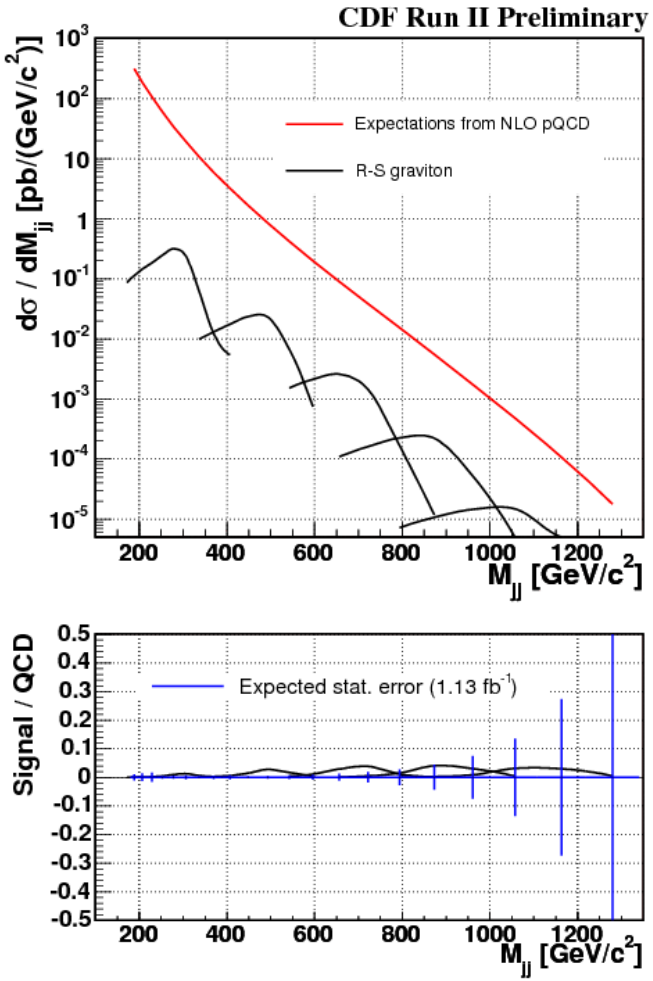




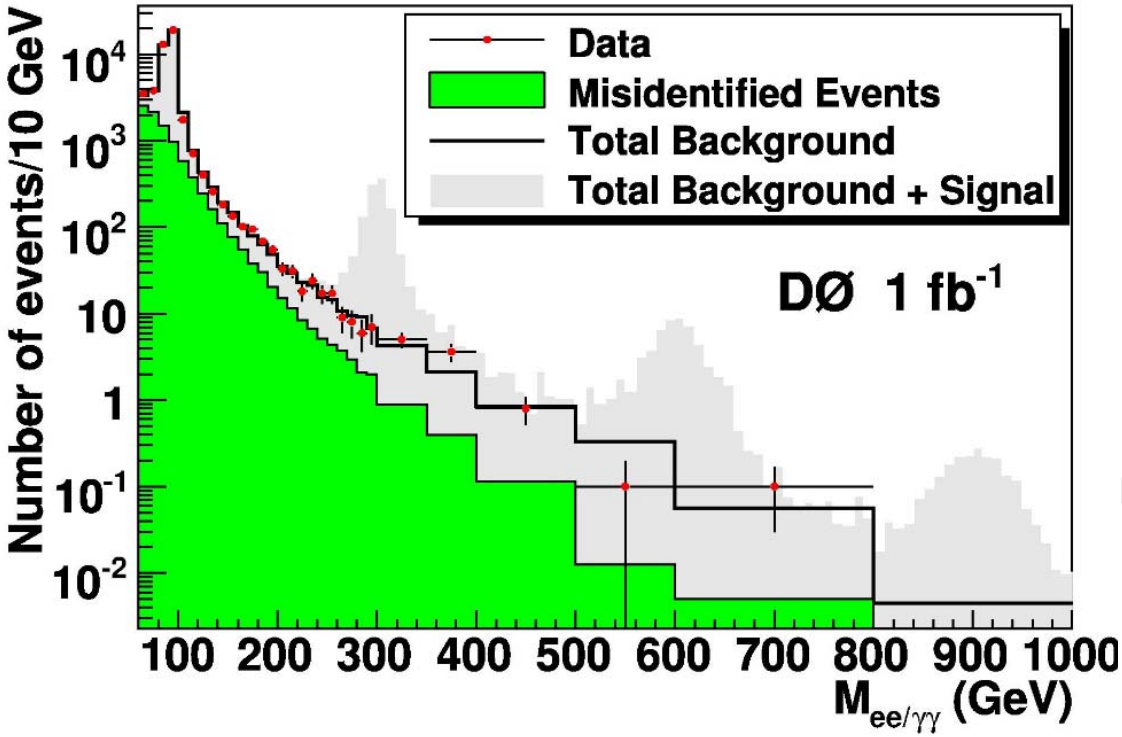
Randall-Sundrum graviton searches

CDF dijets



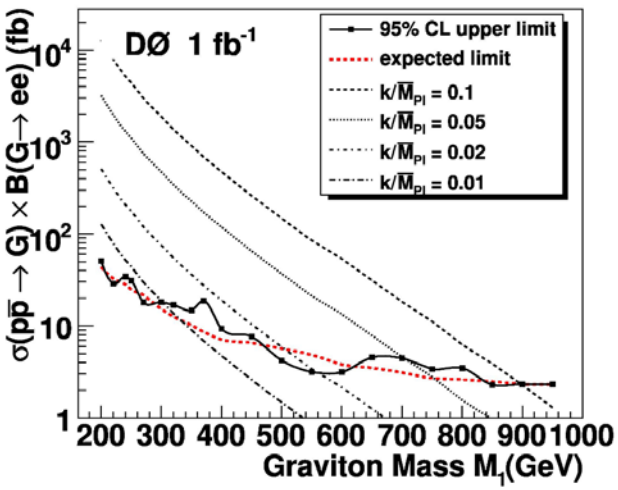


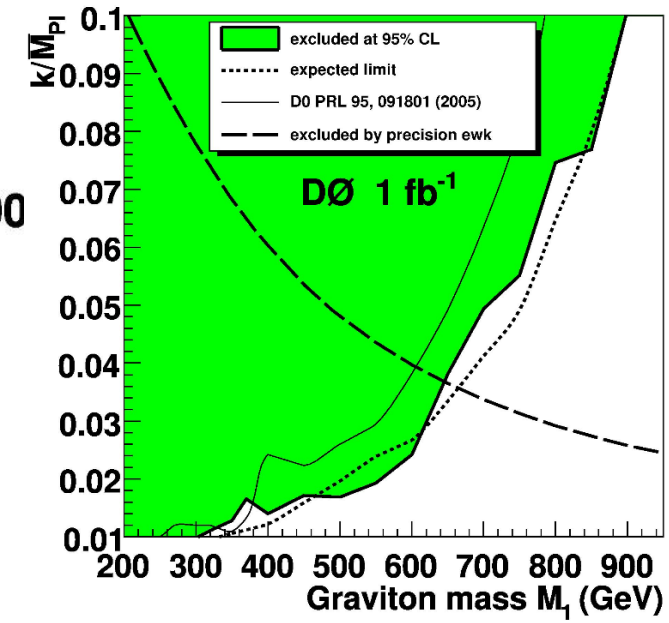
Randall-Sundrum graviton searches



D0 diphoton & dielectron

[PRL 100, 091802 (2008)]





Other exotic physics:

Searches for long lived particles

Slow moving: ***observe large time of flight or dE/dx***

CDF: CHAMP

D0: MSP

Delayed decay: ***detect late secondary from large impact parameter***

CDF: delayed photon

D0: stopped gluino

D0: delayed EM pair

Long lived particle searches

Motivation: ***discovery may be outside the standard BSM models***

- **Employ a new signature:** ***long lived particles***
- **Provide ~ model independent results**

Slow moving: ***observe large time of flight or dE/dx***

CDF: CHAMP

~model independent; interpret w/ long lived stop

D0: MSP

GMSB: long lived stau (NLSP)
AMSB: long lived chargino

Delayed decay: ***detect late secondary from large impact parameter***

CDF: delayed photon

GMSB: long lived neutralino

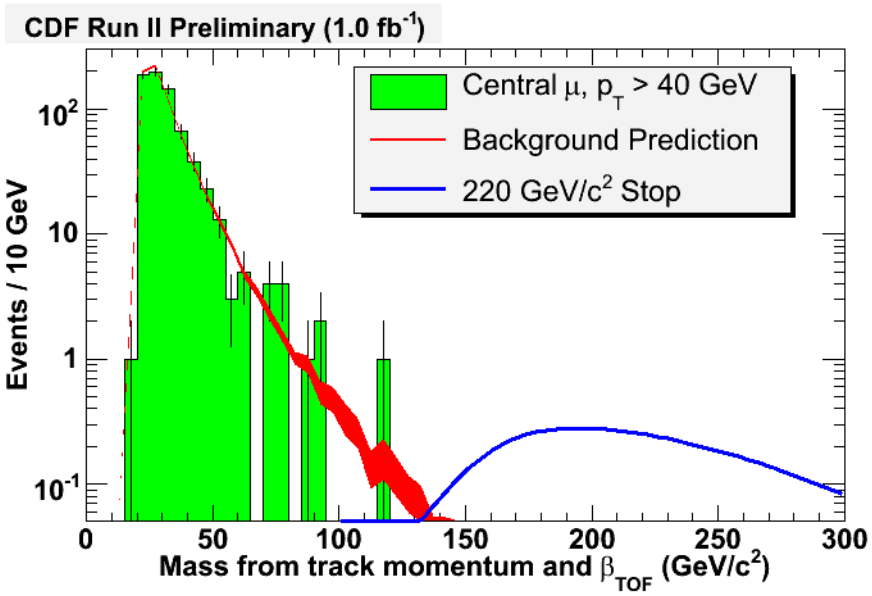
D0: stopped gluino

Split SUSY: long lived gluino

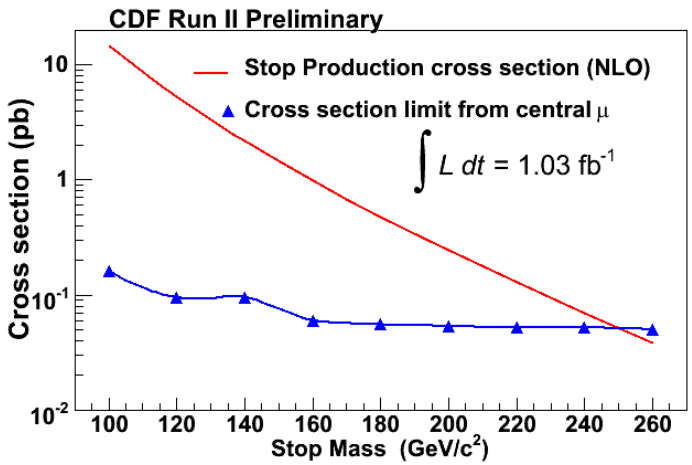
D0: delayed EM pair

MI or b' quark or GMSB neutralino
or hidden valley long lived v-mesons

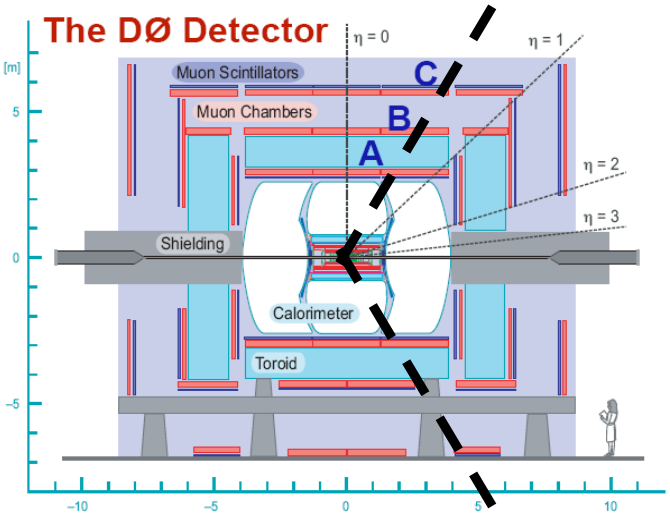
CDF CHArged Massive Particle search (CHAMP)



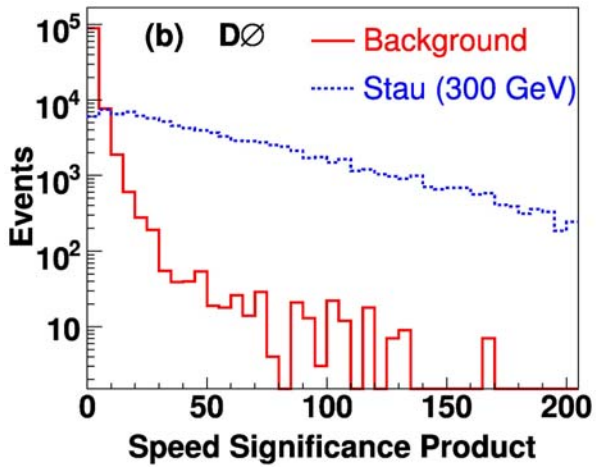
Interpret in AMSB to set a limit on the stop mass



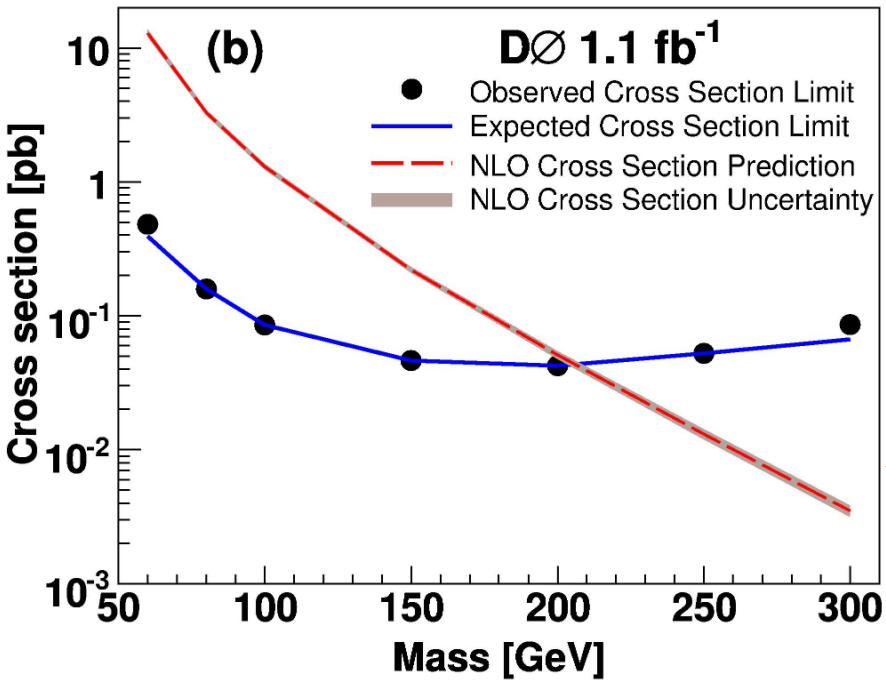
D0 search for Charged Massive Stable Particles (CMSPs)



0809.4472 [hep-ex], *Submitted to PRL*



Derived from time-of-flight measurements

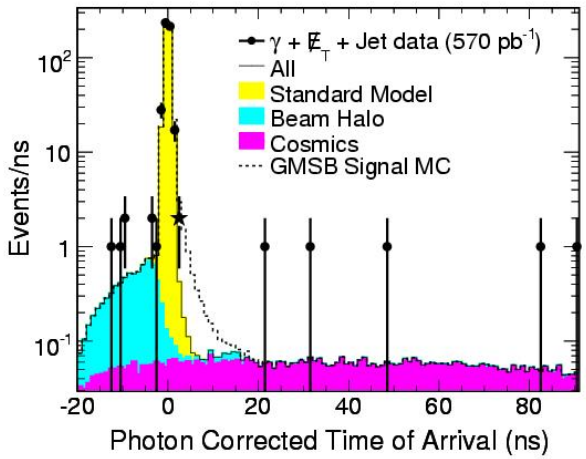


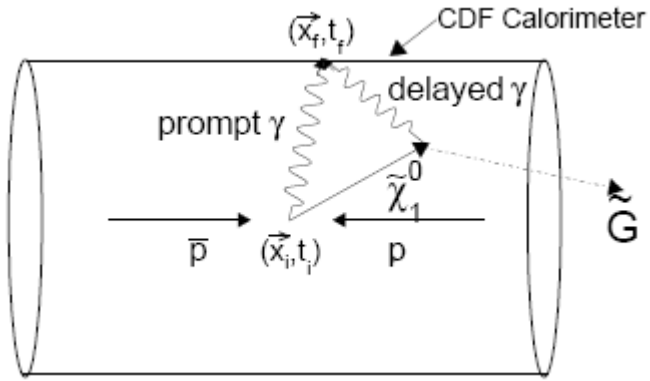
Mass limit of 206 GeV for gaugino-like chargino

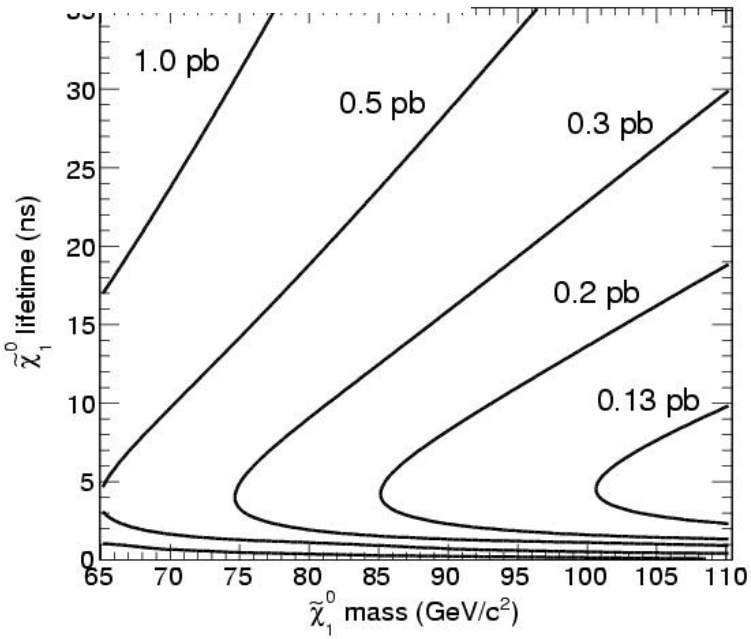
CDF search for long lived neutralinos

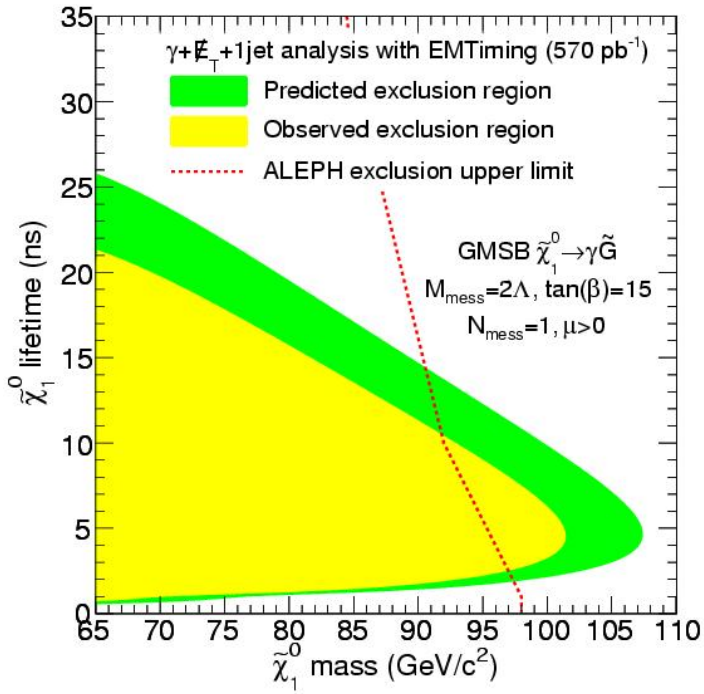
(GMSB)

arXiv:0804.1043 (2008)
PRL 99, 121801 (2007)





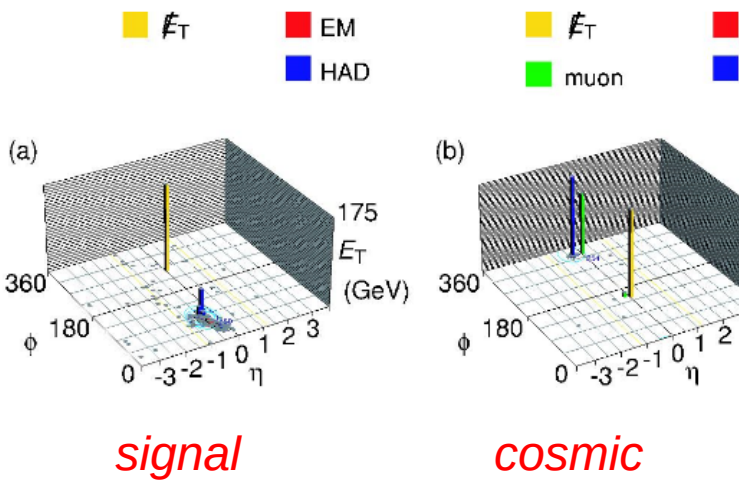




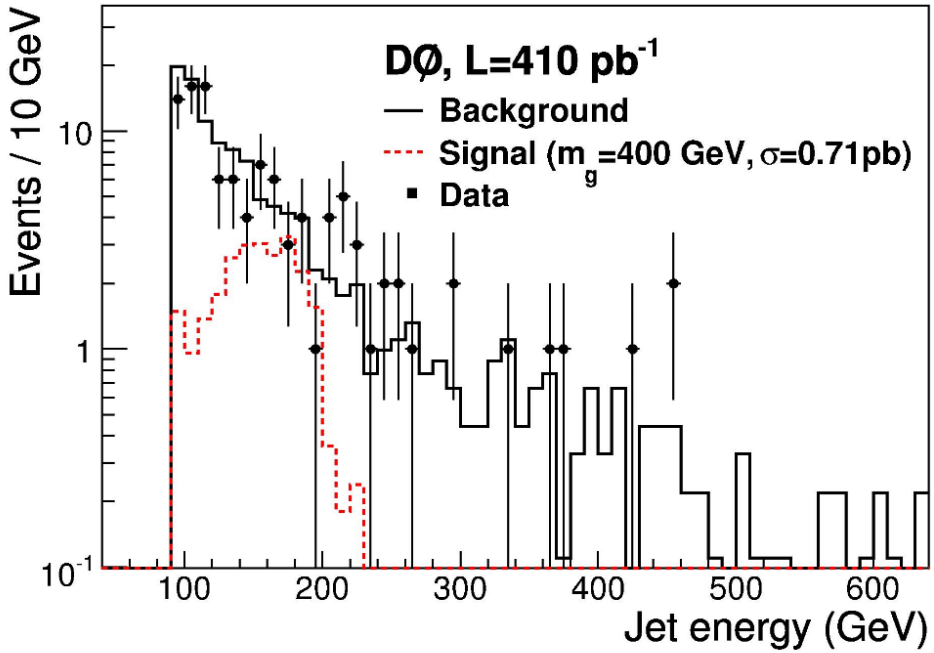
D0 Search for long lived Gluinos

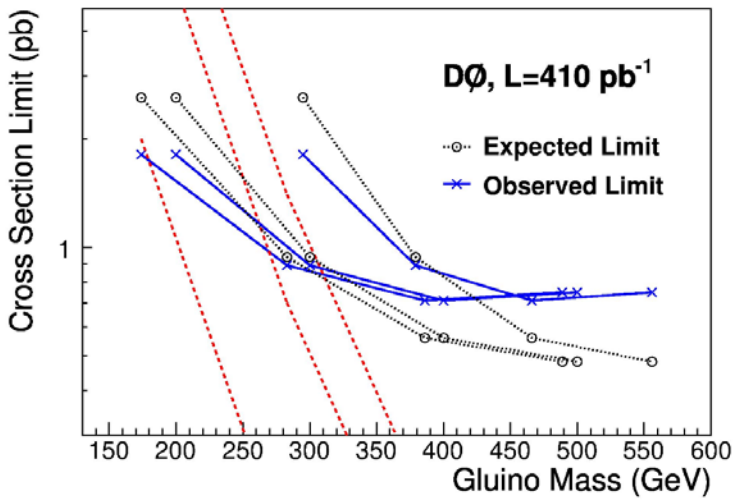
-which stop in the calorimeter

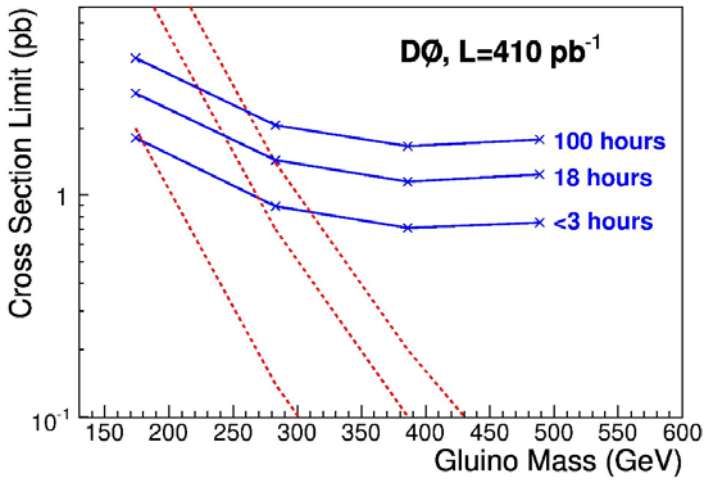
PRL 99, 131801 (2007)



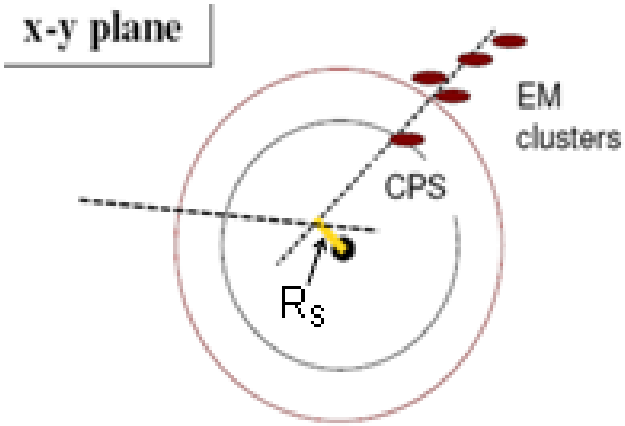
signal *cosmic*



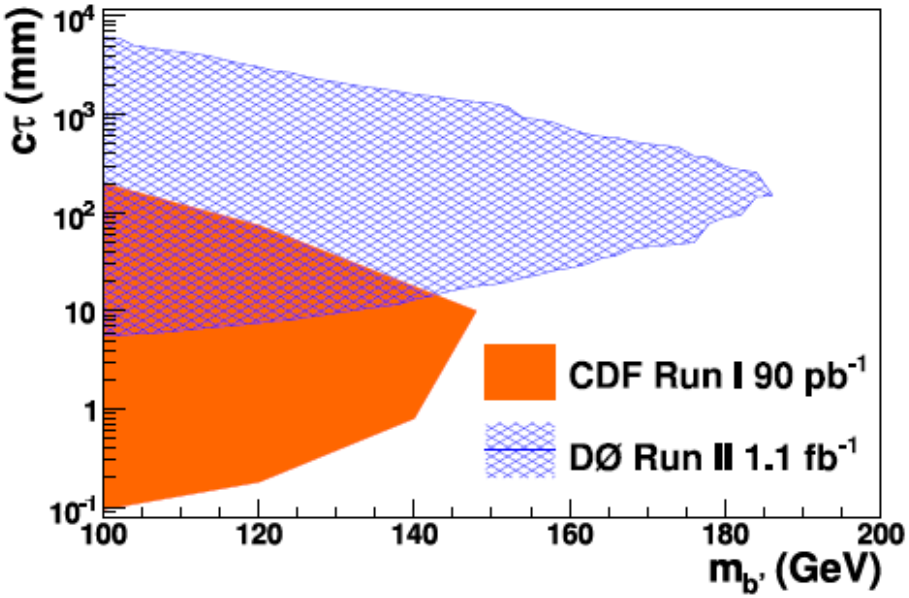


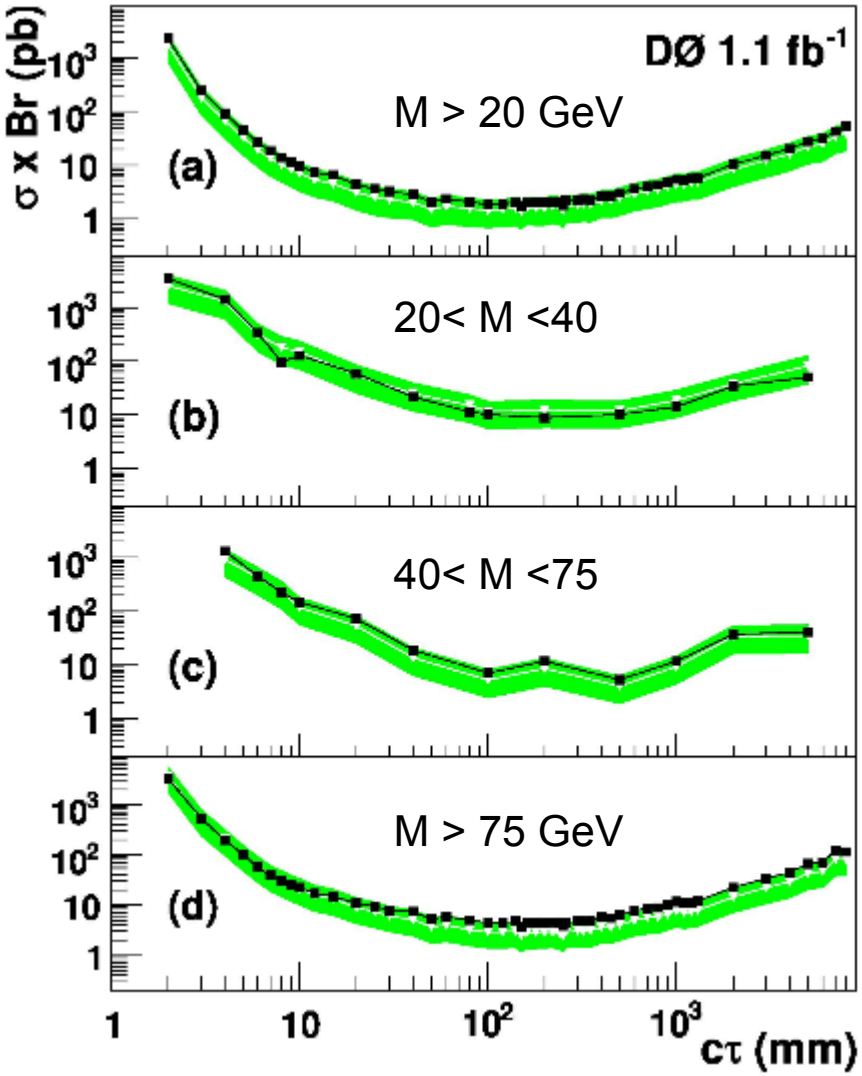


D0: long lived particles decaying to electron & photon pairs



0806.2223 [hep-ex], *Accepted by PRL*

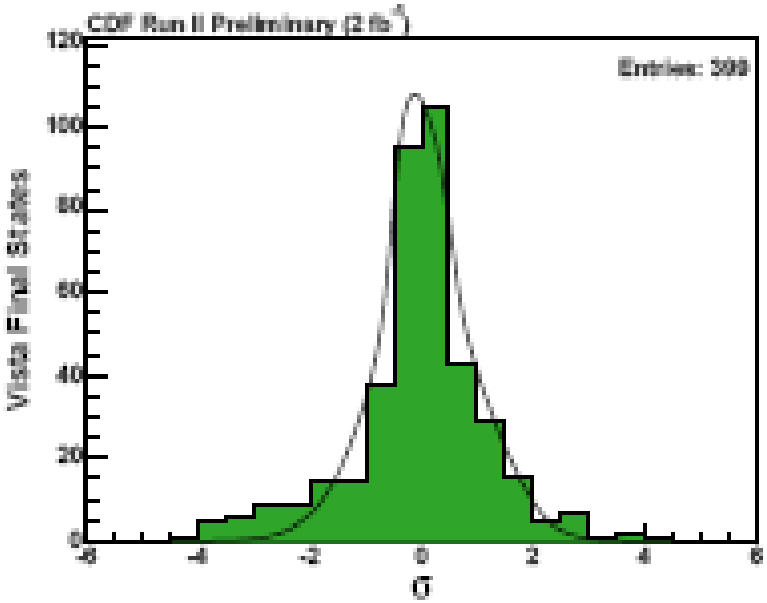




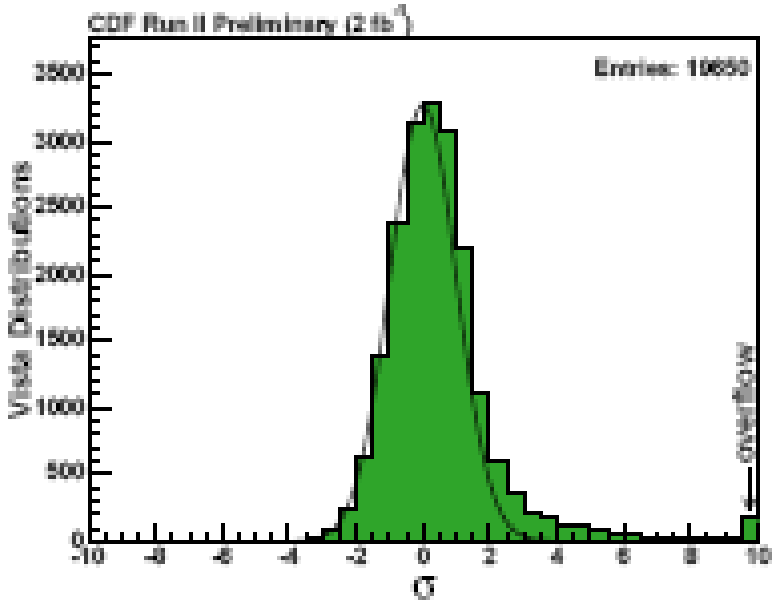
Model Independent Search

CDF: ***Vista: global* comparison of data with SM**

Moriond proceedings (arXiv:0805.0742)



Line = SM: Populations of final states



Kinematic distributions

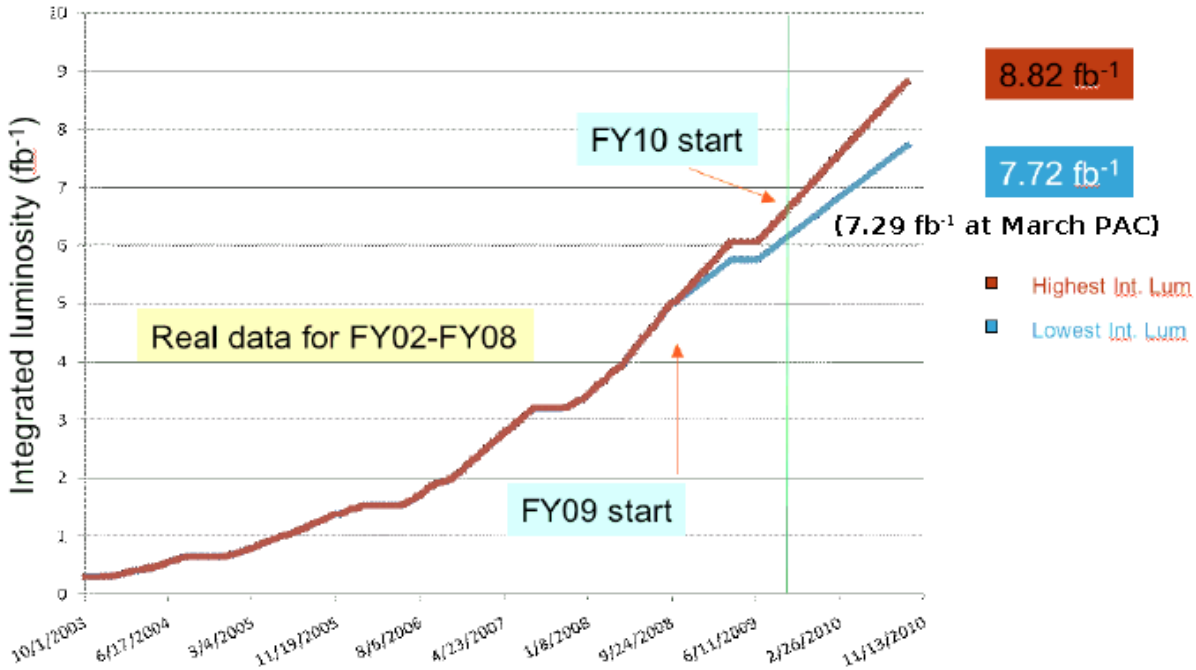
Discrepancies understood as due to imperfect modeling

Conclusion: no new physics discovered in 2.0 fb-1

D0: similar study nearing completion

Important to do!

Prospects for the future



Roger Dixon @ ICFA Seminar – 29 Oct 2008

Expect datasets ~6-7 fb^{-1}
~ x3 most current analyses

Superbly operating collider
Detectors working at high efficiency
Data is well understood

In absence of 3σ effect now, nonetheless there IS hope for a 5 σ discovery

Strategy:
- ❑ **modify selection criteria**
- ❑ **explore new physics**
- ❑ **utilize advanced analysis tools**
- ❑ **accept the challenge as experimentalists!**

Backup slides

CDF multi-muon study

Reported ~ 31-Oct-08

FERMILAB-PUB-08-046-E

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

- observe a *larger than expected* sample of muons with large impact parameter (outside the 1.5 cm radius beam pipe)
- these events referred to as "*ghost events*"
- if silicon tracking is required, then this excess disappears
- source of the excess is not understood