XXIV International Symposium on

Lepton and Photon Interactions at High Energies

(Lepton-Photon 2009)

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Status of Searches at Collider Experiments

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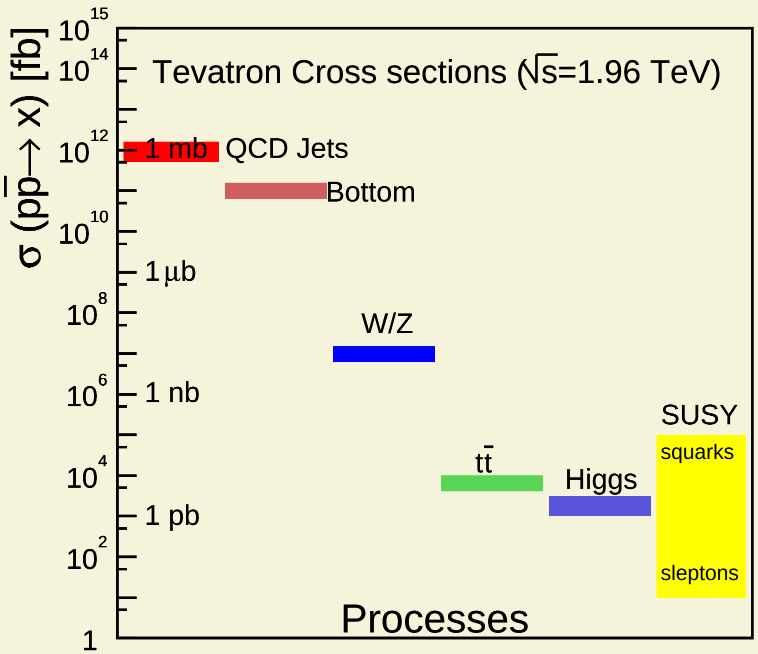
Searches at Colliders

Standard Model (SM): big success during the last 30 years to explain the experimental results in collider physics.

However, there are still some **open questions** about Nature and about the reasons why the SM works so nicely.

At Collider Experiments, where large energies are available, we look for something new ("New Physics" or Physics beyond SM) to complement our knowledge and complete the theory model.



But this also requires to handle the known processes that typically has larger cross sections... and similar topologies hiding the presence of the "New Physics".

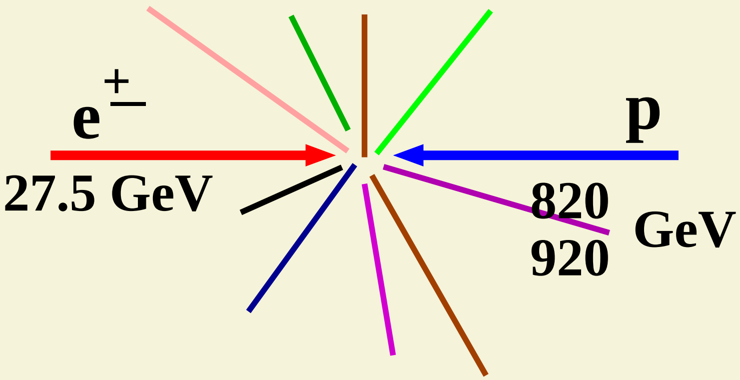
Highest energy colliders by classes:

- $\Rightarrow$ **LEP** ($e^+e^- \to X$) **from 1989 to 2000**
- $\Rightarrow$ **HERA** ($ep \to X$) **from 1991 to 2007**
- $\Rightarrow$ **Tevatron** ($p\bar{p} \to X$) **from 2001 to 2011? (Run II)**

This talk does not directly cover LEP analyses, but some of the results (limits) are shown since they are still competitive in some areas.

HERA Collider at DESY

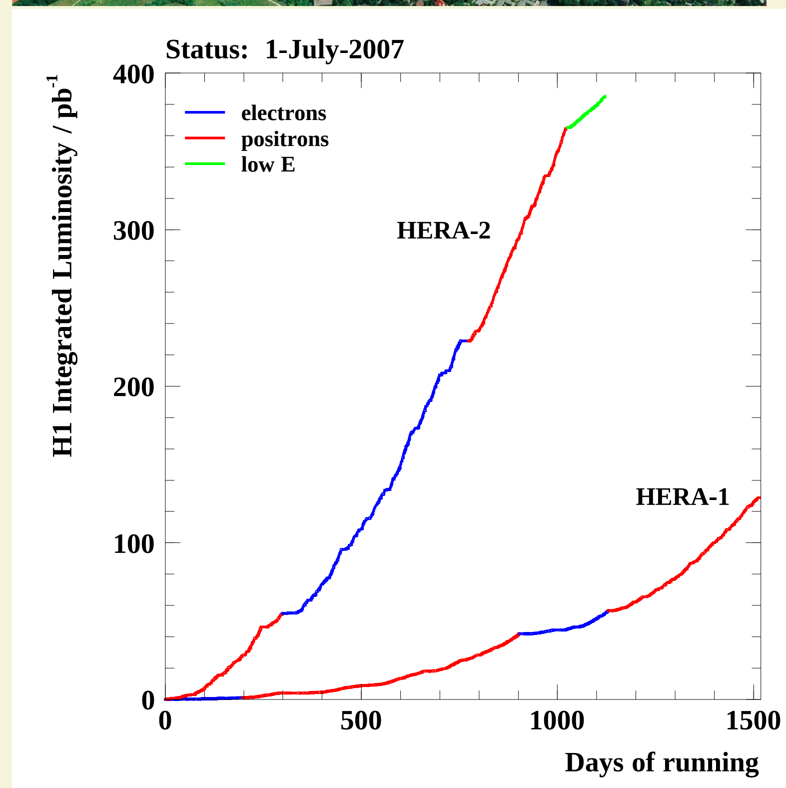
- Only electron-proton collider in the World



$$\sqrt{s} = 300/318 \text{ GeV}$$

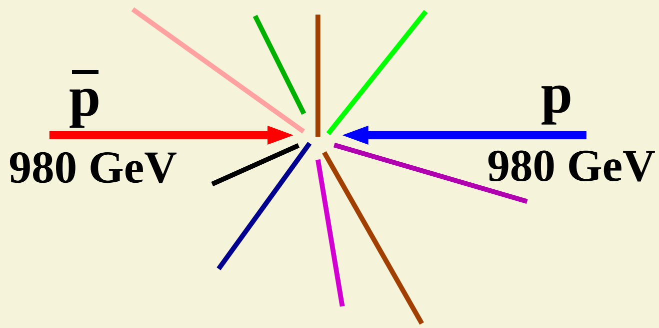
- Located at DESY (Hamburg).
- Operation in Run II ended in 2007
- Data from the two runs are combined to produce final results.
- 0.5 fb^{-1} collected by H1 and ZEUS

Due to its unique initial state at the available energy, searches for new physics and particles are competitive/complementary to LEP and Tevatron



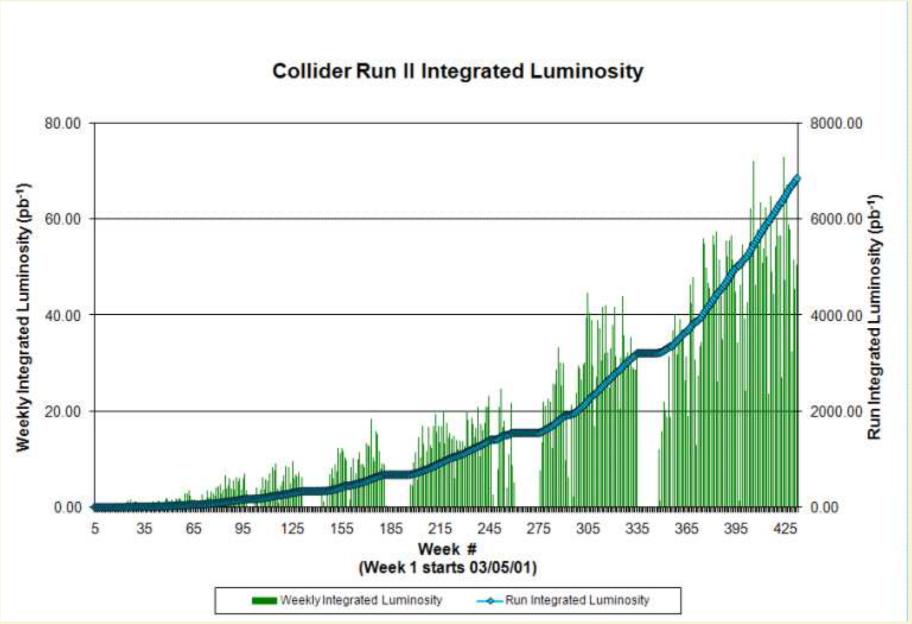
Tevatron Collider at Fermilab

- **Most energetic collider in the world (until LHC starts)**
- **Colliding protons and antiprotons**



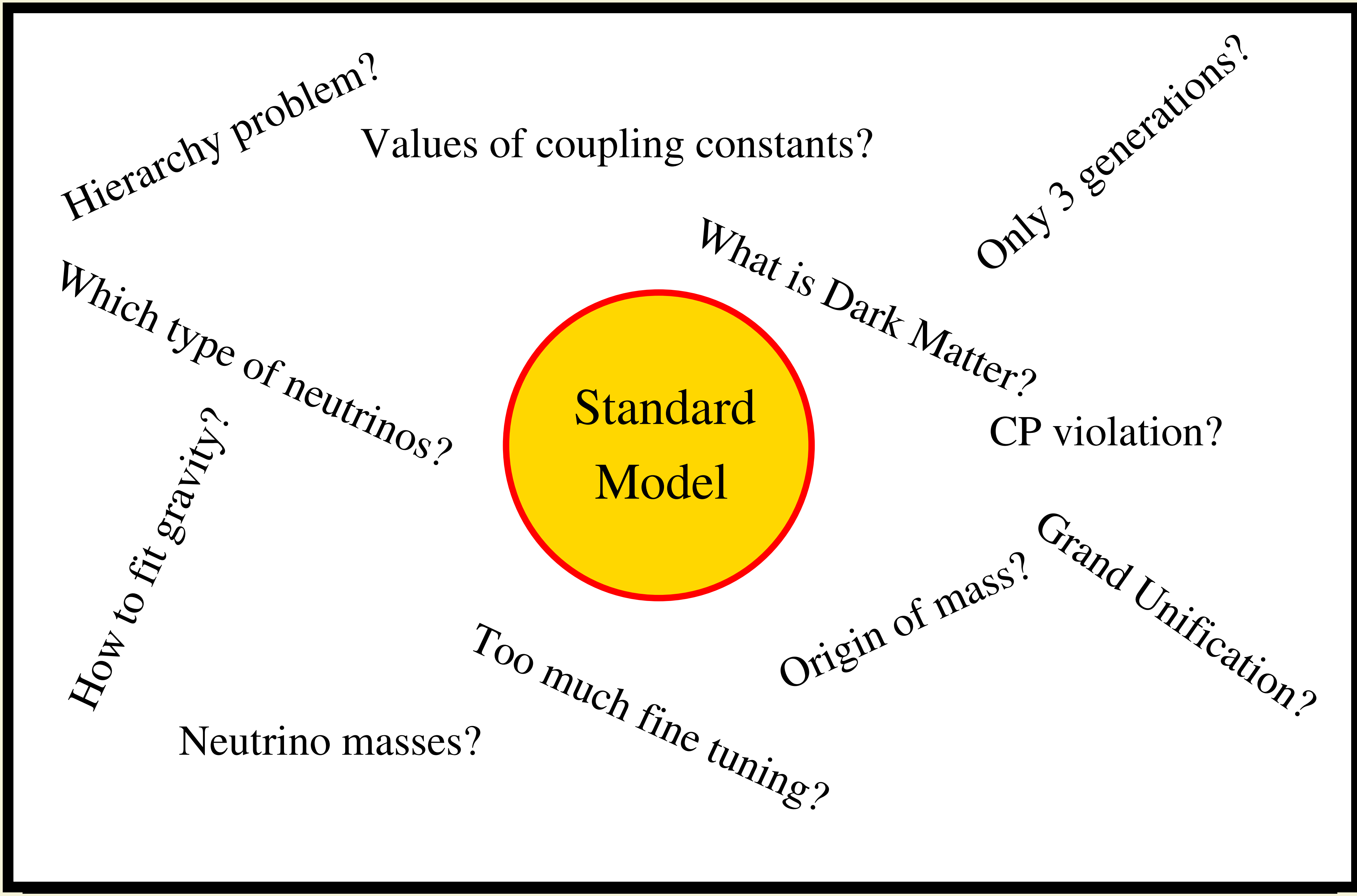
$$\sqrt{s} = 1960 \text{ GeV}$$

- **Still collecting data, and pushing for running until LHC results take over.**
- **~ 6 fb^{-1} collected by CDF and DØ**
- **Currently Tevatron results are the best place to search for new phenomena (a priori).**

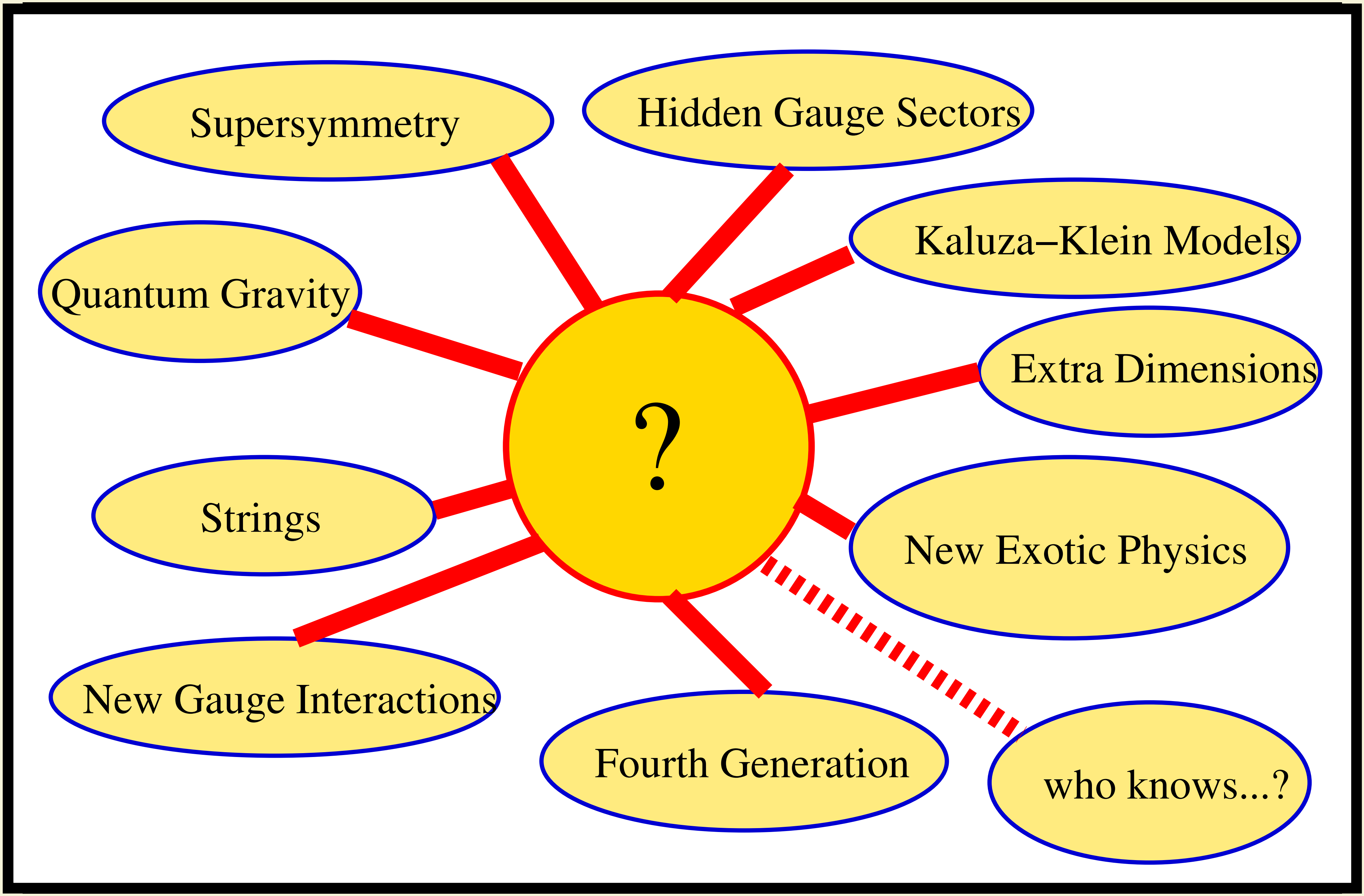


With the collected data sample, Tevatron Run II experiments are sensitive to processes far beyond previosly explored regions.

The big picture

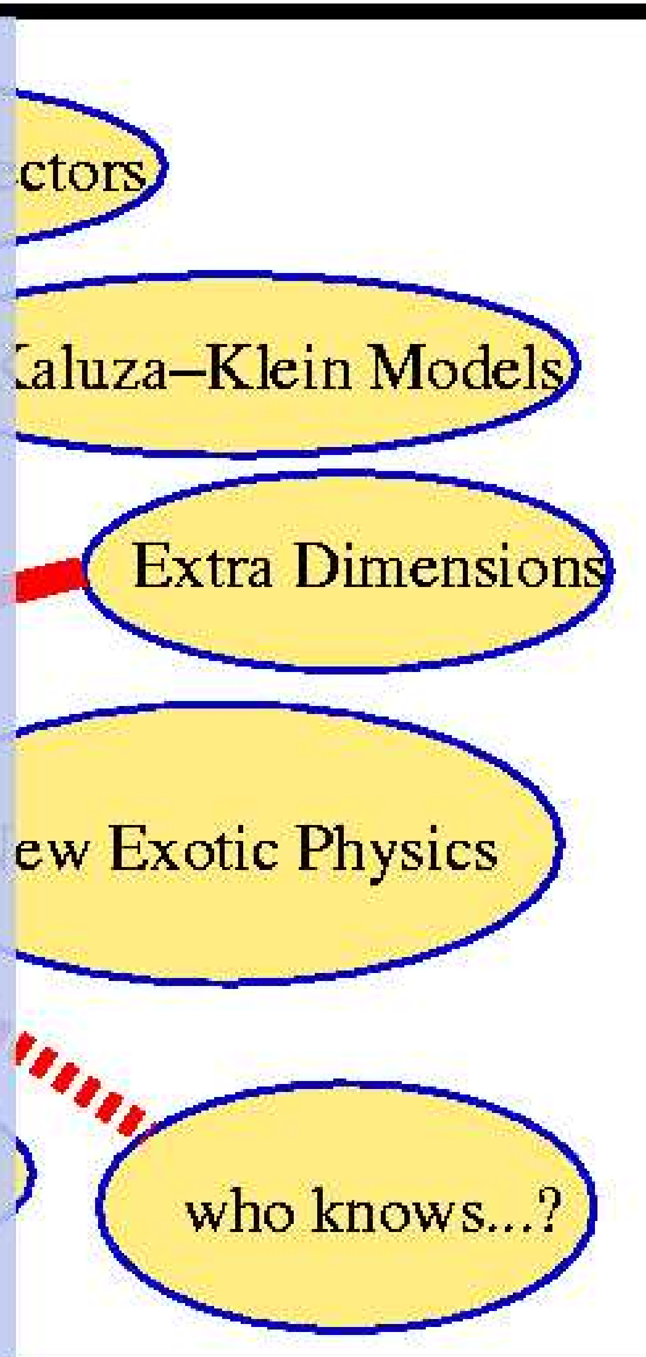


The big picture



Outline of the topics

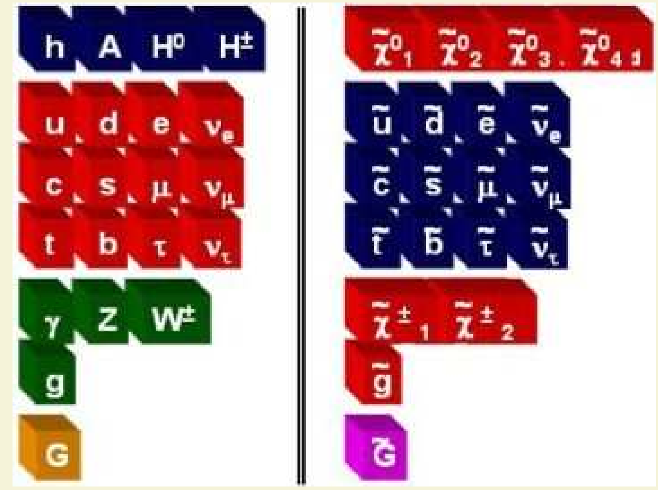
- **Searches for Supersymmetric particles:**
  - Squarks and gluinos
  - Gaugino searches
  - (Supersymmetric Higgses covered by G. Bernardi)
- **Leptoquark Searches**
- **Large Extra Dimensions**
- **Search for High Mass resonances**
- **Search of exotic signatures**
  - Multileptons
  - Unusual topologies
- **General inclusive searches**
- **Summary**



Searches for Supersymmetry

- Supersymmetry (SUSY) makes Nature invariant under the transformation

bosons ⇔ fermions



- For this to be satisfied we require a supersymmetric partner for each known (or to be known) particle.

This symmetry is commonly introduced since it solves some weak points of the SM (on the theoretical side).

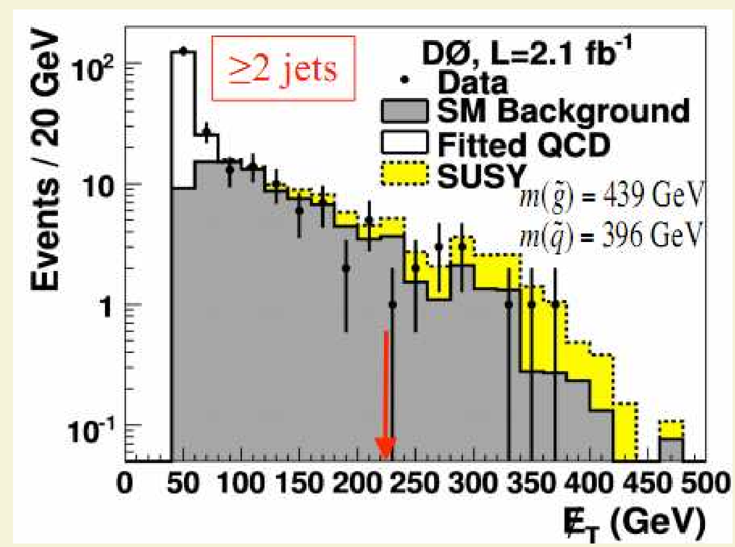
In R_p-conserving models, the lightest supersymmetric particle (LSP) is stable and weakly-interacting (Dark Matter?) and appears in the final state as imbalance in transverse momentum ($\not{E}_T$).

If masses are reachable at the Tevatron, squarks and gluinos are produced via the strong interaction:

$$p\bar{p} \to \tilde{q}\tilde{q}X \to q\tilde{\chi}^0 q\tilde{\chi}^0 X$$

$$p\bar{p} \to \tilde{g}\tilde{q}X \to q\bar{q}\tilde{\chi}^0 q\tilde{\chi}^0 X$$

$$p\bar{p} \to \tilde{g}\tilde{g}X \to q\bar{q}\tilde{\chi}^0 q\bar{q}\tilde{\chi}^0 X$$



which are the final states for which CDF and DØ optimized the analyses.

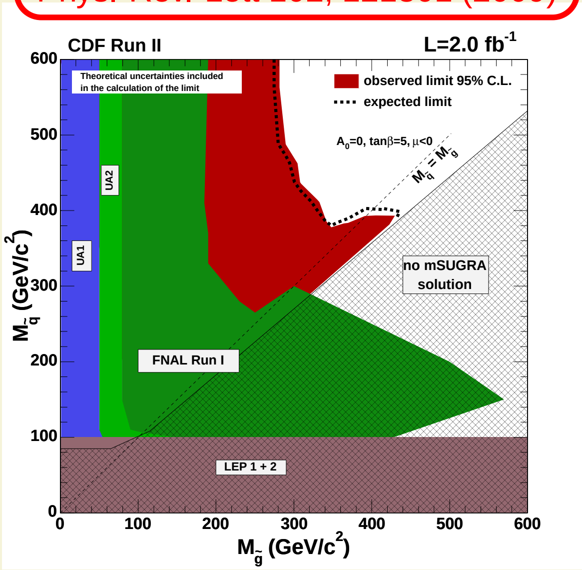
Squarks and gluinos using Jets+ $\not\!\!E_T$

In the tight selections performed in the anlyses, mainly on $\not\!\!E_T$ and $\sum E_T$ (jets)

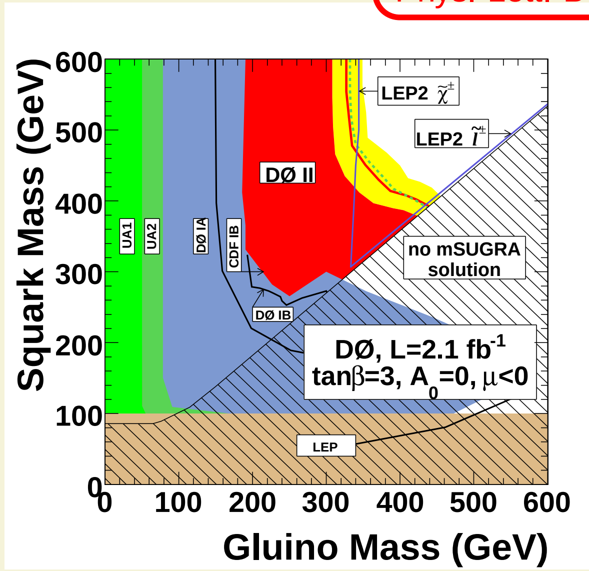
	CDF $(2\ \mathrm{fb}^{-1})$		DØ $(2.1\ \mathrm{fb}^{-1})$	
Analyses	Expected	Observed	Expected	Observed
2-jets	16 ± 5	18	$11 \pm 1^{+3}_{-2}$	11
3-jets	37 ± 12	38	$11 \pm 1^{+3}_{-2}$	9
4-jets	48 ± 17	45	$18 \pm 1^{+6}_{-3}$	20

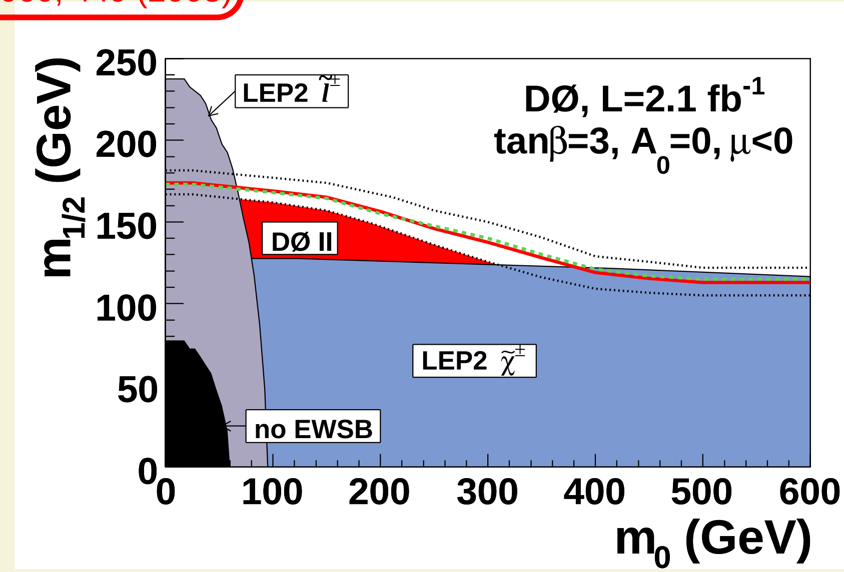
The agreement with SM is used to set limits (at 95% C.L.) on the parameters:

Phys. Rev. Lett 102, 121801 (2009)



Phys. Lett. B 660, 449 (2008)

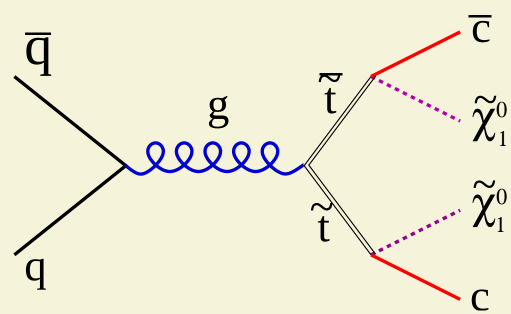


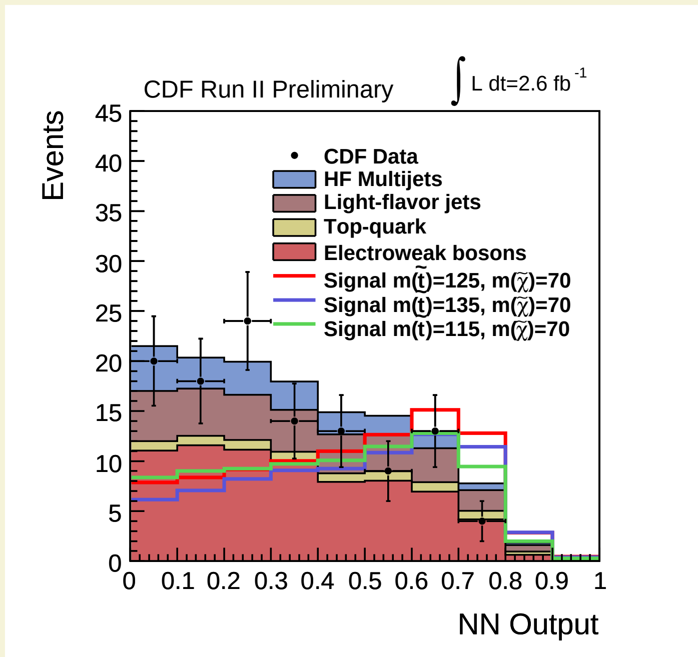


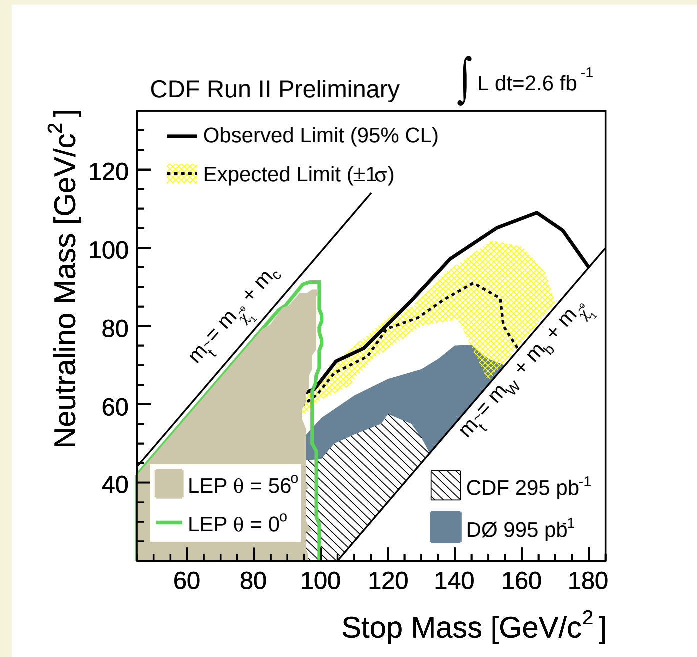
- **gluinos: $m > 280$ GeV$/c^2$ (CDF), > 308 GeV$/c^2$ (DØ), for all squark masses**
- **squarks: $m > 380$ GeV$/c^2$ (CDF, DØ), for all gluino mass**
- **In the mSUGRA interpretation, excluding regions not accessed by LEP**

Scalar top searches

- Due to the specifics of the third generation, there are motivations that the SUSY partners may also have specific properties.
- Having a large mixing of chirality states, the lightest mass eigenstate could be much lighter to “normal” sfermions.
- In fact there is strong motivation to set the scalar top as the next-to-LSP particle (due to large top mass) and its decay into charm and LSP.





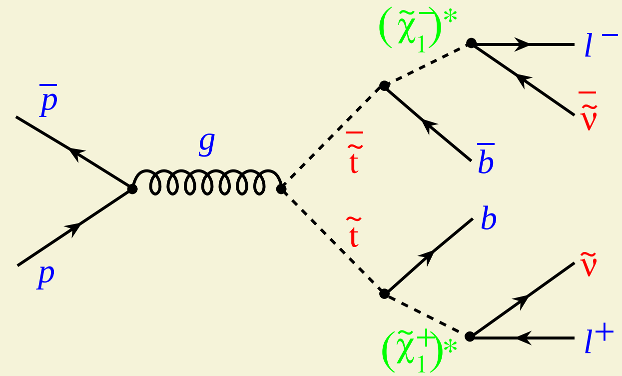


- New CDF analysis exploited properties for charm-tagging of jets to reduce background from bottom jets.
- Kinematic Neural-Network output used as discriminating variable (using tools and experience from Higgs searches).

Scalar top in the dilepton channel

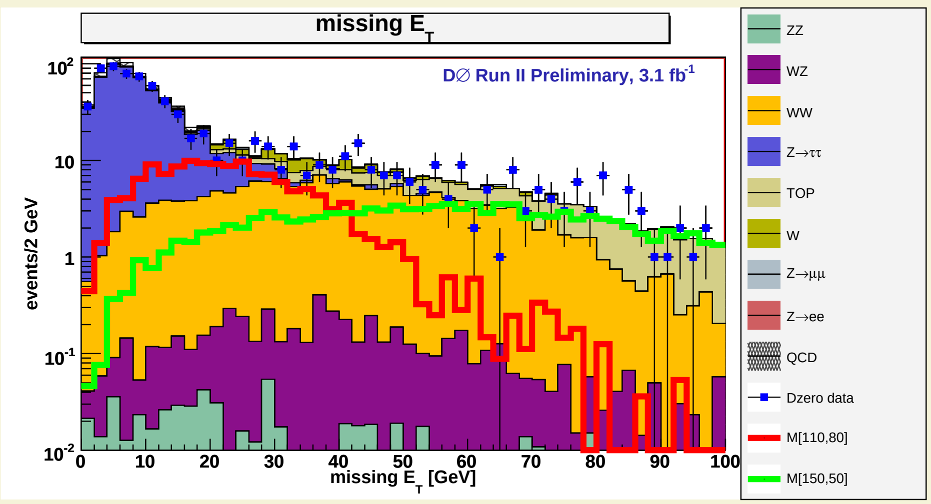
If the sneutrinos are lighter than stop, the dominant decay is into leptons.

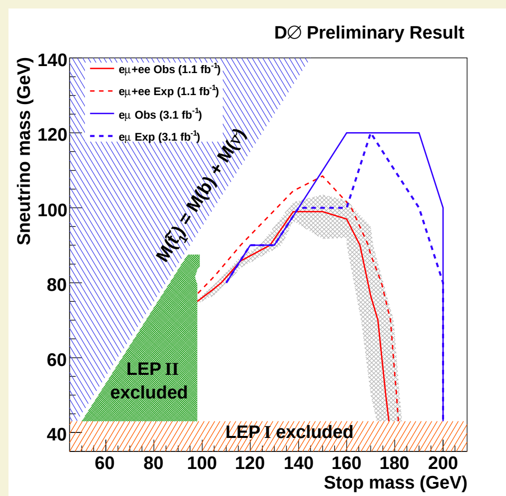
- **Signature similar to $t\bar{t}$ dileptons, but with soft leptons.**
- **Kinematics slightly different due to mass of $\tilde{\nu}$**
- **Assuming a 100% BR to leptons and family symmetry, $e\mu$ is the most sensitive channel.**

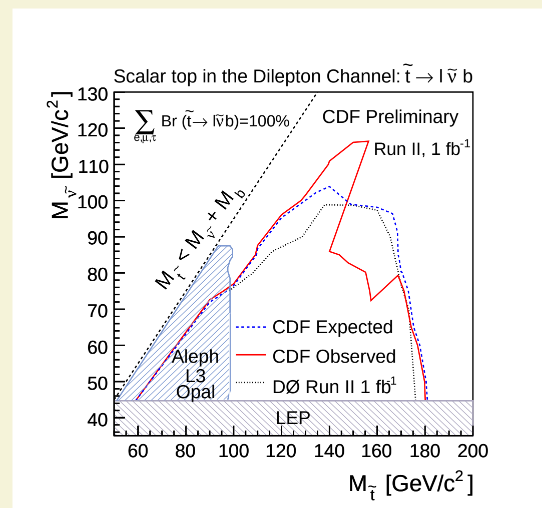


- **Difficult backgrounds: QCD multijets, lepton+"fake" and others with similar topology ($Z \to \tau\tau$, $t\bar{t}$ and WW).**

- **New results from DØ(full dataset, $e\mu$ only) and CDF (1 fb $^{-1}$, all channels)**



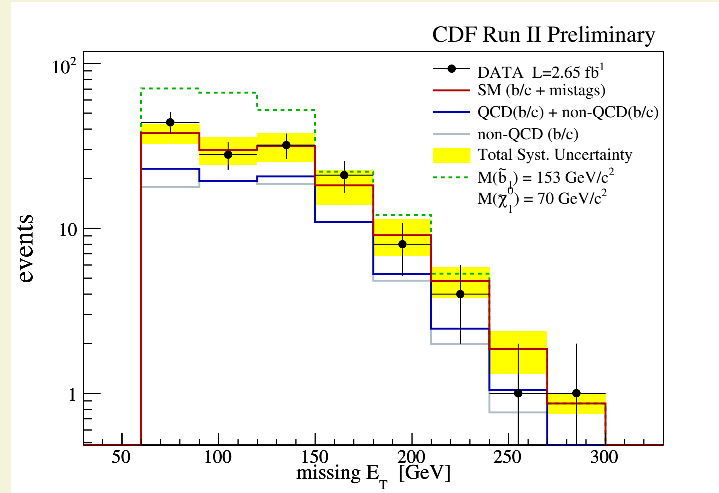




- **Exclusion limits are above top mass: $m(\tilde{t}) > 180 - 200$ GeV$/c^2$**

Scalar bottom searches

- Other motivated option is the search for a similar production of scalar bottom, which may be the lightest coloured SUSY particle (at large $\tan\beta$).
- The decay is 100% to bottom and neutralino.



Optimization based on

$\Rightarrow$ Kinematics: $\not\!\!E_T$, $\sum E_T$ (jets)

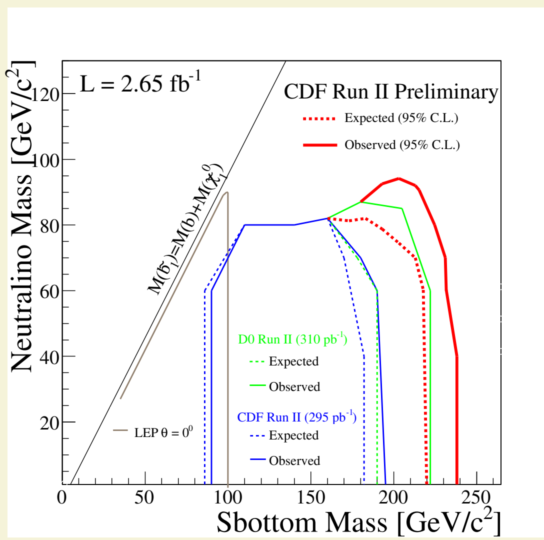
$\Rightarrow$ b-tagging of jets (secondary vertices)

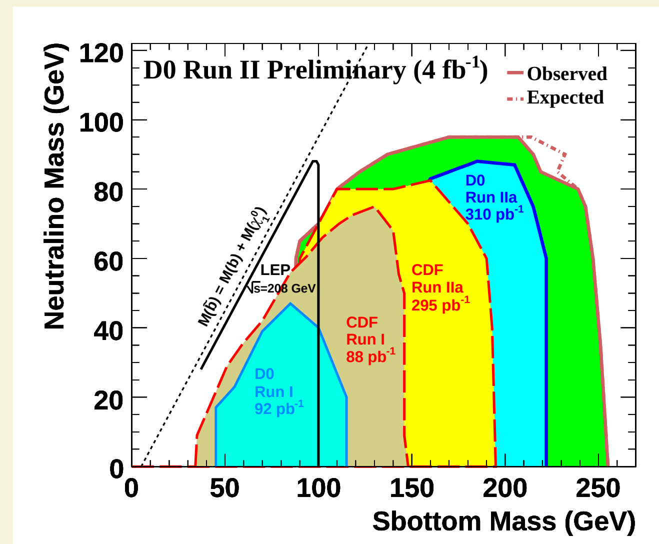
- Very recent efforts by CDF and DØ are pushing the limits towards larger $m(\tilde{b})$.

- 3 optimizations by CDF:

CDF Preliminary $(2.65\ \text{fb}^{-1})$	Expected	Observed
low ΔM	133.8 ± 25.2	139
high ΔM	47.6 ± 8.3	38

Analysis just approved for LP09!





Tevatron is excluding sbottom for masses ~ 250 GeV$/c^2$.

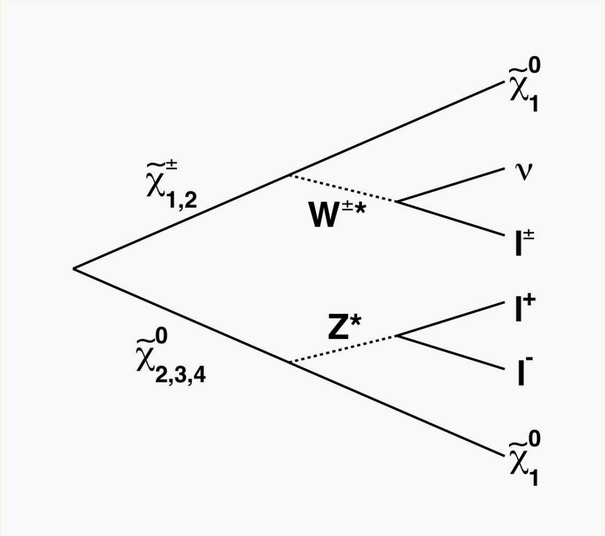
Searching for gauginos

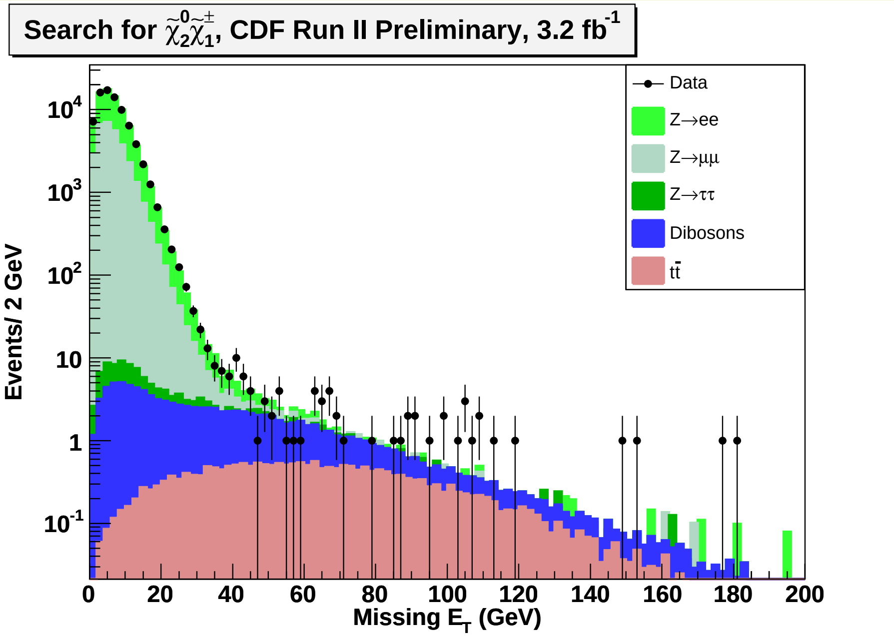
One of the "golden modes" to detect Supersymmetry at Tevatron is the detection of neutralino and chargino production in the trilepton channel.

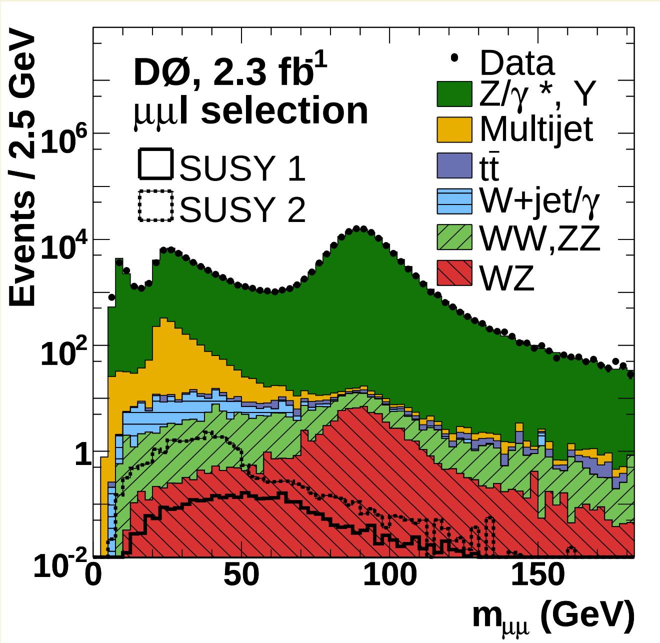
The production of the neutralino-chargino is higher than other SUSY processes in mSUGRA scenarios.

The signature (3 leptons and $\not{E}_T$) is very clean for a hadron collider. Jets faking lepton (+boson production or Drell-Yan) is the background to reduce.

Due to low backgrounds, validation of the predictions is the fundamental part of the analyses.

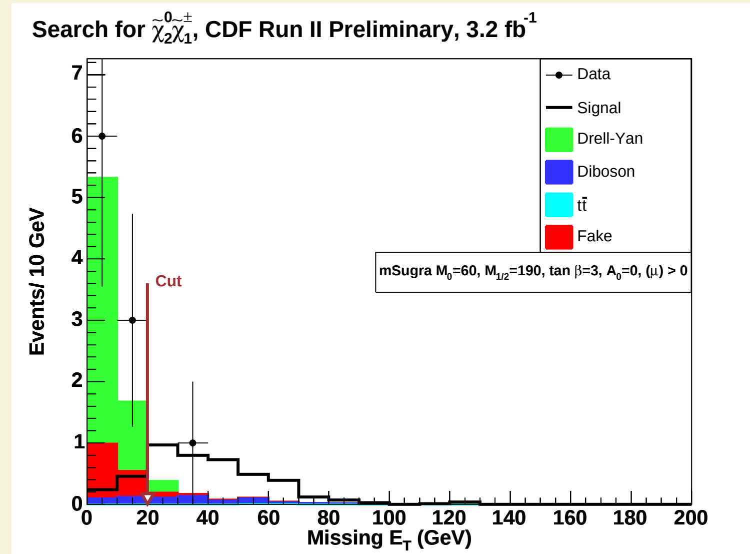






The Trilepton Signature

In the final selection, the fight for sensitivity is translated into the understanding of processes with small-cross sections or hard to estimate: Dibosons, conversions, fake-leptons, . . .

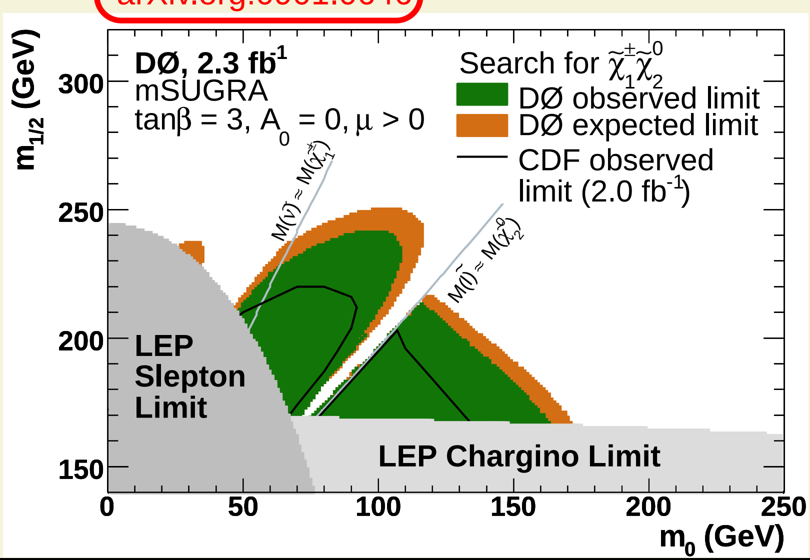


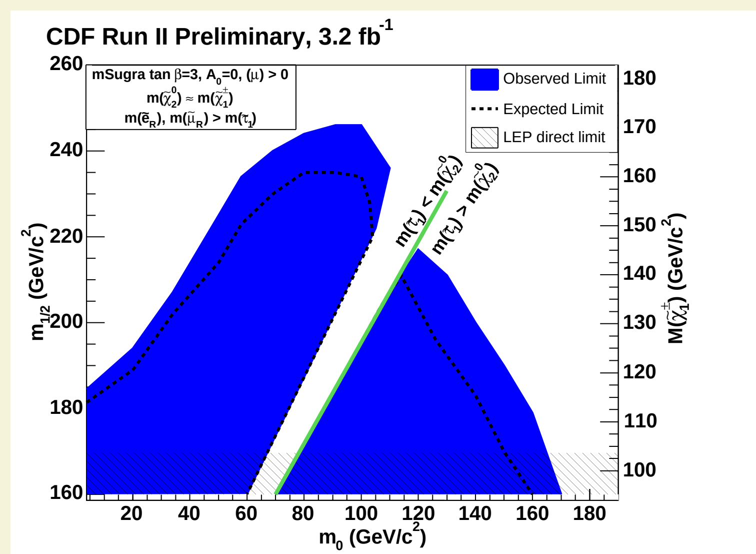
DØ ($2.3\ \mathrm{fb}^{-1}$)	Expected	Observed
Low p_T	5.4 ± 0.6	9
High p_T	3.3 ± 0.4	4
CDF ($3.2\ \mathrm{fb}^{-1}$)	**Expected**	**Observed**
3-leptons	1.5 ± 0.2	1
2-leptons+track	9.4 ± 1.4	6

$\Rightarrow$ **Interpretation complicated due to phenomenology.**

$\Rightarrow$ **Commonly done in the mSUGRA context:**

arXiv.org:0901.0646



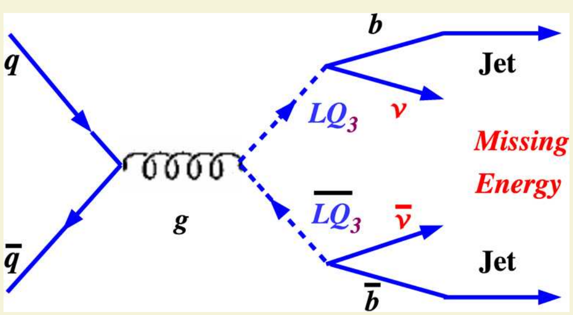


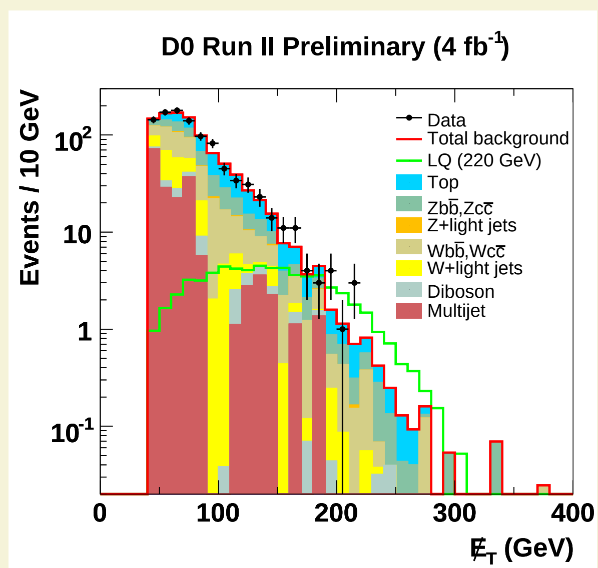
Leptoquark Search

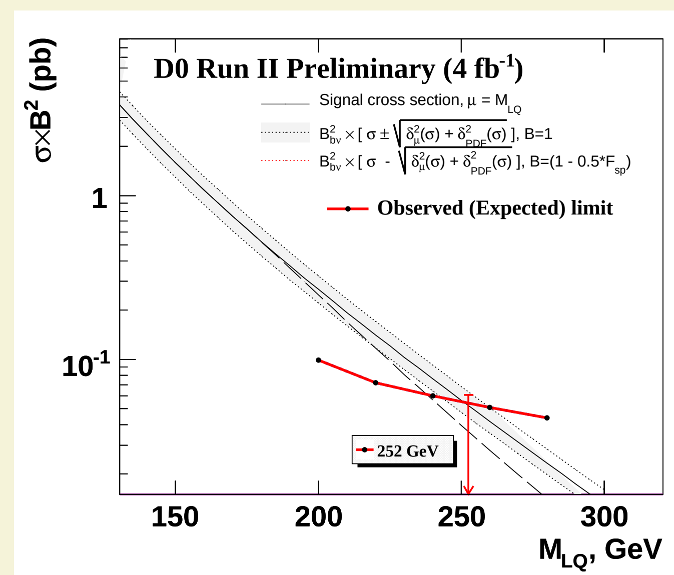
Leptoquarks (LQ) are hypothetical scalar or vector bosons with both baryon and lepton number, **mediating lepton-quark transitions in many extensions of SM: GUT, extended gauge models, compositeness etc.**

- Searches are optimized for different final states, depending on the generation of the LQ particles (i.e. to which families they couple).
- Depending on the generation, interpretation of the results are done in different parameter planes.

Related to third generation LQ, DØ has a very recent analysis using the same topology as in the scalar bottom search:

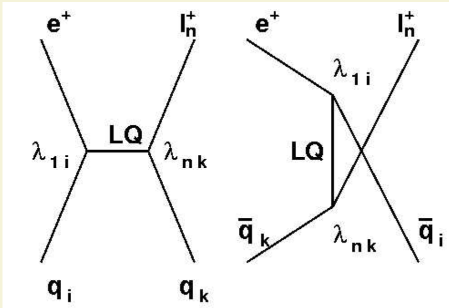


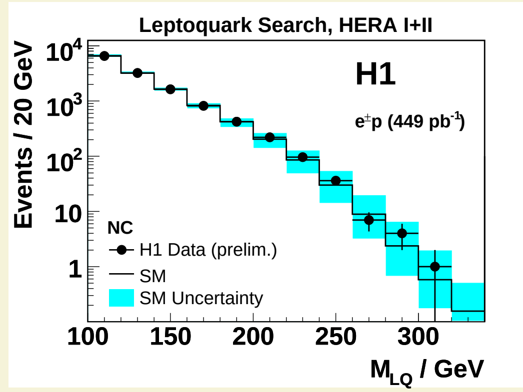


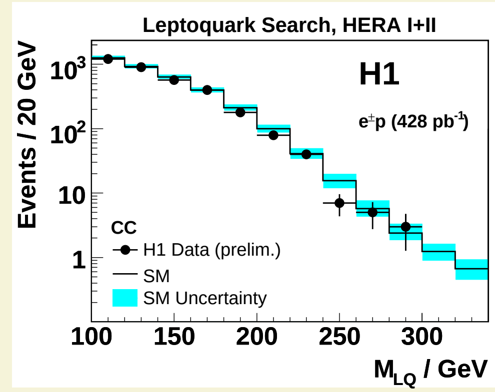


Leptoquark Search at HERA

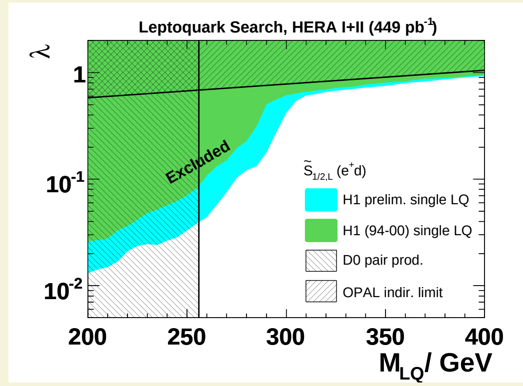
- HERA is the most efficient collider to produce leptoquarks that couple to the first generation.

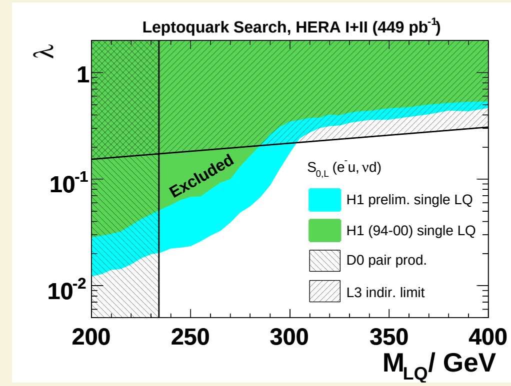






- Good agreement with large SM background in Neutral and Charge Current DIS.





- Limits interpreted within the Buchmüller-Rückl-Wyler Model (set on all 14 LQs).
- At 95% C.L., with the whole dataset:

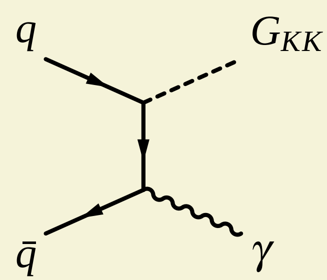
$\rightarrow$ For $\lambda = 0.3$, $M_{LQ} > 291 - 330$ GeV$/c^2$ (H1)
$\rightarrow$ $M_{LQ}/\lambda > 0.41 - 1.88$ TeV$/c^2$ (ZEUS, Contact Interactions)

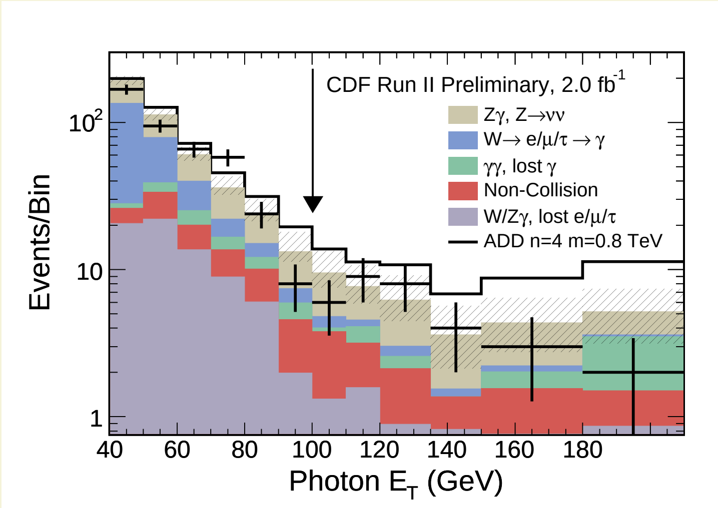
- Strong contraints below the kinematic limit, but final sensitivity goes beyond that point (due to the u-channel).

Large Extra Dimensions (LED)

If gravity propagates in $4+n$ dimensions (as a difference to the other interactions, confined in 3+1 dimensions), **the effective Planck scale could be small (~ 1 TeV) and gravity becomes comparable in strength to the electroweak interaction.**

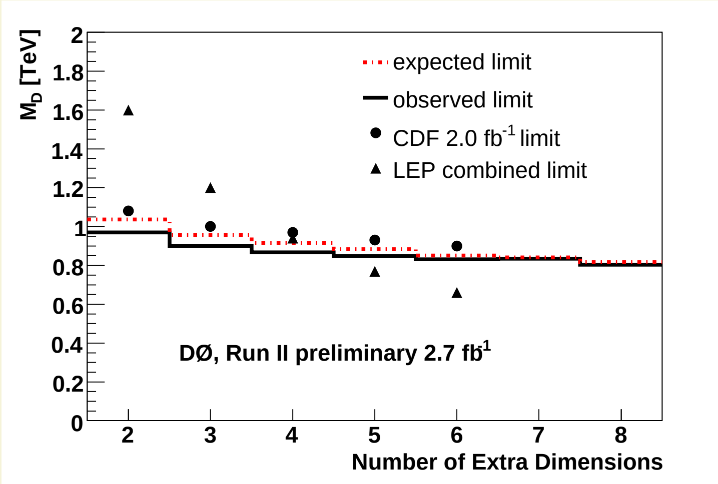
The typical "golden channel" for this at Tevatron is the production of a single high-E_T photon and $\not{E}_T$ (from the graviton, identified as a Kaluza-Klein mode)





Tight selection to achieve a high final sensitivity:

$E_{T,\gamma} > 90$ GeV
$\not{E}_T > 50$ GeV (CDF), > 70 GeV (DØ)



Events	CDF $(2.0\ \text{fb}^{-1})$	DØ$(2.7\ \text{fb}^{-1})$
Expected	46.3 ± 3.0	49.9 ± 4.1
Observed	40	51

LED at HERA

- Effect could see as a deviation of the total ep cross section, especially at high Q^2, where the gravity may be comparable to the electroweak interaction.

- Contribution from the graviton exchange in ep NC DIS may be described as the effective coupling:

$$\eta_G = \pm \frac{\epsilon^2}{M_s^4}$$

where ϵ is related to the energy scale of the interaction and M_s the effective Planck scale.

Data in good agreement with the electroweak predictions, which leads to extract limits.

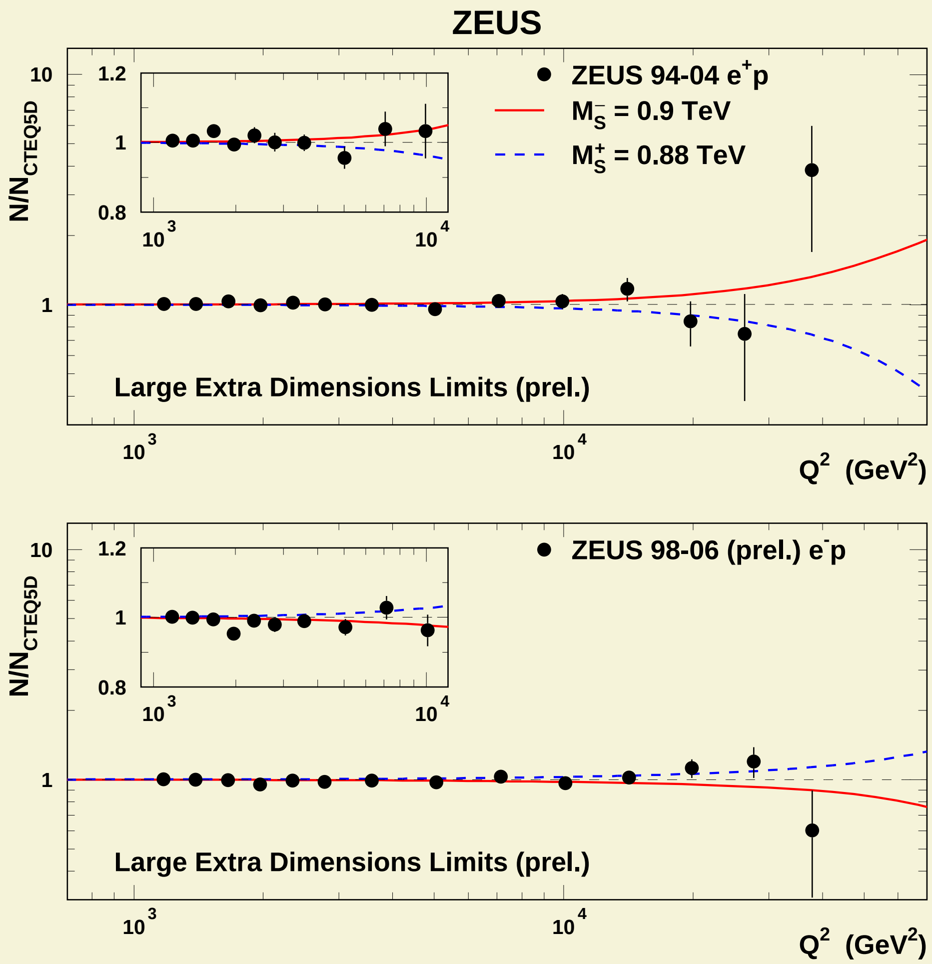
⇒ From ZEUS:

For $M_s(\pm 1) > 0.94$ TeV (at 95% C.L.)

⇒ From H1 (HERA-I)

For $M_s(+1) > 0.48$ TeV (at 95% C.L.)

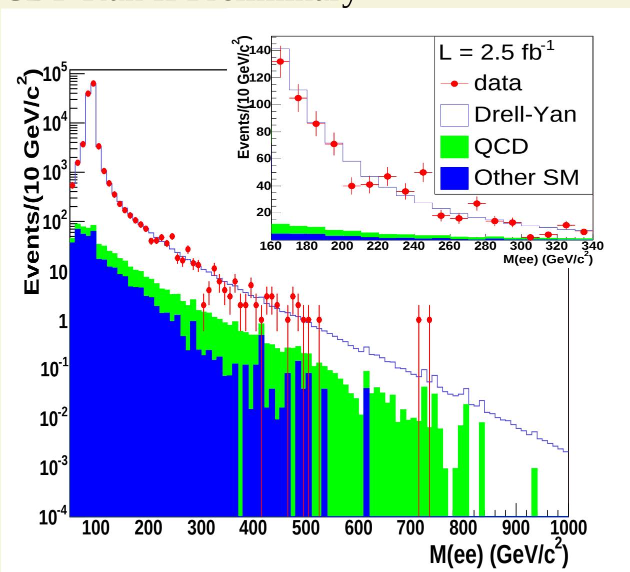
For $M_s(-1) > 0.72$ TeV (at 95% C.L.)

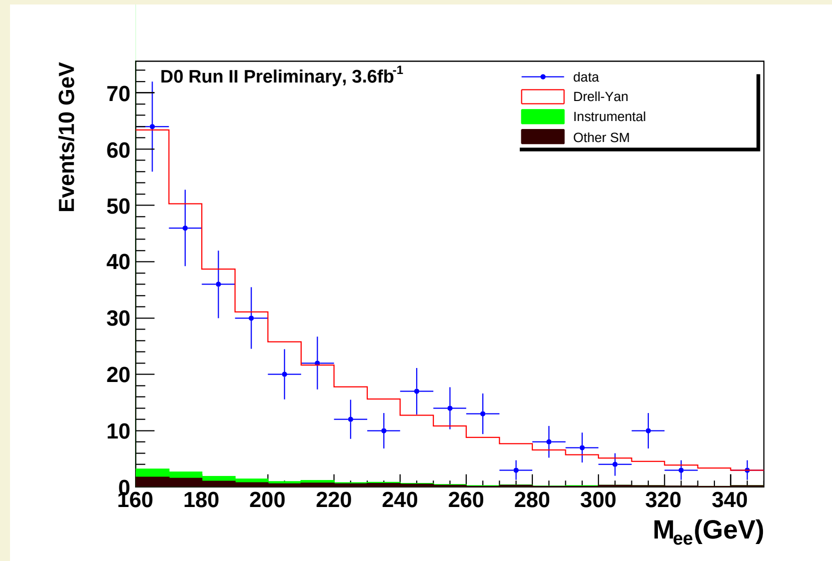


High-Mass Resonances

- Some extensions of the SM suggest the existence of narrow ($\Lambda \ll$ detector resolution) resonances decaying to SM particles.
- However current strategy is more signature-based searches instead of looking for specific model(s).
- Study of the dielectron mass spectrum allows to investigate presence of resonances in a clean (and well understood) event selection.

CDF Run II Preliminary





$\Rightarrow$ CDF excess around 240 GeV not confirmed by DØ analysis

$\Rightarrow$ Discrepancies seem to be just fluctuations in a large sample of points

$\Rightarrow$ Limits sents on various models from agreement with SM.

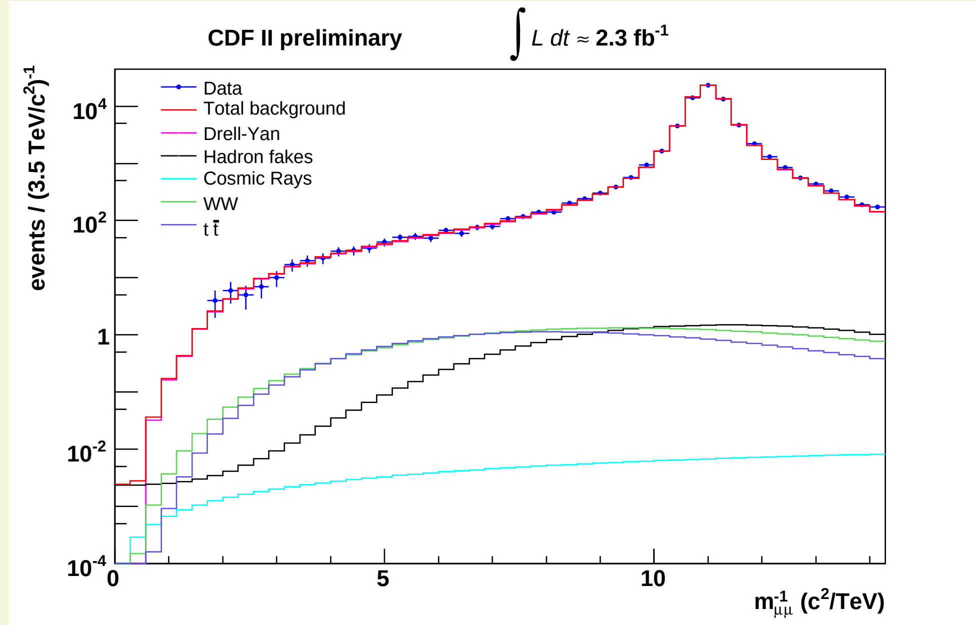
Search for dimuon resonances

$\Rightarrow$ Use of m^{-1} provides constant resolution (of 0.17 $\text{TeV}^{-1}c^2$)

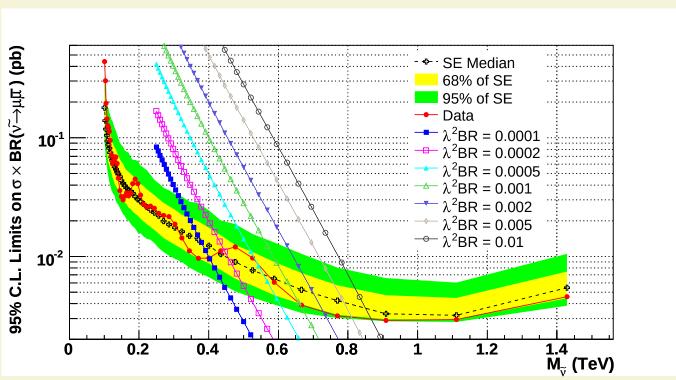
$\Rightarrow$ A narrow resonance would appear as an excess in 3 adjacent bins in plot.

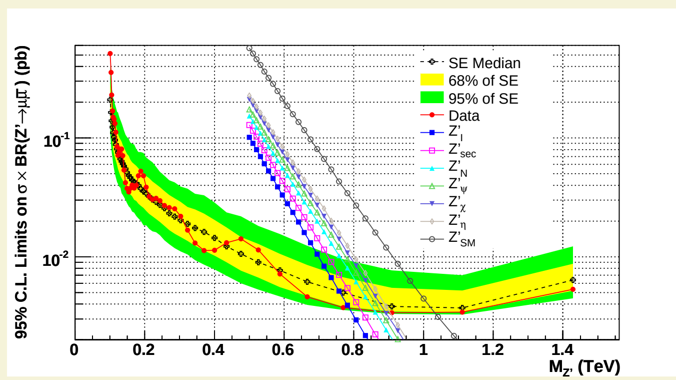
$\Rightarrow$ NO excess at 240 GeV/c^2

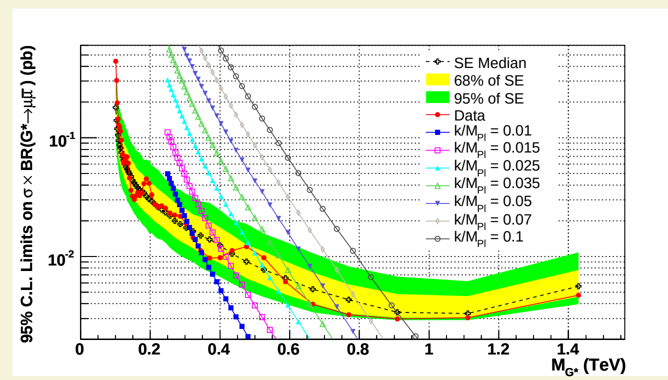
$\Rightarrow$ Observed distribution in very good agreement with SM expectation.



95% C.L. limits set in different models (kinematics/acceptance dependent on mass and spin)







$\tilde{\nu}$ (spin 0)	Z' (spin 1)	RS G^* (spin 2)
$m > 397 - 866\ \mathrm{GeV/c^2}$	$m > 1.03\ \mathrm{TeV/c^2}$ (SM-like)	$m > 293 - 921\ \mathrm{GeV/c^2}$

Search of exotic signatures

- Aside from the most “motivated” signatures, the experiments are searching for other possibilities.

- Several strategies:

  ⇒ Global (inclusive) searches based on comparison of lots of distributions and all possible final states to the predictions given by the Standard Model.

  This should be able to find any discrepancy due to New Physics even if not predicted by any model.

  ⇒ Searches for very strange final states, typically taking advantage of detector components that are not commonly used as discriminants for New Physics, or topologies that are typically disregarded.

- Within the last group several motivations from the theory are very important to set up the search and understand sensitivity.

But typically the guiding rule is to find exotic topologies that are very rarely produced within the Standard Model:

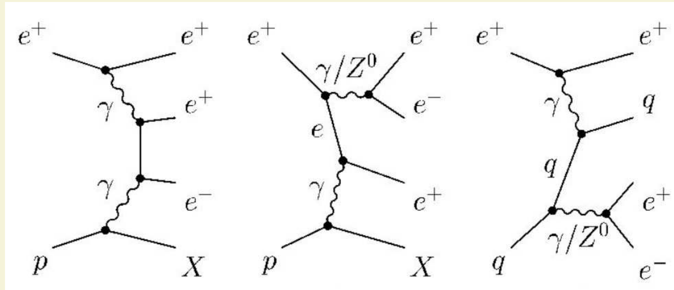
  → Slow-moving very massive long-lived particles (WIMPs, CHAMPs)

  → Exotic properties of produced particles (or combination of particles)

  → Multi-particle final states

Multileptons at HERA

The main SM process in ep interactions with multi-leptons in the final state is the $\gamma\gamma$ process:



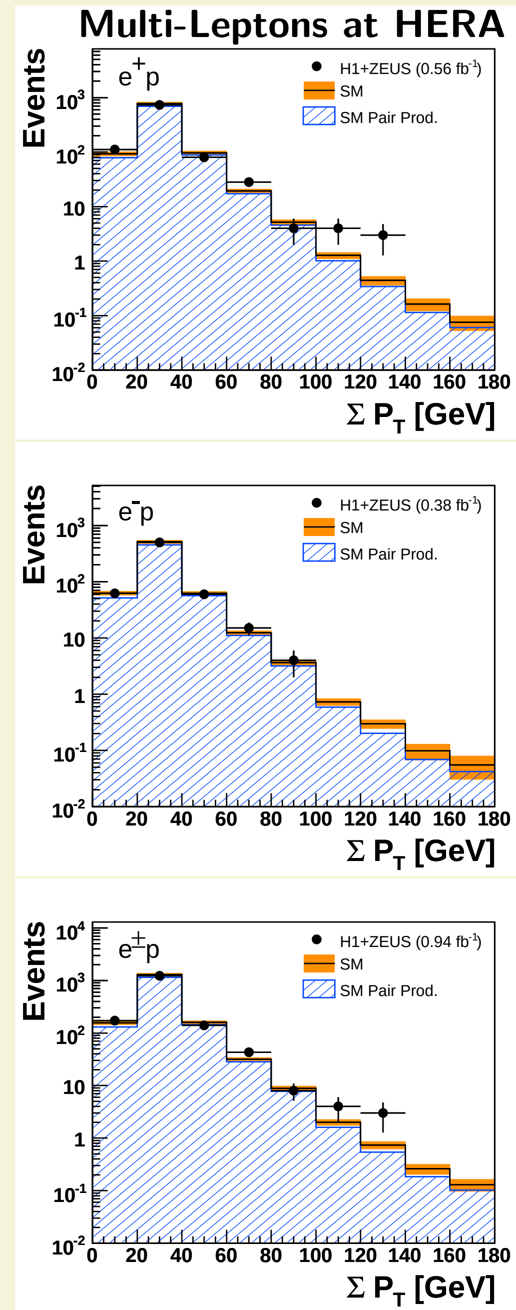
An exotic and rare final state: suitable for New Physics

Events are classified into exclusive samples:

$$ee,\ eee,\ \mu\mu,\ e\mu,\ e\mu\mu, \ldots$$

Results from the two experiments are combined to improve statistical significance in the results.

General agreement with the prediction, with an excess in the high $\sum P_T$ (also at high M_{ll}) in the positron data.



Multi-Leptons at HERA (0.94 fb^{-1})

$\sum P_T > 100$ GeV				
Data sample	Data	SM	Pair Production (GRAPE)	NC DIS + QEDC
e$^+$p (0.56 fb^{-1})	7	1.94 ± 0.17	1.52 ± 0.14	0.42 ± 0.07
e$^-$p (0.38 fb^{-1})	0	1.19 ± 0.12	0.90 ± 0.10	0.29 ± 0.05
All (0.94 fb^{-1})	7	3.13 ± 0.26	2.42 ± 0.21	0.71 ± 0.10

The significance of the excess in the positron data is 2.6σ

SUSY searches using photons

- **Gauge-Mediated Supersymmetry Breaking (GMSB) Models usually allow the neutralino to decay in a photon and a gravitino (LSP).**

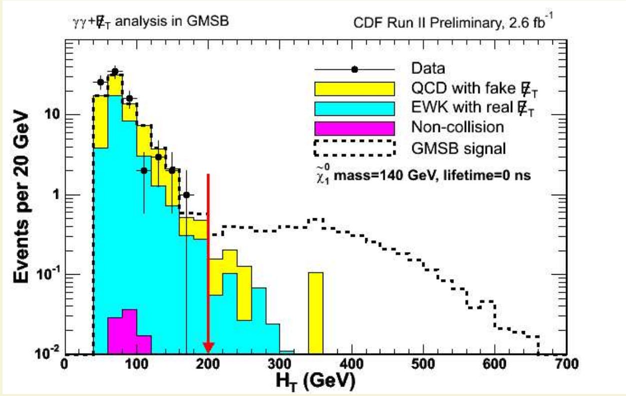
$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$$

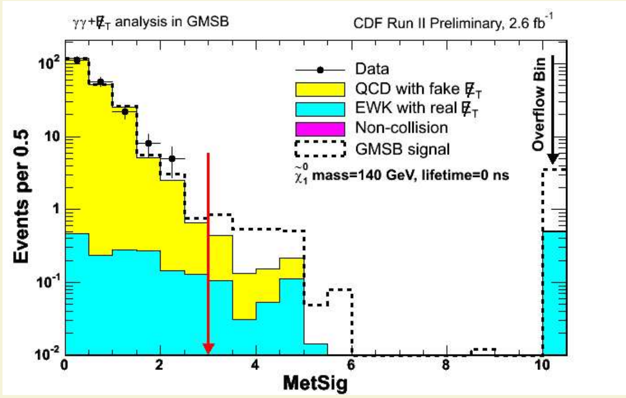
and we expect two photons and $\not{E}_T$ in the final state (among other possible objects depending on the decay chain).

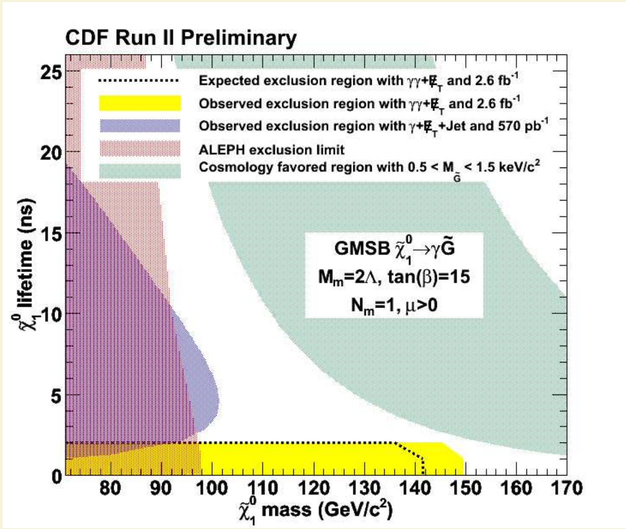
- **Background rejection using**
  - $\Rightarrow$ **EM-CAL Timing**
  - $\Rightarrow$ **$\not{E}_T$ Model to identify fake $\not{E}_T$**

- **QCD background estimated from data using fake $\not{E}_T$ events.**

- **Selecting events with large H_T (scalar sum of E_T of all objects) and $\not{E}_T$ significance.**





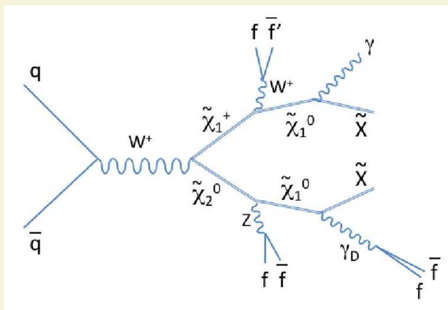


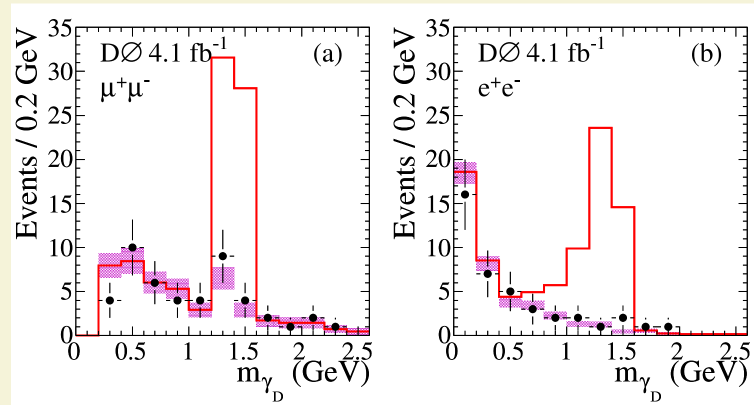
Search for dark photons

Appearing in "Hidden Valley" Models which a new gauge sector very weakly couple to the Standard Model.

Motivated by the recent high-energy positron excess observed in cosmic ray experiments.

- **Dark photons are new light bosons with masses ~ 1 GeV$/c^2$**
- **Appear as decay products of SUSY particles:**





- **Analysis of $ll\gamma$ with spatially close dileptons**

arXiv.org:0905.1478

Selection:

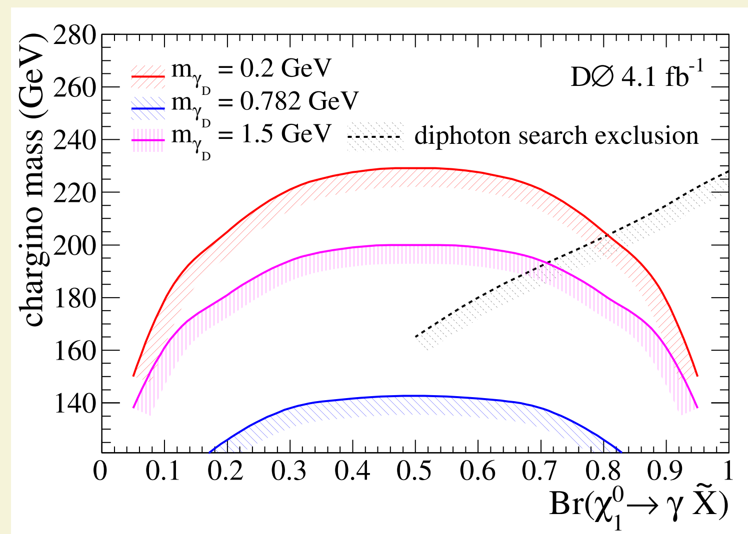
⇒ $E_{T,\gamma} > 30$ **GeV,** $\not{E}_T > 20$ **GeV**

⇒ **2 tracks from the same vertex and $\Delta R < 0.2$**

⇒ $p_{T,1} > 10$ **GeV**$/c$ **and** $p_{T,2} > 5$ **GeV**$/c$

⇒ **Ditrack system is isolated.**

⇒ **Ditrack associated to EM-cluster (for ee) or reconstructed muon (for $\mu\mu$)**



Search for long-lived particles decaying into bb

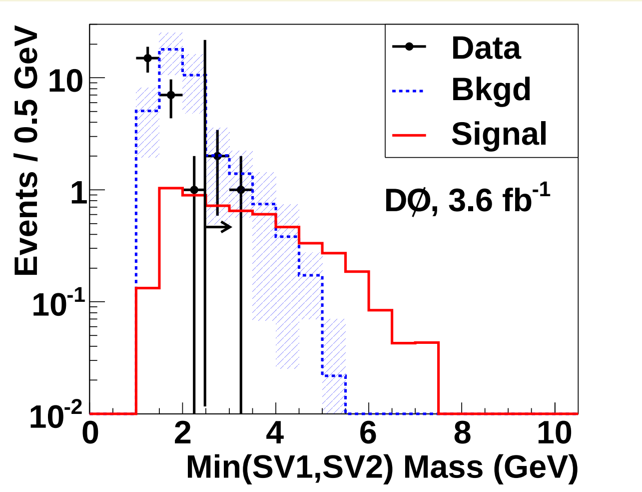
- DØsearch on pairs of displaced vertices at **radii in the range 1.6–20 cm from the beam axis.**

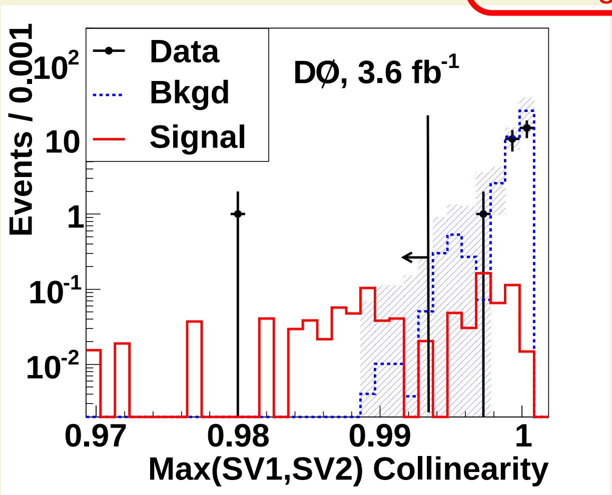
- Signature typically not considered, since **secondary-vertex tagging usually performed with vertices inside the beam pipe.**

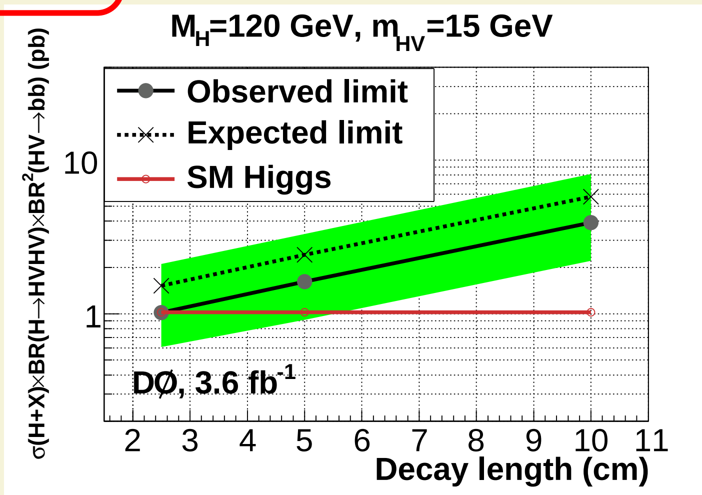
- Very challenging since it require a good understanding of the material and the background due to particle-detector interactions **(conversions, inelastic interaction with nuclei)** or decays in flight of kaons (and others).

This long-lived hadrons may appear in hidden-valley models and could be produced as decay products of the Higgs boson.

arXiv.org:0906.1787







- Good agreement with background predictions.

- Limits set on Higgs (within the HV model)

- First **constraints on pair-production of neutral long-lived particles** decaying in the indicated range (at a hadron collider).

Global Searches of New Phenomena

In order to avoid any possible bias from the assumed model and signature, a different strategy has been put in place which looks for discrepancies in all possible final states (and relevant variables).

- **Completely independent of the model.**
- **Good understanding of the detector and the SM contributions.**

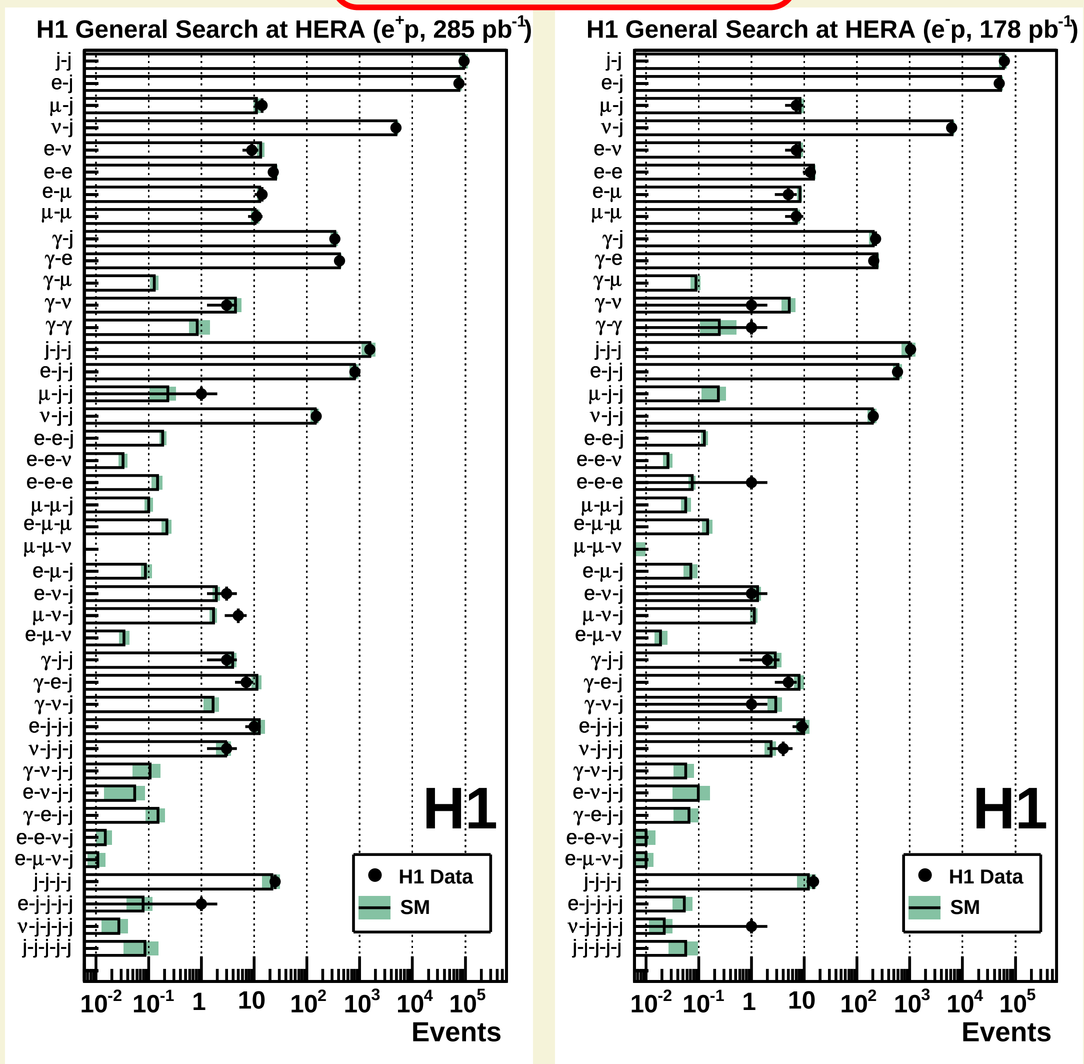
⇒ **Correction factors account for Data/MC differences.**

⇒ **Commonly using hard (and well-understood) objects, which made them not completely sensitive to some final states**

⇒ **But are able to "catch" discrepancies without biases.**

- **H1 performed a global study of the whole HERA sample.**
- **CDF and DØ have their own results with partial datasamples.**

Phys. Lett. B 674 (2009), 257

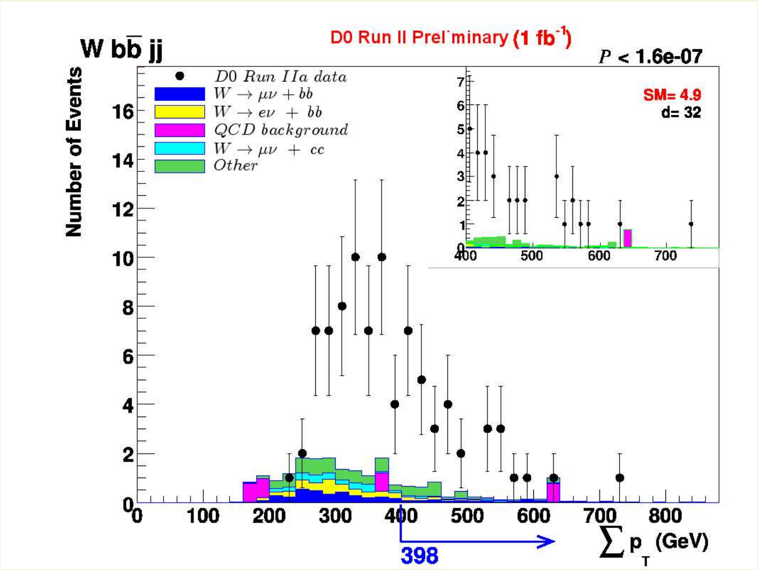


Global Searches of New Phenomena (II)

Two approaches within the same framework:

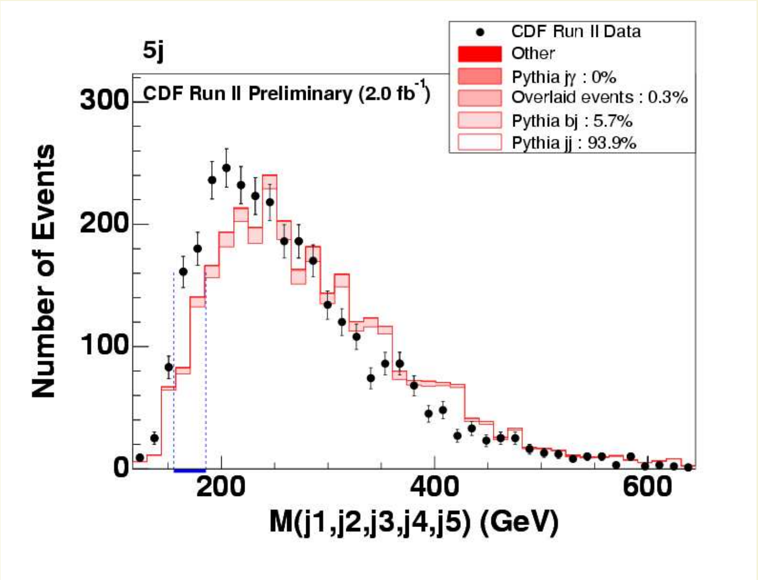
⇒ **Check in each distribution how data and predictions agree.**

In rate (number of events) and shape (KS test)



⇒ **Search for discrepancies in tails sensitive to New Physics: high p_T or looking for bumps on mass-based variables.**

Probabilistic interpretation of discrepancies should account for large number of observables (trial factors)



- **Method tested with the rediscovery of top**

(Corrected probability is $1.6 \cdot 10^{-7}$ (being $10^{-3} \sim 3\sigma$)

- **Some discrepancies found, but not completely significant. . .**
- **or is due to mismodeling in the (difficult) predictions.**

Summary and Conclusions

- Searches for physics beyond the SM in colliders form a very active field covering a long list of topics.
- Here just a general summary...

Check the web pages of the experiments for the latest news!

- No success yet (but a lot of progress and limits significantly improved):

  ⇒ Direct searches are testing very hard the SM to the last corner and exploring regions far from those tested before.

  ⇒ Inclusive analysis are probing that our knowledge of the Collider Physics is very good and able to globally explain the data samples.

  ⇒ In both approaches discrepancies found, but nothing conclusive.

- Analyses of the full HERA dataset and the Tevatron data still to be analyzed (and collected) would provide more stringent tests of the SM, perhaps revealing hints of New Physics somewhere.

For now. . . the main conclusion is:

The Standard Model is still in good shape (even if we do not like that) and getting stronger as we approach the LHC era!!!

(but we won't give it a moment of peace)

Acknowledgements

I would like to thanks the Physics Coordinators

and Group conveners of the CDF, DØ, H1 and ZEUS

for their help in preparing this talk.

We also thank the organizers for their effort,

their support and for giving us this chance

to present our results here.

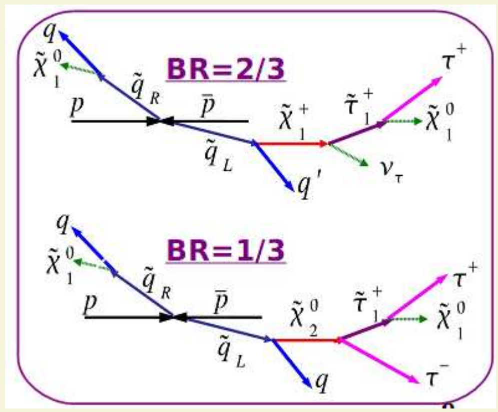
BACK-UP Slides

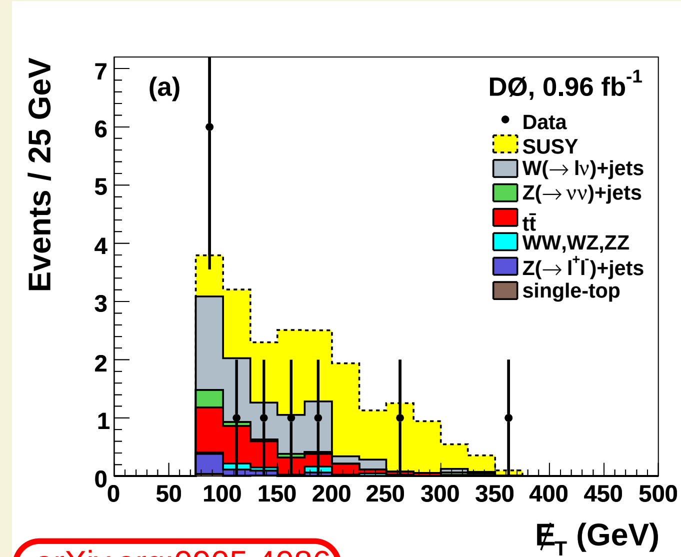
Including some analyses not covered due to time constraints

SUSY with Jets+tau(s)+ $\not{E}_T$ events

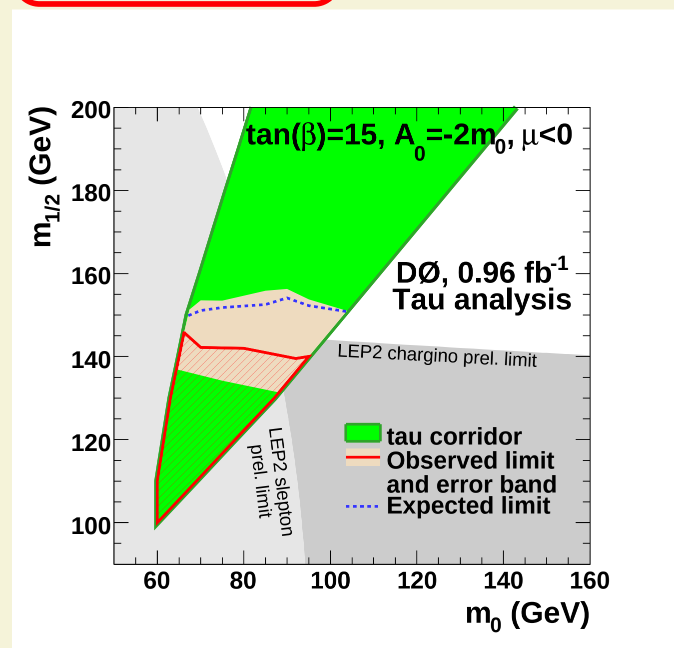
- As with the stop and sbottom, the lightest slepton may be the lightest stau

- This enhances the presence of τ's in the final states for events with SUSY (squarks and gluinos), allowing the reduction of backgrounds.





arXiv.org:0905.4086



- Using hadronic τ reconstruction:
  - $\longrightarrow$ Narrow isolated jet with low multiplicity track (NN)
  - $\longrightarrow$ $p_T > 15$ GeV$/c$, $|\eta| < 2.5$
  - $\longrightarrow$ No overlap w/ 2 leading pT jets
  - $\longrightarrow$ Reject e, μ and jets "faking" τ_h

- After tight optimization, good agreement with prediction.

- Limits beyond those by LEP in the "Tau corridor"

Scalar top searches in top-like events

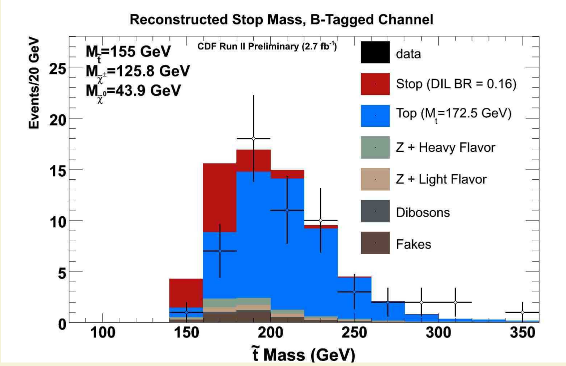
When the $\tilde{t}$ is more massive than the lightest chargino, the dominant decay is very top-like:

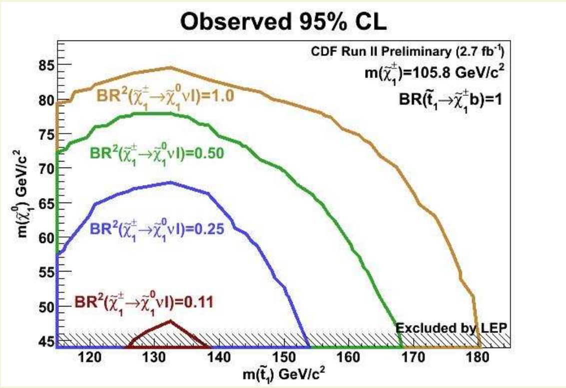
$$\tilde{t} \rightarrow b\tilde{\chi}^{\pm} \rightarrow bl\nu\tilde{\chi}^{0}$$

The differences are:

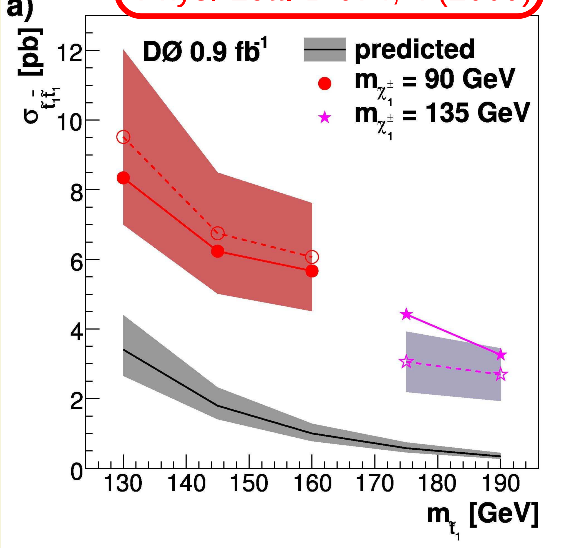
- **Mass distribution of the $\tilde{t}$ is different than that of the top**
- **Different "escaping particles" makes topology slightly different**

CDF uses the dilepton signature (that is enhanced for the scalar top over that of the top) while DØ looked at the Lepton+Jets final state, which is the typical approach for top physics.





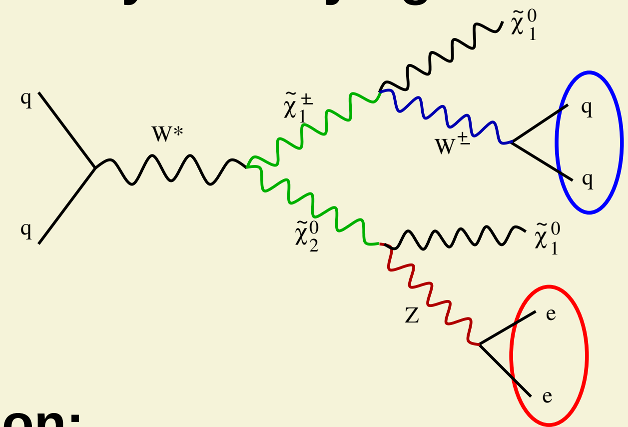
Phys. Lett. B 674, 4 (2009)

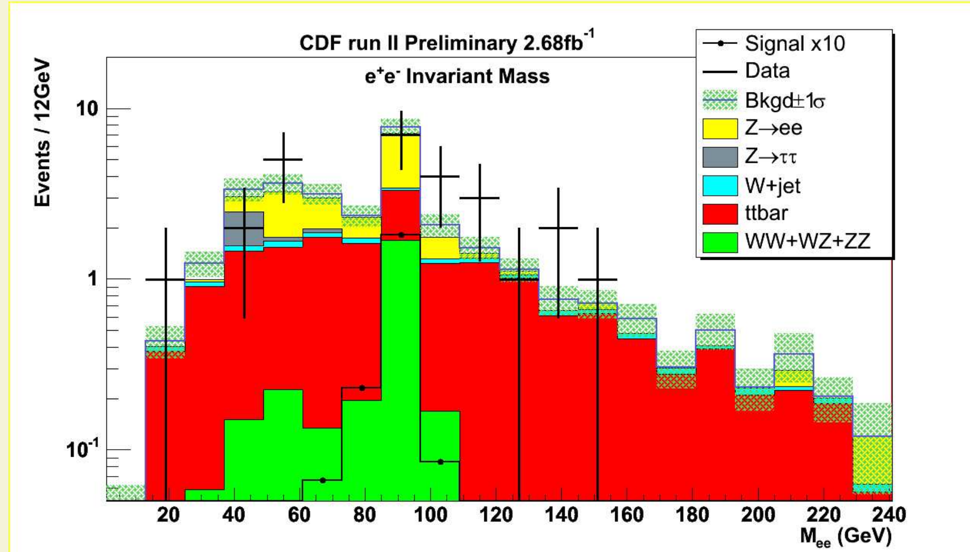


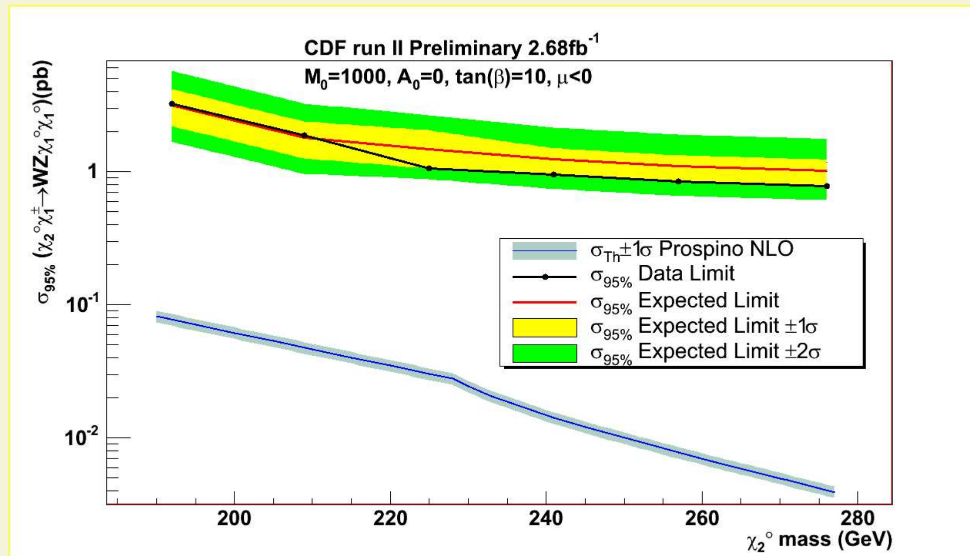
The Lepton+Jets Signature

For high masses, gauginos may decay into real W/Z (and the LSP).

Cross section is smaller but cleaner final states by identifying the bosons.







Selection:

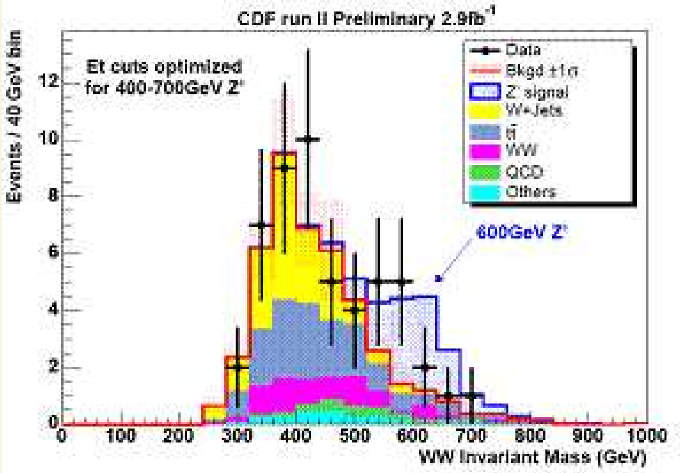
- → **2 electrons ($85 < m_{ee} < 97$ GeV/c^2)**
- → **2 jets ($60 < m_{jj} < 95$ GeV/c^2)**
- → **$\not{E}_T > 40, 50, 60$ GeV (parameter space)**

CDF (2.68 fb^{-1})	SM Expected	Observed
$\not{E}_T > 40$ GeV	6.41 ± 0.92	7
$\not{E}_T > 50$ GeV	3.76 ± 0.58	2
$\not{E}_T > 60$ GeV	2.02 ± 0.33	1

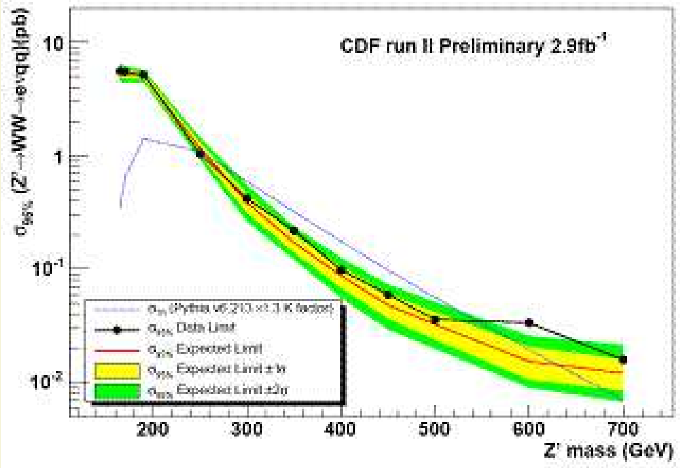
While there is no exclusion within mSUGRA, this channel is interesting to search for new particles decaying to diboson and $\not{E}_T$.

Diboson resonances: $X \to WW/WZ$

- After the observation of diboson production at the Tevatron (talk by F. Canelli), using those events to search for the presence of New Physics.
- Resonances decaying into diboson would enhance the signal over the SM expectations and they also appear as bumps in the diboson invariant mass.



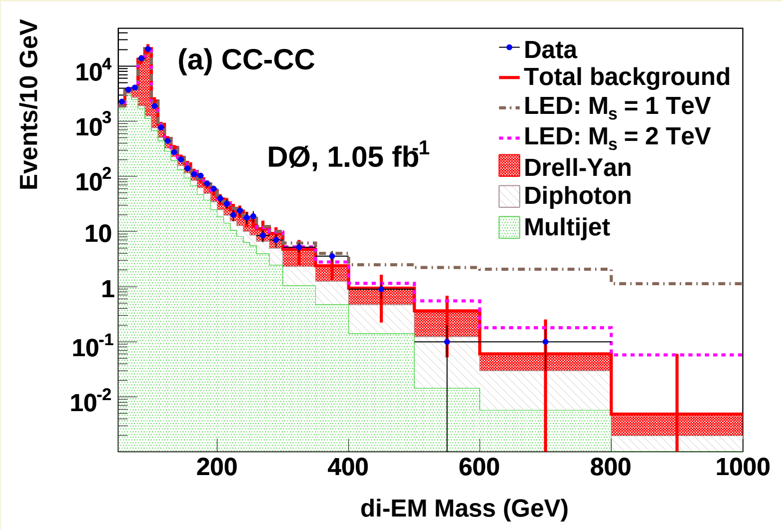
- Search for $X \to WW/WZ \to (e\nu)(jj)$ at CDF reports no evidence of resonances decaying to di-bosons.
- Selection:
  - $\Rightarrow$ $W \to e\nu$ with two solutions
  - $\Rightarrow$ Dijets in [65,95] (for WW)
  - $\Rightarrow$ Dijets in [70,105] (for WZ)
  - $\Rightarrow$ 3-jet events also considered
- Interpretation in several models, but optimized for the expected resonance mass.
- Excess at 600 GeV of $X \to WW$.

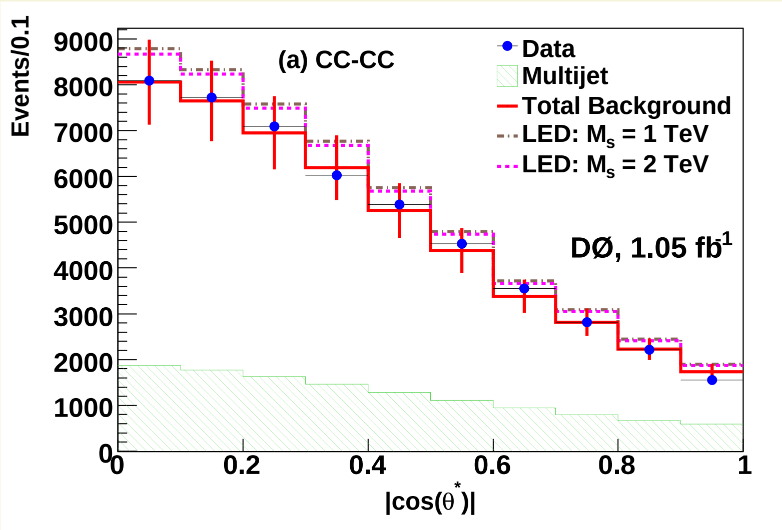


- Limits set in different models for the considered final states.

LED in dielectron and diphotons

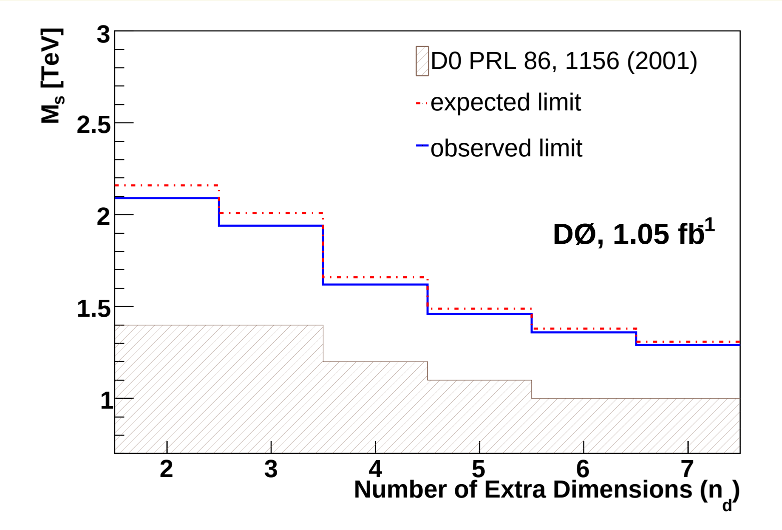
- Look for deviations from the SM in the di-EM and $|\cos\theta^*|$ distributions.
- Good agreement in the total number of events.





- DØ published analysis with Run IIa dataset.

Phys. Rev. Lett. 102, 051601 (2009)



- Set 95% C.L. lower limits on the effective Planck scale, M_s:

$\Rightarrow$ GRW (leading order, n_d independent):

$M_s > 1.62$ TeV

$\Rightarrow$ HLZ (sub-leading, n_d dependent):

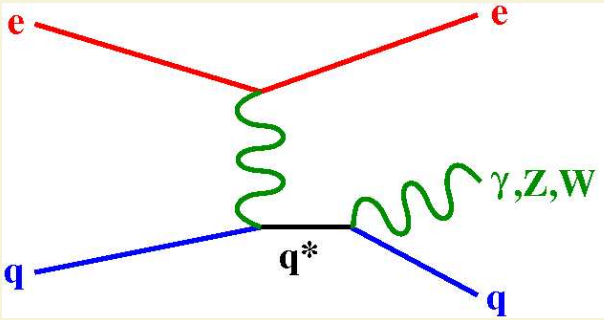
$M_s > 2.1(1.29)$ TeV for $n_d = 2(7)$

Excited fermions

Existence of excited states of the known fermions has been postulated to understand the family structure and mass hierarchy in the SM particles.

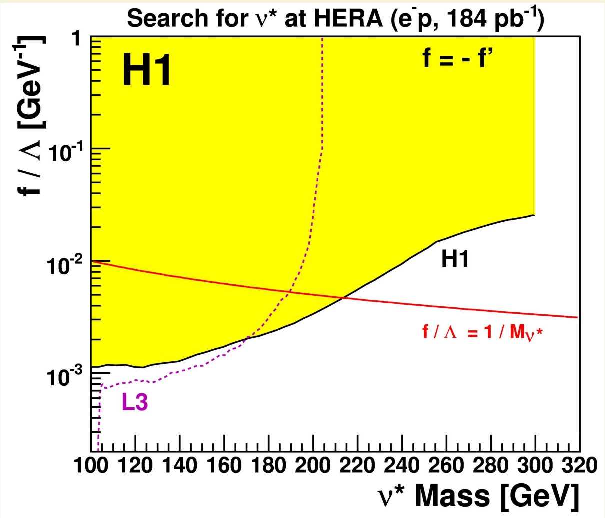
Typically appear as natural consequence of compositeness models.

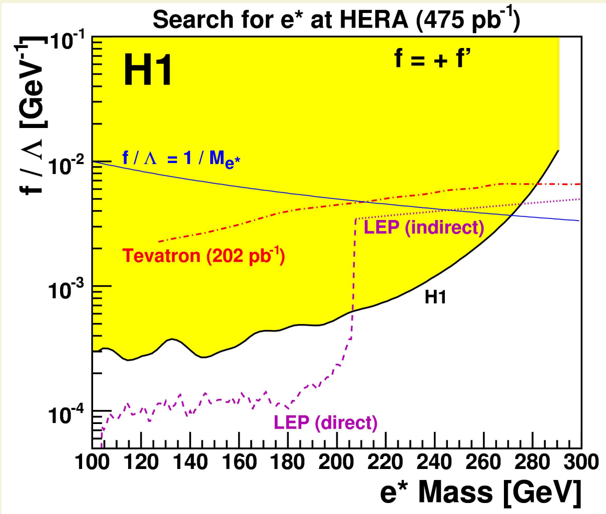
Excited states of fermions may be produced at colliders, depending on the mass and on the dynamics.

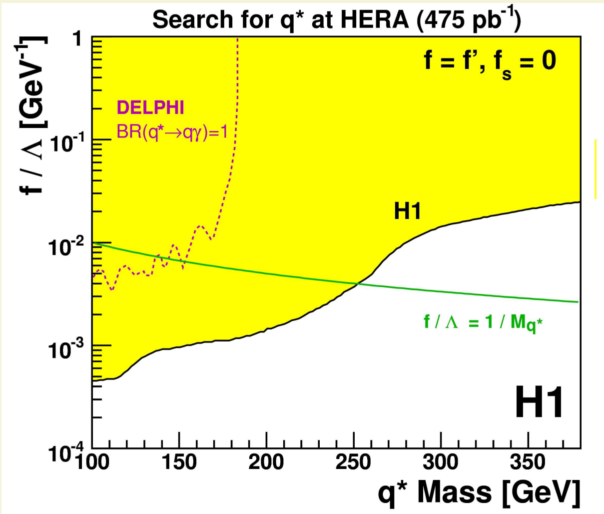


Full HERA statistics analysed and published.

Phys. Lett. B666 (2008) 131







⇒ **Best world limit for excited neutrinos in colliders**

⇒ **Best excited quark limits for $f_s = 0$**

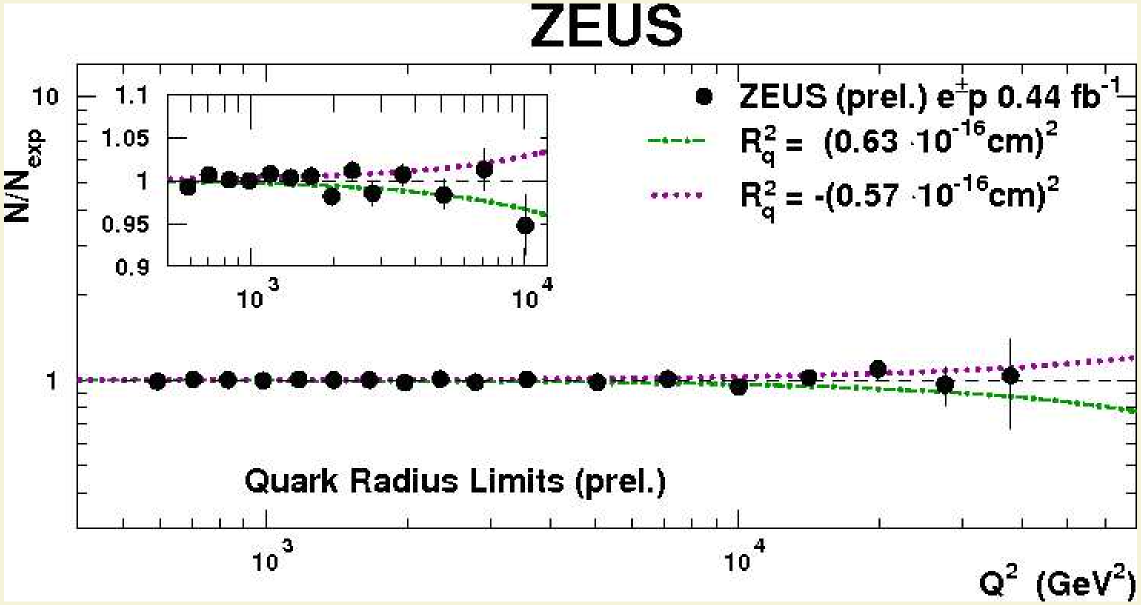
(Search is complementary to those performed at Tevatron, where one assumes $f_s = f$)

Quark radius

HERA is able to measure quark form-factor (electron assumed to be point-like).

If a quark has a finite size, the SM cross section is expected to decrease at higher Q^2:

R_q is a root-mean-square radius of the EW charge distribution in the quark. The same dependence expected for e-p and e+p.



At 95% C.L.

ZEUS (94-07 data): $R_q < 0.63 \times 10^{-3}$ fm
H1 (94-07 data): $R_q < 0.74 \times 10^{-3}$ fm

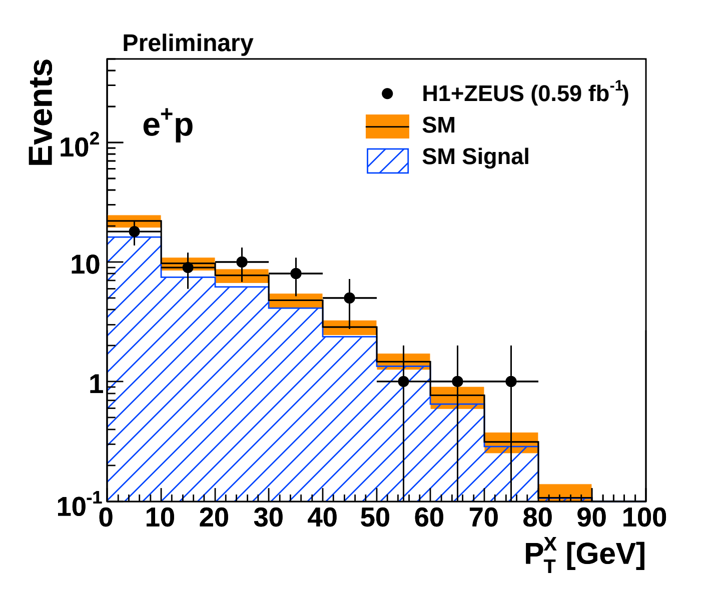
Isolated leptons and $\not{E}_T$ at HERA

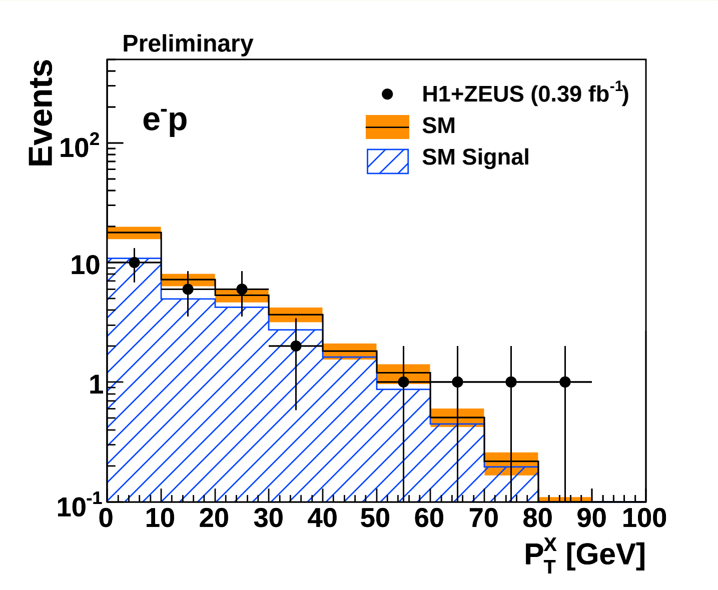
- Events with a high-p_T lepton (e or μ) and large $\not{E}_T$
- Sample dominated by single W production ($\sigma \sim 1.3$ pb)

- Excess in the positron data seen in the published H1 analysis at large P_T^X, an area of phase space where the SM expectation is small

- Not confirmed in the ZEUS analysis.

- Excess still there in the combined analysis (1.9σ), driven by the H1 data.





For $p_T^X > 25$ GeV (in e^+p dataset):

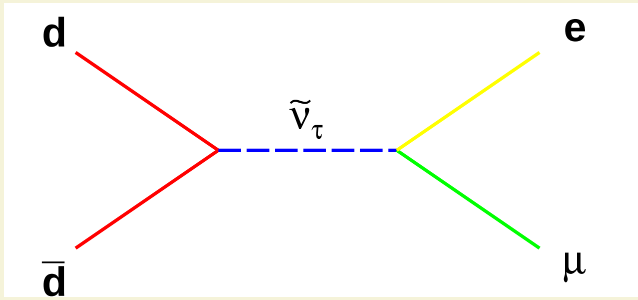
Expected (SM): 14.02 ± 1.94
Observed: 23

This analysis also used to measure the single W production cross section at HERA.

(See talk by F. Canelli for the details)

R-parity violating sneutrino

This particle may be observed as a resonance into electron and muon.



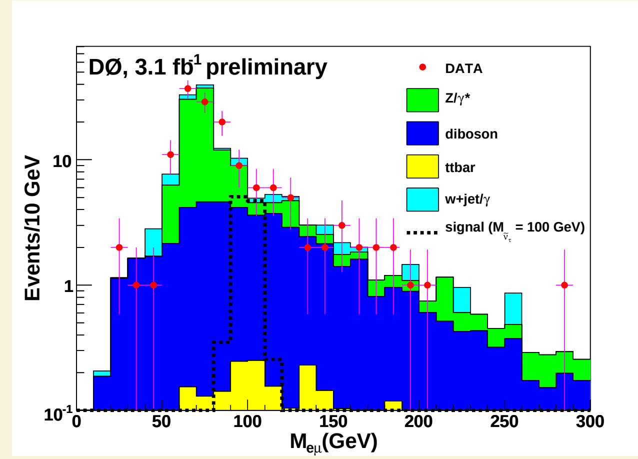
- Very clean topology: 2 isolated leptons with different flavour and charge, no jets, no $\not{E}_T$.
- Low backgrounds: WW, fakes and $Z/\gamma^* \rightarrow \tau\tau$
- Final result for Run IIa from DØ already published
- Analysis perfomed with 3.1 fb^{-1} (Run IIb) and combining results with those from Run IIa.

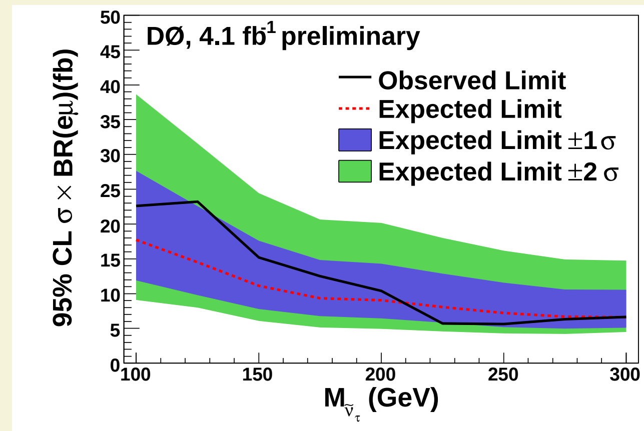
Good agreement:

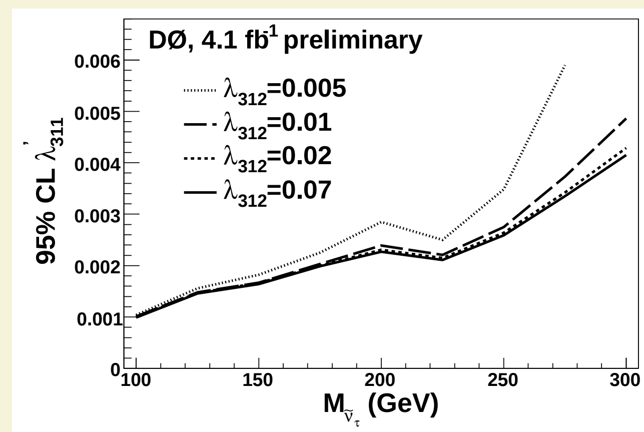
143 events (with 145 ± 4 expected)

Current limits going beyond LEP results.

CDF analysis performed with less luminosity but including τ in the final state (see next slide)

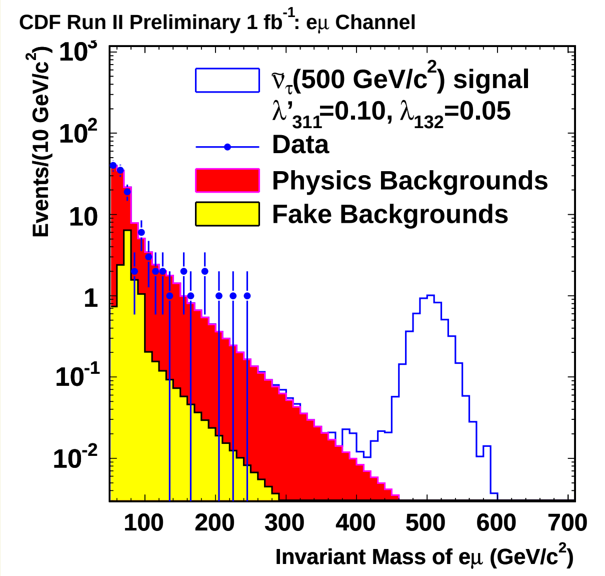


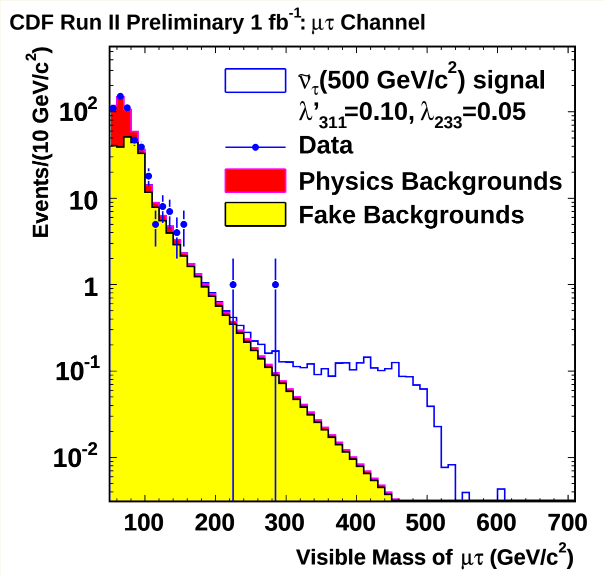


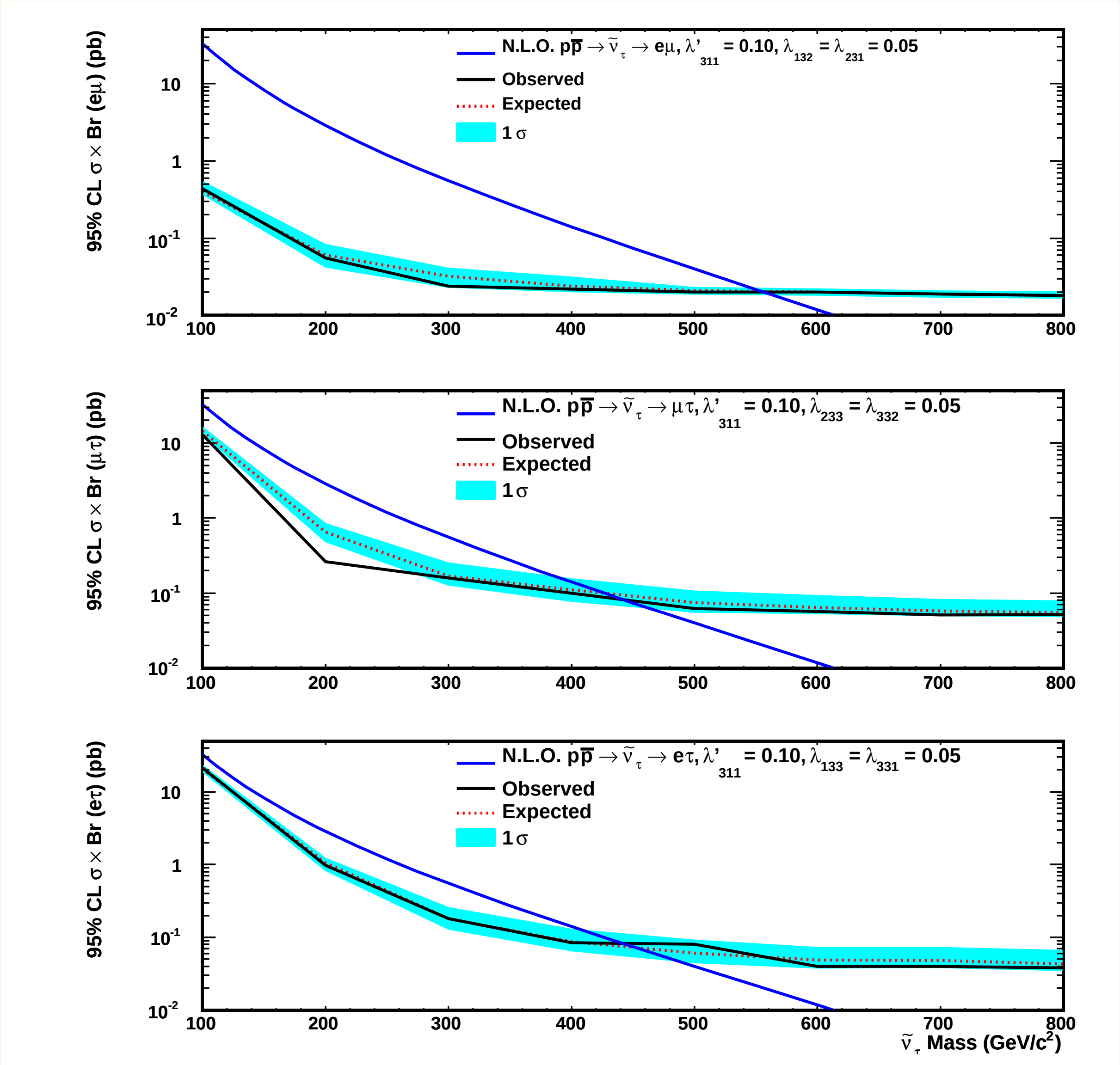


R_p violating sneutrino at CDF

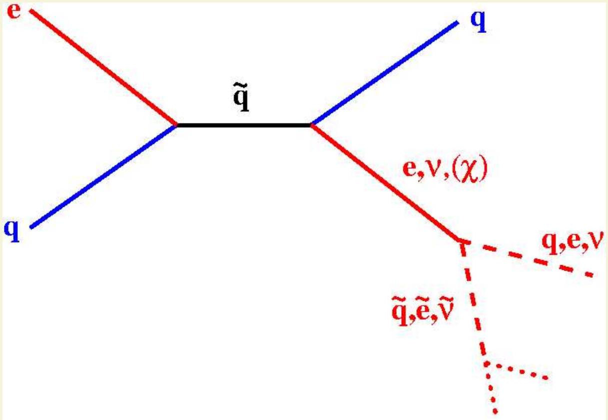
Analysis performed with 1 fb^{-1} of data but also looking at $e\tau$ and $\mu\tau$ final states (sensitive to different classes of sneutrinos)







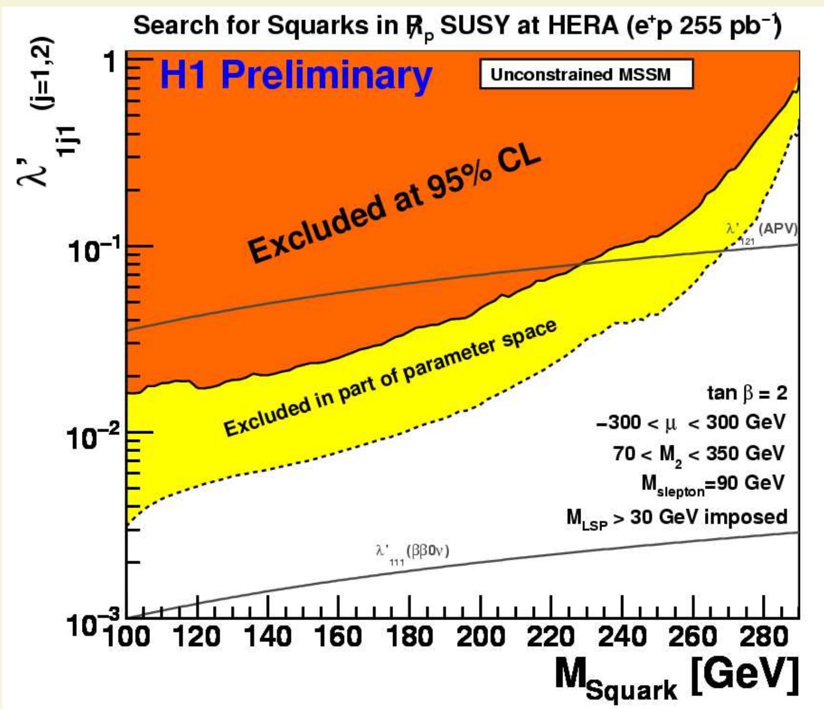
$\not{R}_p$ violating SUSY at HERA

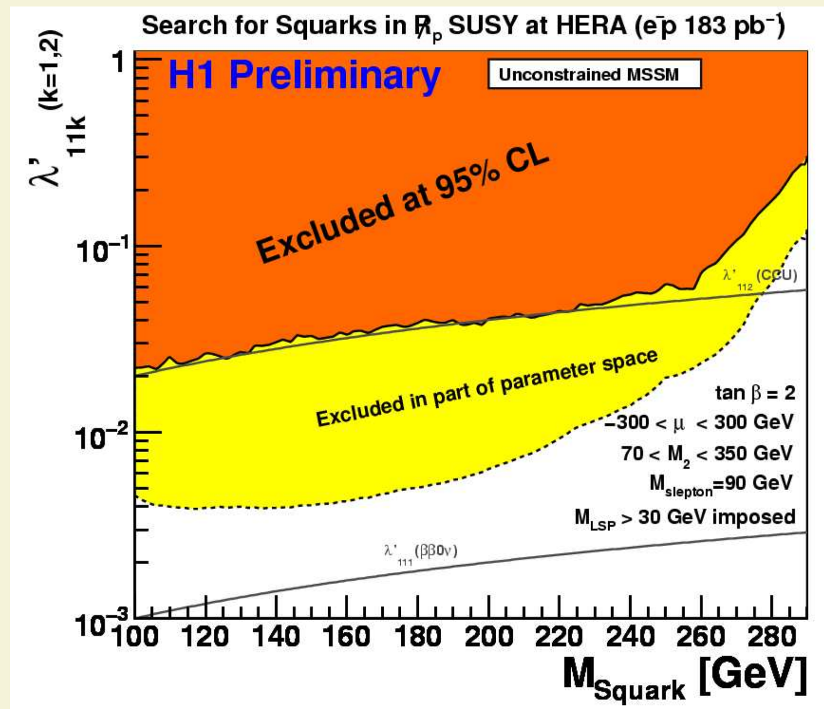


- Resonant production of single squarks
- Many different decay channels possible
- Branching fractions depend on SUSY parameters:

$$M_2, \mu, \tan\beta$$

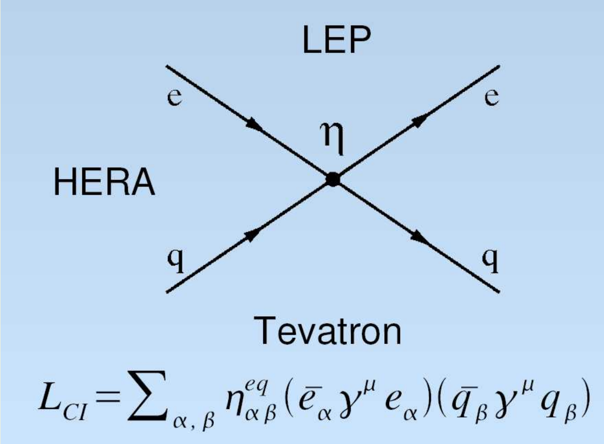
- Search in many topologies
- Scan SUSY parameter space





Contact Interactions

New interactions at high scales ($\Lambda \gg \sqrt{s}$) can be effectively described at lower energies as 4-fermion $eeqq$ Contact Interactions (CI).



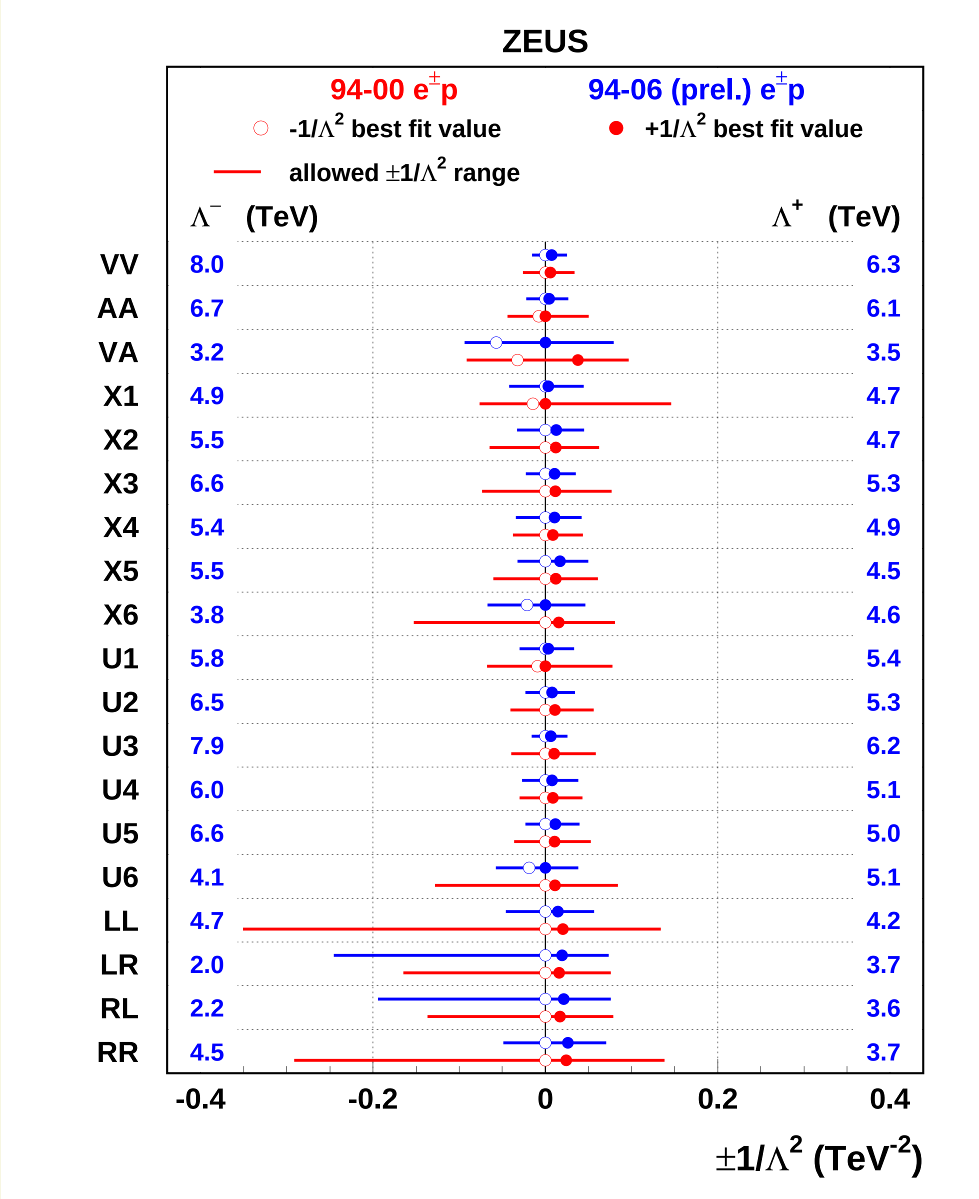
- **Different models assume different helicity structure of the new interactions, which are given by $\eta^{eq}_{\alpha\beta}$, whose relationship with the relevant scale is**

$$\eta^{eq}_{\alpha\beta} = \pm\frac{4\pi}{\Lambda^2}$$

- **All fitted values for Λ^{-2} are in agreement with 0, i.e. no sensitivity to new interactions.**

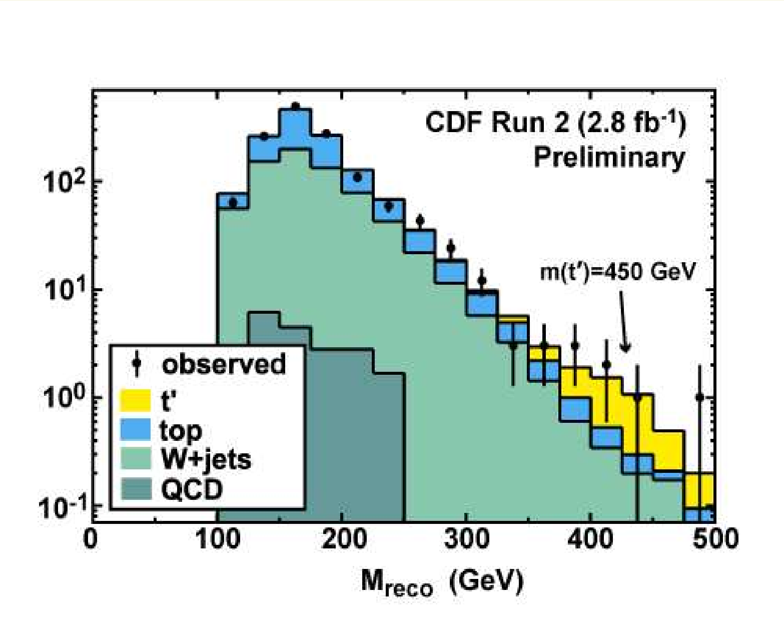
Limits depend on the model, set on the scale for the new interaction:

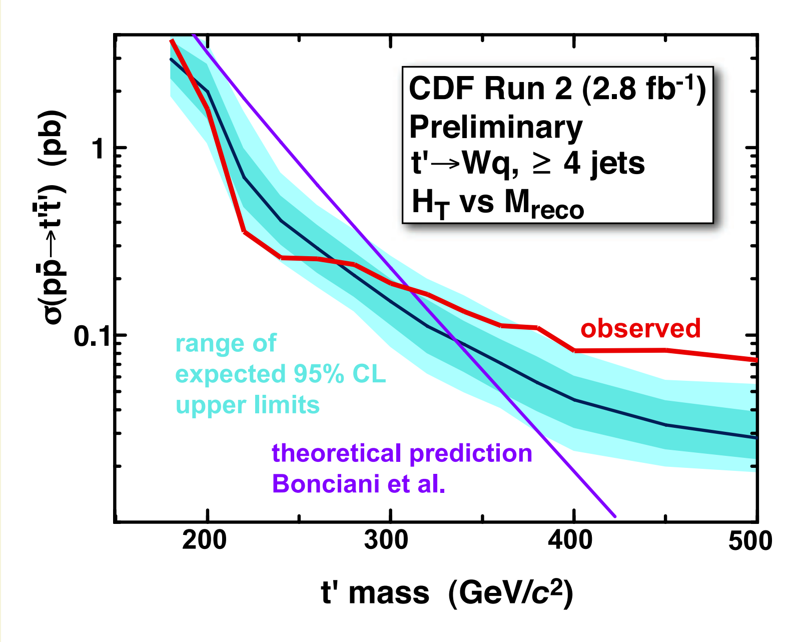
$\Lambda > 3.8 - 8.9$ TeV (at 95% C.L.)



Search for t'

- In the search of particles of a "fourth generation", some effort on the search for t' (and also b').
- The t' is assumed to be (strongly) pair-produced, with a mass larger than top and decaying promptly to Wq final state.
- Analysis exploits similarities with $t\bar{t}$ final states to make use of the experience with that event selection ("lepton+jets").





CDF excluded a standard model fourth-generation t' quark with mass below 311 GeV$/c^2$ at 95% C.L.

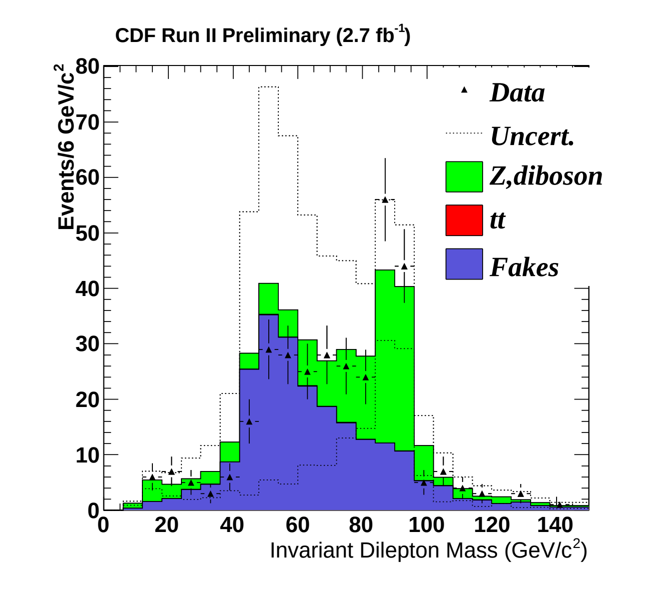
(See talk by F. Canelli for the details)

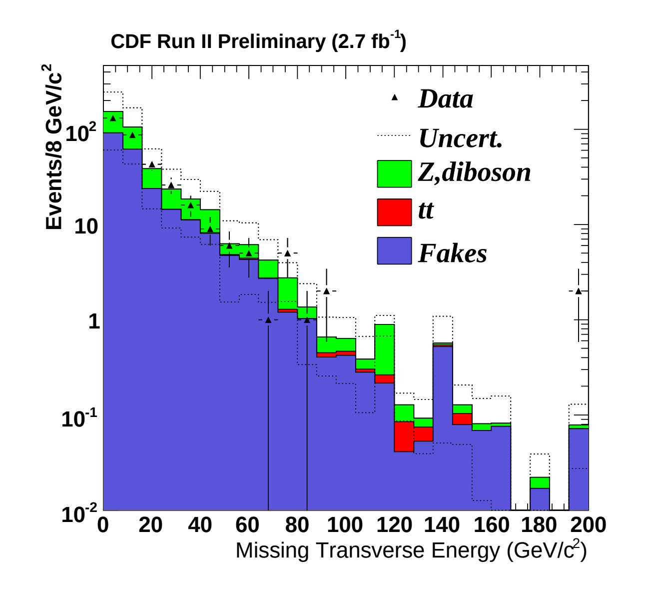
Search for b'

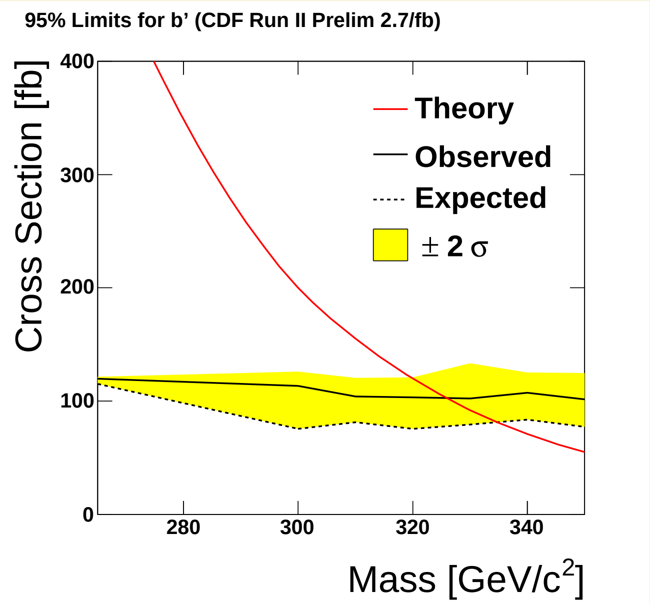
- Existence of a pair-produced b' decaying into W+top may be observed in events with two same-sign high-p_T leptons.

- Validation of the predictions for Drell-Yan and top-quark production in the opposite-sign selection, where backgrounds are large.

- Small number of events in the final selection, dominated for misreconstructed charges and fakes.





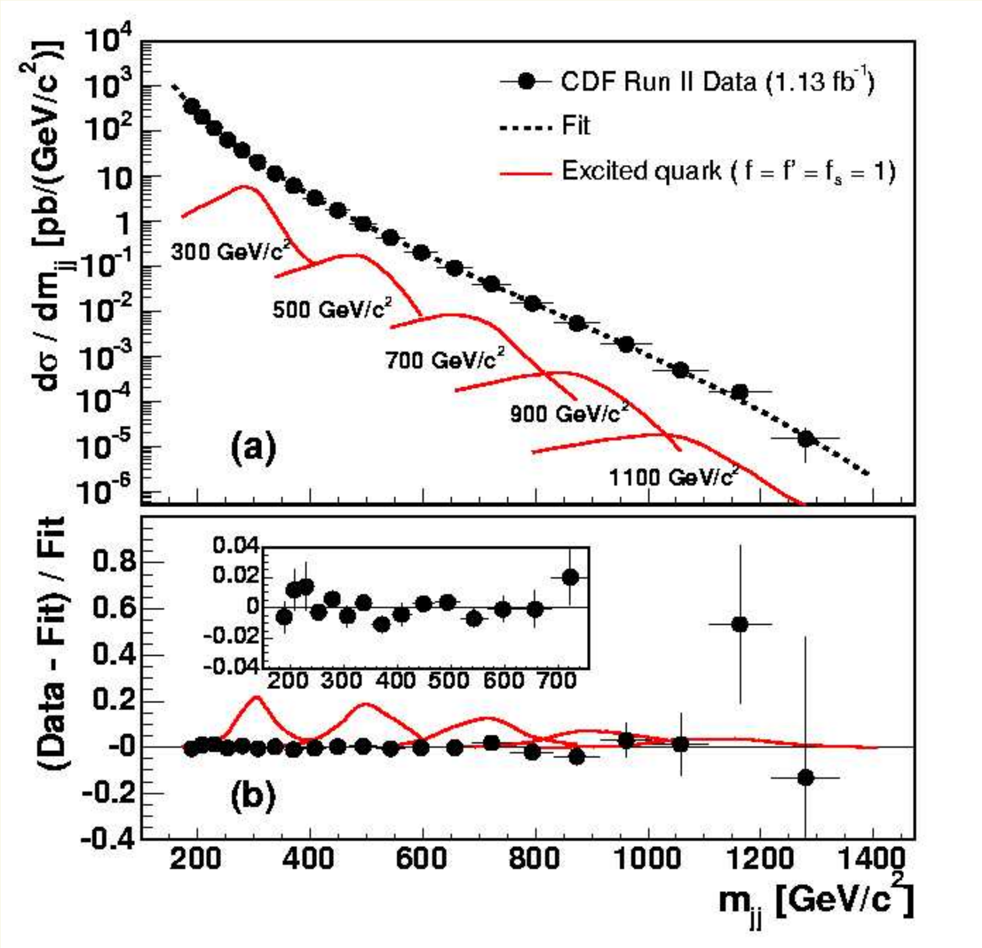


Excluding a b' having $m < 325$ GeV$/c^2$ at 95% C.L.

Dijet mass resonances

- More difficult than in the case of leptons due to poorer resolution.
- Also challenging due to the large (and not easy to handle) QCD background.

Phys. Rev. D79, 112002 (2009)



- Selecting jets in events with
  - ⇒ **Midpoint algorithm ($R = 0.7$)**
  - ⇒ **Central jets: $|y| < 1$**
  - ⇒ **High mass dijet selection**
- Data agrees well with NLO pQCD predictions.
- To search for narrow resonances **a smooth functional form is used to fit the data:**

$$\frac{d\sigma}{dm} = a(1-x)^b/x^{c+d\log(x)}$$

being $x = m/\sqrt{s}$

- No significant indication of resonances has been found.
- Limits set in different models: excited quarks, W', Z',...

Compositeness and LED in dijet angular correlation

- As part of their dijet studies, CDF and DØ look of angular correlations.
- Variable:

$$\chi_{\text{dijet}} = \exp(|y_1 - y_2|) \xrightarrow[\text{massless}]{} \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

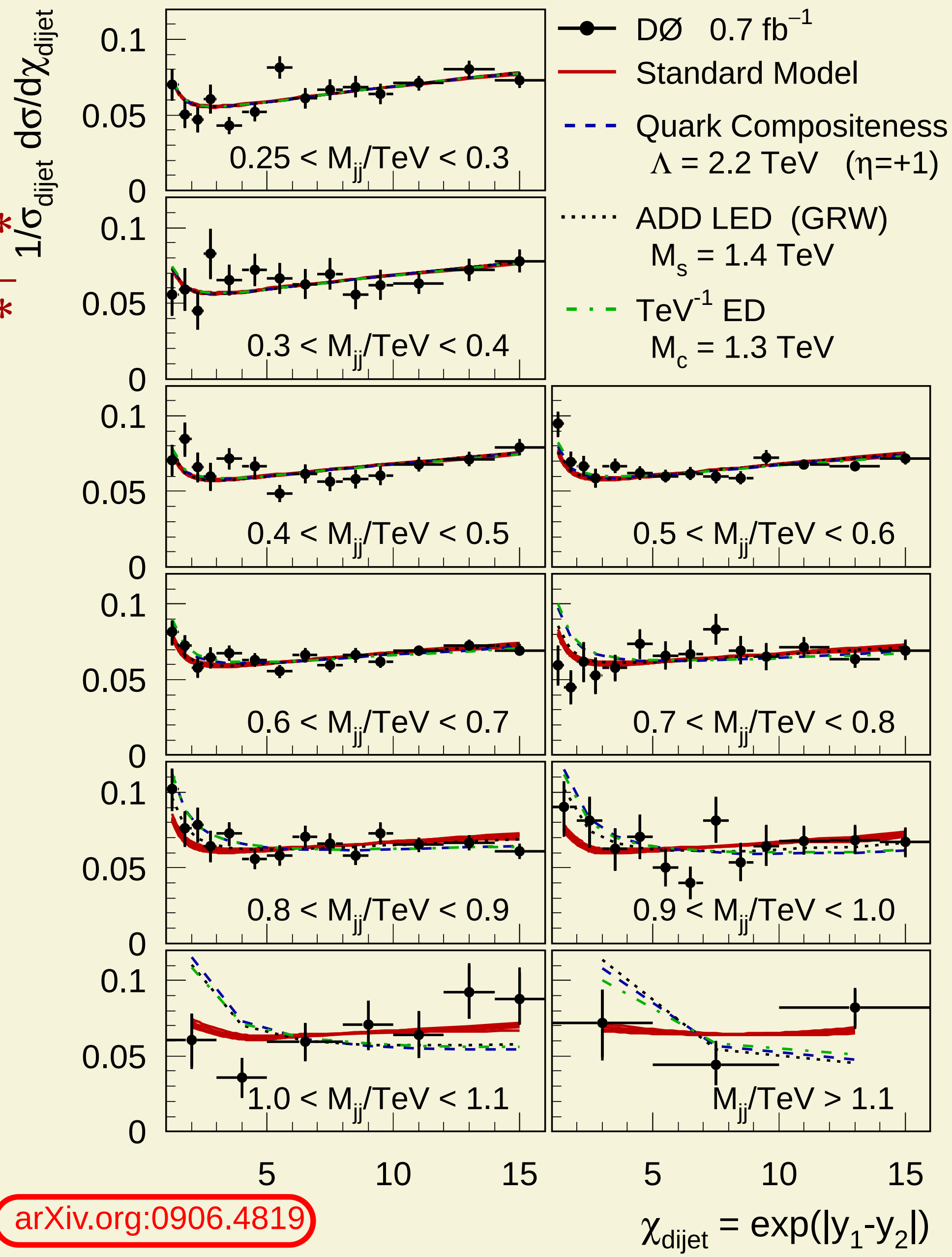
- Sensitive to new physics, where we expect an excess at large m_{jj} and small χ_{dijet}
- 95% C.L. limits on mass scales for New Physics:

$\Rightarrow$ **Quark compositeness:**

CDF: $\Lambda > 2.4$ TeV
DØ : $\Lambda > 2.8$ TeV

$\Rightarrow$ **Large extra dimensions:**

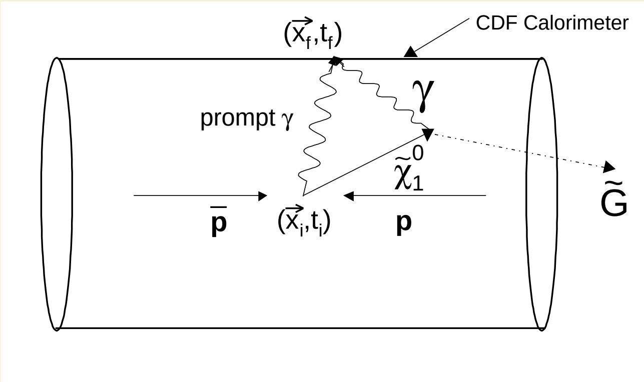
DØ : $\Lambda > 1.6$ TeV [on ADD (GRW) and TeV^{-1}]

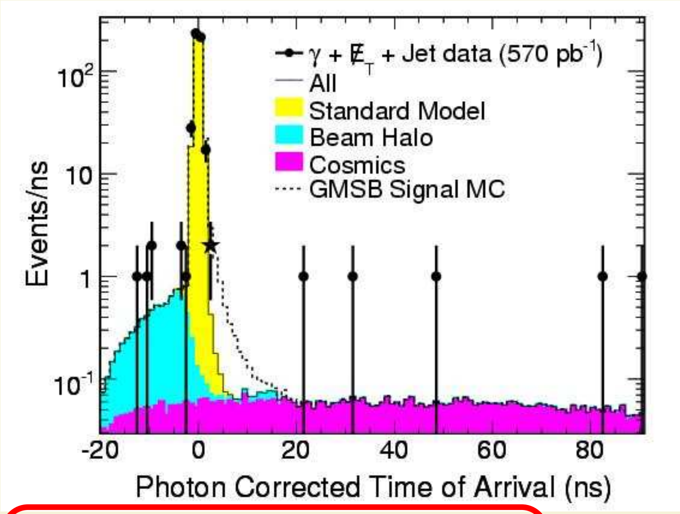


arXiv.org:0906.4819

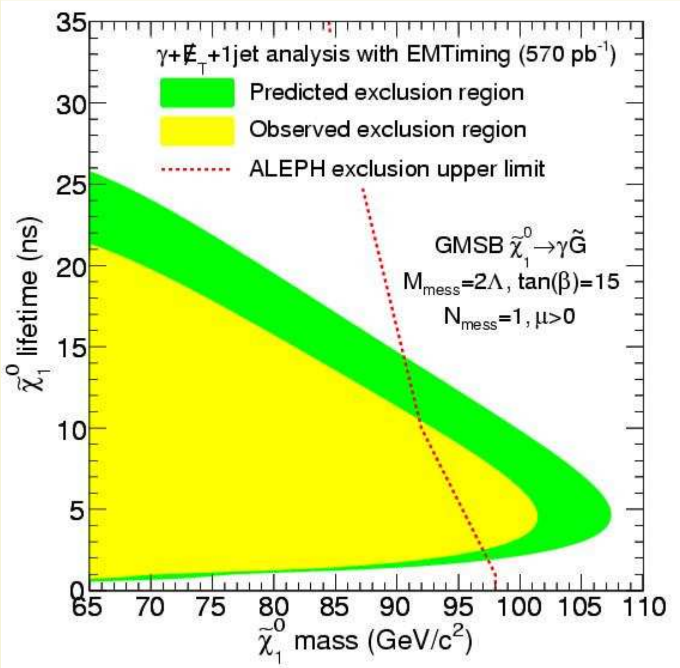
Delayed photons

- The CDF EM Timing System allows to find out-of-time photons
- Intended to reject non-physics events (bremsstrahlung from cosmics or beam halo)
- May be used to search for a Gauge-Mediated Supersymmetry Breaking (GMSB) Model in which the neutralino is relatively long-lived (between 2 and 10 ns).





Phys. Rev. Lett. 99, 121801 (2007)



- Timing selection is the most discriminant.
- 2 events observed in time window (2,10) ns.
- Expected 1.3 ± 0.7:

  $\longrightarrow$ 0.71 from SM ($\sigma = 0.6$ ns)

  $\longrightarrow$ 0.46 from cosmics

  $\longrightarrow$ 0.07 from Beam Halo

Status of the $B_s \to \mu\mu$ search

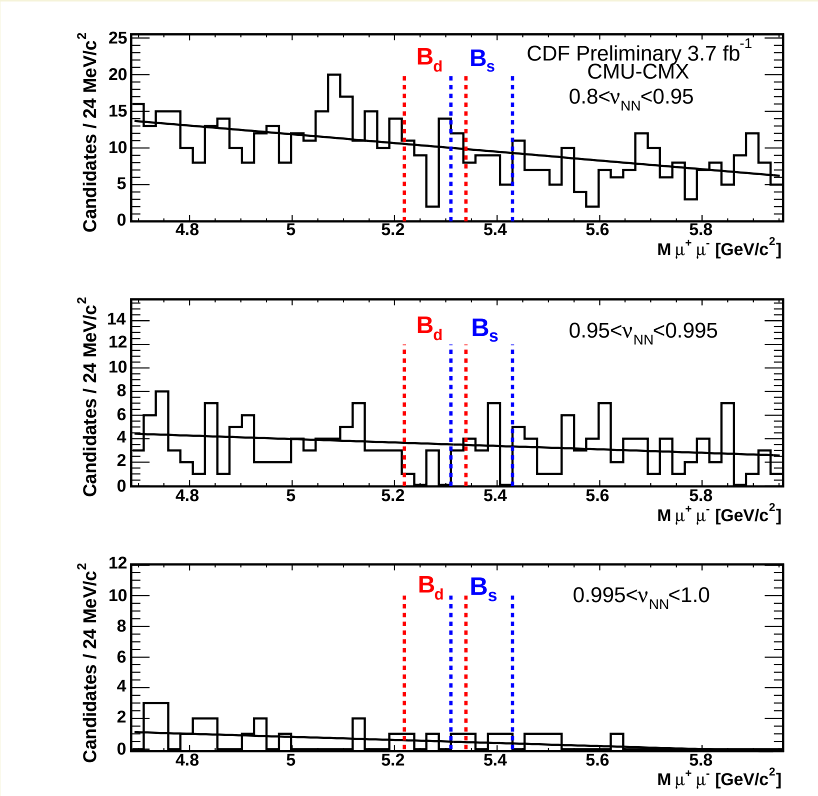
- **Searches for the decays $B_s \to \mu\mu$ and $B_d \to \mu\mu$ are a powerful tool to probe for physics beyond the SM.**
- **Branching Ratio is very small in SM: 3.8×10^{-9}**
- **Various extensions of the SM predict an enhancement of this branching ratio by 1 to 3 orders of magnitude, reachable by Tevatron experiments.**
- **Models motivated by the deviation of the muon (g-2), neutrino oscillations, and dark matter/dark energy results.**

The best limits come from CDF (with 3.7 fb^{-1})

BR($B_s \to \mu\mu$) $< 3.6(4.3) \times 10^{-8}$ at 90 (95)% C.L.
BR($B_d \to \mu\mu$) $< 6.0(7.6) \times 10^{-9}$ at 90 (95)% C.L.

$\Rightarrow$ **JUST BLESSED FOR LP09!**

$\Rightarrow$ **Reaching sensitivity where SM signal may interfere (but not be observable).**



DØ results (2 fb^{-1}):

BR($B_s \to \mu\mu$) $< 7.5(9.3) \times 10^{-8}$ at 90 (95)% C.L.

(See talk by T. Iijima for the details)